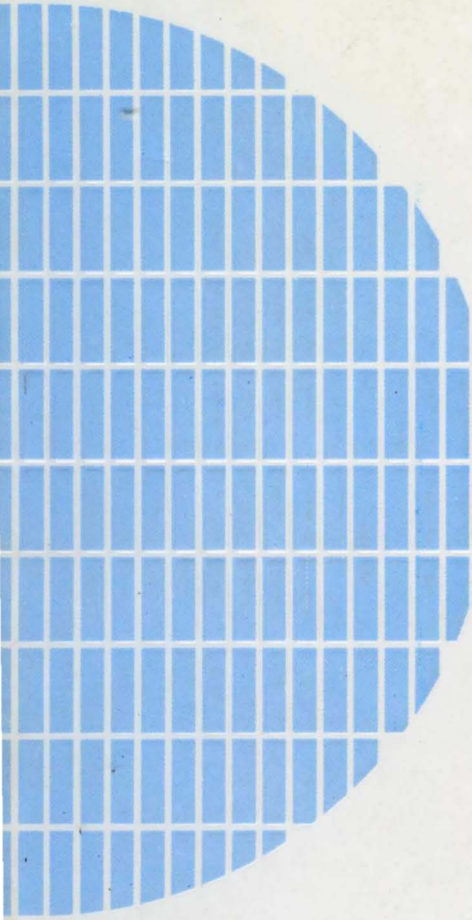
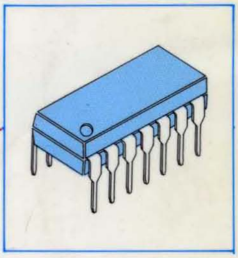
SAMSUNG

Data Book



# Linear IC

VOL. 4, 1990



- Voltage Regulators
- PWM Controllers
- Voltage References
- Operational Amplifiers
- Comparators
- Timer & Miscellaneous

# SAMSUNG
# DATA BOOK LIST

I. Semiconductor Product Guide

II. Transistor Data Book

    Vol. 1: Small Signal TR
    Vol. 2: Bipolar Power TR
    Vol. 3: TR Pellet

III. Linear IC Data Book

    Vol. 1: Audio/CDP/Toy
    Vol. 2: Video
    Vol. 3: Telecom
    Vol. 4: Industrial
    Vol. 5: Data Converters

IV. CMOS Consumer IC Data Book

V. High Speed CMOS Logic Data Book

VI. MOS Memory Data Book

VII. SFET Data Book

VIII. MPR Data Book

IX. CPL Data Book

X. Dot Matrix Data Book

# TABLE OF CONTENTS

# PRODUCT INDEX

# PRODUCT INDEX

| Device | Function | Package | Page |
|---|---|---|---|
| **OPERATIONAL AMPLIFIERS** | | | |
| KA201A/301A | Single Operational Amplifier | 8 DIP/8 SOP | 263 |
| KA733C | Differential Video Amplifier | 14 DIP/14 SOP | 268 |
| KA9256 | Dual Power Operational Amplifier | 10 SIP | 275 |
| KF347C/AC | Quad Jfet Input Operational Amplifiers | 14 DIP | 277 |
| KF351 | Single Operational Amplifier | 8 DIP/8 SOP | 279 |
| KF353 | Dual Operational Amplifier | 8 DIP/8 SOP | 281 |
| KF442C/AC | Dual Jfet Input Operational Amplifier | 8 DIP/8 SIP | 283 |
| KS272C/AC, 272I/AI | Dual CMOS Operational Amplifier | 8 DIP/9 SIP | 285 |
| KS274C/AC, 274I/AI | Quad CMOS Operational Amplifier | 14 DIP | 289 |
| LM2241A, LM324/A/LM2902 | Quad Operational Amplifier | 14 DIP/14 SOP | 293 |
| LM248/348 | Quad Operational Amplifier | 14 DIP/14 SOP | 302 |
| LM258A/LM358/A LM2904 | Dual Operational Amplifier | 8 DIP/8 SOP/9 SIP | 308 |
| LM741C/E/I | Single Operational Amplifiers | 8 DIP/8 SOP | 316 |
| MC1458C/AC/I/AI | Dual Operational Amplifiers | 8 DIP/8 SOP/9 SIP | 322 |
| MC3303/MC3403 | Qual Operational Amplifier | 14 DIP/14 SOP | 326 |
| MC4558C/AC/I | Dual Operational Amplifier | 8 DIP/8 SOP/9 SIP | 333 |
| **COMPARATORS** | | | |
| KA219/KA319 | Dual High Speed Voltage Comparator | 14 DIP/14 SOP | 341 |
| KA710C/I | High Speed Voltage Comparator | 14 DIP/14 SOP | 346 |
| KA711C/I | Dual High-Speed Differential Comparator | 14 DIP/14 SOP | 350 |
| LM239/A, LM339/A, LM2901, LM3302 | Qual Differential Comparator | 14 DIP/14 SOP | 353 |
| LM293/A, LM393/A, LM2903 | Dual Differential Comparator | 8 SIP/8 SOP/9 SIP | 361 |
| LM311 | Voltage Comparator | 8 DIP/8 SOP | 368 |
| **TIMER & MISCELLANEOUS** | | | |
| NE555C/I | Single Timer | 8 DIP/8 SOP | 375 |
| NE556C/I | Dual Timer | 14 DIP/14 SOP | 379 |
| NE558C/I | Qual Timer | 16 DIP/16 SOP | 382 |
| KS555 | CMOS Single Timer | 8 DIP/8 SOP | 385 |
| KS555H | CMOS Single Timer | 8 DIP/8 SOP | 390 |
| KS556 | CMOS Dual Timer | 14 DIP/14 SOP | 394 |
| KA33V | Silicon Monolithic Bipolar Integrated Circuit Voltage Stabilizer for Electronic Tuner | TO-92 | 398 |
| KA331 | Precision Voltage-To-Frequency Converter | 8 DIP | 402 |
| KA2803 | Low Power Consumption Earth Leakage Detector | 8 DIP | 406 |
| KA2804 | Zero Voltage Switch | 8 DIP | 409 |
| KA2807 | Earth Leakage Detector | 8 DIP | 412 |

# QUALITY & RELIABILITY 1

# QUALITY and RELIABILITY

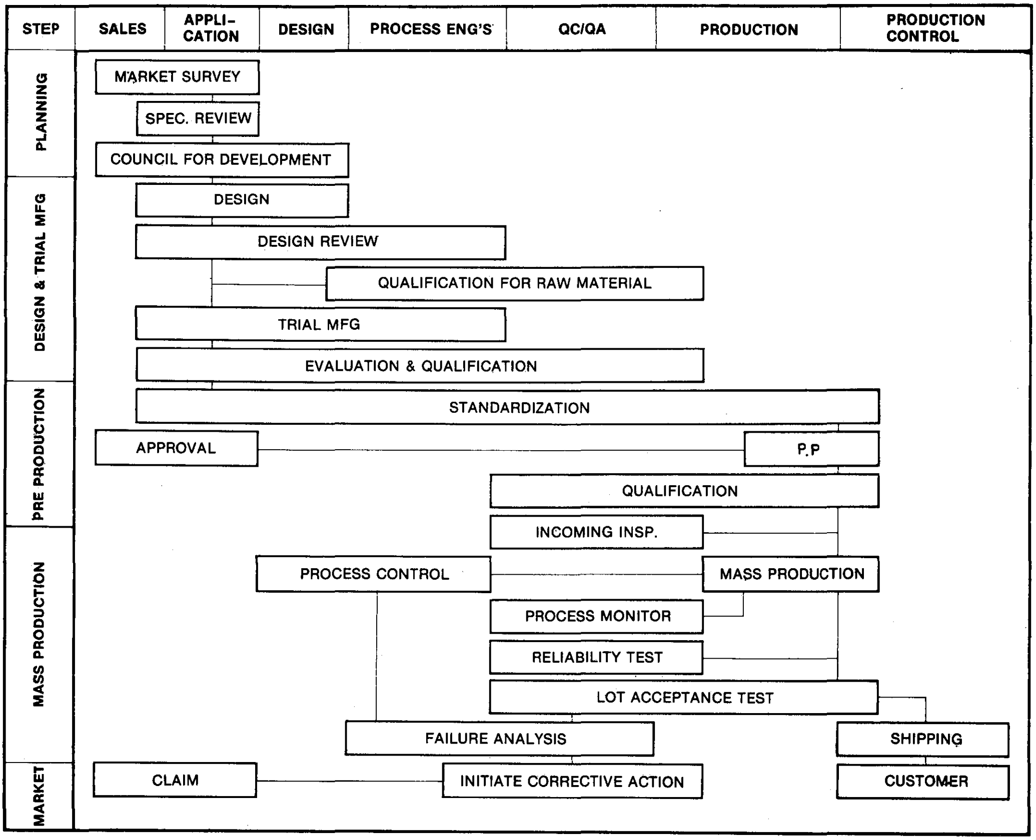
## 1. INTRODUCTION

SEC has been providing a wide variety of semiconductor products to the world since 1974. Since this time, extensive in-sights have been gained to create methods which most effectively result in reliable products. The worldwide customers of SEC have encouraged and helped develop the existing manufacturing and quality philosophy that is a way of life for SEC management and it's employees. This philosophy dictates the need for a zero defect environment through out SEC's processes leading ultimately to total customer satisfaction. By developing and using methods of Statistical Process Control and Statistical Quality Control, SEC has made great strides in improving product quality & reliability. The direct result of these improvements has been reduced product DPM (Defects Per Million) to levels below customer requirements. SEC's repeated ability to exceed requirements for customer's "Dock to Stock" programs and our commitment to all our customers needs, has made SEC the company to watch as we move ahead into the 1990's and beyond.

SEC's linear IC products are among the most reliable in the industry. SEC has always made a commitment to achieve the highest possible quality, reliability, and customer satisfaction with its products. Extensive qualification, monitor and outgoing programs are used to scrutinize product quality and reliability. Stringent controls are applied to every wafer fabrication and assembly lot to achieve reproducibility, and therefore maintain product reliability.

In this chapter, the quality and reliability programs established at SEC will be discussed. In addition, a description of reliability theory, reliability tests and various support efforts provides a broad framework from which to comprehend SEC quality and reliability.

To better understand the Quality Department's role in product development and manufacturing, a detailed diagram is listed below. As can be noted, Quality Engineering is involved in all phases, save that of initial product planning.

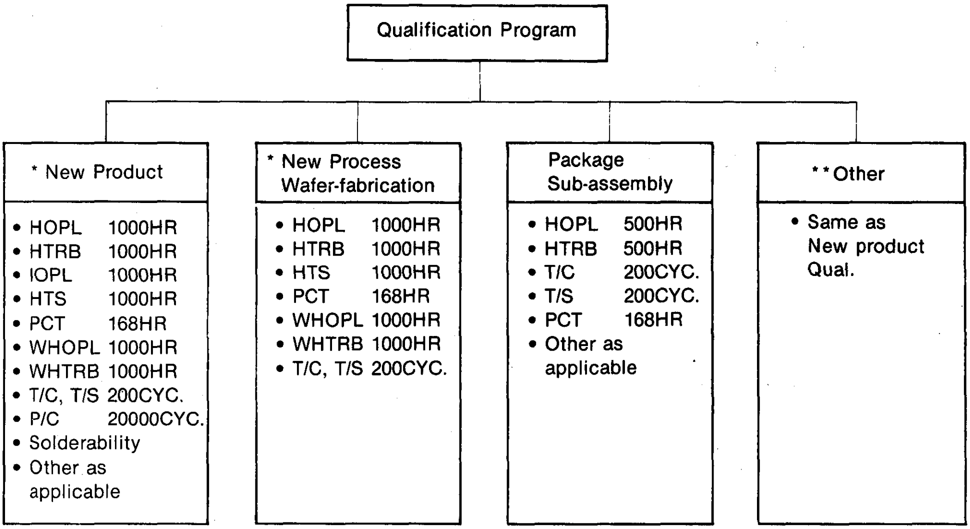


**Quality Assurance During Development**

## 2. QUALITY & RELIABILITY PROGRAM

### 2.1 QUALIFICATION

Procedures to qualify devices are listed below. There are both general and product-specific requirements. Procedures are detailed for new products, die-only qualifications, and package-only qualifications. The latter two are for products and/or packages already qualified, but where there is room for further product optimization.



| * New Product | * New Process Wafer-fabrication | Package Sub-assembly | **Other |
|---|---|---|---|
| • HOPL 1000HR | • HOPL 1000HR | • HOPL 500HR | • Same as New product Qual. |
| • HTRB 1000HR | • HTRB 1000HR | • HTRB 500HR | |
| • IOPL 1000HR | • HTS 1000HR | • T/C 200CYC. | |
| • HTS 1000HR | • PCT 168HR | • T/S 200CYC. | |
| • PCT 168HR | • WHOPL 1000HR | • PCT 168HR | |
| • WHOPL 1000HR | • WHTRB 1000HR | • Other as applicable | |
| • WHTRB 1000HR | • T/C, T/S 200CYC. | | |
| • T/C, T/S 200CYC. | | | |
| • P/C 20000CYC. | | | |
| • Solderability | | | |
| • Other as applicable | | | |

*Testing time for each test items depends on the grade (group) of devices. (see the device group list 2.1 2))

** Design, Equipment, Material(s), etc....

# QUALITY and RELIABILITY

## 1) PROCESS DEVELOPMENT QUALIFICATION

Purpose: To investigate the change of a process parameter and then apply it to a production process by reliability testing of a process which has been newly developed.

**New Process, Wafer Fabrication Qualification**

| No | Test Item | Test Condition | Package | |
|---|---|---|---|---|
| | | | L-IC | Discrete |
| 1 | High Temperature Operating Life (HOPL) | $T_a = T_{opr}(max)$<br>$V_{CC} = V_{CC}(max)$<br>STATIC, DYNAMIC<br>1000HRS | YES | — |
| 2 | High Temperature Reverse Bias (HTRB) | $T_a = T_j(max)$<br>$V_{CB} = 0.8 \times V_{CBO}$<br>1000HRS | — | YES |
| 3 | High Temperature Storage (HTS) | $T_a = T_j(max)$<br>1000HRS | YES | YES |
| 4 | Pressure Cooker Test (PCT) | $T_a = 121°C \pm 2°C$<br>RH = 100% 15 PSIG<br>168HRS | YES | YES |
| 5 | Wet High Temperature Operating Life (WHOPL) | $T_a = 85°C$, RH = 85%<br>$V_{CC} = V_{CC}(min)$<br>1000HRS | YES | — |
| 6 | Wet High Temperature Reverse Bias (WHTRB) | $T_a = 85°C$, RH = 85%<br>$V_{CB} = 0.8 \times V_{CBO}$<br>1000HRS | — | YES |
| 7 | Thermal Shock (T/S) | $-65°C \rightleftharpoons 150°C$ (Liquid)<br>5min, <10sec, 5min<br>200 cycles | YES | YES |
| 8 | Temperature Cycle (T/C) | $-65°C \rightleftharpoons 150°C$ (Air)<br>10min, 10min<br>200 Cycles | YES | YES |

When the results of a reliability test are good, the process characteristics good and the yield level is satisfied, the process can be applied to production. If there are any problems found in a process after it has been applied to production, the problem will be investigated in detail and the process will be revised. Once the process has been revised and approved it will again be applied to production.

## 2) PRODUCT DEVELOPMENT QUALIFICATION

Purpose: To develop a stable and uniform product that satisfies the customer's requirements for quality by using the exact reliability test specification called out for the new product.

Products are grouped according to the importance of their application.

| Group 1 | Group 2 | Group 3 |
|---|---|---|
| 1. A/D, D/A Converter<br>2. IC for LCD<br>3. IC for PC<br>4. ASIC Master<br>5. Codec<br>6. MPR<br>7. IC for Exchange<br>8. New Products | 1. Transistor<br>2. Regulator/OP AMP<br>3. IC for Telephone<br>4. Comparator/Timer<br>5. MICOM<br>6. Audio/Video IC<br>7. General Mos IC | 1. ASIC Opinion Product<br>2. Toy/Melody IC<br>3. MICOM family<br>4. Products Except Group 1, Group 2 Products |

# QUALITY and RELIABILITY

**New Product Qualification Test Items**

| No. | Test Item | Test Condition | Part | | Reference Method | Note |
|---|---|---|---|---|---|---|
| | | | L-IC | Discrete | | |
| 1 | High Temperature Reverse Bias (HTRB) | Ta = $T_j$(max)<br>$V_{CB} = 0.8 \times V_{CBO}$<br>1000HRS | — | YES | | |
| 2 | High Temperature Operating Life (HOPL) | Ta = $T_{opr}$(max)<br>$V_{CC} = V_{CC}$(max)<br>Static, Dynamic<br>1000HRS | YES | — | MIL-STD-883<br>1005 | |
| 3 | High Temperature Storage (HTS) | Ta = $T_{stg}$(max)<br>1000HRS | YES | YES | | |
| 4 | Operating Life (OPL) | Ta = 25°C<br>$P_C = P_C$(max)<br>1000HRS | — | YES | MIL-STD-750<br>1026.3 | For Small-Signal Device |
| 5 | Intermittent OPL (IOPL) | Ta = 25°C<br>$P_C = P_C$(max)<br>2min/2min On/Off<br>1000HRS | — | YES | MIL-STD-750<br>1036.3 | |
| 6 | Power Cycle (P/C) | $\Delta T_j = 125°C$<br>120Sec/120Sec On/Off<br>10000CYC. | YES | YES | | For PWR TR, PWR IC |
| 7 | Pressure Cooker Test (PCT) | Ta = 121°C ± 2°C<br>RH = 100% 15PSIG<br>168HRS | YES | YES | | |
| 8 | Wet High Temperature Reverse Bias (WHTRB) | Ta = 85°C, RH = 85%<br>$V_{CB} = 0.8 \times V_{CBO}$<br>1000HRS | — | YES | | |
| 9 | Wet High Temperature Operating Life (WHOPL) | Ta = 85°C, RH = 85%<br>$V_{CC} = V_{CC}$(min) Pdmin<br>1000HRS | YES | — | | |
| 10 | Thermal Shock (T/S) (Liquid) | −65°C↔150°C<br>5min, <10Sec, 5min<br>200 Cycles | YES | YES | MIL-STD-883<br>1011 | |
| 11 | Temperature Cycle (T/C) (Air) | −65°C↔150°C<br>10min, 10min<br>200 Cycles | YES | YES | MIL-STD-883<br>1011 | |
| 12 | Solder Heat Resistance (S/H) | Ta = 260°C ± 5°C<br>t = 10 ± 2Sec | YES | YES | MIL-STD-750<br>2031.1 | |
| 13 | Solderability | Ta = 245°C ± 5°C<br>t = 5 ± 0.5sec<br>Reject is >10% uncovered surface | YES | YES | MIL-STD-883<br>2003 | |
| 14 | Salt Atmosphere | Ta = 35°C, 5% NaCl<br>24HRS | YES | YES | MIL-STD-883<br>1009A | |

**New Products Qualification Test Item** (Continued)

| No. | Test Item | Test Condition | Part | | Reference Method | Note |
|---|---|---|---|---|---|---|
| | | | L-IC | Discrete | | |
| 15 | Mechanical Shock | 1500G, 0.5ms<br>3 Times Each direction of X, Y and Z Axis | YES | YES | MIL-STD-750<br>2016 | For Hermetic |
| 16 | Vibration | 20G, 3 Axis<br>f=20 to 2000 cps<br>for 4 min, 4 cycles | YES | YES | MIL-STD-883<br>2007 | For Hermetic |
| 17 | Constant Acceleration | 2000G<br>X,Y,Z Axis<br>1min for each Axis | YES | YES | MIL-STD-883<br>2001 | For Hermetic |
| 18 | ESD (Human Body Model) | R=1.5kΩ<br>C=100pF<br>5 Discharge<br>V≥ ±1000V | YES | YES | MIL-STD-883<br>3015 | |
| 19 | Latch-up Test | | YES | — | — | For CMOS |
| 20 | Fine Leak<br>Gross Leak | Helium<br>Fluoro Carbon | YES | YES | MIL-STD-883<br>1014 | For Hermetic |

Note) • SOT-23, TO-92S PKG: PCT-48HR

### 3) PACKAGE DEVELOPMENT QUALIFICATION

Purpose: Whenever a new package type is developed, it must meet the specifications for devices that have been qualified and have maintained certain specified quality levels before the new package type may be applied to production.

| Flow | Contents | Remarks |
|---|---|---|
|  | Beginning of PKG development | Select representative device for product group (proceed at least 2 lots) |
| | Ass'y Qual | • Push Test<br>• Die Thick<br>• Bond Pull<br>• Lead Torque<br>• MPT<br>• Dimension<br>• X-Ray<br>• Solderability |
| | Reliability Qual | • HTRB (TR)<br>• HOPL (IC)<br>• T/C<br>• PCT<br>• LTS<br>• S/H<br>• Vibration<br>• M/S<br>• Const |
| | Approvement of Qual | • New PKG Development will be approved when Rel qual is good for 500HR. |

**Package Sub-Assembly Qualification Test Items**

| No. | Test Item | Test Condition | Package | | Notes |
|---|---|---|---|---|---|
| | | | Plastic | Hermetic | |
| 1 | High Temperature Reverse Bias (HTRB) | $Ta = T_j$(max)<br>$V_{CB} = 0.8 \times V_{CBO}$<br>500HRS | YES | YES | For Discrete |
| 2 | High Temperature Operating Life (HOPL) | $Ta = T_{opr}$(max)<br>$V_{CC} = V_{CC}$(max)<br>Static, Dynamic, 500HRS | YES | YES | For IC |
| 3 | Temperature Cycle (T/C) | $-65°C \rightleftharpoons 25°C \rightleftharpoons 150°C$<br>10min, 5min, 10min<br>200 CYCLES | YES | YES | |
| 4 | Pressure Cooker Test (PCT) | $Ta = 121°C \pm 2°C$<br>RH = 100%, 15PSIG<br>168HRS | YES | — | |
| 5 | Thermal Shock (T/S) | $-65°C \rightleftharpoons 150°C$ (Liquid)<br>5min, < 10sec, 5min<br>200 CYCLES | YES | YES | |
| 6 | Solder Heat Resistance (S/H) | $260°C \pm 5°C$<br>$10 \pm 1$ sec<br>Once without Flux | YES | YES | |
| 7 | Vibration (Variable-Frequency) | 100 ~ 2000 ~ 100Hz<br>20G, 5min, 5Times, X, Y, Z | — | YES | For Discrete, others as applicable |
| 8 | Mechanical Shock (M/S) | 1500G, 0.5ms<br>3 Times, X, Y, Z | — | YES | same as above |
| 9 | Constant Acceleration | 20000G<br>X, Y, Z Axis<br>1 min for each Axis | — | YES | same as above |

### 4) CHANGE QUALIFICATIONS:

Purpose: To apply changes to production processes and designs by evaluating the quality levels for those processes and designs of devices in production.

| Classification | | Change |
|---|---|---|
| Design | | Change of more than 1EA MASK for the product in production. |
| Process | Ass'y | • D/A • Coating<br>• W/B<br>• Mold |
| | Diffusion | • Diffusion/Photo/Etch, etc.<br>• Metalization<br>• Passivation |

Procedure: Issuance of EIN for the change → Review of initial characteristics → Reliability test → Issuance of ECN (register of specification) → Application for production. Evaluation level: LTPD 10% (1/2)

## 2.2 MONITOR PROGRAM

### 1) ON GOING PROCESS CONTROL

All parameters of each process are controlled by SPC (Statistical Process Control). All resultant SPC data is gathered by computers and recorded automatically. Trends of each parameter are plotted on control charts by the computer and corrective actions are immediately taken whenever a parameter goes "out-of-control" beyond the control limits.
Whenever a parameter goes "out-of-control" in a process, engineers involved with that particular process have meetings to decide the disposition of those lots that were effected by the out-of-control process and corrective actions are implemented. In the case of critical defects, all lots are scrapped by MRB (Material Review Board).
As the key item of ongoing process control, Cp or Cpk value is controlled by computer for each process. The UCL and LCL for each process is then determined by the computer generated Cp or Cpk value. Cp or Cpk values are continually upgraded to insure the stabilization of process and a QIP (quality improvement plan) is made out to drive defects down to zero.
Process capabilities of each process are totaled and analyzed and those results of analysis are reflected on the QIP. The stabilization and maximization of process capabilities are driven by SPC.

### 2) PRODUCT RELIABILITY MONITOR

The reliability monitor program begins where the qualification program ends, at the start-up of limited production. Everything that is subject to qualification is considered subject to the monitor program. Generally, the product to be used for reliability monitors is gathered from each fab lot each month, where the product selected is representative of:

1) each fab process technology
2) each generic product type
3) each package technology
4) each subassembly plant

The product is shipped directly to the appropriate Q & R group, which puts the product through a series of electrical, mechanical, thermal, and environmental tests that usually are identical to those used initially for qualifying the product. Most tests are of short duration, but some may extend out to thousands of hours. Each month the test results are evaluated and problems, should they exist, identified.
Each monitor failure is analyzed. If a problem is detected where the failure rate is greater than that considered acceptable, or a reliability problem is suspected, a Material Review Board (MRB) is called. This meeting is attended by appropriate Q & R personnel, scheduling personnel, engineering, and any other affected group.
This group reviews the data, decides on disposition of the affected material, decides on appropriate corrective action, and basically controls the problem or issue until it is satisfactorily resolved.

### 3) FINAL QUALITY ASSURANCE PROGRAM

After the completion of the entire manufacturing process a sample of each lot is pulled and the data sheet verification test is repeated. This final verification objective is to ensure that test system to test system variations are not compromising the quality, and that inadvertent system or handling problems have not occurred.

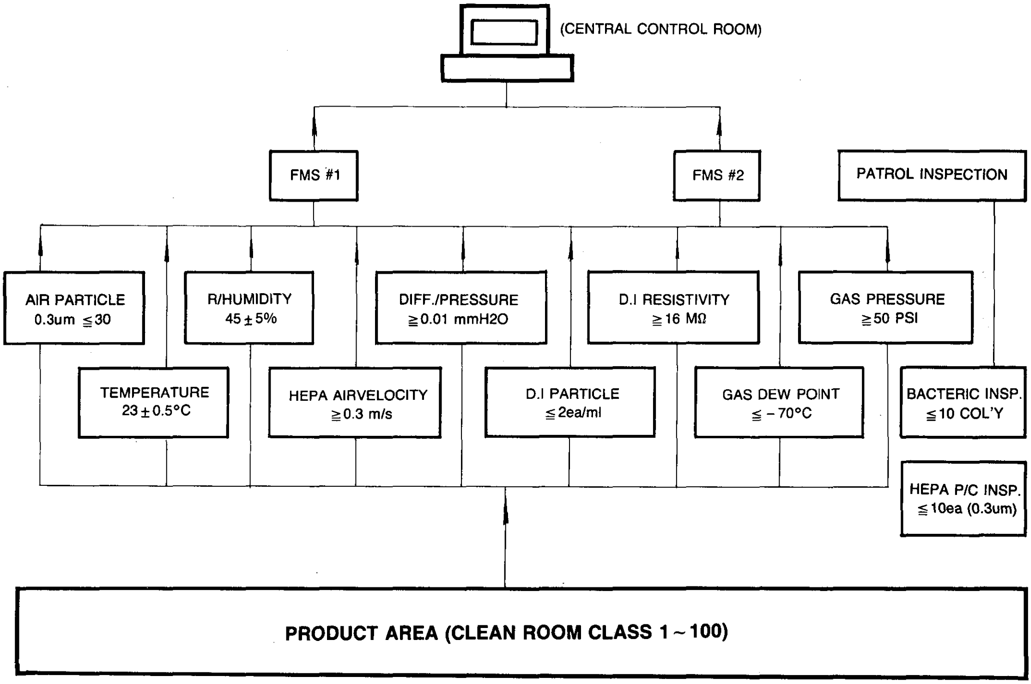
### 4) ENVIRONMENT MONITOR

- **Instruments**

- F.M.S #1 (HIAC/ROYCO System 1 Set)
- F.M.S #2 (P.M.S System 1 Set)
- Control Particle Monitoring System (2 Set)
- Portable Particle Counter, Sensors

On line monitoring system (Central control room)

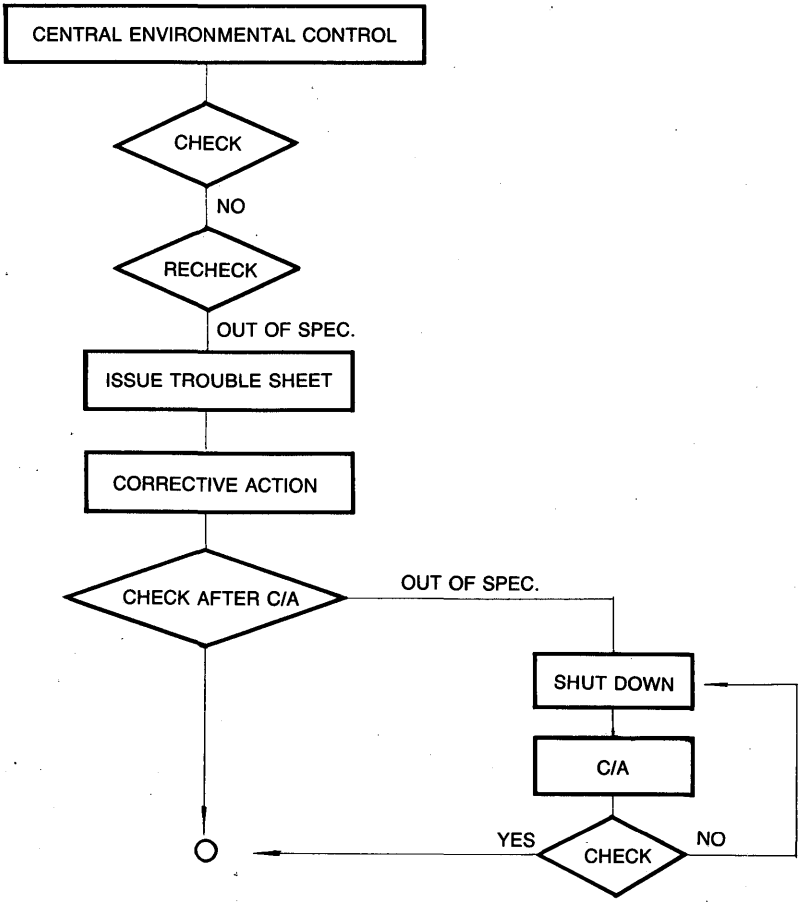
- **Block Diagram**



- **Environment Monitor**

| Item | Frequency |
|---|---|
| 1. Particle (Air, D-I Water) | 5 min |
| 2. Temperature, Relative Humidity | 5 min |
| 3. D.I Resistivity | 5 min |
| 4. Differential Pressure | 5 min |
| 5. HEPA Air Velocity | 5 min |
| 6. Gas ($H_2$, $O_2$, $N_2$, Air) Dew Point | 5 min |
| 7. Gas Pressure | 5 min |
| 8. HEPA Filter Particle | All HEPAs/1 room/Day |
| 9. D-I Bacteria Main Lot | Weekly |
| 10. D-I Bacteria Using Lot | Monthly |

**Corrective Action Requirement**



## 2.3 QUALITY CONFORMANCE PROGRAM

### 1) DESCRIPTION

SEC has established a comprehensive reliability program to monitor and ensure the ongoing reliability of the Linear IC family. This program involves not only reliability data collection and analysis on existing parts, but also rigorous in-line quality controls for all products.
Listed below are details of tests performed to ensure that manufactured product continues to meet SEC's stringent quality standards. In line quality controls are reviewed extensively in later sections.
The tests run by the quality department are accelerated tests, serving to model "real world" applications through boosted temperature, voltage, and/or humidities. Accelerated conditions are used to derive device knowledge through means quicker than that of typical application situations. These accelerated conditions are then used to assess differing failure rate mechanisms that correlate directly with ambient conditions. Following are summaries of various stresses (and their conditions) run by SEC on Linear IC products.

### 2) HIGH TEMPERATURE OPERATING LIFE TEST (HOPL)

($T_j = 125°C$, $V_{CC} = V_{CC}$ max, static)

High temperature operating life test is performed to measure actual field reliability. Life tests of 1000HR to 2000HR durations are used to accelerate failure mechanisms by operating the device at an elevated ambient temperature (125°C). Data obtained from this test are used to predict product infant mortality, early life, and random failure rates. Data are translated to standard operating temperatures via failure analysis to determine the activation energy of each of the observed failures, using the Arrhenius relationship as previously discussed.

### 3) WET HIGH TEMPERATURE OPERATING LIFE TEST (WHOPL)

(Ta = 85°C, R.H. = 85%, $V_{CC} = V_{CC}$ opt, static)
Wet high temperature operating life test is performed to evaluate the moisture resistance characteristics of plastic encapsulated components. Long time testing is performed under static bias conditions at 85°C/85 percent relative humidity with nominal voltages. To maximize metal corrosion, the biasing configuration utilizes low power levels.

### 4) INTERMITTENT OPERATING LIFE (IOPL)

(Pmax, 25°C, 2min on/2 min off)

This test is normally applied to scrutinize die bond thermal fatigue. A stressed device undergoes an "ON" cycle, where there is thermal heating due to power dissipation, and an "OFF " cycle, where there is thermal cooling due to lack of inputted power. Die attach (between die and package) and bond attach (between wire and die) are the critical areas of concern.

### 5) HIGH TEMPERATURE STORAGE TEST (HTS)

(Ta = 125°C, UNBIASED)

High temperature storage is a test in which devices are subjected to elevated temperatures with no applied bias. The test is used to detect mechanical instabilities such as bond integrity, and process wearout mechanisms.

### 6) PRESSURE COOKER TEST (PCT)

(121°C, 15PSIG, 100% R.H., UNBIASED)

The pressure cooker test checks for resistance to moisture penetration. A highly pressurized vessel is used to force water (thereby promoting corrosion) into packaged devices located within the vessel.

### 7) TEMPERATURE CYCLING (T/C)

(−65°C to +150°C, AIR, UNBIASED)

This stess uses a chamber with alternating temperatures of −65°C and +150°C (air ambient) to thermally cycle devices within it. No bias is applied. The cycling checks for mechanical integrity of the packaged device, in particular bond wires and die attach, along with metal/polysilicon microcracks.

### 8) THERMAL SHOCK (T/S)

(−65°C to +150°C, LIQUID, UNBIASED)
This stress uses a chamber with alternating temperatures of −65°C to +150°C (liquid ambient) to thermally cycle devices within it. No bias is applied. The cycling is very rapid, and primarily checks for die/package compatibility.

## 9) RESISTANCE TO SOLDER HEAT

(UNBIASED, 260°C, 10 sec)

Solder Heat Resistance is performed to establish that devices can withstand the thermal effects of solder dip, soldering iron, or solder wave operations.

## 10) MECHANICAL SHOCK

(UNBIASED, 1500g, Pulse = 0.5msec)

This test determines the suitability of a device to be used in equipment where mechanical "shocks" may occur. Such shocks result from sudden or abrupt changes produced by rough (non-standard) handling, transportation, or field operations.

## 11) VARIABLE FREQUENCY VIBRATION

(UNBIASED, Range = 100 to 2000Hz)

Variable Frequency Vibration is done to model the effects of differential vibration in the specified range. Die attach and bonding integrity are particularly stressed, testing the mechanical soundness of device packaging.

## 12) CONSTANT ACCELERATION

(UNBIASED, 10kg to 20kg)

This is an accelerated test designed to indicate types or modes of structural and mechanical weaknesses not necessarily detectable in Mechanical Shock and Variable Frequency Vibration stressing.

## 13) RELATIVE STRESS COMPARISONS

Many stresses are run at SEC on many different devices. Through both theoretical and actual results, it was clearly determined which stresses were most effective. Also established were the stresses which weren't fully effective.

Comparisons have been made on the basis of defects able to be determined, efficiency in detection, and cost. For the reader's benefit, SEC provides the results of its conclusions on the following pages.

# 3. CUSTOMER SUPPORT SYSTEM

## 3.1 INTRODUCTION

Manufacturing companies have developed customer support systems for the purpose of uniting communications. Through these communications pass the information and knowledge required to satisfy the customers needs in areas such as quality and reliability, customer claims, customer training, field service technical issues, pricing or availability and above all, trust. Open lines of communication establishes thorough trust between the customer and vendor and are essential for such programs as dock-to-stock in order to achieve the ultimate in customer/vendor relations. SEC, in its commitment to customer satisfaction, has installed within its organization a support system that is designed to produce the open lines of communication between all facets of relations for both the customer and SEC.

## 3.2 POLICY

SEC has developed within its organization, a customer support system. SEC's policy requires that this system be manned with the proper personnel that are thoroughly trained in the areas that each represent and are dedicated to opening and maintaining lines of communication with the customer. Technical data used by SEC to support the customer must be up to date and always available for use by the customer (privileged or confidential information maybe excluded). Customer training is provided to the customer by only the most knowledgeable SEC personnel. SEC will provide customer field service in the form of periodic goodwill visits to customer sites or specialized problem solving services as required. Process change notification procedures as well as safety standards are also strictly adhered to.

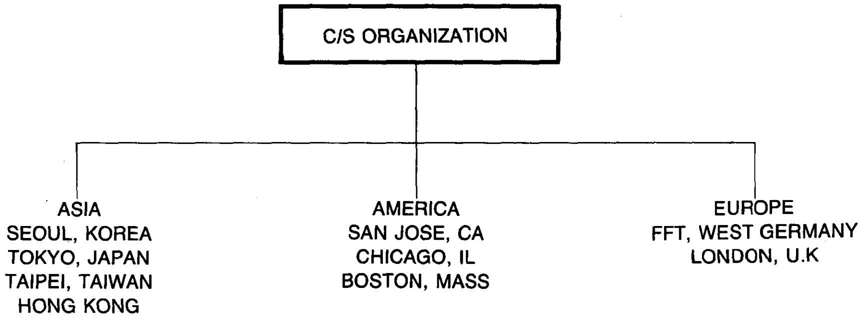
## 3.3 CUSTOMER SUPPORT SYSTEM

### 1) QUALITY ASSURANCE SERVICE

SEC has felt the need to reorganize its current Quality Assurance Sections in order to better service our customers. From this new organizational change, a new QA section was born. This new QA section, known as QA Section 3, was developed specifically for the customer. The customer service team in QA3, was organized to respond prombtly to customers quality requirements. The purpose of this team is to form a more responsive communication channel between plant R & D, the sales department and the customer. Customers will achieve satisfaction with our company's products by use of the newly organized customer service system. This service system is openly available to customers for comments concerning problems or opinions about SEC's devices. An 800 number is published on the inside of the handbooks cover.

### 2) CUSTOMER SERVICE TEAM

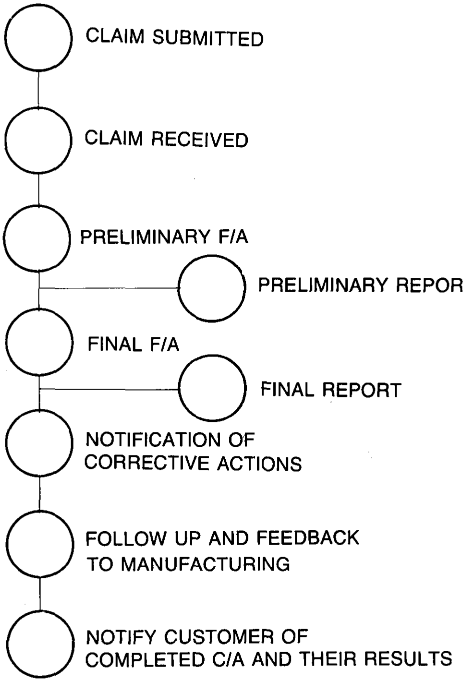
The following organizational chart illustrates the world-wide base that the customer service team of SEC has established. Maintaining continuity between all of SEC's worldwide customer service teams is accomplished through the use of a newly installed computer network which allows constant communication between all teams.



## 3) CUSTOMER CLAIM SUPPORT SYSTEM

Information from the field concerning quality is an essential factor for the improvement of product quality. Equally important, is the investigation of field failures. Timely feedback of the results from the analysis is required to better service customers properly. This data also serves as a direct guide to the improvement of reliability and quality for both SEC and our customers.

The flowchart below demonstrates the process in which SEC currently follows for customer claims.



## 4) CUSTOMER TRAINING SYSTEM

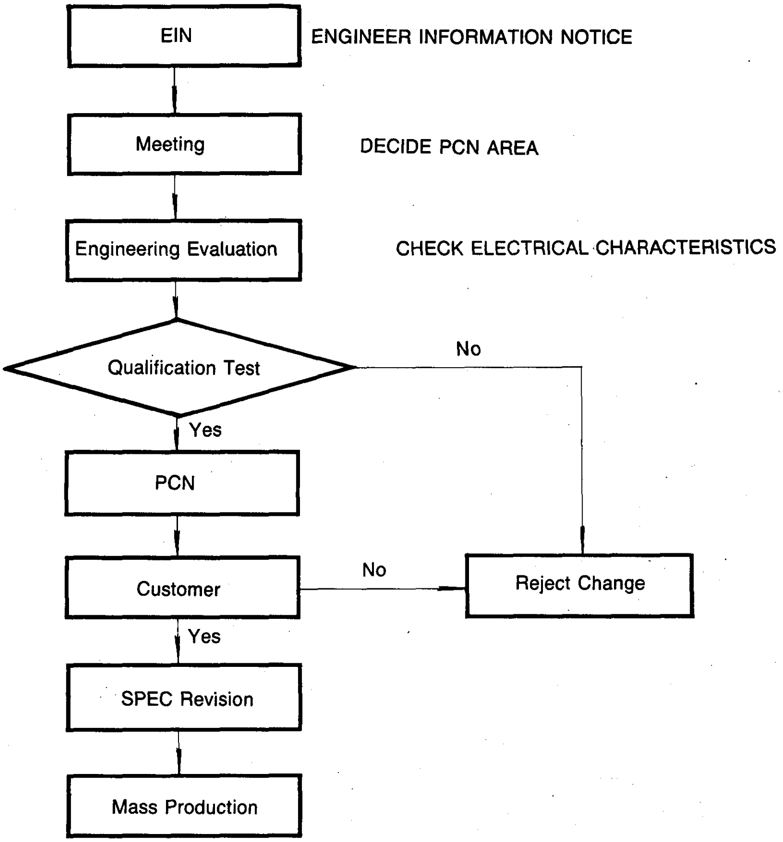
SEC has recently established a training team for the purpose of teaching SEC's customers the methods currently used by SEC to insure the product quality and reliability at the customers site. SEC offers this training in the form of group seminars or presentations and when requested or deemed necessary, individualized training is offered. In some cases, the training will take place at the customers site at the customers convenience while in other cases, SEC will extend on invitation to the customer to visit our manufacturing site.

## 5) CUSTOMER FIELD SERVICE

SEC has developed field service teams that are devoted to making customer contact when there aren't any problems. In other words, SEC is interested in making periodic goodwill visits. The visiting team would be comprised of those managers and engineers that are involved with the product types that the customer currently uses. The main goal of this team is to establish customer trust through communication.

## 3.4 PROCESS CHANGE NOTIFICATION SYSTEM (PCN)

Changes in a process are sometimes required to produce a higher quality product at a lower price. These changes can include new or different types of material, new or modified designs and new or different processes. SEC has developed a PCN procedure that is followed whenever a major or critical change is to be considered for any process. The idea behind the PCN is to allow change to a process by submitting the planned change for qualification by SEC engineering and then presenting the PCN to the customer for final approval. By following this procedure, the customer is assured that no major or critical change will occur to the process without the customers consent.



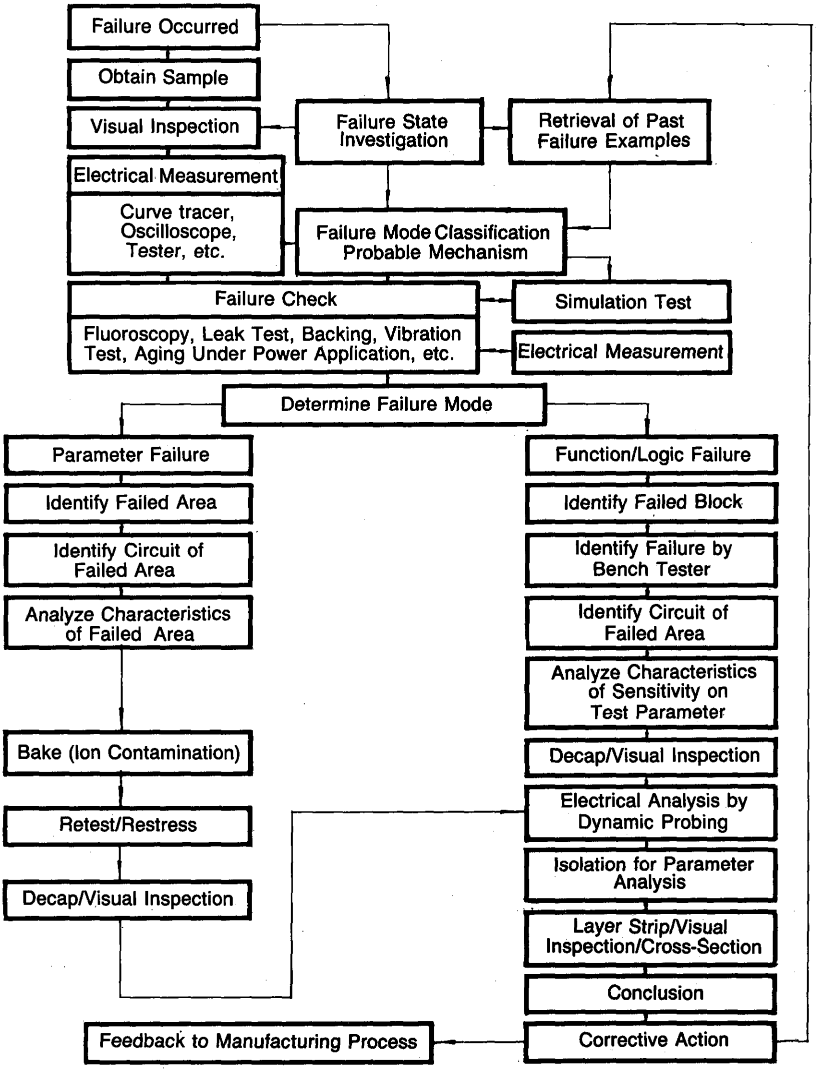
## 3.5 SAFETY STANDARDS

Most customers express the desire to use only products which have been manufactured with materials that meet the safety specifications of the Underwriters Laboratories. SEC has chosen to adhere to the specifications called out in the UL standard 94 by purchasing and using only those plastic materials that conform to this standard. UL 94 tests for a number of different flammability conditions that effect the plastic material used in semiconductor devices including horizontal burning, vertical burning and flame spread.

# 4. FAILURE ANALYSIS

## 4.1 PROCEDURE

A general failure analysis procedure is shown below. The method demonstrated in the flow chart applies to all rejects. However, each analysis is specific unto itself, so that a completely exhaustive analytical flow is impossible for the limits of this manual. Specific instances and examples of interest are provided later in the chapter. Also included in this section is a typical day-by-day accounting of a failure analysis in progress. A two-week turnaround is the objective, with greater than 90% of analysis lasting equal to or less than this duration. A sample analysis plan and report are attached at the conclusion of this section.



Failure Analysis Procedure Flow Chart

Applicable Comments for the above flow chart are made below.

### 1) DETERMINATION OF FAILURE MODE

The basic failure mode shall be determined with data from computer and bench testing. As a defect can represent various electrical failure modes, it is critical to determine the most basic failure mode. (For example, a $V_{OL}/V_{OH}$ parameter failure may be also analyzed as a functional failure. However, it is very important to determine $V_{OL}/V_{OH}$ as the basic failure mode.)

### 2) IDENTIFICATION AND ANALYSIS OF FAILED CIRCUIT AREA

Correlation shall be derived with general (macroscopic) failure phenomenon through circuit interpretation of the failed area.

### 3) SENSITIVITY OF TEST

Parametric value of failed sample shall be determined through adjusting DC and AC parameters, temperature range, etc.

### 4) ION CONTAMINATION

For a sample assumed to have an inversion phenomenon caused by ionic contamination, characteristics shall be identified by conducting a Ta = 150°C, 24 hour cure and repeating test/restress.
Contamination of a specific layer shall be determined by stripping each layer.

### 5) DECAPSULATION

There are 5 decap methods with respective merits and demerits. The appropriate method must be utilized on the basis of the characteristics and potential cause for each failure.

### 6) ISOLATION AND DYNAMIC PROBING

It is essential to isolate the probable failing part of the circuit for its electrical failure mode. Without isolation, exact detection of a failed part can not be accurately accomplished as an electrical failure mode has an influence on other parts of the circuit.

### 7) LAYER STRIPPING

Each layer strip should meet specification requirements with respect to time. It should never be the case that chemical attack is mistaken for causing the failure of a part.

### 8) GENERATION OF ACTIVATION ENERGY

Accelerated life testing requires generation of actual activation energies based upon establishing a definitive failure mode. This generation has a great effect in determining the acceleration factor of Arrehenius' model.

### 9) CORRECTIVE ACTION

Failure analysis is fully completed only by establishing a future plan and corrective action, which are taken to resolve a problem and prevent its recurrence.

## 4.2 Failure Modes and Mechanisms

1) Failure mechanisms for devices vary widely. They are caused by both front-end (wafer) and back-end (assembly) processing. To classify problems and their instigations, the table listed below is provided.

**Items and Causes of Failure Modes**

| Item | Type of Failure | Failure Mode | Cause |
|---|---|---|---|
| **Wire Bonding** | Wire Disconnection | Open | Incomplete Manufacture or Misuse |
| | Wire Short | Short | |
| | Purple Plague | Open, High Resistance | |
| | Bond Detaching | Open, High Resistance | |
| | Misplaced Bonding,<br>Loose Contact | Open, High Resistance<br>Short | Incomplete Manufacture |
| | Improper Bond Shape<br>Erroneous Bonding | Open, High Resistance<br>Open, High Resistance | |
| **Junction Region** | Destruction by Surge | Low Breakdown Voltage, Short, Open | Incomplete Manufacture or Misuse |
| | Hot Spot | | |
| **Case** | Lead Disconnection | Open, High Resistance | Same as above |
| | Lead Short | Short, High Leakage | |
| **Seal** | Incomplete Seal | Breakdown Voltage Deterioration, High Leakage | Same as above |
| | Enclosed High Humidity Gas | | |
| | Contamination of Surface | | |
| | Dust and Dirt | Short, Low Breakdown Voltage<br>Large Leakage | |
| **Metallization** | High Current Density | Open, Short | Misuse |
| | Electromigration | Open, High Resistance | |
| | Scratch | Open, Short | Incomplete Manufacture |
| | Insufficient Thickness<br>Excessive Etching | Open, High Resistance | |
| | Contamination, Dust and Dirt | Open, High Resistance | Incomplete Manufacture or Misuse |
| | Poor Wiring and Element Connection | | |
| **Chip Mounting** | Chip Crack | Open, Short | Same as above |
| | Chip Detaching | Open, Short, High Thermal Resistance | |
| **Oxidized Film** | Pinhole, Crack | Low Breakdown Voltage, Short | Incomplete Manufacture |
| | Insufficiently Oxidized Film Thickness | Low Breakdown Voltage | |
| **Surface Treatment** | Channel Formation | Low Breakdown Voltage<br>High Leakage | Same as above |
| | Contamination | | |
| **Mask** | Insufficient Photoresist | Low Breakdown Voltage<br>Short, Open, High Leakage | Same as above |
| | Mask Misalignment | | |
| **Material and Diffusion** | Improper Impurity Density | Same as above | Same as above |

2) Standard product reliability tests can naturally generate failures. Here, in this section, a table is given which lists tests and their associated rejects. Each test has a specific purpose, and if there exists a particular product weakness, a given test will expose it. In this manner, by knowing a test and it's function, a clear determination can be made as to the relevance of a failure for that particular test.

**Reliability Tests and Associated Failure Modes**

| | Failure Cause | Diffusion | Oxide | Metalization | Wire Bonding | Package Environment | Package Seal | Lead Fatigue | Solderability | Mark | Die bonding |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Item | Test Condition | •Contamination<br>•Crystal Defect<br>•Photoresist Reject | •Contamination<br>•Pin Hole<br>•Crack<br>•Thickness Unstable | •Conpos.<br>•Scratch<br>•Void<br>•Open | •Interface<br>•Corrosion<br>•Misbonding<br>•Wire Open<br>•Chemical Interface | •Conductive ions<br>•Inadequate<br>•Environments | •Sealing Reject | •Conpos. | •Marking | •Themal Reject | Resistance Reject<br>•Crack<br>•Chip Position Reject |
| T/C | −65°C→150°C<br>200 Cycles | | 0 | 0 | 0 | | 0 | | | | 0 |
| T/S | −65°C→125°C<br>200 Cycles | | 0 | 0 | 0 | | 0 | | | | 0 |
| Moisture Resistance | 90-98%R.H./65°C3HRS<br>80-98%R.H./25°C8HRS<br>90-98%R.H./65°C3HRS<br>10 Cycles | | 0 | 0 | 0 | 0 | 0 | | | | |
| Vibration Fatigue | 20G-3 Axis Orientation<br>f=20 to 2000 cpe<br>for 4 min. 4 cycles | | | | 0 | 0 | | | | | 0 |
| Constant Acceleration | Pulse Duration:<br>0.1-1m sec<br>Shock pulse: 0.5-3Kg | | | | 0 | | | | | | 0 |
| Mechanical Shock | 1500g, 0.5ns<br>Each Direction of X, Y and Z Axis | | | | 0 | | | | | | 0 |
| Lead Integrity | W=227g<br>90°C 3 times | | | | | | 0 | | | | |
| Marking | Isoprophylalcohol | | | | | | | | | 0 | |
| Solderability | Ta=230° 5 Sec.<br>Once With Flux | | | | | | | | 0 | | |
| Salt Spray | Ta=35°C, 5% NaCl | | | | 0 | | | | 0 | | |
| OPL | Individual Spec | 0 | 0 | 0 | 0 | 0 | | | | | 0 |
| IOPL | Individual Spec | 0 | 0 | 0 | 0 | 0 | | | | | 0 |
| HTRB | Individual Spec | 0 | 0 | 0 | 0 | 0 | | | | | 0 |
| HTS | Individual Spec | | 0 | | 0 | 0 | | | 0 | | |
| WHTS | 80°C, 90% RH<br>85°C, 85% RH | | 0 | 0 | | | 0 | 0 | 0 | | |
| WHTRB | 85°C, 85% RH<br>Bias | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 |

3) An anomalous manufacturing step can manifest itself in many ways with respect to product reliability. The chart below depicts process steps, the types of rejects they can generate, and the way to defect such failures. Of course, there are numerous QC and Production checks along all stages of the manufacturing process. However, a semiconductor product typically involves so many operations it's nearly impossible to detect all potential reliability hazards. Thus, there are final electrical and visual tests, reliability tests, and statistical analyses which are run prior to product releasal. The chart below speaks to the electrical, visual, and reliability tests.

**Failure Mechanisms of Integrated Circuits**

| **Process Step *Affecting* Reliability** | **Failure Mechanism** | **Failure Mode** | **Failure Detection Method** |
|---|---|---|---|
| **Wafer Fabrication** | Dislocation and Stacking Fault | Degradation of Function Characteristics | Electrical Test<br>Operation Life |
| | Non-Uniform Resistivity | Unpredictable Characteristic Values | Electrical Test |
| | Surface Abnormalities | Improper Electrical Characteristics,<br>Short and Open | Electrical Test<br>Operation Test |
| | Cracks, Chips, Scratches (Usually Caused During Handling) | Open and Short | Electrical Test<br>Visual Inspection (Before Seal)<br>Temperature Cycling |
| | Contamination | Degradation of Junction Characteristics | Visual Inspection (Before Seal), Temperature Cycling, High Temperature Storage, Reverse Bias |
| **Passivation** | Cracks and Pin Holes | Shorts, Low Breakdown Voltage | Temperature Cycling<br>High Temperature Storage<br>High-Voltage Test,<br>Operation Life<br>Visual Inspection (Before Seal) |
| | Non-Uniformity of Film Thickness | Low Breakdown Voltage<br>Increase of Leakage Current in Oxide Film | Same as Above |
| **Mask** | Scratch, Crack, Scar of Photo Mask | Open, Short | Visual Inspection (Before Seal),<br>Electrical Test |
| | Misalignment | Open, Short | Same as Above |
| | Abnormality of Photo-Resist Pattern (Line-Width, Space, Pin Hole) | Degradation of Characteristics Due to Parameter Drift<br>Open, Short | Same as Above |
| **Etching** | Improper Elimination of Oxide Film | Open, Short, Intermittent Failure | Visual Inspection (Before Seal)<br>Electrical Test<br>Operation Life |
| | Under-Cut | Short or Open in Metallization | Visual Inspection (Before Seal)<br>Electrical Test |

**Failure Mechanisms of Integrated Circuits** (Continued)

| Process Step Affecting Reliability | Failure Mechanism | Failure Mode | Failure Detection Method |
|---|---|---|---|
| **Etching** | Spotting (Smear)<br>Inhomogeneous Etching | Latent Short | Visual Inspection (Before Seal)<br>Temperature Cycle,<br>High Temperature Storage<br>Operation Life |
| | Contamination (Photo Resist, Residue of Chemical Substance) | Low Breakdown Voltage<br>Increase of Leak Current | Same as Above<br>Reverse Bias |
| **Diffusion** | Improper Control of Doping Profile | Performance Degradation Caused by Instability and Fault | High Temperature Storage<br>Temperature Cycling<br>Operation Life<br>Electrical Test |
| **Metallization** | Scratched and Smeared Metallization (Caused During Handling) | Open and Short | Visual Inspection (Before Seal)<br>Temperature Cycling<br>Operation Life |
| | Thin Metallization Due to Insufficient Deposition or Oxide Film Step | Open or High Impedance Internal Connection | Electrical Test<br>Operation Life<br>Temperature Cycle |
| | Oxid Film Contamination<br>Material Incompatibility | Open Metallization Caused by Poor Adhesion | High Temperature Storage<br>Temperature Cycling<br>Operation Life Test |
| | Corrosion (Residue of Chemical Substance) | Open Metallization | Visual Inspection (Before Seal),<br>High Temperature Storage<br>Temperature Cycle,<br>Operation Life |
| | Displacement<br>Contaminated Contact | High Contact Resistance, Open | Visual Inspection (Before Seal),<br>Electrical Test, High Temperature Storage<br>Temperature Cycle,<br>Operation Life |
| | Improper Temperature and Period for Metallization | Peeled Metallization<br>Poor Adhesion<br>Short | Electrical Test<br>High Temperature Storage<br>Temperature Cycle<br>Operation Life |
| **Die Separation** | Cracks and Chips Caused by Improper Dicing | Open | Visual Inspection (Before Seal)<br>Temperature Cycling<br>Thermal Shock<br>Vibration Shock |

**Failure Mechanisms of Integrated Circuits** (Continued)

| Process Step Affecting Reliability | Failure Mechanism | Failure Mode | Failure Detection Method |
|---|---|---|---|
| **Die Bonding** | Void Between Header and Die | Degradation Due to Overheating | Radiography, Operation Life<br>Constant Acceleration<br>Shock, Vibration |
| | Over-Spreading of Eutectic Solder | Short, Intermittent Short | Visual Inspection (Before Seal), Radiography, Vibration Shock |
| | Poor Bonding of Die to Header | Die Crack and Lifting | Visual Inspection (Before Sealing), Constant Acceleration, Shock, Vibration |
| | Mismatching of Materials | Crack or Peeling of Die | Temperature Cycling<br>High Temperature Storage<br>Constant Acceleration |
| **Wire Bonding** | Poor Bonding Strength | Open Wire, Open, Lifting Vibration Shock | Constant Acceleration |
| | Mismatched Material and Contaminated Bonding Pad | Lead Bond Peeling | Temperature Cycling<br>High Temperature Storage<br>Constant Acceleration<br>Shock, Vibration |
| | Formation of Intermetallic Plague | Open Bonding | High temperature storage, Temperature Cycling. Constant Acceleration Shock, Vibration |
| | Insufficient Bonding Area or Spacing | Open<br>Bonding Short | Operation Life Test, Constant Acceleration, Shock Vibration, Visual Inspection (Before Seal) |
| | Improper Bonding Arrangement | Open, Short | Visual Inspection (Before Seal)<br>Electrical Test |
| | Die Cracks or Chips | Open, Shock | Visual Inspection (Before Seal)<br>High Temperature Storage<br>Temperature Cycling<br>Constant Acceleration, Shock Vibration |
| | Excessive Loop or Sag in Wire | Short to the Case, Substrate or other Parts of the Leads | Visual Inspection (Before Seal), Radiography, Constant Acceleration, Vibration |
| | Crack, Scratch, or Scar on Lead | Wire Disconnection Causing Open, Short | Visual Inspection (Before Seal), Constant Acceleration, Shock Vibration |

**Failure Mechanisms of Integrated Circuits** (Continued)

| Process Step Affecting Reliability | Failure Mechanism | Failure Mode | Failure Detection Method |
|---|---|---|---|
| | Insufficent Elimination of Tail Wire | Short, Intermittent Short | Same as Above<br>Radiography |
| **Sealing** | Incomplete Hermetic Seal | Performance Degradation, Shorts and Opens Caused by Chemical Corrosion and Moisture | Fine Leak, Gross Leak |
| | Bad Atmosphere in Package | Performance Degradation Due to Inversion Layer Channeling | Operation Life<br>Reverse Bias, High Temp. Storage, Temperature Cycling |
| | Bending or Breaking of the External Lead | Open | Visual Inspection,<br>Lead Fatique |
| | Crack or Void in Seal Glass | Short or Open in Metallization Due to Leak | Seal, Electrical Test<br>High Temperature Storage<br>Temperature Cycling<br>High Voltage Test |
| | Migration on Seal between Outer Lead and Metal Case | Intermittent Short | Low Voltage Test |
| | Electro-Conducting Particles Floating in Package | Same as Above | Constant Acceleration,<br>Vibration<br>Radiography |
| | Mismarking | Inoperable | Electrical Test |

**4) Equipment**

A listing of important equipment used for failure analysis is shown below in tabular from, SEC's committment to comprehensive analysis of all relevant rejects necessarily implies a usefulness for key analytical instruments. Constant efforts are made to both use and modify equipment to meet specialized investigations. However, only standard equipment, not a listing of hybrids (for confidential development purposes), is listed below.

**Equipment for failure analysis**

| Category | Item | Application |
|---|---|---|
| **Visual** | 1. Stereo Microscope | Use for visual inspection |
| | 2. SEM (Scanning Electron Microscope) | Use to inspect the surface or cross-section of a device at high magnification. Through voltage contrast techniques, it is possible to analyze voltage levels while the device is operating |
| | 3. Infrared Microscope | Using the infrared radiation emitted by a functioning device, a thermal map can be produced. |
| | 4. X-Ray | Use to inspect the bonding wire of encapsulated devices. |
| | 5. Metallugical Microscope | Inspect interconnects, contacts, bonds |
| | 6. Radiographic Scope | Inspect bond wires, die attach |

**Equipment for failure analysis** (Continued)

| Category | Item | Application |
|---|---|---|
| **Elemental Analysis** | 1. Auger Electron Spectrometer (AES) | Used to detect and analyze contamination on the surface of a die |
| | 2. EDX Spectrometer | Used with SEM to analyze elements present in a device. This is done by measuring the energy distribution of X-rays produced by the interaction of primary electrons and the sample. |
| | 3. Differential Interference Microscope | Used for elemental analysis |
| | 4. Electron Probe Micro Analyzer (EPMA) | Used for current analysis |
| | 5. Ion Micro Mass Analyzer (IMMA) | Spectral analysis of chemical constituents |
| | 6. Surface Eveness Micrometer | Measures planarity |
| | 7. Differential Scanning Calorimeter (DSC) | Permits the analysis of glasses and polymers-especially encapsulation resins-through the measurement of reaction heat |
| | 8. Thermo Gravimetric Analyser | Used to determine the thermal stability of polymers and glasses by measuring variations in mass with temperature. |
| | 9. Plasma Etcher | Used to open devices encapsulated in epoxy resins, to remove silicon nitride, and to remove thin oxide films |
| | 10. Transmission Electron Microscope (TEM) | Used for elemental analysis and high resolution surface on spectron |
| | 11. Surface Tunneling Microscope (STM) | Used for elemental analysis |
| | 12. Electron Spectrometry for Chemical Analysis (ESCA) | Used for elemental analysis |
| | 13. Secondary Ion Mass Spectroscope | Used for elemental analysis |
| **Decapsulation System** | 1. Grinding Machines<br>2. Angle Lapping<br>3. Evaporation<br>4. Diamond Cutter (Cross Section Cutter)<br>5. Molding System<br>6. Jet-Etching System<br>7. Etching Solution<br>8. Hot Plates<br>9. Ventilation Hoods | Used to decapsulate devices,<br>to cut the cross section of die,<br>to remove a surface layer. |

**Equipment for failure analysis** (Continued)

| Category | Item | Application |
|---|---|---|
| **Electrical Test** | 1. Curve Tracer<br>2. TR, IC, MOS Tester<br>3. ESD Simulator<br>4. LCR Meter<br>5. DC-Analyzer<br>6. Noise Tester<br>7. Logic State Analyzer<br>8. Manipulator Probe Ssytem<br>9. Electron Beam Tester<br>10. Hot Electron Analyzer<br>11. I.R Scope | Used to measure electrical characteristic of devices, to establish the cause of failure. |
| **Stress Test** | 1. Temperature Probe System<br>2. Constant Temperature Oven<br>3. Ovenn for Oper Life Test<br>4. Humidity Oven<br>5. Vibration System | Used to stress or cure the failed devices to identify a failure mechanism. This is a very important tool for analyzing degradation phenomena and intermittent failures. |

**Methods and Equipment for Failure Analysis**

| Item | Contents of Inspection | Equipment for Analysis |
|---|---|---|
| **External Visual Check** | • Condition of Lead, Plating, Soldering, Welding Area<br>• Mark, Date Code<br>• Package damage<br>• Solderability<br>• Sealing | Stereo-Optical-Scope x 40<br>Optical Microscope x 100<br>Helium Leak Detector<br>Gross Leak Detector (Using Fluorocarbon) |
| **Electrical Test** | • DC Parameter, AC Parameter Test<br>• Function Test<br>• Margin Test of Voltage and Temp.<br>• Diode Characteristics between Each Pin<br>• Disconnection, Short Circuit and / or Electrical Characteristic detected by the above Inspection | IC Tester<br>Curve Tracer (HP4145)<br>Oscilloscope<br>DC Power Supply<br>Oscillator (Sine Wave Pulse)<br>Heat-Gun, Cooling Gas Spray<br>Thermo-Spot |
| **Radiography** | • Internal Structure of Device is Checked Non-Destructively | Soft X-Ray |
| **Decapping** | • Internal Structure is observed after decapping | Metal Cutting Scissors, Nippers<br>Cap opener, plastic etcher,<br>Hot plate, Drill, $HNO_3$ |
| **Internal Visual Check** | • Detection of Defective Spot on the Chip Surface<br>• Detection of Discrepancy of Internal Connection (Metallization, Wire Bonding, Etc.)<br>• Electrical Characteristics are Checked by Mechanical Prober<br>• Detection of Hot Spot<br>• Existence of Foreign Material | Optical Microscope<br>Micro-Prober<br>SEM<br>Laser Cutter<br>Infrared Micro Scanner<br>Thermal Plotter<br>Infrared Microscope |
| **Internal Structure Analysis** | • Cross Sectional Analysis of Chips to Observe Diffusion Layer of Oxide Film<br>• Analysis of Metallic Elements<br>• Removing of Over-Coating Glass and Aluminum Metallization | Optical Microscope<br>SEM, MAX, AES, SAM, IMA<br>Spectrometer<br>Micro-Prober |
| **Simulation Test** | • Operational Test on Actual Equipment | Actual Electronic Equipment |

## 4.3 FAILURE MODE EFFECT ANALYSIS (FMEA)

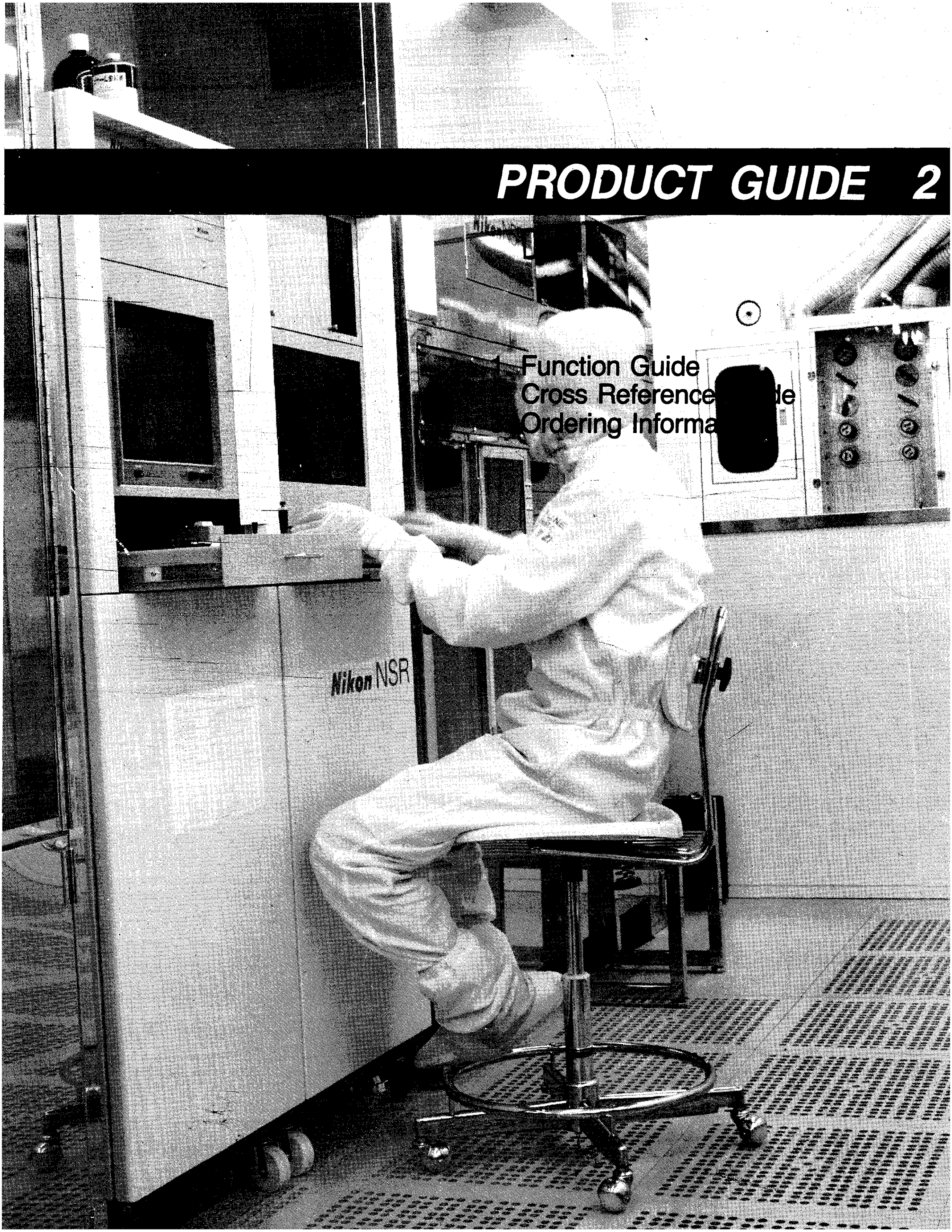
Failure Mode Effect Analysis is a method used for checking if measures are taken against every possible failure in the design, the manufacturing process, the operating method, etc. For this analysis, factors such as design, manufacturing process, packaging, and operating method are divided into small units, and its functions are clearly defined. All possible failure modes are listed for each item, its effect on the product and the cause of each failure is examined. Each item is then evaluated to clarify the corrective actionto be taken.
Table shows an example of FMEA in the manufacturing process of plastic encapsulated MOS LSI. The incident column pertaining to the Evaluation Points show the failure rate; Effectiveness column shows the impact of the effect by the failure of the product, device, or system; and Detectability shows the rate of detection of the failure. These are individually graded on the basis of ten points. The result is then evaluated by multiplying the points. The larger value indicates the importance of the item. A counterplan for each iten is then specified and action taken.

**Manufacturing Process FMEA Example (Plastic Encapsulated Products)**

| Process Name (Process Function) | Failure Mode | Failure Effect | Failure Cause | Counterplan |
|---|---|---|---|---|
| Al metallization | Improper thickness<br>Lack of Al wiring<br>Breakage defect | Electromigration open circuit | Operator's mis-handling, dirt/foreign matter attachment, poor adjustment of equipment | Improvement and adjustment of written working process, dust control of clean room, SEM test in the process |
| Glassivation | Lack of glassivation film, failure film thickness | Increased leak current, improper operation | Dirt/foreign matter attachment, operator's mishandling | Dust control of clean room, improvement and adjustment of written working process |
| Visual Inspection | Scratch, die crack, dirt, spot, residual resist | Open circuit, increased junction leak current | Mishandling of wafer, Misclearning of water | Improvement and adjustment of written working process |
| Assembly Process Die Selection | Die crack | Increased junction leak current, improper operation | Poor adjustment of equipment, operator's mishandling | Corrective action to device control operator, improvement and adjustment of written working process |
| Die Bonding | Die crack<br>Die floating | Open circuit, increased junction leak current, improper operation | Operator's mishandling temperature too low | Corrective action to device control operator, improvement and adjustment of written working process, visual inspection |
| Wire Bonding | Open bonding, improper bonding position, shorted bonding wire | Open circuit, short circuit | Poor bonding strength, operator's mishandling, poor adjustment of equipment, looped bonding wire, shape defact | Improvement and adjustment of written working process, corrective action to device control operator, visual inspection |

**Manufacturing Process FMEA Example (Plastic Encapsulated Products)** *(Continued)*

| Process Name (Process Function) | Failure Mode | Failure Effect | Failure Cause | Counterplan |
|---|---|---|---|---|
| Sealing (Resin) | Open bonding wire, shorted bonding wire, package crack, corrosion | Open circuit, short circuit, defective appearance | Poor adjustment of equipment, insufficient cure | Ditto |
| Lead Surface Treatment (plating) | Poor metal-plating thickness, dirt | Poor soldering, poor contact | Operator's mishandling poor adjustment of equipment, insufficient cleaning | Adjustment of written working process, corrective action to control operator |
| Lead Formation | Abnormal shape, broken lead | Failure inserting in the printed substrate poor operation | Operator's mishandling poor adjustment of equipment | Ditto |
| Marking | Marking error illegible marking | Operating destruction | Operator's mishandling insufficient cure | Improvement and adjustment of written working process |



# PRODUCT GUIDE 2

# 1. FUNCTION GUIDE

## 1.1 Voltage Regulator

### A. 3-Terminal Fixed Positive Voltage Regulator

| Function | Type | Package | Features | Application |
|---|---|---|---|---|
| Very High Output Current (3A) | KA78T05 | TO-220 | Output current in excess of 3A<br>Internal thermal overload protection<br>Internal short circuit current limiting | 5V output voltage |
| | LM323 | TO-3P | | 5V output voltage |
| High Output Current ($I_O$ = 1A) | MC78XX series | TO-220 | Maximum output current 1A<br>External components are minimized<br>Internal protection circuit for output short | 5V, 6V, 8V, 9V, 10V, 11V, 12V, 15V, 18V and 24V fixed output voltage |
| | KA340TXX series | TO-220 | Output current in excess of 1A<br>Very low line regulation: 0.01%<br>Very low load regulation: 0.3% | 5V, 6V, 8V, 9V, 10V, 11V, 12V, 15V, 18V and 24V fixed output voltage |
| Medium Output Current ($I_O$ = 500mA) | MC78MXX series | TO-220 | Maximum output current 500mA<br>External components are minimized<br>Internal protection circuit for output short | 5V, 6V, 8V, 10V, 12V, 15V, 18V, 20V and 24V fixed output voltage |
| Low Output Current ($I_O$ = 100mA) | MC78LXXAC series | TO-92<br>8-SOP | Output current in excess of 100mA<br>External components minimized<br>Internal protection circuit for output short | 5V, 6V, 8V, 9V, 10V, 12V, 15V, 18V and 24V fixed output voltage |

### B. 3-Terminal Fixed Negative Voltage Regulator

| Function | Type | Package | Features | Application |
|---|---|---|---|---|
| High Output Current ($I_O$ = 1A) | MC79XX series | TO-220 | Output current in excess of 1A<br>Internal thermal overload protection<br>Internal short circuit current limiting | −2V, −5V, −6V, −8V, −9V, −10V, −12V, −15V, −18V and −24V fixed output |
| Medium Output Current ($I_O$ = 500mA) | MC79MXX series | TO-220 | Output current in excess of 500mA<br>Internal thermal over load protection<br>Internal short circuit current limiting | −5V, −6V, −8V, −10V, −12V, −15V, −18V and −24V fixed output voltage |
| Low Output Current ($I_O$ = 100mA) | MC79L05AC | TO-92 | Output current in excess of 100mA<br>Internal short circuit current limiting<br>External components minimized | −5V output voltage |

## C. Adjustable Voltage Regulator

| Function | Type | Package | Features | Application |
|---|---|---|---|---|
| Precision Voltage Regulator | LM723 | 14 DIP<br>14 SOP | Positive or negative supply operation<br>Series, shunt, switching or floating operation<br>0.01% line and load regulation<br>Output current up to 150mA without external pass transistor | Output voltage adjustable from 2 to 37V |
| Adjustable Regulator | LM317 | TO-220 | Output current in excess of 1.5A<br>Positive output adjustable from 1.2V to 37V<br>Internal short circuit current limiting | Floating operation for high-voltage operation |
| | KA337 | TO-220 | Output current in excess of 1.5A<br>Negative output adjustable from 1.2V to 37V<br>Internal short circuit current limiting | Floating operation for high-voltage operation |
| | KA350 | TO-220 | Output current in excess of 3A<br>Positive output adjustable from 1.2V to 33V<br>Internal short circuit current limiting | Floating operation for high-voltage operation |
| | †KA317L | TO-92 | Output current in excess of 100mA<br>Positive output adjustable from 1.2V to 37V<br>Internal short circuit current limiting | Floating operation for high-voltage operation |
| | †KA317M | TO-220 | Output current in excess of 500mA<br>Positive output adjustable from 1.2V to 37V<br>Internal short circuit current limiting | Floating operation for high-voltage operation |
| | †KA337L | TO-92 | Output current in excess of 100mA<br>Negative output adjustable from −1.2V to −37V<br>Internal short circuit current limiting | Floating operation for high-voltage operation |

## 1.2 PWM Controller

| Function | Type | Package | Features | Application |
|---|---|---|---|---|
| Voltage Mode PWM Control IC | KA3524 | 16 DIP | Complete PWM power control circuitry<br>Internal short circuit current limiting<br>Complementary output<br>Output current up to 100mA | Flyback converter<br>Voltage inverter<br>Voltage step-down<br>Voltage step-up |
| | KA7500 | 16 DIP | Complete PWM power control circuitry<br>Dead-time control<br>Complementary output<br>Output current up to 200mA | Voltage inverter<br>Voltage step-down<br>Voltage step-up |
| | †KA3525A | 16 DIP | Adjustable dead-time control<br>Internal soft-start<br>Separate oscillator sync terminal<br>Pulse-by-pulse shutdown<br>Input undervoltage lockout with hysteresis | Flyback coverter<br>Voltage inverter<br>Voltage step-down<br>Voltage step-up |
| | ††KA3526B | 18 DIP | Programmable dead time<br>Under voltage lockout<br>Programmable soft-start<br>Digital current limiting | Push-pull converter<br>Voltage inverter<br>Voltage step-down<br>Voltage step-up |
| Current Mode PWM Control IC | †KA3842 | 8 DIP<br>14 SOP | Automatic feed forward compensation<br>Pulse-by-pulse current limiting<br>Undervoltage lockout with hysteresis<br>Double pulse suppression<br>High current totem pole output | Flyback converter<br>Voltage inverter<br>Voltage step-down<br>Voltage step-up |
| | ††KA3846 | 16 DIP | Programmable pulse-by-pulse<br>Current limiting<br>Double pulse suppression<br>Under voltage lockout<br>Soft-start capability<br>Automatic feed forward compensation | Push-pull converter<br>Voltage inverter<br>Voltage step-down<br>Voltage step-up |
| DC to DC Converter | †KA34063A<br>KA34063 | 8 DIP | Low standby current<br>Current Limiting<br>Output switch current of 1.5A<br>Output voltage adjustable from 1.25 to 40V | Voltage inverter<br>Voltage step-down<br>Voltage step-up |

## 1.3 Voltage Reference

| Function | Type | Package | Features | Application |
|---|---|---|---|---|
| Adjustable Reference | KA431 | TO-92<br>8 DIP<br>8 SOP | Programmable output voltage from $V_{ref}$ to 36V<br>Voltage reference tolerance: ±1.0%<br>Low output noise voltage | Switching regulator<br>Constant current source<br>Constant current sink |
| Reference | KA336 | TO-92 | Adjustable 4V to 6V<br>Low temperature coefficient<br>0.6Ω dynamic impedance<br>Fast turn-on | Adjustable shunt regulator<br>Precision power regulator |

## 1.4 Operational Amplifier

| Function | Type | Package | Features | Application |
|---|---|---|---|---|
| OP AMP | LM741C/I/E | 8 DIP<br>8 SOP | Internal frequency compensation<br>Short circuit protection | Comparator, DC amp,<br>Multivibrator, Summing amp,<br>Integrator or differentiator,<br>Narrow band or BPF |
| | LM301A | 8 DIP<br>8 SOP | Short circuit protection<br>External frequency compensation | Variable capacitance<br>Multiplier<br>Sine wave oscillator |
| | KF351 | 8 DIP<br>8 SOP | Internally trimmed offset<br>Voltage: 10mV<br>Low input bias current<br>High input impedance: $10^{12}\Omega$<br>High slew rate: 13V/μs<br>Wide gain bandwidth: 4MHz | Hi-Zin inverting amp<br>Ultra low duty cycle<br>Pulse generator<br>Sample and Hold |
| Dual<br>OP AMP | MC4558C/I | 8 DIP<br>8 SOP<br>9 SIP | Internal frequency compensation<br>Low noise operation | Phone pre-amplifier<br>Tape playback amplifier |
| | MC1458C/I | 8 DIP<br>8 SOP<br>9 SIP | Internal frequency compensation<br>Short circuit protection | Filter<br>Schmitt trigger<br>Comparator Multivibrator |
| | LM358/A<br>LM258/A<br>LM2904 | 8 DIP<br>8 SOP<br>9 SIP | Internal frequency compensation<br>for unit gain<br>Large DC voltage gain<br>Wide power supply range<br>Single supply operation | DC summing amplifier<br>Power amplification<br>RC active bandpass filter<br>Compatible with all forms<br>of logic. |
| | KA5532 | 8 DIP | Low input noise voltage<br>High gain bandwidth: 10MHz<br>High slew rate: 9V/μs<br>Large supply voltage range:<br>~ ±3 to ±20V | DC Amp<br>Telephone channel amplifiers<br>Audio equipment |
| | KA9256 | 10 SIP H/S | Internal current limiting: $I_{SC}=350mA$<br>Internal frequency compensation<br>Minimal cross over distortion | High power amplifier<br>CD motor driver |
| | KF442 | 8 DIP<br>8 SOP<br>9 SIP | Low supply current: 500μA (max)<br>Low input bias current<br>High input impedance<br>High gain bandwidth: 1MHz<br>High slew rate: 1V/μs | Active filter<br>DC summing amplifier<br>Oscillator |
| | ††KS272 | 8 DIP | Wide range of supply voltage<br>: 3V ~ 16V<br>Common mode input voltage<br>including the negative rail | Battery-powered application<br>Active filter<br>Signal buffer |
| | †KF353 | 8 DIP | Low bias current<br>Wide band width<br>High input impedance: 45MHz<br>High slew rate: 13V/μs | Sample and hold<br>D/A converter integrator |

## OPERATIONAL AMPLIFIER (Continued)

| Function | Type | Package | Features | Application |
|---|---|---|---|---|
| Quad OP AMP | †KA420 | 14 DIP | Low supply current (Max: 600$\mu$A)<br>Single supply: DC +5V ~ +30V<br>Dual supply: DC ±2.5V ~ ±30V<br>Low offset voltage | Battery-powered application<br>Energy-conserving application<br>DC amp |
| | LM324/A<br>LM224/A<br>LM2902 | 14 DIP<br>14 SOP | Internal frequency compensation<br>Wide supply voltage range<br>Single supply: DC 3V ~ 32V<br>Dual supply: DC ±1.5V ~ ±16V | Audio power booster<br>DC amp, Multivibrator<br>Switch, Comparator<br>Schmitt trigger |
| | LM348<br>LM248 | 14 DIP<br>14 SOP | Each amplifier is functionally equivalent to the LM741C<br>Pin compatible with LM324<br>Short circuit protection | Comparator with hysteresis<br>Voltage reference |
| | MC3403<br>MC3303 | 14 DIP<br>14 SOP | Class AB output stage for minimal crossover distortion<br>Single or split supply operation<br>Internal frequency compensation | Comparator with hysteresis<br>BI-Quad filter |
| | KF347 | 14 DIP<br>14 SOP | Low bias current<br>Wide gain bandwidth: 4MHz<br>High slew rate: 13V/$\mu$s<br>High input impedance | D/A converter<br>Sample and hold<br>Integrator |
| | ††KS274 | 14 DIP | Wide range of supply voltage : 3V ~ 16V<br>Single supply operation<br>Very low input bias current, Typ 1pA | Battery-powered application<br>Energy-conserving application |

## 1.5 Voltage Comparator

| Function | Type | Package | Features | Application |
|---|---|---|---|---|
| Single Comparator | LM311 | 8 DIP<br>8 SOP | Operates from single 5V supply<br>Maximum input current: 250mA<br>Maximum offset current: 50nA<br>Differential input voltage range: ±30V | Multivibrator output is compatible with DTL and as well as MOS circuits<br>voltage controlled oscillator |
| | KA710C/I | 14 DIP | Low offset and thermal drift<br>Compatible with practically all types of integrated logic | Line receiver<br>A/D converter<br>Memory sense amplifier |
| Dual Comparator | LM393/A<br>LM2903<br>LM293/A | 8 DIP<br>8 SOP<br>9 SIP | High precision comparators<br>Reduced $V_{OS}$ drift over temperature<br>Eliminates need for dual supply<br>Allows sensing near ground<br>Compatible with all form of logic<br>Power drain suitable for battery operation<br>Low input biasing current: 25nA<br>Low output saturation voltage 250mA | Output voltage compatible with TTL, DTL, ECL and CMOS logic system<br>Basic comparator<br>Pulse comparator<br>MOS clock driver |
| | LM319<br>LM219 | 14 DIP | Two independent comparators<br>Operates from a single 5V<br>High common mode slew rate | Relay driver<br>Window detector |
| | KA711C/I | 14 DIP<br>14 SOP | Separate differential input and single output<br>Strobing each side | Sense amplifier for core memory<br>Dual comparator with ORed output<br>Double-ended limit detector |
| Quad Comparator | LM339/A<br>LM2901<br>LM239/A<br>LM3302 | 14 DIP<br>14 SOP | Wide single supply voltage range or dual supplies<br>Very low supply current drain (0.8mA)-independent of supply voltage (2mW/Comparator at +5V DC)<br>Low input biasing current: 25nA<br>Input common-mode voltage range included GND<br>Low output saturation voltage 250mV at 4mA | Compatible with all forms of logic<br>Bi-stable multivibrator<br>One-shot multivibrator<br>Time delay generatory<br>Square wave oscillator<br>Pulse generator<br>Limit comparator<br>Crystal controlled oscillator |

## 1.6 Timer

| Function | Type | Package | Features | Application |
|---|---|---|---|---|
| Single Timer | NE555 | 8 DIP<br>8 SOP | Maximum operating frequency: 500KHz<br>Adjustable duty cycle | Precision timing<br>Pulse generator |
| | KS555<br>KS555H | 8 DIP<br>8 SOP | Low power consumption by using CMOS process<br>High speed operation<br>Wide operation supply voltage: 2 to 18 volts<br>Pin compatible with NE555 | Precision timing<br>Pulse generator |
| Dual Timer | NE556 | 14 DIP<br>14 SOP | TTL Compatible<br>Dual NE555 | Time delay generation |
| | KS556 | 14 DIP<br>14 SOP | Low power consumption by using CMOS process<br>Pin compatible with NE556 | Time delay generation |
| Quad Timer | NE558 | 16 DIP | Wide supply voltage range: 4.5 to 16V<br>100mA output current per section<br>Time period equal RC | Quad monostable<br>Sequential timing<br>Precision timing |

## 1.7 Miscellaneous

| Function | Type | Package | Features | Application |
|---|---|---|---|---|
| Voltage to Frequency Converter | †KA331 | 8 DIP | V-F Conversion<br>F-V Conversion<br>Wide range of full scale frequency: 1Hz to 100KHz | Light intensity to frequency converter<br>Temperature to frequency converter |
| Earth Leakage Detector | KA2803 | 8 DIP | Low power consumption<br>Built-in voltage regulator<br>1mA output current pulse to trigger SCR's | Earth leakage detector |
| Zero Voltage Switch | KA2804 | 8 DIP | Very few external compontents<br>Reference voltage output<br>Supply voltage control | On-Off temperature control<br>Time proportional temperature control |
| Earth Leakage Detector | KA2807 | 8 DIP | Full advantage of the UL943<br>Direct interface to SCR<br>Trip time in normal | Earth leakage detector |

# 2. CROSS REFERENCE GUIDE

## 2.1 Voltage Regulator

### A. 3-Terminal Fixed Positive Voltage Regulator

| Description | SAMSUNG | MOTOROLA | FAIRCHILD | NEC | MATSUSHITA | Package |
|---|---|---|---|---|---|---|
| KA78TXX<br>Series<br>($I_O = 3A$) | KA78T05 | MC78T05 | | | | TO-220<br>TO-3P |
| | ††KA78T06 | MC78T06 | | | | |
| | ††KA78T08 | MC78T08 | | | | |
| | ††KA78T12 | MC78T12 | | | | |
| | ††KA78T15 | MC78T15 | | | | |
| | ††KA78T18 | MC78T18 | | | | |
| | ††KA78T24 | MC78T24 | | | | |
| LM323 ($I_O = 3A$) | LM323 | LM323 | | | | TO-3P |
| MC78XXAC/C<br>Series<br>($I_O = 1A$) | MC7805AC/C | MC7805AC/C | μA7805 | μPC7805 | AN7805 | TO-220 |
| | MC7852C | | | | | |
| | MC7806AC/C | MC7806AC/C | μA7806 | | AN7806 | |
| | MC7808AC/C | MC7808AC/C | μA7808 | μPC7808 | AN7808 | |
| | MC7885AC/C | | μA7885 | | | |
| | MC7809AC/C | | | | | |
| | MC7810AC/C | | | | | |
| | MC7811AC/C | | | | | |
| | MC7812AC/C | MC7812AC/C | μA7812 | μPC7812 | AN7812 | |
| | MC7815AC/C | MC7815AC/C | μA7815 | μPC7815 | AN7815 | |
| | MC7818AC/C | MC7818AC/C | μA7818 | μPC7818 | AN7818 | |
| | MC7824AC/C | MC7824AC/C | μA7824 | μPC7824 | AN7824 | |
| KA340XX<br>Series<br>($I_O = 1A$) | †KA340T05 | LM340-5.0 | | | | TO-220 |
| | †KA340T06 | LM340-6.0 | | | | |
| | †KA340T08 | LM340-8.0 | | | | |
| | †KA340T09 | | | | | |
| | †KA340T10 | | | | | |
| | †KA340T11 | | | | | |
| | †KA340T12 | LM340-12 | | | | |
| | †KA340T15 | LM340-15 | | | | |
| | †KA340T18 | LM340-18 | | | | |
| | †KA340T24 | LM340-24 | | | | |
| MC78MXXC<br>Series<br>($I_O = 0.5A$) | MC78M05C | MC78M05C | μA78M05C | μPC78M05 | AN78M05 | TO-220 |
| | MC78M06C | MC78M06C | μA78M06C | | AN78M06 | |
| | MC78M08C | MC78M08C | μA78M08C | μPC78M08 | AN78M08 | |
| | MC78M10C | | | μPC78M10 | AN78M10 | |
| | MC78M12C | MC78M12C | μA78M12C | μPC78M12 | AN78M12 | |
| | MC78M15C | MC78M15C | μA78M15C | μPC78M15 | AN78M15 | |
| | MC78M18C | MC78M18C | | μPC78M18 | AN78M18 | |
| | MC78M20C | MC78M20C | μA78M20C | μPC78M20 | AN78M20 | |
| | MC78M24C | MC78M24C | μA78M24C | μPC78M24 | AN78M24 | |
| MC78LXXAC<br>($I_O = 0.1A$) | MC78L26AC | | | | | TO-92<br>8 SOP |
| | MC78L05AC | MC78L05AC | μA78L05AC | | | |
| | MC78L62AC | | μA78L62AC | | | |
| | MC78L08AC | MC78L08AC | | | | |
| | MC78L82AC | | μA78L82AC | | | |
| | MC78L10AC | | μA78L10AC | | | |
| | MC78L09AC | | μA78L09AC | | | |
| | MC78L12AC | MC78L12AC | μA78L12AC | | | |
| | MC78L15AC | MC78L15AC | μA78L15AC | | | |
| | MC78L18AC | MC78L18AC | | | | |
| | MC78L24AC | MC78L24AC | | | | |

† New Product
†† Under Development

### B. 3-Terminal Fixed Negative Voltage Regulator

| Description | SAMSUNG | MOTOROLA | FAIRCHILD | NEC | MATSUSHITA | Package |
|---|---|---|---|---|---|---|
| MC79XXC Series ($I_O = 1A$) | MC7902C | | | | | TO-220 |
| | MC7905C | MC7905C | μA7905 | μPC7905 | AN7905 | |
| | MC7906C | MC7906C | | | AN7906 | |
| | MC7908C | MC7908C | μA7908 | μPC7908 | AN7908 | |
| | MC7912C | MC7912C | μA7912 | μPC7912 | AN7912 | |
| | MC7915C | MC7915C | μA7915 | μPC7915 | AN7915 | |
| | MC7918C | MC7918C | | μPC7918 | AN7918 | |
| | MC7924C | MC7924C | | μPC7924 | AN7924 | |
| MC79MXXC ($I_O = 0.5A$) | MC79M05C | MC79M05C | μA79M05 | | | TO-220 |
| | MC79M06C | | | | | |
| | MC79M08C | | μA79M08 | | | |
| | MC79M12C | MC79M12 | μA79M12 | | | |
| | MC79M15C | MC79M15 | μA79M15 | | | |
| | MC79M18C | | | | | |
| | MC79M24C | | | | | |
| MC79LXXAC ($I_O = 0.1A$) | MC79L05AC | MC79L05AC | | | | TO-92 |
| | ††MC79L12AC | MC79L12AC | | | | |
| | ††MC79L15AC | MC79L15AC | | | | |
| | ††MC79L18AC | MC79L18AC | | | | |
| | ††MC79L24AC | MC79L24AC | | | | |

### C. Precision Voltage Regulator

| Description | SAMSUNG | MOTOROLA | FAIRCHILD | NEC | MATSUSHITA | Package |
|---|---|---|---|---|---|---|
| Adjustable Voltage | LM723 | MC1723 | μA723 | LM723 | | 14 DIP/14 SOP |
| | LM317 | LM317 | μA317 | LM317 | | TO-220 |
| | KA337 | LM337 | | LM337 | | TO-220 |
| 33V Regulator | KA33V | | | | μPC574 | TO-92 |
| Adjustable Voltage | KA350 | LM350 | μA350 | LM350 | | TO-220 |
| | †KA317L | LM317L | | | | TO-92 |
| | †KA317M | LM317M | | LM317M | | TO-220 |
| | †KA337L | LM337L | | | | TO-92 |

## 2.2 PWM Controller

| Description | SAMSUNG | MOTOROLA | FAIRCHILD | SGS | UNITRODE | Package |
|---|---|---|---|---|---|---|
| DC to DC Converter | †KA34063 | MC34063 | | | | 8 DIP |
| | †KA34063A | MC34063A | | | | |
| PWM Controller IC | KA3524 | SG3524 | SG3524 | SG3524 | UC3524 | 16 DIP |
| | KA7500 | TL494 | μA494 | | UC494AC | 16 DIP |
| | †KA3842 | UC3842A | | UC3842 | UC3842 | 8 DIP/14 SOP |
| | †KA3525A | SG3525A | | SG3525A | UC3525A | 16 DIP |
| | ††KA3526B | SG3526 | | SG3526B | UC3526A | 18 DIP |
| | ††KA3846 | | | UC3846 | UC3846 | 16 DIP |

## 2.3 Voltage Reference

| Description | | SAMSUNG | MOTOROLA | FAIRCHILD | N/S | TI | Package |
|---|---|---|---|---|---|---|---|
| Adjustable Reference (2.5V ~ 36V) | | KA431 | TL431 | μA431 | | TL431 | TO-92<br>8 DIP<br>8 SOP |
| Reference | 5V | KA336 | | | LM336 | | TO-92 |
| | 2.5V | KA336 | | | LM336 | | TO-92 |

## 2.4 Operational Amplifier

| Description | SAMSUNG | MOTOROLA | NATIONAL | FAIRCHILD | JRC | Others |
|---|---|---|---|---|---|---|
| Single OP Amp | LM741 | MC1741 | LM741 | μA741 | NJM741 | μPC301A |
| | KA301 | LM301 | LM301 | μA301 | | |
| | KF351 | LF351 | LF351 | | | TL081 |
| Dual OP Amp | KA5532 | | | | NJM5532 | NE5532, RC5332 |
| | LM358/A | LM358/A | LM358/A | | NJM358 | TA75358 |
| | LM258/A | LM258 | LM258/A | | | |
| | LM2904 | LM2904 | LM2904 | | NJM2904 | |
| | MC1458 | MC1458 | LM1458 | μA1458 | NJM1458 | |
| | MC4558 | MC4558 | | μA4558 | NJM4558 | BA4558 |
| | KA9256 | | | | | TA7256 |
| | †KF353 | LF353 | LF353 | NJM353 | | TL082 |
| | KF442 | | LF442 | | | |
| | KS272 | | | | | TLC272, ICL7621 |
| Quad OP Amp | †KA420 | | | | | OP420 |
| | LM324/A | LM324/A | LM324/A | μA324 | NJM324 | TA75324 |
| | LM224/A | LM224 | LM224/A | μA224 | | CA224 |
| | LM2902 | LM2902 | LM2902 | μA2902 | NJM2902 | μPC451 |
| | LM348 | LM348 | LM348 | μA348 | | |
| | LM248 | LM248 | LM248 | μA248 | | |
| | MC3403 | LM3403 | | μA3403 | NJM3403 | μPC3403 |
| | MC3303 | MC3303 | | μA3303 | | μPC452 |
| | KF347 | LF347 | LF347 | | | TL084 |
| | KS274 | | | | | TLC274, ICL7641 |

## 2.5 Voltage Comparator

| Description | SAMSUNG | MOTOROLA | NATIONAL | FAIRCHILD | JRC | Others |
|---|---|---|---|---|---|---|
| Single Comparator | LM311 | LM311 | LM311 | LM311 | NJM311 | μPC311 |
| | KA710C | MC710C | LM710C | μA710C | | MB4001 |
| Dual Comparator | LM393/A | LM393/A | LM393/A | μA393 | | TA75393 |
| | LM2903 | LM2903 | LM2903 | | NJM2903 | μPC277 |
| | LM293 | LM293 | LM293 | | | |
| | KA319 | | LM319 | | NJM319 | |
| | KA219 | | LM219 | | | |
| | KA711C | | LM711C | μA711C | | |
| Quad Comparator | LM339/A | LM339/A | LM339/A | μA339 | | TA75339 |
| | LM2901 | LM2901 | LM2901 | μA2901 | NJM2901 | μPC177 |
| | LM239 | LM239 | LM239 | μA239 | | CA239 |
| | LM3302 | | LM3302 | μA3302 | | CA3302 |

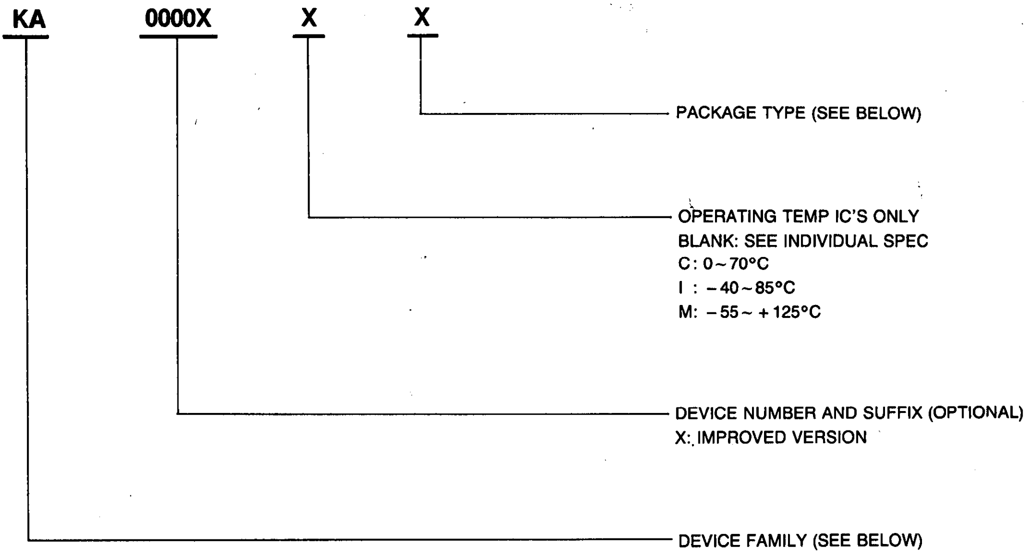
## 2.6 Timer

| Function | SAMSUNG | MOTOROLA | NATIONAL | SIGNETICS | TI | Others |
|---|---|---|---|---|---|---|
| Single Timer | NE555<br>KS555<br>KS5357 | MC1455 | LM555 | NE555 | TA75555<br>TLC555 | ICM7555 |
| Dual Timer | NE556<br>KS556 | | LM556 | NE556 | NE555<br>TLC556 | ICM7556 |
| Quad Timer | NE558 | | | NE558 | | |

## 2.7 Miscellaneous ICs

| Function | SAMSUNG | TOSHIBA | NATIONAL | MATSUSHITA | NEC | Others |
|---|---|---|---|---|---|---|
| Toy Radio Control Actuator | KA2303 | | | | | 3 Function |
| | KA2304 | | | | | 2 Function |
| | †KA2309 | TA7657D | | | Turbo + | 7 Function (RX) |
| | †KA2310 | TA7330 | | | Turbo + | 7 Function (TX) |
| DC Motor Speed Controller | KA2401 | | | | $\mu$PC1470H | |
| | KA2402 | | | AN6612 | | *LA5521D |
| | KA2404 | | | AN6610 | | $\mu$PC1470H |
| | †KA2407 | | | *AN6651 | | |
| Earth Leakage Detector | KA2803 | | LM1851 | | | *M54123 |
| Earth Leakage Detector | KA2807 | | LM1851 | | | |
| Zero Voltage SW | KA2804 | | | | $\mu$PC1701C | |
| FDD Read AMP | KA6201 | | | | | *HA16631P |
| Smoke Detector | KS3502 | | | | | S566 |
| Conventional Timer | KS8701 | TD6347S | | | | |
| Flasher Controller | KA8702 | TA8027P | | | | UAA1041 |
| V/F Converter | KA331 | | LM331 | | | |

## 3. ORDERING INFORMATION



KA 0000X X X

PACKAGE TYPE (SEE BELOW)

OPERATING TEMP IC'S ONLY
BLANK: SEE INDIVIDUAL SPEC
C: 0~70°C
I : −40~85°C
M: −55~ +125°C

DEVICE NUMBER AND SUFFIX (OPTIONAL)
X: IMPROVED VERSION

DEVICE FAMILY (SEE BELOW)

### DEVICE FAMILY

**TRANSISTOR / FET**

| | |
|---|---|
| DKS | DALINGTON TR |
| • IRF | MOS POWER |
| • IRFA | MOS POWER, TO-126 |
| • IRFP | MOS POWER, TO-3P |
| • KSA | PNP TR |
| KSB | PNP TR |
| KSC | NPN TR |
| KSD | NPN TR |
| • MMBT | TR, SOT-23 |
| • MMBTA | TR, SOT-23 |
| • MMBTH | TR, SOT-23 |
| • MPS | TR, SOT-23 |
| • MPSA | TR, TO-92 |
| • MPSH | TR, TO-92 |
| • PN | TR, TO-92 |
| SSH | MOS POWER, TO-3P |
| SSM | MOS POWER, TO-3 |
| SSP | MOS POWER, TO-220 |
| • TIP | BIPOLAR TR |
| • 2N | TR |

**INTEGRATED CIRCUIT**

| | |
|---|---|
| KA | LINEAR IC |
| KF | J-FET OP AMP |
| KG | GATE ARRAY |
| KS | CMOS IC |
| KT | TELECOM |
| • LM | NATIONAL |
| • MC | MOTOROLA |
| • NE | SIGNETICS |
| SA | LINEAR ARRAY |
| SD | H.D AND LINEAR ARRAY |
| KSV | A/D-D/A CONVERTER |
| KAD | A/D CONVERTER |
| KDA | D/A CONVERTER |

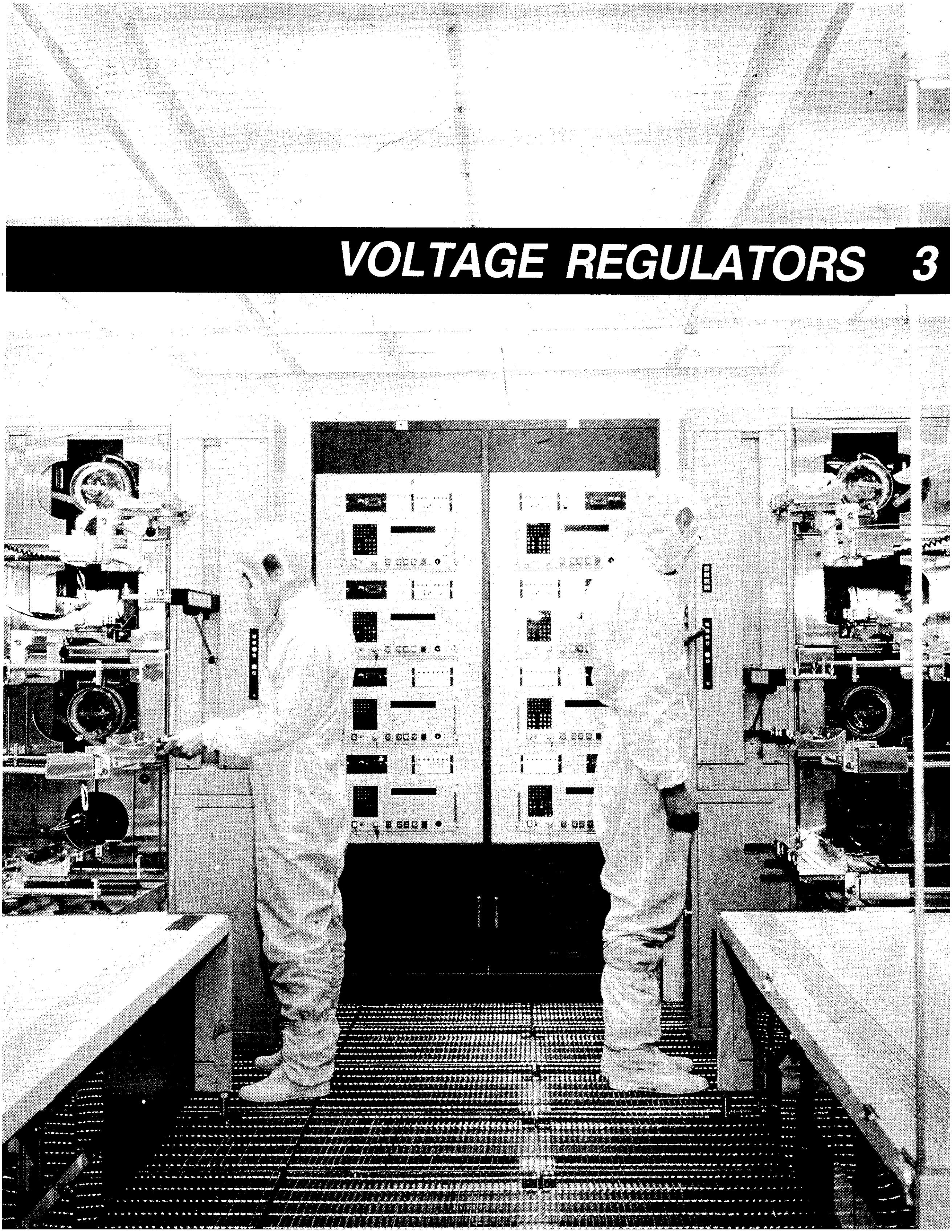
### PACKAGE TYPE

**IC'S ONLY**

| | |
|---|---|
| D | SOP |
| DT | D-PACK |
| J | CERAMIC |
| K | TO-3P |
| L | LCCC |
| N | PLASTIC |
| PL | PLCC |
| R | TO-126 |
| T | TO-220 |
| Z | TO-92 |
| V | TO-92L |
| W | ZIP |
| S | SIP |
| G | BARE CHIP |
| E | SSM |

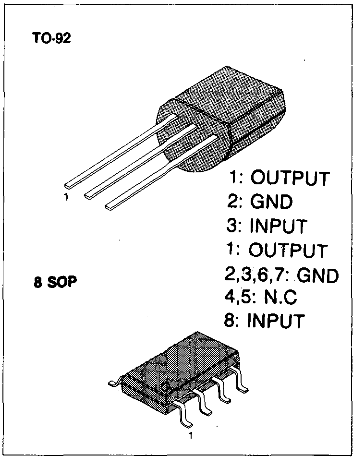
• NOTE: Direct-Replacement parts for products initiated by other manufacturers.

# VOLTAGE REGULATORS 3



## 3-TERMINAL POSITIVE VOLTAGE REGULATORS

These regulators employ internal current-limiting and thermal-shutdown, making them essentially indestructible. If adequate heat sinking is provided, they can deliver up to 100mA output current. They are intended as fixed voltage regulators in a wide range of applications including local (on-card) regulation for elimination of noise and distribution problems associated with single-point regulation. In addition, they can be used with power pass elements to make high-current voltage regulators. The MC78LXXAC used as a Zener diode/resistor combination replacement, offers an effective output impedance improvement of typically two orders of magnitude, along with lower quiescent current and lower noise.



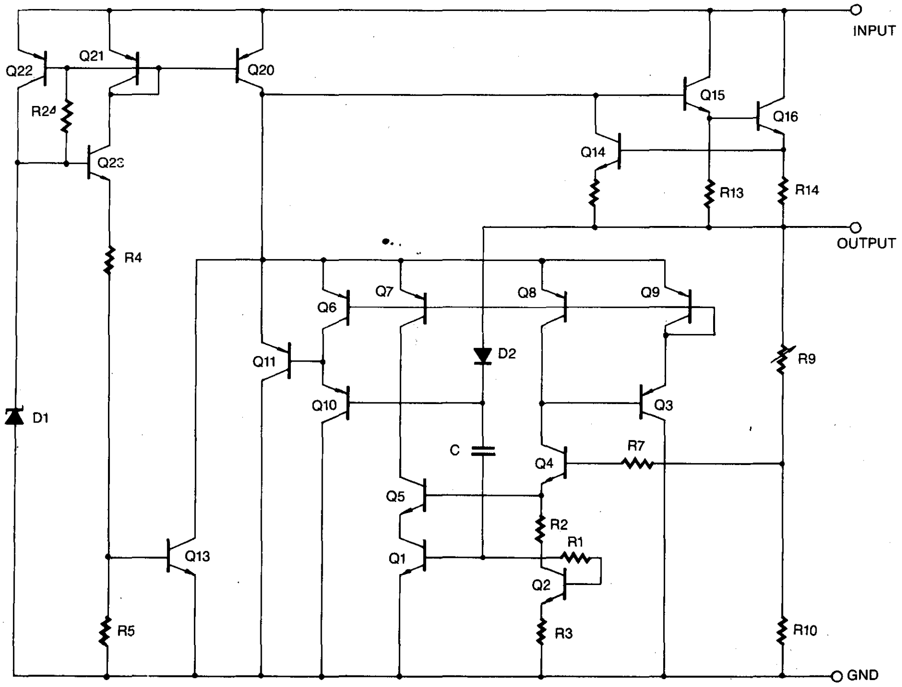
## FEATURES

- **Output current up to 100mA.**
- **No external components required**
- **Internal thermal overload protection.**
- **Internal short circuit current limiting.**
- **Output voltage of 5V, 6V, 8V, 9V, 10V, 12V, 15V, 18V, and 24V.**
- **Output voltage tolerances of ±5% over the temperature range.**
- **Complementary negative regulators offered (MC79LXXAC)**

## ORDERING INFORMATION

| Device | Package | Operating Temperature |
|---|---|---|
| MC78LXXACZ | TO-92 | 0 ~ +125°C |
| †MC78LXXACD | 8-SOP | 0 ~ +125°C |

## SCHEMATIC DIAGRAM



## ABSOLUTE MAXIMUM RATINGS ($T_a$=25°C)

| Characteristic | Symbol | Value | Unit |
|---|---|---|---|
| Input Voltage (for $V_O$ = 2.6V to 9V)<br>(for $V_O$ = 12V to 18V)<br>(for $V_O$ = 24V) | $V_{IN}$ | 30<br>35<br>40 | V<br>V<br>V |
| Operating Junction Temperature Range | $T_{opr}$ | 0 ~ +125 | °C |
| Storage Temperature Range | $T_{stg}$ | −65 ~ +150 | °C |

## MC78L05AC ELECTRICAL CHARACTERISTICS

$V_{IN}$=10V, $I_{OUT}$=40mA, 0°C ≤ Tj ≤ 125°C, $C_{IN}$=0.33μF, $C_{OUT}$=0.1μF, unless otherwise specified. (Note 1)

| Characteristic | | Symbol | Test Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|---|
| Output Voltage | | $V_O$ | $T_j$=25°C | | 4.8 | 5.0 | 5.2 | V |
| Line Regulation | | $\Delta V_O$ | $T_j$=25°C | 7V ≤ $V_{IN}$ ≤ 20V | | 55 | 150 | mV |
| | | | | 8V ≤ $V_{IN}$ ≤ 20V | | 45 | 100 | mV |
| Load Regulation | | $\Delta V_O$ | $T_j$=25°C | 1mA ≤ $I_{OUT}$ ≤ 100mA | | 11 | 60 | mV |
| | | | | 1mA ≤ $I_{OUT}$ ≤ 40mA | | 5.0 | 30 | mV |
| Output Voltage | | $V_O$ | 7V ≤ $V_{IN}$ ≤ 20V | 1mA ≤ $I_{OUT}$ ≤ 40mA | 4.75 | | 5.25 | V |
| | | | 7V ≤ $V_{IN}$ ≤ $V_{max}$ (Note 2) | 1mA ≤ $I_{OUT}$ ≤ 70mA | 4.75 | | 5.25 | V |
| Quiescent Current | | $I_d$ | $T_j$=25°C | | | 2.0 | 5.5 | mA |
| Quiescent Current Change | with line | $\Delta I_d$ | 8V ≤ $V_{IN}$ ≤ 20V | | | | 1.5 | mA |
| | with load | $\Delta I_d$ | 1mA ≤ $I_{OUT}$ ≤ 40mA | | | | 0.1 | mA |
| Output Noise Voltage | | $V_N$ | $T_a$=25°C, 10Hz ≤ f ≤ 100KHz | | | 40 | | μV |
| Temperature Coefficient of $V_{OUT}$ | | $\frac{\Delta V_O}{\Delta T}$ | $I_{OUT}$ = 5mA | | | −0.65 | | mV/°C |
| Ripple Rejection | | RR | f=120Hz, 8V ≤ $V_{IN}$ ≤ 18V, Tj=25°C | | 41 | 49 | | dB |
| Dropout Voltage | | $V_D$ | $T_j$=25°C | | | 1.7 | | V |
| Peak Output/Short-Circuit Current | | $I_{SC}$ | $T_j$=25°C | | | 140 | | mA |

## MC78L06AC ELECTRICAL CHARACTERISTICS

($V_{IN} = 12V$, $I_{OUT} = 40mA$, $0°C < T_j < 125°C$, $C_{IN} = 0.33\mu F$, $C_{OUT} = 0.1\mu F$, unless otherwise specified. (Note 1)

| Characteristic | | Symbol | Test Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|---|
| Output Voltage | | $V_o$ | $T_j = 25°C$ | | 5.75 | 6.0 | 6.25 | V |
| Line Regulation | | $\triangle V_o$ | $T_j = 25°C$ | $8.5V < V_{IN} < 20V$ | | 64 | 175 | mV |
| | | | | $9V \geq V_{IN} \geq 20V$ | | 54 | 125 | |
| Load Regulation | | $\triangle V_o$ | $T_j = 25°C$ | $1mA < I_{OUT} < 100mA$ | | 12.8 | 80 | mV |
| | | | | $1mA < I_{OUT} < 70mA$ | | 5.8 | 40 | |
| Output Voltage | | $V_o$ | $8.5V < V_{IN} < 20V$, $1mA < I_{OUT} < 40mA$ | | 5.7 | | 6.3 | V |
| | | | $8.5V < V_{IN} < V_{MAX}$(Note 2), $1mA < I_{OUT} < 70mA$ | | 5.7 | | 6.3 | |
| Quiescent Current | | $I_d$ | $T_j = 25°C$ | | | 3.9 | 6.0 | mA |
| | | | $T_j = 125°C$ | | | | 5.5 | |
| Quiescent Current Change | With Line | $\triangle_d$ | $9V < V_{IN} < 20V$ | | | | 1.5 | mA |
| | With Load | | $1mA < I_{OUT} < 40mA$ | | | | 0.1 | |
| Output Noise Voltage | | $V_N$ | $Ta = 25°C$, $10Hz < f < 100KHz$ | | | 49 | | $\mu V$ |
| Temperature Coefficient of $V_{OUT}$ | | $V_O$<br>$T$ | $I_{OUT} = 5mA$ | | | 0.75 | | mV/°C |
| Ripple Rejection | | RR | $f = 120Hz$, $T_j = 25°C$<br>$10V < V_{IN} < 20V$ | | 40 | 46 | | dB |
| Drop Voltage | | $V_D$ | $T_j = 25°C$ | | | 1.7 | | V |
| Peak Output/Short Circuit Current | | $I_{SC}$ | $T_j = 25°C$ | | | 140 | | mA |

## MC78L08AC ELECTRICAL CHARACTERISTICS

$V_{IN} = 14V$, $I_{OUT} = 40mA$, $0°C \leq Tj \leq 125°C$, $C_{IN} = 0.33\mu F$, $C_{OUT} = 0.1\mu F$, unless otherwise specified. (Note 1)

| Characteristic | | Symbol | Test Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|---|
| Output Voltage | | $V_O$ | $T_j = 25°C$ | | 7.7 | 8.0 | 8.3 | V |
| Line Regulation | | $\Delta V_O$ | $T_j = 25°C$ | $10.5 \leq V_{IN} \leq 23V$ | | 80 | 17.5 | mV |
| | | | | $11V \leq V_{IN} \leq 23V$ | | 70 | 125 | mV |
| Load Regulation | | $\Delta V_O$ | $T_j = 25°C$ | $1mA \leq I_{OUT} \leq 100mA$ | | 15 | 80 | mV |
| | | | | $1mA \leq I_{OUT} \leq 40mA$ | | 8.0 | 40 | mV |
| Output Voltage | | $V_O$ | $10.5V \leq V_{IN} \leq 23V$ | $1mA \leq I_{OUT} \leq 40mA$ | 7.6 | | 8.4 | V |
| | | | $10.5V \leq V_{IN} \leq V_{max}$ (Note 2) | $1mA \leq I_{OUT} \leq 70mA$ | 7.6 | | 8.4 | V |
| Quiescent Current | | $I_d$ | $T_j = 25°C$ | | | 2.0 | 5.5 | mA |
| Quiescent Current Change | with line | $\Delta I_d$ | $11V \leq V_{IN} \leq 23V$ | | | | 1.5 | mA |
| | with load | $\Delta I_d$ | $1mA \leq I_{OUT} \leq 40mA$ | | | | 0.1 | mA |
| Output Noise Voltage | | $V_N$ | $T_a = 25°C$, $10Hz \leq f \leq 100KHz$ | | | 60 | | $\mu V$ |
| Temperature Coefficient of $V_{OUT}$ | | $\frac{\Delta V_O}{\Delta T}$ | $I_{OUT} = 5mA$ | | | -0.8 | | mV/°C |
| Ripple Rejection | | RR | $f = 120Hz$, $11V \leq V_{IN} \leq 21V$, $T_j = 25°C$ | | 39 | 45 | | dB |
| Dropout Voltage | | $V_D$ | $Tj = 25°C$ | | | 1.7 | | V |
| Peak Output/Short-Circuit Current | | $I_{SC}$ | $Tj = 25°C$ | | | 140 | | mA |

## MC78L09AC ELECTRICAL CHARACTERISTICS

$V_{IN}=15V$, $I_{OUT}=40mA$, $0°C \leq Tj \leq 125°C$, $C_{IN}=0.33\mu F$, $C_{OUT}=0.1\mu F$, unless otherwise specified. (Note 1)

| Characteristic | | Symbol | Test Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|---|
| Output Voltage | | $V_O$ | $T_j=25°C$ | | 8.64 | 9.0 | 9.36 | V |
| Line Regulation | | $\Delta V_O$ | $T_j=25°C$ | $11.5V \leq V_{IN} \leq 24V$ | | 90 | 200 | mV |
| | | | | $13V \leq V_{IN} \leq 24V$ | | 100 | 150 | mV |
| Load Regulation | | $\Delta V_O$ | $T_j=25°C$ | $1mA \leq I_{OUT} \leq 100mA$ | | 20 | 90 | mV |
| | | | | $1mA \leq I_{OUT} \leq 40mA$ | | 10 | 45 | mV |
| Output Voltage | | $V_O$ | $11.5V \leq V_{IN} \leq 24V$ | $1mA \leq I_{OUT} \leq 40mA$ | 8.55 | | 9.45 | V |
| | | | $11.5V \leq V_{IN} \leq V_{max}$ (Note 2) | $1mA \leq I_{OUT} \leq 70mA$ | 8.55 | | 9.45 | V |
| Quiescent Current | | $I_d$ | $T_j=25°C$ | | | 2.1 | 6.0 | mA |
| Quiescent Current Change | with line | $\Delta I_d$ | $13V \leq V_{IN} \leq 24V$ | | | | 1.5 | mA |
| | with load | $\Delta I_d$ | $1mA \leq I_{OUT} \leq 40mA$ | | | | 0.1 | mA |
| Output Noise Voltage | | $V_N$ | $T_a=25°C$, $10Hz \leq f \leq 100KHz$ | | | 70 | | $\mu V$ |
| Temperature Coefficient of $V_{OUT}$ | | $\frac{\Delta V_O}{\Delta T}$ | $I_{OUT}=5mA$ | | | −0.9 | | mV/°C |
| Ripple Rejection | | RR | $f=120Hz, 12V \leq V_{IN} \leq 22V, T_j=25°C$ | | 38 | 44 | | dB |
| Dropout Voltage | | $V_D$ | $T_j=25°C$ | | | 1.7 | | V |
| Peak Output/Short-Circuit Current | | $I_{SC}$ | $T_j=25°C$ | | | 140 | | mA |

## MC78L10AC ELECTRICAL CHARACTERISTICS

($V_{IN}=16V$, $I_{OUT}=40mA$, $0°C < T_j < 125°C$, $C_{IN}=0.33\mu F$, $C_{OUT}=0.1\mu F$, unless otherwise specified. (Note 1)

| Characteristic | | Symbol | Test Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|---|
| Output Voltage | | $V_o$ | $T_j=25°C$ | | 9.6 | 10.0 | 10.4 | V |
| Line Regulation | | $\triangle V_o$ | $T_j=25°C$ | $12.5V < V_{IN} < 25V$ | | 100 | 220 | mV |
| | | | | $14V \geq V_{IN} \geq 25V$ | | 100 | 170 | |
| Load Regulation | | $\triangle V_o$ | $T_j=25°C$ | $1mA < I_{OUT} < 100mA$ | | 20 | 94 | mV |
| | | | | $1mA < I_{OUT} < 70mA$ | | 10 | 47 | |
| Output Voltage | | $V_o$ | $12.5V < V_{IN} < 25V$, $1mA < I_{OUT} < 40mA$ | | 9.5 | | 10.5 | V |
| | | | $12.5V < V_{IN} < V_{MAX}$(Note 2), $1mA < I_{OUT} < 70mA$ | | 9.5 | | 10.5 | |
| Quiescent Current | | $I_d$ | $T_j=25°C$ | | | 4.2 | 6.5 | mA |
| | | | $T_j=125°C$ | | | | 6.0 | |
| Quiescent Current Change | With Line | $\triangle_d$ | $12.5V < V_{IN} < 25V$ | | | | 1.5 | mA |
| | With Load | | $1mA < I_{OUT} < 40mA$ | | | | 0.1 | |
| Output Noise Voltage | | $V_N$ | $Ta=25°C$, $10Hz < f < 100KHz$ | | | 74 | | $\mu V$ |
| Temperature Coefficient of $V_{OUT}$ | | $V_O$<br>$T$ | $I_{OUT}=5mA$ | | | 0.95 | | mV/°C |
| Ripple Rejection | | RR | $f=120Hz$, $T_j=25°C$<br>$15V < V_{IN} < 25V$ | | 38 | 43 | | dB |
| Drop Voltage | | $V_D$ | $T_j=25°C$ | | | 1.7 | | V |
| Peak Output/Short Circuit Current | | $I_{SC}$ | $T_j=25°C$ | | | 140 | | mA |

## MC78L12AC ELECTRICAL CHARACTERISTICS

$V_{IN} = 19V$, $I_{OUT} = 40mA$, $0°C \leq Tj \leq 125°C$, $C_{IN} = 0.33\mu F$, $C_{OUT} = 0.1\mu F$, unless otherwise specified. (Note 1)

| Characteristic | | Symbol | Test Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|---|
| Output Voltage | | $V_O$ | $T_j = 25°C$ | | 11.5 | 12 | 12.5 | V |
| Line Regulation | | $\Delta V_O$ | $T_j = 25°C$ | $14.5V \leq V_{IN} \leq 27V$ | | 120 | 250 | mV |
| | | | | $16V \leq V_{IN} \leq 27V$ | | 100 | 200 | mV |
| Load Regulation | | $\Delta V_O$ | $T_j = 25°C$ | $1mA \leq I_{OUT} \leq 100mA$ | | 20 | 100 | mV |
| | | | | $1mA \leq I_{OUT} \leq 40mA$ | | 10 | 50 | mV |
| Output Voltage | | $V_O$ | $14.5V \leq V_{IN} \leq 27V$ | $1mA \leq I_{OUT} \leq 40mA$ | 11.4 | | 12.6 | V |
| | | | $14.5V \leq V_{IN} \leq V_{max}$ (Note 2) | $1mA \leq I_{OUT} \leq 70mA$ | 11.4 | | 12.6 | V |
| Quiescent Current | | $I_d$ | $T_j = 25°C$ | | | 2.1 | 6.0 | mA |
| Quiescent Current Change | with line | $\Delta I_d$ | $16V \leq V_{IN} \leq 27V$ | | | | 1.5 | mA |
| | with load | $\Delta I_d$ | $1mA \leq I_{OUT} \leq 40mA$ | | | | 0.1 | mA |
| Output Noise Voltage | | $V_N$ | $T_a = 25°C$, $10Hz \leq f \leq 100KHz$ | | | 80 | | $\mu V$ |
| Temperature Coefficient of $V_{OUT}$ | | $\frac{\Delta V_O}{\Delta T}$ | $I_{OUT} = 5mA$ | | | −1.0 | | mV/°C |
| Ripple Rejection | | RR | $f = 120Hz$, $15V \leq V_{IN} \leq 25V$, $Tj = 25°C$ | | 37 | 42 | | dB |
| Dropout Voltage | | $V_D$ | $T_j = 25°C$ | | | 1.7 | | V |
| Peak Output/Short-Circuit Current | | $I_{SC}$ | $T_j = 25°C$ | | | 140 | | mA |

## MC78L15AC ELECTRICAL CHARACTERISTICS

$V_{IN} = 23V$, $I_{OUT} = 40mA$, $0°C \leq Tj \leq 125°C$, $C_{IN} = 0.33\mu F$, $C_{OUT} = 0.1\mu F$, unless otherwise specified. (Note 1)

| Characteristic | | Symbol | Test Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|---|
| Output Voltage | | $V_O$ | $T_j = 25°C$ | | 14.4 | 15 | 15.6 | V |
| Line Regulation | | $\Delta V_O$ | $T_j = 25°C$ | $17.5V \leq V_{IN} \leq 30V$ | | 130 | 300 | mV |
| | | | | $20V \leq V_{IN} \leq 30V$ | | 110 | 250 | nV |
| Load Regulation | | $\Delta V_O$ | $T_j = 25°C$ | $1mA \leq I_{OUT} \leq 100mA$ | | 25 | 150 | mV |
| | | | | $1mA \leq I_{OUT} \leq 40mA$ | | 12 | 75 | mV |
| Output Voltage | | $V_O$ | $17.5V \leq V_{IN} \leq 30V$ | $1mA \leq I_{OUT} \leq 40mA$ | 14.25 | | 15.75 | V |
| | | | $17.5V \leq V_{IN} \leq V_{max}$ (Note 2) | $1mA \leq I_{OUT} \leq 70mA$ | 14.25 | | 15.75 | V |
| Quiescent Current | | $I_d$ | $T_j = 25°C$ | | | 2.2 | 6.0 | mA |
| Quiescent Current Change | with line | $\Delta I_d$ | $20V \leq V_{IN} \leq 30V$ | | | | 1.5 | mA |
| | with load | $\Delta I_d$ | $1mA \leq I_{OUT} \leq 40mA$ | | | | 0.1 | mA |
| Output Noise Voltage | | $V_N$ | $T_a = 25°C$, $10Hz \leq f \leq 100KHz$ | | | 90 | | $\mu V$ |
| Temperature Coefficient of $V_{OUT}$ | | $\frac{\Delta V_O}{\Delta T}$ | $I_{OUT} = 5mA$ | | | −1.3 | | mV/°C |
| Ripple Rejection | | RR | $f = 120Hz$, $18.5V \leq V_{IN} \leq 28.5V$, $Tj = 25°C$ | | 34 | 39 | | dB |
| Dropout Voltage | | $V_D$ | $T_j = 25°C$ | | | 1.7 | | V |
| Peak Output/Short-Circuit Current | | $I_{SC}$ | $T_j = 25°C$ | | | 140 | | mA |

## MC78L18AC ELECTRICAL CHARACTERISTICS

$V_{IN}$=27V, $I_{OUT}$=40mA, 0°C ≤ Tj ≤ 125°C, $C_{IN}$=0.33μF, $C_{OUT}$=0.1μF, unless otherwise specified. (Note 1)

| Characteristic | | Symbol | Test Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|---|
| Output Voltage | | $V_O$ | $T_j$=25°C | | 17.3 | 18 | 18.7 | V |
| Line Regulation | | $\Delta V_O$ | $T_j$=25°C | 21V ≤ $V_{IN}$ ≤ 33V | | 145 | 300 | mV |
| | | | | 22V ≤ $V_{IN}$ ≤ 33V | | 135 | 250 | mV |
| Load Regulation | | $\Delta V_O$ | $T_j$=25°C | 1mA ≤ $I_{OUT}$ ≤ 100mA | | 30 | 170 | mV |
| | | | | 1mA ≤ $I_{OUT}$ ≤ 40mA | | 15 | 85 | mV |
| Output Voltage | | $V_O$ | 21V ≤ $V_{IN}$ ≤ 33V | 1mA ≤ $I_{OUT}$ ≤ 40mA | 17.1 | | 18.9 | V |
| | | | 21V ≤ $V_{IN}$ ≤ $V_{max}$ (Note 2) | 1mA ≤ $I_{OUT}$ ≤ 70mA | 17.1 | | 18.9 | V |
| Quiescent Current | | $I_d$ | $T_j$=25°C | | | 2.2 | 6.0 | mA |
| Quiescent Current Change | with line | $\Delta I_d$ | 21V ≤ $V_{IN}$ ≤ 33V | | | | 1.5 | mA |
| | with load | $\Delta I_d$ | 1mA ≤ $I_{OUT}$ ≤ 40mA | | | | 0.1 | mA |
| Output Noise Voltage | | $V_N$ | $T_a$=25°C, 10Hz ≤ f ≤ 100KHz | | | 150 | | μV |
| Temperature Coefficient of $V_{OUT}$ | | $\frac{\Delta V_O}{\Delta T}$ | $I_{OUT}$ = 5mA | | | – 1.8 | | mV/°C |
| Ripple Rejection | | RR | f=120Hz, 23V ≤ $V_{IN}$ ≤ 33V, Tj=25°C | | 34 | 48 | | dB |
| Dropout Voltage | | $V_D$ | $T_j$=25°C | | | 1.7 | | V |
| Peak Output/Short-Circuit Current | | $I_{SC}$ | $T_j$=25°C | | | 140 | | mA |

## MC78L24AC ELECTRICAL CHARACTERISTICS

$V_{IN}$ = 33V, $I_{OUT}$ = 40mA, 0°C ≤ Tj ≤ 125°C, $C_{IN}$ = 0.33μF, $C_{OUT}$ = 0.1μF, unless otherwise specified. (Note 1)

| Characteristic | | Symbol | Test Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|---|
| Output Voltage | | $V_O$ | $T_j$=25°C | | 23 | 24 | 25 | V |
| Line Regulation | | $\Delta V_O$ | $T_j$=25°C | 27V ≤ $V_{IN}$ ≤ 38V | | 160 | 300 | mV |
| | | | | 28V ≤ $V_{IN}$ ≤ 38V | | 150 | 250 | mV |
| Load Regulation | | $\Delta V_O$ | $T_j$=25°C | 1mA ≤ $I_{OUT}$ ≤ 100mA | | 40 | 200 | mV |
| | | | | 1mA ≤ $I_{OUT}$ ≤ 40mA | | 20 | 100 | mV |
| Output Voltage | | $V_O$ | 27V ≤ $V_{IN}$ ≤ 38V | 1mA ≤ $I_{OUT}$ ≤ 40mA | 22.8 | | 25.2 | V |
| | | | 27V ≤ $V_{IN}$ ≤ $V_{max}$ (Note 2) | 1mA ≤ $I_{OUT}$ ≤ 70mA | 22.8 | | 25.2 | V |
| Quiescent Current | | $I_d$ | $T_j$=25°C | | | 2.2 | 6.0 | mA |
| Quiescent Current Change | with line | $\Delta I_d$ | 28V ≤ $V_{IN}$ ≤ 38V | | | | 1.5 | mA |
| | with load | $\Delta I_d$ | 1mA ≤ $I_{OUT}$ ≤ 40mA | | | | 0.1 | mA |
| Output Noise Voltage | | $V_N$ | $T_a$=25°C, 10Hz ≤ f ≤ 100KHz | | | 200 | | μV |
| Temperature Coefficient of $V_{OUT}$ | | $\frac{\Delta V_O}{\Delta T}$ | $I_{OUT}$ = 5mA | | | – 2.0 | | mV/°C |
| Ripple Rejection | | RR | f=120Hz, 28V ≤ $V_{IN}$ ≤ 38V, Tj=25°C | | 34 | 45 | | dB |
| Dropout Voltage | | $V_D$ | $T_j$=25°C | | | 1.7 | | V |
| Peak Output/Short-Circuit Current | | $I_{SC}$ | $T_j$=25°C | | | 140 | | mA |

**Notes**

1. The maximum steady state usable output current and input voltage are very dependent on the heat sinking and/or lead length of the package. The date above represent pulse test conditions with junction temperatures as indicated at the initiation of tests.
2. Power dissipation ≤ 0.75W.

# TYPICAL PERFORMANCE CHARACTERISTICS

Fig. 1 **QUIESCENT CURRENT vs A FUNCTION OF INPUT VOLTAGE**

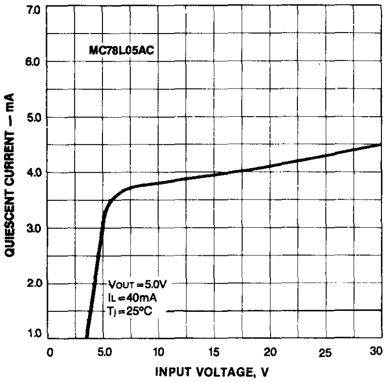


Fig. 2 **DROPOUT VOLTAGE vs A FUNCTION O FJUNCTION TEMPERATURE**

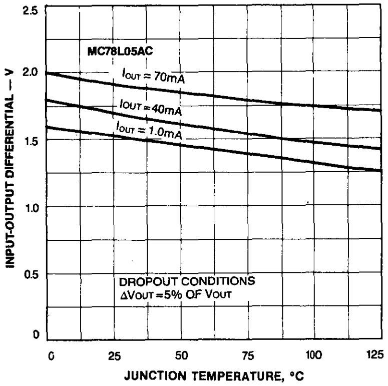


Fig. 3 **QUIESCENT CURRENT vs A FUNCTION OF TEMPERATURE**

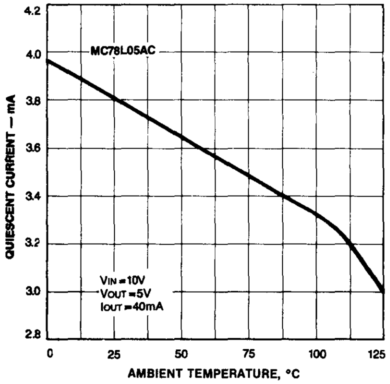


Fig. 4 **DROPOUT CHARACTERISTICS**

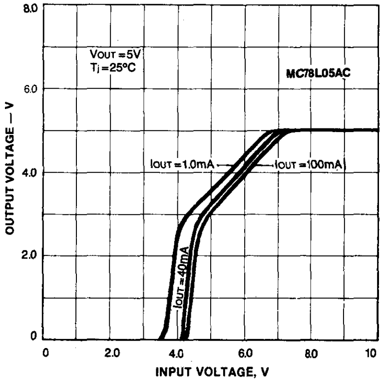


Fig. 5 **RIPPLE REJECTION vs A FUNCTION OF FREQUENCY**

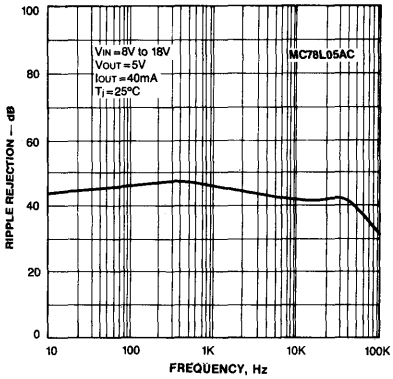


Fig. 6 **LINE TRANSIENT RESPONSE**

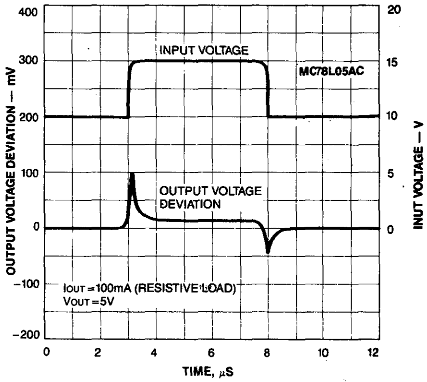


Fig. 7 LOAD TRANSIENT RESPONSE

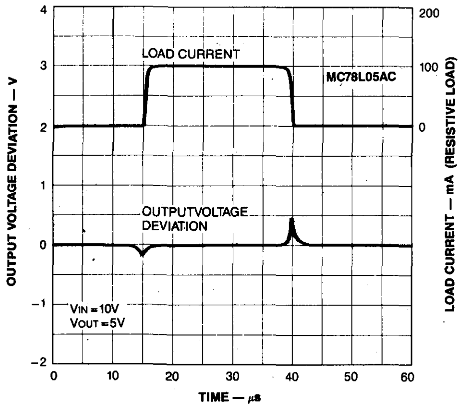
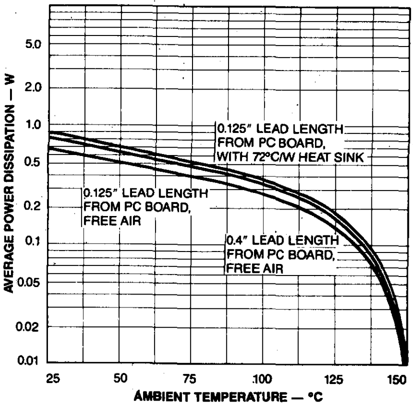


Fig. 8 TO-92 WORST CASE POWER DISSIPATION vs AMBIENT TEMPERATURE



## APPLICATION INFORMATION

The MC78LXXAC series regulators have thermal overload protection from excessive power, internal short-circuit protection which limits each circuit's maximum current, and output transistor safe-area protection for reducing the output current as the voltage across each pass transistor is increased.

Although the internal power dissipation is limited, the junction temperature must be kept below the maximum specified temperature (125°C) in order to meet data sheet specifications. To calculate the maximum junction temperature or heat sink required, the following thermal resistance values should be used:

### Thermal Considerations

The TO-92 molded package manufactured by SST is capable of unusually high power dissipation due to the lead frame design. However, its thermal capabilities are generally overlooked because of a lack of understanding of the thermal paths from the semiconductor junction to ambient temperature. While thermal resistance is normally specified for the device mounted 1cm above an infinite heat sink, very little has been mentioned of the options available to improve on the conservatively rated thermal capability.

An explanation of the thermal paths of the TO-92 will allow the designer to determine the thermal stress he is applying in any given application.

### The TO-92 Package

The TO-92 package thermal paths are complex. In addition to the path through the molding compound to ambient temperature, there is another path through the pins, in parallel with the case path, to ambient temperature, as shown in Figure 9.

The total thermal resistance in this model is then:

$$\theta_{JA} = \frac{(\theta_{JC} + \theta_{CA})\,(\theta_{JL} + \theta_{LA})}{\theta_{JC} + \theta_{CA} + \theta_{JL} + \theta_{LA}}$$

Where: $\theta_{JC}$ = thermal resistance of the case between the regulator die and a point on the case directly above the die location.
$\theta_{CA}$ = thermal resistance between the case and air at ambient temperature.
$\theta_{JL}$ = thermal resistance from transistor die through the collector lead to a point 1/16 inch below the regulator case.
$\theta_{LA}$ = total thermal resistance of the collector-base-emitter pins to ambient temperature.
$\theta_{JA}$ = junction to ambient thermal resistance.

**TO-92 Thermal Equivalent Circuit**

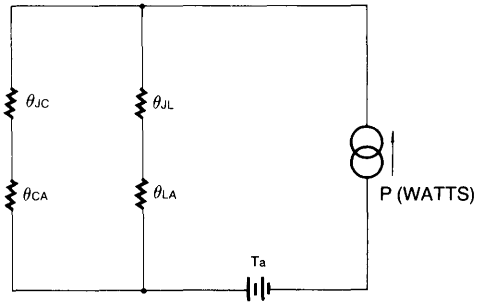


Fig. 9

**TO-92 Thermal Equivalent Circuit**
**(PIN at Other Than Ambient Temperature)**

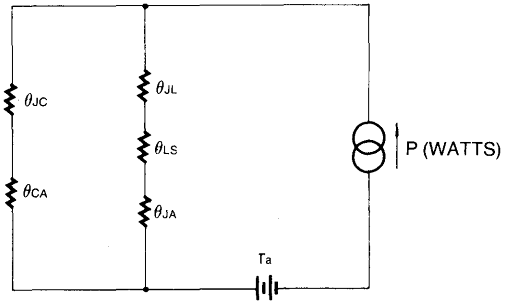


Fig. 10

## Methods of Heat Sinking

With two external thermal resistances in each leg of a parallel network available to the circuit designer as variables, he can choose the method of heat sinking most applicable to his particular situation. To demonstrate, consider the effect of placing a small 72°C/W flag type heat sink, such as the Staver F1-7D-2, on the 78LXX molded case. The heat sink effectively replaces the $\theta_{CA}$ (Figure 10) and the new thermal resistance, $\theta_{JA} = 145°C/W$ (assuming, 0.125 inch lead length).

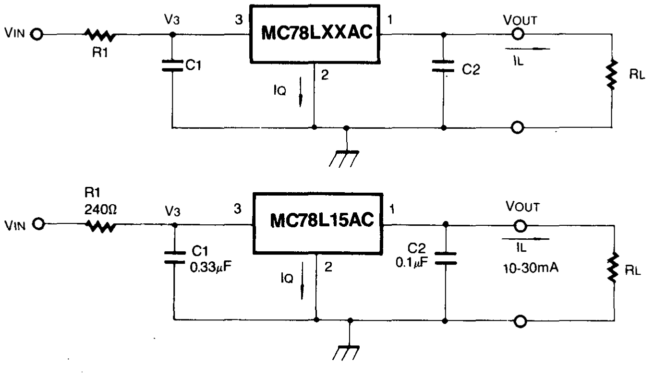
The net change of 15°C/W increases the allowable power dissipation to 0.86W with an inserted cost of 1-2 cents. A still further decrease in $\theta_{JA}$ could be achieved by using a heat sink rated at 46°C/W, such as the Staver FS-7A. Also, if the case sinking does not provide an adequate reduction in total $\theta_{JA}$, the other external thermal resistance, $\theta_{LA}$, may be reduced by shortening the lead length from package base to mounting medium. However, one point must be kept in mind. The lead thermal path includes a thermal resistance, $\theta_{SA}$, from the pins at the mounting points to ambient, that is, the mounting medium, $\theta_{LA}$ is then equal to $\theta_{LS} + \theta_{SA}$. The new model is shown in Figure 10.

In the case of a socket, $\theta_{SA}$ could be as high as 270°C/W, thus causing a net increase in $\theta_{JA}$ and a consequent decrease in the maximum dissipation capability. Shortening the lead length may return the net $\theta_{JA}$ to the original value, but pin sinking would not be accomplished.

In those cases where the regulator is inserted into a copper clad printed circuit board, it is advantageous to have a maximum area of copper at the entry points of the pins. While it would be desirable to rigorously define the effect of PC board copper, the real world variables are too great to allow anything more than a few general observations.

The best analogy for PC board copper is to compare it with parallel resistors. Beyond some point, additional resistors are not significantly effective; beyond some point, additional copper area is not effective.

Fig. 11 High Dissipation Applications



*When it is necessary to operate a MC78LXXAC regulator with a large input-output differential voltage, the addition of* series resistor R1 will extend the output current range of the device by sharing the total power dissipation between R1 and the regulator.

$$R1 = \frac{V_{IN\,(MIN)} - V_{OUT} - 2.0V}{I_{L\,(MAX)} + I_Q}$$

Where $I_o$ is the regulator quiescent current.

Regulator power dissipation at maximum input voltage and maximum load current is now

$P_{D\,(MAX)} = (V_3 - V_{OUT})\, I_{L\,(MAX)} + V_3 I_Q$

where $V_3 = V_{IN\,(MAX)} - (I_{C\,(MAX)} + I_Q)\, R_1$

*The presence of R1 will affect load regulation according to the equation:*
load regulation (at constant $V_{IN}$)
=load regulation (at constant $V_3$)
+(line regulation, mV per V)
×(R1)×(ΔIL).

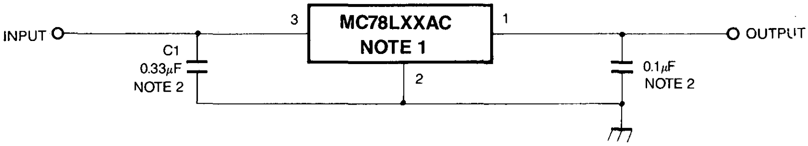
As an example, consider a 15V regulator with a supply voltage of 30±5V, required to supply a maximum load current of 30mA. $I_Q$ is 4.3mA, and minimum load current is to be 10mA.

$$R_1 = \frac{25 - 15 - 2}{30 + 4.3} = \frac{34.3}{8} = 240\Omega$$

$V_3 = 35 - (30 + 4.3) \times 0.24 = 35.82 = 26.8V$
$P_{D\,(MAX)} = (26.8 - 15)\, 30 + 26.8\, (4.3)$
$= 354 + 115$
=470mW, which permit operation up to 70°C
in most applications.

Line regulation of this circuit is typically 110mV for an input range of 25~35V at a constant load current; i.e. 11mV/V
*Load regulation=constant $V_1$ load regulation (typically 10mV, 10~30mA $I_L$)*
+(11mV/V×0.24×20mA (typically 53mV)
=63mV for a load current change of 20mA at a constant $V_{IN}$ of 30V.

Fig. 12 Typical Application



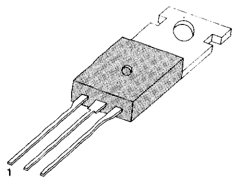
**Notes**

1. To specify an output voltage, substitute voltage value for "xx".
2. Bypass Capacitors are recommended for optimum stability and transient response and should be located as close as possible to the regulator.

## 3-TERMINAL POSITIVE VOLTAGE REGULATORS

The KA340XX series of three-terminal positive voltage regulators are available in TO-220 package and with several fixed output voltages, providing better performance than 78XX series regulators. These are designed to have outstanding ripple rejection, superior line and load regulation in high power applications (over 15W). Each type employs internal current limiting, thermal shutdown and safe area protection.
Although designed primarily as fixed voltage regulators, these devices can be used with external components to obtain adjustable voltage and currents.

TO-220



1: Input 2: GND 3: Output

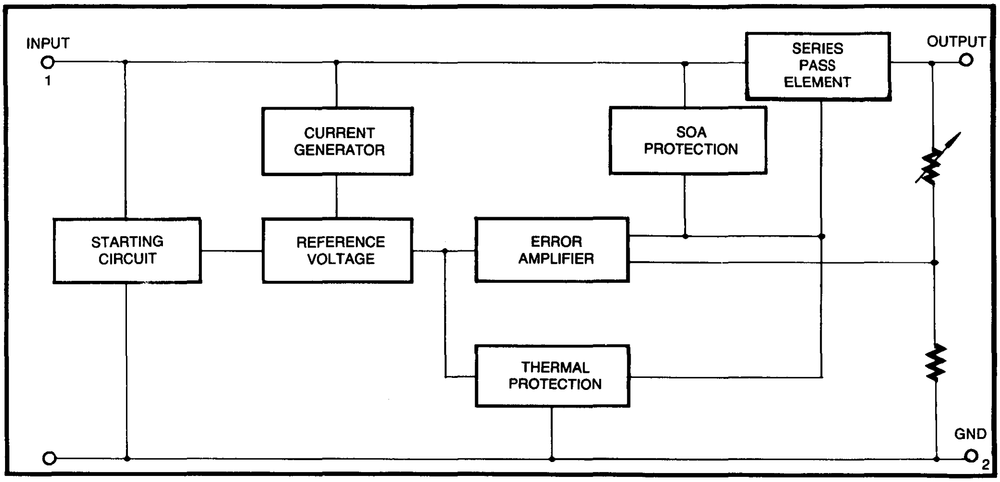
## FEATURES

- **Maximum output current: 1.5A**
- **Output voltage of 5, 6, 8, 9, 10, 11, 12, 15, 18, 24V**
- **Superior line and load regulation than 78XX series**
- **Output transistor SOA protection**
- **Internal short-circuit current limit**
- **Thermal overload protection**
- **Output voltage tolerances of ±4% at 25°C and ±5% over the temperature range**

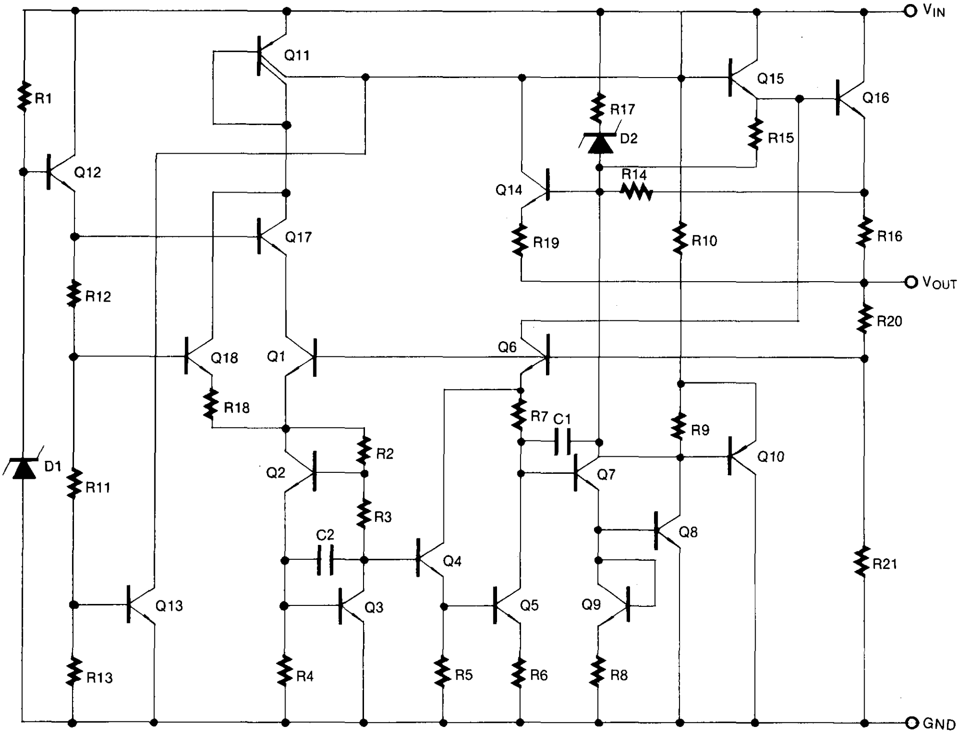
## ORDERING INFORMATION

| Device | Package | Operating Temperature |
|---|---|---|
| KA340TXX | TO-220 | 0 ~ +125°C |

## BLOCK DIAGRAM



## SCHEMATIC DIAGRAM



## ABSOLUTE MAXIMUM RATINGS

| Characteristic | Symbol | Value | Unit |
|---|---|---|---|
| Input Voltage (for $V_O = 5V$) | $V_i$ | 35 | V |
| Thermal Resistance Junction-Cases | θ jc | 5 | °C/W |
| Thermal Resistance Junction-Air | θ ja | 65 | °C/W |
| Junction Operating Temperature | $T_{opr}$ | 0 ~ +150 | °C |
| Storage Temperature | $T_{stg}$ | −65 ~ +150 | °C |

## ELECTRICAL CHARACTERISTICS KA340T05

(Refer to test circuit, $0°C \le T_j \le 125°C$, $V_i = 10V$, $I_O = 0.5A$, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| Output Voltage | $V_O$ | $T_j = 25°C$, $5mA \le I_O \le 1.0A$ | | 4.80 | 5.00 | 5.20 | V |
| | | $5mA \le I_O \le 1.0A$, $PD \le 15W$<br>$V_i = 7.5V$ to 20V | | 4.75 | — | 5.25 | |
| Line Regulation | $\triangle V_O$ | $T_j = 25°C$, $V_i = 7V$ to 25V | | — | 3 | 50 | mV |
| | | $V_i = 8V$ to 20V | | — | — | 50 | |
| | | $I_O \le 1A$ | $V_i = 8V$ to 12V | — | — | 25 | |
| | | | $V_i = 7.5V$ to 20V<br>$T_j = 25°C$ | — | — | 50 | |
| Load Regulation | $\triangle V_O$ | $T_j = 25°C$ | $5mA \le I_O \le 1.5A$ | — | 10 | 50 | mV |
| | | | $0.25A \le I_O \le 0.75A$ | — | — | 25 | |
| | | $5mA \le I_O \le 1A$ | | — | — | 50 | |
| Quiescent Current | $I_d$ | $I_O = 1A$ | $T_j = 25°C$ | — | — | 8 | mA |
| | | | $0°C \le T_j \le 125°C$ | — | — | 8.5 | |
| Quiescent Current Change | $\triangle I_d$ | $5mA \le I_O \le 1A$ | | — | — | 0.5 | mA |
| | | $T_j = 25°C$<br>$I_O \le 1A$, $V_i = 7.5V$ to 20V | | — | — | 1.0 | |
| | | $V_i = 7V$ to 25V | | — | — | 1.0 | |
| Output Noise Voltage | $V_n$ | $T_a = 25°C$, $f = 10Hz$ to 100KHz | | — | 40 | — | μV |
| Ripple Rejection | RR | $f = 120Hz$, $V_i = 8V$ to 18V<br>$T_j = 25°C$ | | 62 | 80 | — | dB |
| | | $f = 120Hz$, $V_i = 8V$ to 18V<br>$0°C \le T_j \le 125°C$ | | 62 | — | — | |
| Dropout Voltage | $V_d$ | $I_O = 1A$, $T_j = 25°C$ | | — | 2.0 | — | V |
| Peak Output Current | $I_{peak}$ | $T_j = 25°C$ | | — | 2.2 | — | A |
| Short-Circuit Current | $I_{sc}$ | $V_i = 35V$, $T_j = 25°C$ | | — | 250 | — | mA |
| Average TC of $V_{out}$ | $\triangle V_O/\triangle T$ | $I_O = 5mA$ | | — | ±0.6 | — | mV/°C |
| Output Resistance | $R_O$ | $f = 1KHz$ | | — | 17 | — | mΩ |

* Load and line regulation are specified at a constant junction temperature. Changes in $V_O$ due to heating effects must be taken into account separately. Pulse testing with low duty cycle is used.

## ELECTRICAL CHARACTERISTICS KA340T06

(Refer to test circuit, $0°C \leq T_j \leq 125°C$, $V_i = 11V$, $I_O = 0.5A$, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| Output Voltage | $V_O$ | $T_j = 25°C$, $5mA \leq I_O \leq 1.0A$ | | 5.75 | 6.00 | 6.26 | V |
| | | $5mA \leq I_O \leq 1.0A$, $PD \leq 15W$<br>$V_i = 8.5V$ to $21V$ | | 5.70 | — | 6.30 | |
| Line Regulation | $\triangle V_O$ | $T_j = 25°C$, $V_i = 8V$ to $25V$ | | — | 3 | 60 | mV |
| | | $V_i = 9V$ to $21V$ | | — | — | 60 | |
| | | $I_O \leq 1A$ | $V_i = 9V$ to $13V$ | — | — | 30 | |
| | | | $V_i = 8.5V$ to $21V$<br>$T_j = 25°C$ | — | — | 60 | |
| Load Regulation | $\triangle V_O$ | $T_j = 25°C$ | $5mA \leq I_O \leq 1.5A$ | — | 10 | 60 | mV |
| | | | $0.25A \leq I_O \leq 0.75A$ | — | — | 30 | |
| | | $5mA \leq I_O \leq 1A$ | | — | — | 60 | |
| Quiescent Current | $I_d$ | $I_O = 1A$ | $T_j = 25°C$ | — | — | 8 | mA |
| | | | $0°C \leq T_j \leq 125°C$ | — | — | 8.5 | |
| Quiescent Current Change | $\triangle I_d$ | $5mA \leq I_O \leq 1A$ | | — | — | 0.5 | mA |
| | | $T_j = 25°C$<br>$I_O \leq 1A$, $V_i = 8.5V$ to $22V$ | | — | — | 1.0 | |
| | | $V_i = 8V$ to $25V$ | | — | — | 1.0 | |
| Output Noise Voltage | $V_n$ | $T_a = 25°C$, $f = 10Hz$ to $100KHz$ | | — | 45 | — | $\mu V$ |
| Ripple Rejection | RR | $f = 120Hz$, $V_i = 9V$ to $19V$<br>$T_j = 25°C$ | | 59 | 75 | — | dB |
| | | $f = 120Hz$, $V_i = 9V$ to $19V$<br>$0°C \leq T_j \leq 125°C$ | | 59 | — | — | |
| Dropout Voltage | $V_d$ | $I_O = 1A$, $T_j = 25°C$ | | — | 2.0 | — | V |
| Peak Output Current | $I_{peak}$ | $T_j = 25°C$ | | — | 2.2 | — | A |
| Short-Circuit Current | $I_{sc}$ | $V_i = 35V$, $T_j = 25°C$ | | — | 250 | — | mA |
| Average TC of $V_{out}$ | $\triangle V_O / \triangle T$ | $I_O = 5mA$ | | — | ±0.7 | — | mV/°C |
| Output Resistance | $R_O$ | $f = 1KHz$ | | — | 18 | — | mΩ |

* Load and line regulation are specified at a constant junction temperature. Changes in $V_O$ due to heating effects must be taken into account separately. Pulse testing with low duty cycle is used.

## ELECTRICAL CHARACTERISTICS KA340T08

(Refer to test circuit, 0°C$\le T_j \le$125°C, $V_i$ = 14V, $I_O$ = 0.5A, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| Output Voltage | $V_O$ | $T_j$ = 25°C, 5mA $\le I_O \le$ 1.0A | | 7.70 | 8.00 | 8.30 | V |
| | | 5mA $\le I_O \le$ 1.0A, PD $\le$ 15W<br>$V_i$ = 10.5V to 23V | | 7.60 | — | 8.40 | |
| Line Regulation | $\Delta V_O$ | $T_j$ = 25°C, $V_i$ = 10.5V to 25V | | — | 3 | 80 | mV |
| | | $V_i$ = 11V to 23V | | — | — | 80 | |
| | | $I_O \le$ 1A | $V_i$ = 11.5V to 17V | — | — | 40 | |
| | | | $V_i$ = 10.5V to 23V<br>$T_j$ = 25°C | — | — | 80 | |
| Load Regulation | $\Delta V_O$ | $T_j$ = 25°C | 5mA $\le I_O \le$ 1.5A | — | 10 | 80 | mV |
| | | | 0.25A $\le I_O \le$ 0.75A | — | — | 40 | |
| | | 5mA $\le I_O \le$ 1A | | — | — | 80 | |
| Quiescent Current | $I_d$ | $I_O$ = 1A | $T_j$ = 25°C | — | — | 8 | mA |
| | | | 0°C $\le T_j \le$ 125°C | — | — | 8.5 | |
| Quiescent Current Change | $\Delta I_d$ | 5mA $\le I_O \le$ 1A | | — | — | 0.5 | mA |
| | | $T_j$ = 25°C<br>$I_O \le$ 1A, $V_i$ = 10.5V to 23V | | — | — | 1.0 | |
| | | $V_i$ = 10.5V to 25V | | — | — | 1.0 | |
| Output Noise Voltage | $V_n$ | $T_a$ = 25°C, f = 10Hz to 100KHz | | — | 52 | — | μV |
| Ripple Rejection | RR | f = 120Hz, $V_i$ = 11.5V to 21.5V<br>$T_j$ = 25°C | | 56 | 72 | — | dB |
| | | f = 120Hz, $V_i$ = 11.5V to 21.5V<br>0°C $\le T_j \le$ 125°C | | 56 | — | — | |
| Dropout Voltage | $V_d$ | $I_O$ = 1A, $T_j$ = 25°C | | — | 2.0 | — | V |
| Peak Output Current | $I_{peak}$ | $T_j$ = 25°C | | — | 2.2 | — | A |
| Short-Circuit Current | $I_{sc}$ | $V_i$ = 35V, $T_j$ = 25°C | | — | 250 | — | mA |
| Average TC of $V_{out}$ | $\Delta V_O / \Delta T$ | $I_O$ = 5mA | | — | ±0.9 | — | mV/°C |
| Output Resistance | $R_O$ | f = 1KHz | | — | 20 | — | mΩ |

* Load and line regulation are specified at a constant junction temperature. Changes in $V_O$ due to heating effects must be taken into account separately. Pulse testing with low duty cycle is used.

## ELECTRICAL CHARACTERISTICS KA340T09

(Refer to test circuit, 0°C≤$T_j$≤125°C, $V_i$ = 15V, $I_O$ = 0.5A, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| Output Voltage | $V_O$ | $T_j$ = 25°C, 5mA≤$I_O$≤1.0A | | 8.65 | 9.00 | 9.35 | V |
| | | 5mA≤$I_O$≤1.0A, PD≤15W<br>$V_i$ = 11.5V to 24V | | 8.60 | — | 9.40 | |
| Line Regulation | $\triangle V_O$ | $T_j$ = 25°C, $V_i$ = 11.5V to 25V | | — | 3 | 90 | mV |
| | | $V_i$ = 12V to 24V | | — | — | 90 | |
| | | $I_O$≤1A | $V_i$ = 12V to 19V | — | — | 45 | |
| | | | $V_i$ = 11.5V to 24V<br>$T_j$ = 25°C | — | — | 90 | |
| Load Regulation | $\triangle V_O$ | $T_j$ = 25°C | 5mA≤$I_O$≤1.5A | — | 10 | 90 | mV |
| | | | 0.25A≤$I_O$≤0.75A | — | — | 45 | |
| | | 5mA≤$I_O$≤1A | | — | — | 90 | |
| Quiescent Current | $I_d$ | $I_O$ = 1A | $T_j$ = 25°C | — | — | 8 | mA |
| | | | 0°C≤$T_j$≤125°C | — | — | 8.5 | |
| Quiescent Current Change | $\triangle I_d$ | 5mA≤$I_O$≤1A | | — | — | 0.5 | mA |
| | | $T_j$ = 25°C<br>$I_O$≤1A, $V_i$ = 11.5V to 24V | | — | — | 1.0 | |
| | | $V_i$ = 11.5V to 25V | | — | — | 1.0 | |
| Output Noise Voltage | $V_n$ | $T_a$ = 25°C, f = 10Hz to 100KHz | | — | 58 | — | μV |
| Ripple Rejection | RR | f = 120Hz, $V_i$ = 12.5V to 22.5V<br>$T_j$ = 25°C | | 56 | 72 | — | dB |
| | | f = 120Hz, $V_i$ = 12.5V to 22.5V<br>0°C≤$T_j$≤125°C | | 56 | — | — | |
| Dropout Voltage | $V_d$ | $I_O$ = 1A, $T_j$ = 25°C | | — | 2.0 | — | V |
| Peak Output Current | $I_{peak}$ | $T_j$ = 25°C | | — | 2.2 | — | A |
| Short-Circuit Current | $I_{sc}$ | $V_i$ = 35V, $T_j$ = 25°C | | — | 250 | — | mA |
| Average TC of $V_{out}$ | $\triangle V_O/\triangle T$ | $I_O$ = 5mA | | — | ± 1.0 | — | mV/°C |
| Output Resistance | $R_O$ | f = 1KHz | | — | 22 | — | mΩ |

* Load and line regulation are specified at a constant junction temperature. Changes in $V_O$ due to heating effects must be taken into account separately. Pulse testing with low duty cycle is used.

## ELECTRICAL CHARACTERISTICS KA340T10

(Refer to test circuit, $0°C \leq T_j \leq 125°C$, $V_i = 16V$, $I_O = 0.5A$, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| Output Voltage | $V_O$ | $T_j = 25°C$, $5mA \leq I_O \leq 1.0A$ | | 9.60 | 10.00 | 10.40 | V |
| | | $5mA \leq I_O \leq 1.0A$, $PD \leq 15W$<br>$V_i = 12.5V$ to $25V$ | | 9.50 | — | 10.50 | |
| Line Regulation | $\triangle V_O$ | $T_j = 25°C$, $V_i = 12.5V$ to $25V$ | | — | 3 | 100 | mV |
| | | $V_i = 13V$ to $25V$ | | — | — | 100 | |
| | | $I_O \leq 1A$ | $V_i = 13V$ to $20V$ | — | — | 50 | |
| | | | $V_i = 12.5V$ to $25V$<br>$T_j = 25°C$ | — | — | 100 | |
| Load Regulation | $\triangle V_O$ | $T_j = 25°C$ | $5mA \leq I_O \leq 1.5A$ | — | 10 | 100 | mV |
| | | | $0.25A \leq I_O \leq 0.75A$ | — | — | 50 | |
| | | $5mA \leq I_O \leq 1A$ | | — | — | 100 | |
| Quiescent Current | $I_d$ | $I_O = 1A$ | $T_j = 25°C$ | — | — | 8 | mA |
| | | | $0°C \leq T_j \leq 125°C$ | — | — | 8.5 | |
| Quiescent Current Change | $\triangle I_d$ | $5mA \leq I_O \leq 1A$ | | — | — | 0.5 | mA |
| | | $T_j = 25°C$<br>$I_O \leq 1A$, $V_i = 12.6V$ to $25V$ | | — | — | 1.0 | |
| | | $V_i = 12.6V$ to $25V$ | | — | — | 1.0 | |
| Output Noise Voltage | $V_n$ | $T_a = 25°C$, $f = 10Hz$ to $100KHz$ | | — | 58 | — | $\mu V$ |
| Ripple Rejection | RR | $f = 120Hz$, $V_i = 13V$ to $23V$<br>$T_j = 25°C$ | | 56 | 72 | — | dB |
| | | $f = 120Hz$, $V_i = 13V$ to $23V$<br>$0°C \leq T_j \leq 125°C$ | | 56 | — | — | |
| Dropout Voltage | $V_d$ | $I_O = 1A$, $T_j = 25°C$ | | — | 2.0 | — | V |
| Peak Output Current | $I_{peak}$ | $T_j = 25°C$ | | — | 2.2 | — | A |
| Short-Circuit Current | $I_{sc}$ | $V_i = 35V$, $T_j = 25°C$ | | — | 250 | — | mA |
| Average TC of $V_{out}$ | $\triangle V_O / \triangle T$ | $I_O = 5mA$ | | — | ± 1.1 | — | mV/°C |
| Output Resistance | $R_O$ | $f = 1KHz$ | | — | 24 | — | mΩ |

* Load and line regulation are specified at a constant junction temperature. Changes in $V_O$ due to heating effects must be taken into account separately. Pulse testing with low duty cycle is used.

## ELECTRICAL CHARACTERISTICS KA340T11

(Refer to test circuit, $0°C \leq T_j \leq 125°C$, $V_i = 18V$, $I_O = 0.5A$, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| Output Voltage | $V_O$ | $T_j = 25°C$, $5mA \leq I_O \leq 1.0A$ | | 11.60 | 11.00 | 11.40 | V |
| | | $5mA \leq I_O \leq 1.0A$, $PD \leq 15W$<br>$V_i = 13.5V$ to $26V$ | | 10.50 | — | 11.50 | |
| Line Regulation | $\triangle V_O$ | $T_j = 25°C$, $V_i = 13.5V$ to $25V$ | | — | 3 | 110 | mV |
| | | $V_i = 14V$ to $26V$ | | — | — | 110 | |
| | | $I_O \leq 1A$ | $V_i = 14V$ to $21V$ | — | — | 55 | |
| | | | $V_i = 13.5V$ to $26V$<br>$T_j = 25°C$ | — | — | 110 | |
| Load Regulation | $\triangle V_O$ | $T_j = 25°C$ | $5mA \leq I_O \leq 1.5A$ | — | 10 | 110 | mV |
| | | | $0.25A \leq I_O \leq 0.75A$ | — | — | 55 | |
| | | $5mA \leq I_O \leq 1A$ | | — | — | 110 | |
| Quiescent Current | $I_d$ | $I_O = 1A$ | $T_j = 25°C$ | — | — | 8 | mA |
| | | | $0°C \leq T_j \leq 125°C$ | — | — | 8.5 | |
| Quiescent Current Change | $\triangle I_d$ | $5mA \leq I_O \leq 1A$ | | — | — | 0.5 | mA |
| | | $T_j = 25°C$<br>$I_O \leq 1A$, $V_i = 13.7V$ to $26V$ | | — | — | 1.0 | |
| | | $V_i = 13.5V$ to $25V$ | | — | — | 1.0 | |
| Output Noise Voltage | $V_n$ | $T_a = 25°C$, $f = 10Hz$ to $100KHz$ | | — | 70 | — | $\mu V$ |
| Ripple Rejection | RR | $f = 120Hz$, $V_i = 14V$ to $24V$<br>$T_j = 25°C$ | | 55 | 72 | — | dB |
| | | $f = 120Hz$, $V_i = 14V$ to $24V$<br>$0°C \leq T_j \leq 125°C$ | | 55 | — | — | |
| Dropout Voltage | $V_d$ | $I_O = 1A$, $T_j = 25°C$ | | — | 2.0 | — | V |
| Peak Output Current | $I_{peak}$ | $T_j = 25°C$ | | — | 2.2 | — | A |
| Short-Circuit Current | $I_{sc}$ | $V_i = 35V$, $T_j = 25°C$ | | — | 250 | — | mA |
| Average TC of $V_{out}$ | $\triangle V_O / \triangle T$ | $I_O = 5mA$ | | — | ±1.3 | — | mV/°C |
| Output Resistance | $R_O$ | $f = 1KHz$ | | — | 26 | — | mΩ |

* Load and line regulation are specified at a constant junction temperature. Changes in $V_O$ due to heating effects must be taken into account separately. Pulse testing with low duty cycle is used.

## ELECTRICAL CHARACTERISTICS KA340T12

(Refer to test circuit, $0°C \leq T_j \leq 125°C$, $V_i = 19V$, $I_O = 0.5A$, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| Output Voltage | $V_O$ | $T_j = 25°C$, $5mA \leq I_O \leq 1.0A$ | | 11.50 | 12.00 | 12.50 | V |
| | | $5mA \leq I_O \leq 1.0A$, $PD \leq 15W$<br>$V_i = 14.5V$ to $27V$ | | 11.40 | — | 12.60 | |
| Line Regulation | $\Delta V_O$ | $T_j = 25°C$, $V_i = 14.5V$ to $30V$ | | — | 4 | 120 | mV |
| | | $V_i = 15V$ to $27V$ | | — | — | 120 | |
| | | $I_O \leq 1A$ | $V_i = 16V$ to $22V$ | — | — | 60 | |
| | | | $V_i = 14.6V$ to $27V$<br>$T_j = 25°C$ | — | — | 120 | |
| Load Regulation | $\Delta V_O$ | $T_j = 25°C$ | $5mA \leq I_O \leq 1.5A$ | — | 12 | 120 | mV |
| | | | $0.25A \leq I_O \leq 0.75A$ | — | — | 60 | |
| | | $5mA \leq I_O \leq 1A$ | | — | — | 120 | |
| Quiescent Current | $I_d$ | $I_O = 1A$ | $T_j = 25°C$ | — | — | 8 | mA |
| | | | $0°C \leq T_j \leq 125°C$ | — | — | 8.5 | |
| Quiescent Current Change | $\Delta I_d$ | $5mA \leq I_O \leq 1A$ | | — | — | 0.5 | mA |
| | | $T_j = 25°C$<br>$I_O \leq 1A$, $V_i = 14.8V$ to $27V$ | | — | — | 1.0 | |
| | | $V_i = 14.5V$ to $30V$ | | — | — | 1.0 | |
| Output Noise Voltage | $V_n$ | $T_a = 25°C$, $f = 10Hz$ to $100KHz$ | | — | 75 | — | $\mu V$ |
| Ripple Rejection | RR | $f = 120Hz$, $V_i = 15V$ to $25V$<br>$T_j = 25°C$ | | 55 | 72 | — | dB |
| | | $f = 120Hz$, $V_i = 15V$ to $25V$<br>$0°C \leq T_j \leq 125°C$ | | 55 | — | — | |
| Dropout Voltage | $V_d$ | $I_O = 1A$, $T_j = 25°C$ | | — | 2.0 | — | V |
| Peak Output Current | $I_{peak}$ | $T_j = 25°C$ | | — | 2.2 | — | A |
| Short-Circuit Current | $I_{sc}$ | $V_i = 35V$, $T_j = 25°C$ | | — | 250 | — | mA |
| Average TC of $V_{out}$ | $\Delta V_O / \Delta T$ | $I_O = 5mA$ | | — | ± 1.5 | — | mV/°C |
| Output Resistance | $R_O$ | $f = 1KHz$ | | — | 28 | — | mΩ |

* Load and line regulation are specified at a constant junction temperature. Changes in $V_O$ due to heating effects must be taken into account separately. Pulse testing with low duty cycle is used.

## ELECTRICAL CHARACTERISTICS KA340T15

(Refer to test circuit, $0°C \leq T_j \leq 125°C$, $V_i = 23V$, $I_O = 0.5A$, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| Output Voltage | $V_O$ | $T_j = 25°C$, $5mA \leq I_O \leq 1.0A$ | | 14.40 | 15.00 | 15.60 | V |
| | | $5mA \leq I_O \leq 1.0A$, $PD \leq 15W$<br>$V_i = 17.5V$ to $30V$ | | 14.25 | — | 15.75 | |
| Line Regulation | $\Delta V_O$ | $T_j = 25°C$, $V_i = 17.5V$ to $30V$ | | — | 4 | 150 | mV |
| | | $V_i = 18.5V$ to $30V$ | | — | — | 150 | |
| | | $I_O \leq 1A$ | $V_i = 20V$ to $26V$ | — | — | 60 | |
| | | | $V_i = 17.7V$ to $30V$<br>$T_j = 25°C$ | — | — | 120 | |
| Load Regulation | $\Delta V_O$ | $T_j = 25°C$ | $5mA \leq I_O \leq 1.5A$ | — | 12 | 150 | mV |
| | | | $0.25A \leq I_O \leq 0.75A$ | — | — | 75 | |
| | | $5mA \leq I_O \leq 1A$ | | — | — | 150 | |
| Quiescent Current | $I_d$ | $I_O = 1A$ | $T_j = 25°C$ | — | — | 8 | mA |
| | | | $0°C \leq T_j \leq 125°C$ | — | — | 8.5 | |
| Quiescent Current Change | $\Delta I_d$ | $5mA \leq I_O \leq 1A$ | | — | — | 0.5 | mA |
| | | $T_j = 25°C$<br>$I_O \leq 1A$, $V_i = 17.9V$ to $30V$ | | — | — | 1.0 | |
| | | $V_i = 17.5V$ to $30V$ | | — | — | 1.0 | |
| Output Noise Voltage | $V_n$ | $T_a = 25°C$, $f = 10Hz$ to $100KHz$ | | — | 90 | — | $\mu V$ |
| Ripple Rejection | RR | $f = 120Hz$, $V_i = 18.5V$ to $28.5V$<br>$T_j = 25°C$ | | 54 | 70 | — | dB |
| | | $f = 120Hz$, $V_i = 15V$ to $25V$<br>$0°C \leq T_j \leq 125°C$ | | 54 | — | — | |
| Dropout Voltage | $V_d$ | $I_O = 1A$, $T_j = 25°C$ | | — | 2.0 | — | V |
| Peak Output Current | $I_{peak}$ | $T_j = 25°C$ | | — | 2.2 | — | A |
| Short-Circuit Current | $I_{sc}$ | $V_i = 35V$, $T_j = 25°C$ | | — | 250 | — | mA |
| Average TC of $V_{out}$ | $\Delta V_O / \Delta T$ | $I_O = 5mA$ | | — | ±1.8 | — | mV/°C |
| Output Resistance | $R_O$ | $f = 1KHz$ | | — | 29 | — | mΩ |

* Load and line regulation are specified at a constant junction temperature. Changes in $V_O$ due to heating effects must be taken into account separately. Pulse testing with low duty cycle is used.

## ELECTRICAL CHARACTERISTICS KA340T18

(Refer to test circuit, 0°C$\le T_j \le$125°C, $V_i$=27V, $I_O$=0.5A, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| Output Voltage | $V_O$ | $T_j$=25°C, 5mA$\le I_O \le$1.0A | | 17.30 | 18.00 | 18.70 | V |
| | | 5mA$\le I_O \le$1.0A, PD$\le$15W<br>$V_i$=21V to 33V | | 17.10 | — | 18.90 | |
| Line Regulation | $\triangle V_O$ | $T_j$=25°C, $V_i$=21V to 33V | | — | 5 | 180 | mV |
| | | $V_i$=22V to 33V | | — | — | 180 | |
| | | $I_O \le$1A | $V_i$=24V to 30V | — | — | 90 | |
| | | | $V_i$=21V to 33V<br>$T_j$=25°C | — | — | 180 | |
| Load Regulation | $\triangle V_O$ | $T_j$=25°C | 5mA$\le I_O \le$1.5A | — | 12 | 180 | mV |
| | | | 0.25A$\le I_O \le$0.75A | — | — | 90 | |
| | | 5mA$\le I_O \le$1A | | — | — | 180 | |
| Quiescent Current | $I_d$ | $I_O$=1A | $T_j$=25°C | — | — | 8 | mA |
| | | | 0°C$\le T_j \le$125°C | — | — | 8.5 | |
| Quiescent Current Change | $\triangle I_d$ | 5mA$\le I_O \le$1A | | — | — | 0.5 | mA |
| | | $T_j$=25°C<br>$I_O \le$1A, $V_i$=21.5V to 33V | | — | — | 1.0 | |
| | | $V_i$=21V to 33V | | — | — | 1.0 | |
| Output Noise Voltage | $V_n$ | $T_a$=25°C, f=10Hz to 100KHz | | — | 110 | — | $\mu$V |
| Ripple Rejection | RR | f=120Hz, $V_i$=22V to 32V<br>$T_j$=25°C | | 53 | 69 | — | dB |
| | | f=120Hz, $V_i$=22V to 32V<br>0°C$\le T_j \le$125°C | | 53 | — | — | |
| Dropout Voltage | $V_d$ | $I_O$=1A, $T_j$=25°C | | — | 2.0 | — | V |
| Peak Output Current | $I_{peak}$ | $T_j$=25°C | | — | 2.2 | — | A |
| Short-Circuit Current | $I_{sc}$ | $V_i$=35V, $T_j$=25°C | | — | 250 | — | mA |
| Average TC of $V_{out}$ | $\triangle V_O/\triangle T$ | $I_O$=5mA | | — | ±2.2 | — | mV/°C |
| Output Resistance | $R_O$ | f=1KHz | | — | 32 | — | mΩ |

* Load and line regulation are specified at a constant junction temperature. Changes in $V_O$ due to heating effects must be taken into account separately. Pulse testing with low duty cycle is used.

## ELECTRICAL CHARACTERISTICS KA340T24

(Refer to test circuit, $0°C \le T_j \le 125°C$, $V_i = 33V$, $I_O = 0.5A$, unless otherwise specified)

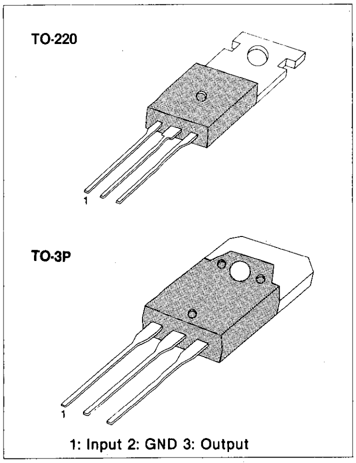
| Characteristic | Symbol | Test Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| Output Voltage | $V_O$ | $T_j = 25°C$, $5mA \le I_O \le 1.0A$ | | 23.00 | 24.00 | 25.00 | V |
| | | $5mA \le I_O \le 1.0A$, $PD \le 15W$<br>$V_i = 27V$ to $38V$ | | 22.80 | — | 25.20 | |
| Line Regulation | $\triangle V_O$ | $T_j = 25°C$, $V_i = 27V$ to $38V$ | | — | 5 | 240 | mV |
| | | $V_i = 28V$ to $38V$ | | — | — | 240 | |
| | | $I_O \le 1A$ | $V_i = 30V$ to $36V$ | — | — | 120 | |
| | | | $V_i = 27V$ to $38V$<br>$T_j = 25°C$ | — | — | 240 | |
| Load Regulation | $\triangle V_O$ | $T_j = 25°C$ | $5mA \le I_O \le 1.5A$ | — | 12 | 240 | mV |
| | | | $0.25A \le I_O \le 0.75A$ | — | — | 120 | |
| | | $5mA \le I_O \le 1A$ | | — | — | 240 | |
| Quiescent Current | $I_d$ | $I_O = 1A$ | $T_j = 25°C$ | — | — | 8 | mA |
| | | | $0°C \le T_j \le 125°C$ | — | — | 8.5 | |
| Quiescent Current Change | $\triangle I_d$ | $5mA \le I_O \le 1A$ | | — | — | 0.5 | mA |
| | | $T_j = 25°C$<br>$I_O \le 1A$, $V_i = 28V$ to $38V$ | | — | — | 1.0 | |
| | | $V_i = 27V$ to $38V$ | | — | — | 1.0 | |
| Output Noise Voltage | $V_n$ | $T_a = 25°C$, $f = 10Hz$ to $100KHz$ | | — | 170 | — | μV |
| Ripple Rejection | RR | $f = 120Hz$, $V_i = 28V$ to $38V$<br>$T_j = 25°C$ | | 50 | 66 | — | dB |
| | | $f = 120Hz$, $V_i = 28V$ to $38V$<br>$0°C \le T_j \le 125°C$ | | 50 | — | — | |
| Dropout Voltage | $V_d$ | $I_O = 1A$, $T_j = 25°C$ | | — | 2.0 | — | V |
| Peak Output Current | $I_{peak}$ | $T_j = 25°C$ | | — | 2.2 | — | A |
| Short-Circuit Current | $I_{sc}$ | $V_i = 35V$, $T_j = 25°C$ | | — | 250 | — | mA |
| Average TC of $V_{out}$ | $\triangle V_O / \triangle T$ | $I_O = 5mA$ | | — | ±2.8 | — | mV/°C |
| Output Resistance | $R_O$ | $f = 1KHz$ | | — | 37 | — | mΩ |

* Load and line regulation are specified at a constant junction temperature. Changes in $V_O$ due to heating effects must be taken into account separately. Pulse testing with low duty cycle is used.

## 3A POSITIVE VOLTAGE REGULATOR

This family of fixed voltage regulators are monolithic integrated circuits capable of driving loads in excess of 3.0 amperes. These three-terminal regulators employ internal current limiting, thermal shutdown, and safe-area compensation.

Although designed primarily as fixed voltage regulators, these devices can be used with external components to obtain adjustable voltages and currents.



1: Input 2: GND 3: Output

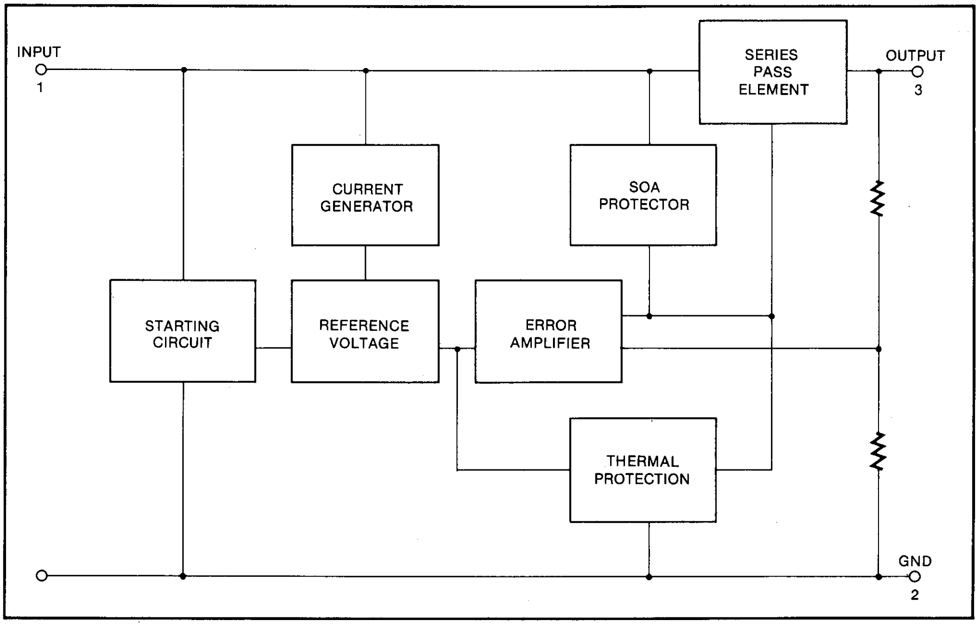
## FEATURES

- **Output current in excess of 3.0 ampere**
- **Output transistor safe-area compensation**
- **Power dissipation: 25W (To-220)**
- **Internal short-circuit current limiting**
- **Internal thermal overload protection**
- **Output voltage offered in 2% and 4% tolerance (2% regulators are available in 5, 12 and 15 volt devices)**
- **No external components required**
- **Thermal regulation is specified**
- **Output voltage of 5; 6; 8; 12; 15; 18; 24V**
- **Mass production: KA78T05**
- **Under develop: 6; 8; 12; 15; 18; 24V**

## ORDERING INFORMATION

| Device | Package | Operating Temperature |
|---|---|---|
| KA78TXXCT | TO-220 | 0 ~ 125°C |
| KA78TXXCH | TO-3P | |

## BLOCK DIAGRAM



## ABSOLUTE MAXIMUM RATINGS

| Characteristic | Symbol | Value | Unit |
|---|---|---|---|
| Input Voltage (5.0V – 12V)<br>(15V – 24V) | $V_{IN}$ | 35<br>40 | V<br>V |
| Power Dissipation | $P_D$ | Internally limited | |
| Thermal Resistance, Junction to Air Tc = 25°C | $\Theta_{JA}$ | 65 | °C/W |
| Thermal Resistance, Junction to Case | $\Theta_{JC}$ | 2.5 | °C/W |
| Operating Temperature Range | $T_{opr}$ | 0 to +125 | °C |
| Storage Temperature Range | $T_{stg}$ | –65 to +150 | °C |

## KA78T05C, KA78T05AC ELECTRICAL CHARACTERISTICS

($V_{IN}$ = 10V, $I_o$ = 3.0A, $T_j$ = 0°C to 125°C, $P_o \leq P_{max}$, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | KA78T05C | | | Unit |
|---|---|---|---|---|---|---|
| | | | Min | Typ | Max | |
| Output Voltage | $V_o$ | $5mA \leq I_o \leq 3.0A$, $T_j = 25°C$<br>$5mA \leq I_o \leq 3A$;<br>$7.3V \leq V_{IN} \leq 20V$, $5mA \leq I_o \leq 2A$ | 4.8<br>4.75 | 5.0<br>5.0 | 5.2<br>5.25 | $V_{DC}$ |
| Line Regulation | $\triangle V_o$ | $7.2V \leq V_{IN} \leq 35V$, $I_o = 5mA$, $T_j = 25°C$<br>$7.2V \leq V_{IN} \leq 35V$, $I_o = 1.0A$, $T_j = 25°C$<br>$7.5V \leq V_{IN} \leq 20V$, $I_o = 2.0A$<br>$8.0V \leq V_{IN} \leq 12V$, $I_o = 3.0A$ | | 3.0 | 25 | mV |
| Load Regulation | $\triangle V_o$ | $5mA \leq I_o \leq 3.0A$, $T_j = 25°C$<br>$5mA \leq I_o \leq 3.0A$ | | 10<br>15 | 30<br>80 | mV<br>mV |
| Thermal Regulation | $REG_{therm}$ | Pulse = 10ms, P = 20W,<br>Ta = 25°C | | 0.002 | 0.03 | %$V_o$/W |
| Quiescent Current | $I_d$ | $5mA \leq I_o \leq 3A$, $T_j = 25°C$<br>$5mA \leq I_o \leq 3A$ | | 3.5<br>4.0 | 5.0<br>6.0 | mA<br>mA |
| Quiescent Current Change | $\triangle I_o$ | $7.2V \leq V_{IN} \leq 35V$, $I_o = 5mA$,<br>$T_j = 25°C$;<br>$7.5V \leq V_{IN} \leq 20V$, $I_o = 2A$;<br>$5mA \leq I_o \leq 3A$ | | 0.1 | 0.8 | mA |
| Ripple Rejection | RR | $8V \leq V_{IN} \leq 18V$, f = 120Hz, $I_o = 2.0A$ | | 75 | | dB |
| Dropout Voltage | $V_D$ | $I_o = 3A$, $T_j = 25°C$ | | 2.2 | 2.5 | $V_{DC}$ |
| Output Noise Voltage | $V_N$ | $10Hz \leq f \leq 100KHz$, $T_j = 25°C$ | | 10 | | $\mu V/V_o$ |
| Output Resistance | $R_o$ | f = 1.0KHz | | 2.0 | | mΩ |
| Short Circuit Current Limit | $I_{SC}$ | $V_{IN} = 35V$, $T_j = 25°C$ | | 1.5 | 2.5 | A |
| Peak Output Current | $I_{peak}$ | $T_j = 25°C$ | | 5.0 | | A |
| Average Temperature Cofficient of Output Voltage | $\triangle V_o / \triangle T$ | $I_o = 5.0mA$ | | 0.2 | | mV/°C |

* Load and line regulation are specified at constant junction temperature. Change in $V_o$ due to heating effects must be taken into account separately. Pulse testing with low duty is used.

## KA78T06C ELECTRICAL CHARACTERISTICS

($V_{IN}=11V$, $I_o=3.0V$, $T_j=0°C$ to $125°C$, $P_o \leq P_{max}$, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | KA78T06C | | | Unit |
|---|---|---|---|---|---|---|
| | | | Min | Typ | Max | |
| Output Voltage | $V_o$ | $5.0mA \leq I_o \leq 3A$, $T_j=+25°C$<br>$5.0mA \leq I_o \leq 3A$;<br>$8.3V \leq V_{IN} \leq 21V$, $5mA \leq I_o \leq 2A$ | 5.75<br>5.7 | 6.0<br>6.0 | 6.25<br>6.3 | V |
| Line Regulation | $\Delta V_o$ | $8.25V \leq V_{IN} \leq 35V$ $I_o=5.0mA$, $T_j=+25°C$;<br>$8.25V \leq V_{IN} \leq 35V$ $I_o=1.0A$, $T_j=+25°C$;<br>$8.6V \leq V_{IN} \leq 21V$ $I_o=2.0A$<br>$9.0V \leq V_{IN} \leq 13V$ $I_o=3.0A$ | | 4.0 | 30 | mV |
| Load Regulation | $\Delta V_o$ | $5mA \leq I_o \leq 3A$, $T_j=+25°C$<br>$5mA \leq I_o \leq 3A$ | | 10<br>15 | 30<br>80 | mV |
| Thermal Regulation | $REG_{therm}$ | Pulse = 10ms, P = 20W, Ta = 25°C | | 0.002 | 0.03 | % $V_o$/W |
| Quiescent Current | $I_d$ | $5mA \leq I_o \leq 3A$, $T_j=+25°C$<br>$5mA \leq I_o \leq 3A$ | | 3.5<br>4.0 | 5.0<br>6.0 | mA |
| Quiescent Current Change | $\Delta I_d$ | $8.25V \leq V_{IN} \leq 35V$, $I_o=5mA$, $T_j=+25°C$;<br>$8.6V \leq V_{IN} \leq 21V$, $I_o=2A$;<br>$5mA \leq I_o \leq 3.0A$ | | 0.1 | 0.8 | mA |
| Ripple Rejection | RR | $9V \leq V_{IN} \leq 19V$, f = 120Hz, $I_o=2A$ | 61 | 71 | | dB |
| Dropout Voltage | $V_D$ | $I_o=3A$, $T_j=+25°C$ | | 2.2 | 2.5 | V |
| Output Noise Voltage | $V_N$ | $10Hz \leq f \leq 100KHz$, $T_j=+25°C$ | | 10 | | $\mu V/V_o$ |
| Output Resistance | $R_o$ | f = 1.0KHz | | 2.0 | | mΩ |
| Short Circuit Current Limit | $I_{SC}$ | $V_{IN}=35V$, $T_j=+25°C$ | | 1.5 | 2.5 | A |
| Peak Output Current | $I_{peak}$ | $T_j=+25°C$ | | 5.0 | | A |
| Average Temperature Cofficient of Output Voltage | $\Delta V_O/\Delta T$ | $I_o=5.0mA$ | | 0.3 | | mV/°C |

* Load and line regulation are specified at constant junction temperature. Change in $V_o$ due to heating effects must be taken into account separately. Pulse testing with low duty is used.

## KA78T08C ELECTRICAL CHARACTERISTICS

($V_{IN} = 14V$, $I_o = 3.0V$, $T_j = 0°C$ to $125°C$, $P_o \leq P_{max}$, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | KA78T08C | | | Unit |
|---|---|---|---|---|---|---|
| | | | Min | Typ | Max | |
| Output Voltage | $V_o$ | $5.0mA \leq I_o \leq 3A$, $T_j = +25°C$<br>$5.0mA \leq I_o \leq 3A$;<br>$10.4V \leq V_{IN} \leq 23V$, $5mA \leq I_o \leq 2A$ | 7.7<br>7.6 | 8.0<br>8.0 | 8.3<br>8.4 | $V_{DC}$ |
| Line Regulation | $\triangle V_o$ | $10.3V \leq V_{IN} \leq 35V$, $I_o = 5mA$, $T_j = +25°C$<br>$10.3V \leq V_{IN} \leq 35V$, $I_o = 1.0A$, $T_j = +25°C$<br>$10.7V \leq V_{IN} \leq 23V$, $I_o = 2.0A$<br>$11V \leq V_{IN} \leq 17V$, $I_o = 3.0A$ | | 4.0 | 35 | mV |
| Load Regulation | $\triangle V_o$ | $5mA \leq I_o \leq 3A$, $T_j = +25°C$<br>$5mA \leq I_o \leq 3A$ | | 10<br>15 | 30<br>80 | mV |
| Thermal Regulation | $REG_{therm}$ | Pulse = 10ms, P = 20W, Ta = 25°C | | 0.002 | 0.03 | $\%V_o/W$ |
| Quiescent Current | $I_d$ | $5mA \leq I_o \leq 3A$, $T_j = +25°C$<br>$5mA \leq I_o \leq 3A$ | | 3.5<br>4.0 | 5.0<br>6.0 | mA |
| Quiescent Current Change | $\triangle I_d$ | $10.3V \leq V_{IN} \leq 35V$, $I_o = 5mA$, $T_j = +25°C$<br>$10.7V \leq V_{IN} \leq 23V$, $I_o = 2A$<br>$5mA \leq I_o \leq 3A$ | | 0.1 | 0.8 | mA |
| Ripple Rejection | RR | $11V \leq V_{IN} \leq 21V$, f = 120Hz, $I_o = 2A$ | 61 | 71 | | dB |
| Dropout Voltage | $V_D$ | $I_o = 3A$, $T_j = +25°C$ | | 2.2 | 2.5 | $V_{DC}$ |
| Output Noise Voltage | $V_N$ | $10Hz \leq f \leq 100KHz$, $T_j = +25°C$ | | 10 | | $\mu V/V_o$ |
| Output Resistance | $R_o$ | f = 1.0KHz | | 2.0 | | mΩ |
| Short Circuit Current Limit | $I_{SC}$ | $V_{IN} = 35V$, $T_j = +25°C$ | | 1.5 | 2.5 | A |
| Peak Output Current | $I_{peak}$ | $T_j = +25°C$ | | 5.0 | | A |
| Average Temperature Cofficient of Output Voltage | $\triangle V_O/\triangle T$ | $I_o = 5.0mA$ | | 0.3 | | mV/°C |

* Load and line regulation are specified at constant junction temperature. Change in $V_o$ due to heating effects must be taken into account separately. Pulse testing with low duty is used.

## KA78T12C, KA78T12AC ELECTRICAL CHARACTERISTICS

($V_{IN} = 19V$, $I_o = 3.0A$, $T_j = 0°C$ to $125°C$, $P_o \leq P_{max}$, unless otherwise noted)

| Characteristic | Symbol | Test Conditions | KA78T12C | | | Unit |
|---|---|---|---|---|---|---|
| | | | Min | Typ | Max | |
| Output Voltage | $V_o$ | $5mA \leq I_o \leq 3A$, $T_j = 25°C$<br>$5mA \leq I_o \leq 3A$;<br>$5mA \leq I_o \leq 2A$, $14.5V \leq V_{IN} \leq 27V$ | 11.5<br>11.4 | 12<br>12 | 12.5<br>12.6 | $V_{DC}$ |
| Line Regulation | $\triangle V_o$ | $14.5V_{DC} \leq V_{IN} \leq 35V_{DC}$, $I_o = 5mA$, $T_j = 25°C$;<br>$14.5V_{DC} \leq V_{IN} \leq 35V_{DC}$, $I_o = 1.0A$, $T_j = 25°C$<br>$14.9V_{DC} \leq V_{IN} \leq 27V_{DC}$, $I_o = 2.0A$<br>$16V_{DC} \leq V_{IN} \leq 22V_{DC}$, $I_o = 3.0A$ | | 6.0 | 45 | mV |
| Load Regulation | $\triangle V_o$ | $5mA \leq I_o \leq 3A$, $T_j = 25°C$<br>$5mA \leq I_o \leq 3A$ | | 10<br>15 | 30<br>80 | mV<br>mV |
| Thermal Regulation | $REG_{therm}$ | Pulse = 10ms, P = 20W,<br>Ta = 25°C | | 0.002 | 0.03 | $\%V_o/W$ |
| Quiescent Current | $I_d$ | $5mA \leq I_o \leq 3A$, $T_j = 25°C$<br>$5mA \leq I_o \leq 3A$ | | 3.5<br>4.0 | 5.0<br>6.0 | mA<br>mA |
| Quiescent Current Change | $\triangle I_d$ | $14.5V_{DC} \leq V_{IN} \leq 35V_{DC}$, $I_O = 5mA$, $T_j = 25°C$;<br>$14.9V_{DC} \leq V_{IN} \leq 27V_{DC}$, $I_o = 2A$;<br>$5.0mA \leq I_o \leq 3.0A$ | | 0.1 | 0.8 | mA |
| Ripple Rejection | RR | $15V_{DC} \leq V_{IN} \leq 25V_{DC}$,<br>f = 120Hz, $I_o = 2.0A$ | 57 | 67 | | dB |
| Dropout Voltage | $V_D$ | $I_o = 3A$, $T_j = 25°C$ | | 2.2 | 2.5 | $V_{DC}$ |
| Output Noise Voltage | $V_N$ | $10Hz \leq f \leq 100KHz$, $T_j = 25°C$ | | 10 | | $\mu V/V_o$ |
| Output Resistance | $R_o$ | f = 1.0KHz | | 2.0 | | mΩ |
| Short Circuit Current Limit | $I_{SC}$ | $V_{IN} = 35V$, $T_j = 25°C$ | | 1.5 | 2.5 | A |
| Peak Output Current | $I_{peak}$ | $T_j = 25°C$ | | 5.0 | | A |
| Average Temperature Cofficient of Output Voltage | $\triangle V_o/\triangle T$ | $I_o = 5.0mA$ | | 0.5 | | mV/°C |

* Load and line regulation are specified at constant junction temperature. Change in $V_o$ due to heating effects must be taken into account separately. Pulse testing with low duty is used.

## KA78T15C, KA78T15AC ELECTRICAL CHARACTERISTICS

($V_{IN}=23V$, $I_o=3.0A$, $T_j=0°C$ to $125°C$, $P_o \leq P_{max}$, unless otherwise noted)

| Characteristic | Symbol | Test Conditions | KA78T15C | | | Unit |
|---|---|---|---|---|---|---|
| | | | Min | Typ | Max | |
| Output Voltage | $V_o$ | $5mA \leq I_o \leq 3A$, $T_j = +25°C$<br>$5mA \leq I_o \leq 3A$;<br>$17.5V_{DC} \leq V_{IN} \leq 30V_{DC}$, $5mA \leq I_o \leq 2A$ | 14.4<br>14.25 | 15<br>15 | 15.6<br>15.75 | $V_{DC}$ |
| Line Regulation | $\triangle V_o$ | $17.6V \leq V_{IN} \leq 40V$, $I_o=5mA$, $T_j = +25°C$<br>$17.6V \leq V_{IN} \leq 40V$, $I_o=1A$, $T_j = +25°C$<br>$18V \leq V_{IN} \leq 30V$, $I_o=2.0A$;<br>$20V \leq V_{IN} \leq 26V$, $I_o=3.0A$ | | 7.5 | 55 | mV |
| Load Regulation | $\triangle V_o$ | $5mA \leq I_o \leq 3A$, $T_j = +25°C$<br>$5mA \leq I_o \leq 3A$ | | 10<br>15 | 30<br>80 | mV<br>mV |
| Thermal Regulation | $REG_{therm}$ | Pulse = 10ms, P = 20W,<br>Ta = 25°C | | 0.002 | 0.03 | %$V_o$/W |
| Quiescent Current | $I_d$ | $5mA \leq I_o \leq 3A$, $T_j = +25°C$<br>$5mA \leq I_o \leq 3A$ | | 3.5<br>4.0 | 5.0<br>6.0 | mA<br>mA |
| Quiescent Current Change | $\triangle I_o$ | $17.6V \leq V_{IN} \leq 40V$, $I_o=5mA$,<br>$T_j = +25°C$;<br>$18V \leq V_{IN} \leq 30V$, $I_o=2A$;<br>$5mA \leq I_o \leq 3A$ | | 0.1 | 0.8 | mA |
| Ripple Rejection | RR | $18.5V_{DC} \leq V_{IN} \leq 28.5V_{DC}$, f = 120Hz, $I_o=2.0A$ | 55 | 65 | | dB |
| Dropout Voltage | $V_D$ | $I_o=3A$, $T_j = +25°C$ | | 2.2 | 2.5 | $V_{DC}$ |
| Output Noise Voltage | $V_N$ | $10Hz \leq f \leq 100KHz$, $T_j = +25°C$ | | 10 | | $\mu V/V_o$ |
| Output Resistance | $R_o$ | f = 1.0KHz | | 2.0 | | mΩ |
| Short Circuit Current Limit | $I_{SC}$ | $V_{IN}=40V$, $T_j = +25°C$ | | 1.0 | 2.0 | A |
| Peak Output Current | $I_{peak}$ | $T_j = +25°C$ | | 5.0 | | A |
| Average Temperature Cofficient of Output Voltage | $\triangle V_o/\triangle T$ | $I_o=5.0mA$ | | 0.6 | | mV/°C |

* Load and line regulation are specified at constant junction temperature. Change in $V_o$ due to heating effects must be taken into account separately. Pulse testing with low duty is used.

## KA78T18C ELECTRICAL CHARACTERISTICS

($V_{IN}=27V$, $I_o=3.0V$, $T_j=0°C$ to 125°C, $P_o \leq P_{max}$, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | KA78T18C | | | Unit |
|---|---|---|---|---|---|---|
| | | | Min | Typ | Max | |
| Output Voltage | $V_o$ | $5.0mA \leq I_o \leq 3A$, $T_j = +25°C$<br>$5.0mA \leq I_o \leq 3A$;<br>$20.6V \leq V_{IN} \leq 33V$, $5mA \leq I_o \leq 2A$ | 17.3<br>17.1 | 18<br>18 | 18.7<br>18.9 | $V_{DC}$ |
| Line Regulation | $\triangle V_o$ | $20.7V \leq V_{IN} \leq 40V$, $I_o=5mA$, $T_j = +25°C$;<br>$20.7V \leq V_{IN} \leq 40V$, $I_o=1A$, $T_j = +25°C$;<br>$21.2V \leq V_{IN} \leq 33V$, $I_o=2.0A$<br>$24V \leq V_{IN} \leq 30V$, $I_o=3A$ | | 9.0 | 80 | mV |
| Load Regulation | $\triangle V_o$ | $5mA \leq I_o \leq 3A$, $T_j = +25°C$<br>$5mA \leq I_o \leq 3A$ | | 10<br>15 | 30<br>80 | mV |
| Thermal Regulation | $REG_{therm}$ | Pulse = 10ms, P = 20W, Ta = 25°C | | 0.002 | 0.03 | $\%V_o/W$ |
| Quiescent Current | $I_d$ | $5mA \leq I_o \leq 3A$, $T_j = +25°C$<br>$5mA \leq I_o \leq 3A$ | | 3.5<br>4.0 | 5.0<br>6.0 | mA |
| Quiescent Current Change | $\triangle I_d$ | $20.7V \leq V_{IN} \leq 40V$, $I_o=5mA$, $T_j = +25°C$;<br>$21.2V \leq V_{IN} \leq 33V$, $I_o=2.0A$;<br>$5mA \leq I_o \leq 3.0A$ | | 0.1 | 0.8 | mA |
| Ripple Rejection | RR | $22V \leq V_{IN} \leq 32V$, f = 120Hz, $I_o=2.0A$ | 54 | 64 | | dB |
| Dropout Voltage | $V_D$ | $I_o=3A$, $T_j = +25°C$ | | 2.2 | 2.5 | $V_{DC}$ |
| Output Noise Voltage | $V_N$ | $10Hz \leq f \leq 100KHz$, $T_j = +25°C$ | | 10 | | $\mu V/V_o$ |
| Output Resistance | $R_O$ | f = 1.0KHz | | 2.0 | | mΩ |
| Output Circuit Current Limit | $I_{SC}$ | $V_{IN}=40V$, $T_j = +25°C$ | | 1.0 | 2.0 | A |
| Peak Output Current | $I_{peak}$ | $T_j = +25°C$ | | 5.0 | | A |
| Average Temperature Coefficient of Output Voltage | $\triangle V_O/\triangle T$ | $I_o=5.0mA$ | | 0.7 | | mV/°C |

* Load and line regulation are specified at constant junction temperature. Change in $V_o$ due to heating effects must be taken into account separately. Pulse testing with low duty is used.

## KA78T24C ELECTRICAL CHARACTERISTICS

($V_{IN}=33V$, $I_o=3.0A$, $T_j=0°C$ to $125°C$, $P_O \leq P_{max}$, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | KA78T24C | | | Unit |
|---|---|---|---|---|---|---|
| | | | Min | Typ | Max | |
| Output Voltage | $V_o$ | $5.0mA \leq I_o \leq 3A$, $T_j=+25°C$ | 23 | 24 | 25 | $V_{DC}$ |
| | | $5.0mA \leq I_o \leq 3A$;<br>$27.3V \leq V_{IN} \leq 39V$, $5mA \leq I_o \leq 2A$ | 22.8 | 24 | 25.2 | |
| Line Regulation | $\triangle V_o$ | $27V \leq V_{IN} \leq 40V$, $I_o=5mA$, $T_j=+25°C$;<br>$27V \leq V_{IN} \leq 40V$, $I_o=1.0A$, $T_j=+25°C$;<br>$27.5V \leq V_{IN} \leq 39V$, $I_o=2.0A$;<br>$30V \leq V_{IN} \leq 36V$, $I_o=3.0A$ | | 12 | 90 | mV |
| Load Regulation | $\triangle V_o$ | $5mA \leq I_o \leq 3A$, $T_j=+25°C$<br>$5mA \leq I_o \leq 3A$ | | 10<br>15 | 30<br>80 | mV |
| Thermal Regulation | $REG_{therm}$ | Pulse = 10mS, P = 20W, Ta = 25°C | | 0.002 | 0.03 | $\%V_o/W$ |
| Quiescent Current | $I_d$ | $5mA \leq I_o \leq 3A$, $T_j=+25°C$<br>$5mA \leq I_o \leq 3A$ | | 3.5<br>4.0 | 5.0<br>6.0 | mA |
| Quiescent Current Change | $\triangle I_d$ | $27V \leq V_{IN} \leq 40V$, $I_o=5mA$, $T_j=+25°C$;<br>$27.5V \leq V_{IN} \leq 39V$, $I_o=2A$;<br>$5mA \leq I_o \leq 3A$ | | 0.1 | 0.8 | mA |
| Ripple Rejection | RR | $28V \leq V_{IN} \leq 38V$, f = 120Hz, $I_o=2.0A$ | 51 | 61 | | dB |
| Dropout Voltage | $V_D$ | $I_o=3A$, $T_j=+25°C$ | | 2.2 | 2.5 | $V_{DC}$ |
| Output Noise Voltage | $V_N$ | $10Hz \leq f \leq 100KHz$, $T_j=+25°C$ | | 10 | | $\mu V/V_o$ |
| Output Resistance | $R_O$ | f = 1.0KHz | | 2.0 | | mΩ |
| Short Circuit Current Limit | $I_{SC}$ | $V_{IN}=40V$, $T_j=+25°C$ | | 1.0 | 2.0 | A |
| Peak Output Current | $I_{peak}$ | $T_j=+25°C$ | | 5.0 | | A |
| Average Temperature Coefficient of Output Voltage | $\triangle V_O/\triangle T$ | $I_o=5.0mA$ | | 1.0 | | mV/°C |

* Load and line regulation are specified at constant junction temperature. Change in $V_o$ due to heating effects must be taken into account separately. Pulse testing with low duty is used.

# TYPICAL PERFORMANCE CHARACTERISTICS

**Fig. 1 TEMPERATURE STABILITY**

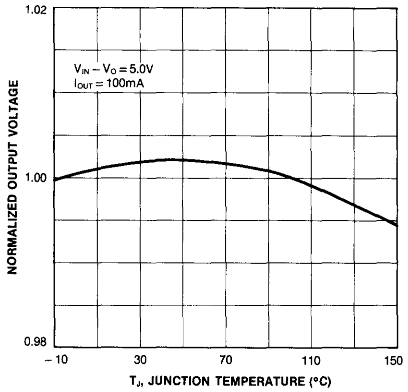


**Fig. 2 OUTPUT IMPEDANCE**

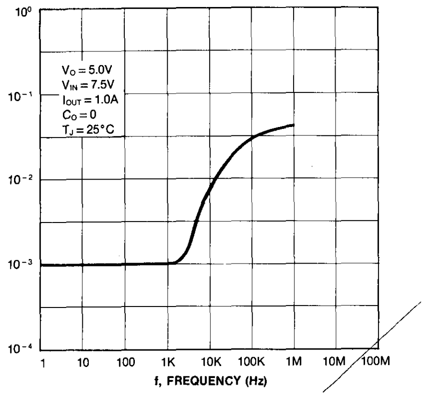


**Fig. 3 RIPPLE REJECTION $V_S$ FREQUENCY**

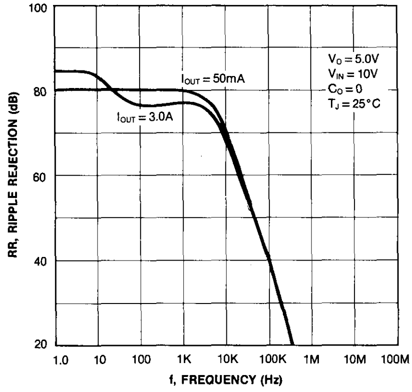


**Fig. 4 RIPPLE REJECTION $V_S$ OUTPUT CURRENT**

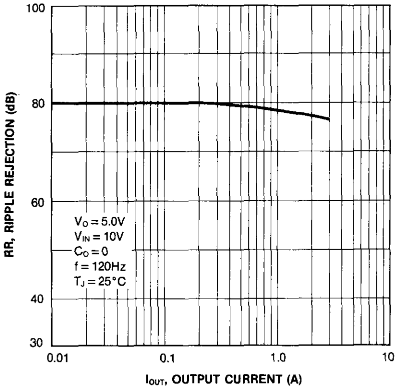


**Fig. 5 QUIESCENT CURRENT $V_S$ INPUT VOLTAGE**

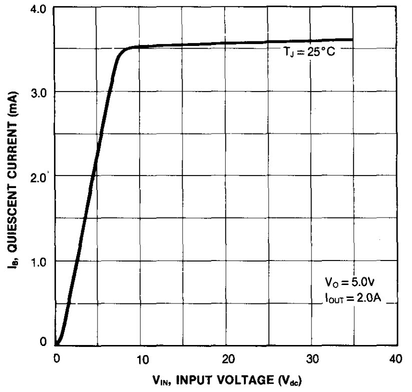


**Fig. 6 QUIESCENT CURRENT $V_S$ OUTPUT CURRENT**

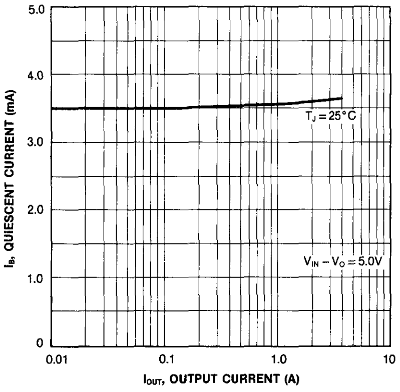


Fig. 7 DROPOUT VOLTAGE

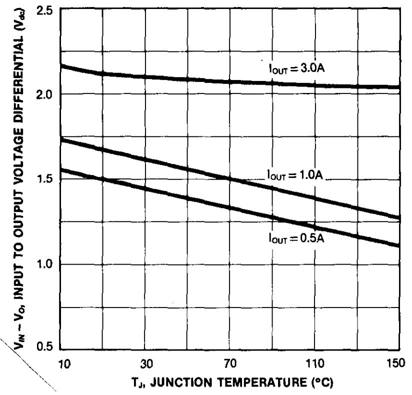


Fig. 8 PEAK OUTPUT CURRENT

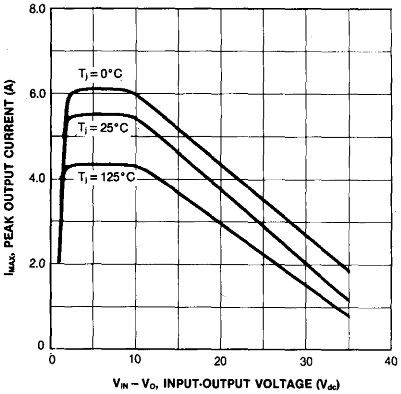


Fig. 9 LINE TRANSIENT RESPONSE

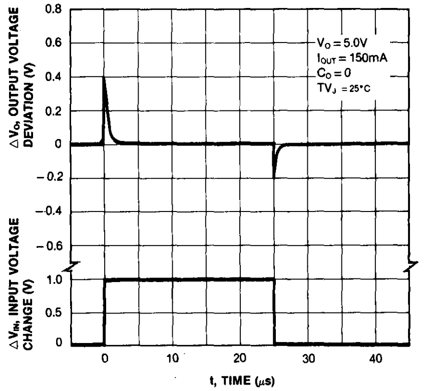


Fig. 10 LOAD TRANSIENT RESPONSE

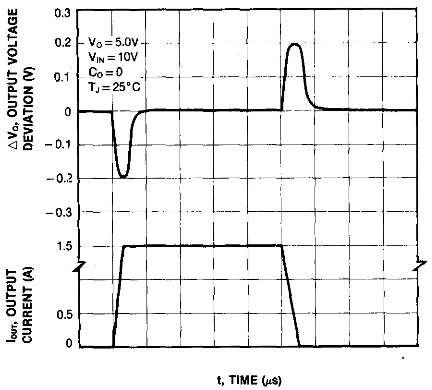
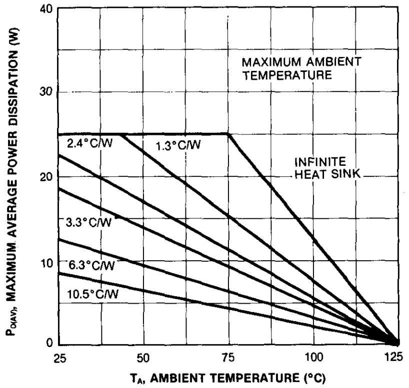


Fig. 11 MAXIMUM AVERAGE POWER DISSIPATION

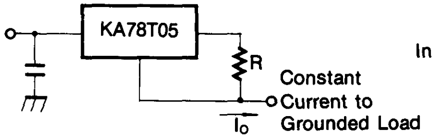


## APPLICATION INFORMATIONS

The KA78TXX Series of fixed voltage regulators are designed with Thermal Overload Protection that shuts down the circuit when subjected to an excessive power overload. Internal Short-Circuit Protection that limits the maximum current the circuit will pass, and Output Transistor Safe-Area Compensation that reduces the output short-circuit current as the voltage across the pass transistor is increased.

In many low current applications, compensation capacitors are not required. However, it is recommended that the regulator input be bypassed with a capacitor if the regulator is connected to the power supply filter with long wire lengths, or if the output load capacitance is large. An input bypass capacitor should be selected to provide good high-frequency characteristics to insure stable operation under all load conditions. A 0.33 μF or larger tantalum, mylar, or other capacitors having low internal impedance at high frequencies should be chosen. The bypass capacitor should be mounted with the shortest possible leads directly across the regulator's input terminals. Normally good construction techniques should be used to minimize ground loops and lead resistance drops since the regulator has no external sense lead.

**Fig. 12—CURRENT REGULATOR**



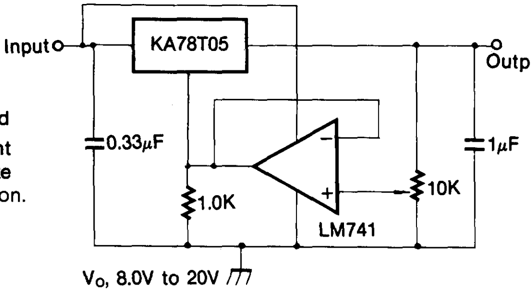
The KA78T05 regulator can also be used as a current source when connected as above. In order to minimize dissipation, the KA78T05 is used in this application. Resistor R determines the current as follows:

$$I_O = \frac{5.0V}{R} + I_B$$

$\triangle I_B = 0.7mA$ over line, load and temperature changes
$I_B = 3.5mA$

For example, a 2-ampere current source would require R to be a 2.5 ohm, 15W resistor and the output voltage compliance would be the input voltage less 7.5 volts.

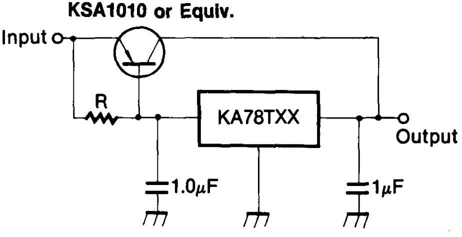
**Fig. 13—ADJUSTABLE OUTPUT REGULATOR**



$V_O$, 8.0V to 20V
$V_{IN} - V_O \geq 2.5V$

The addition of an operational amplifier allows adjustment to higher or intermediate values while retaining regulation characteristics. The minimum voltage obtainable with this arrangement is 3.0 volts greater than the regulator voltage.

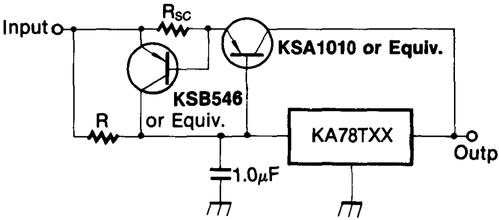
**Fig. 14—CURRENT BOOST REGULATOR**



XX = 2 digits of type number indicating voltage.

The KA78TXX series can be current boosted with a PNP transistor. The 2N4398 provides current to 15 amperes. Resistor R in conjunction with the $V_{BE}$ of the PNP determines when the pass transistor begins conducting; this circuit is not short-circuit proof. The input-output differential voltage minimum is increased by the $V_{BE}$ of the pass transistor.

**Fig. 15—CURRENT BOOST WITH SHORT-CIRCUIT PROTECTION**

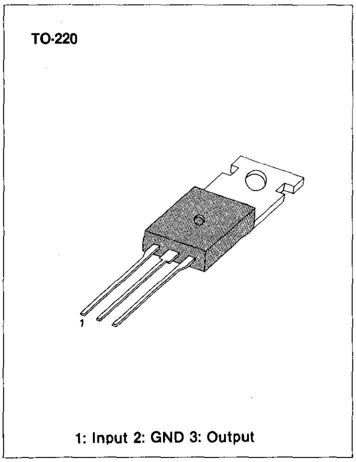


XX = 2 digits of type number indicating voltage.

The circuit shown in Figure 18 can be modified to provide supply protection against short circuits by adding a short-circuit sense resistor, $R_{SC}$, and an additional PNP transistor. The current sensing PNP must be able to handle the short-circuit current of the three-terminal regulator. Therefore, an eight-ampere power transistor is specified.

## 3-TERMINAL 1A POSITIVE VOLTAGE REGULATORS

The MC78XX/MC78XXA series of three-terminal positive regulators are available in the TO-220 package and with several fixed output voltages, making it useful in a wide range of applications. These regulators can provide local oncard regulation, eliminating the distribution problems associated with single point regulation. Each type employs internal current limiting, thermal shut-down and safe area protection, making it essentially indestructible. If adequate heat sinking is provided, they can deliver over 1A output current. Although designed primarily as fixed voltage regulators, these devices can be used with external components to obtain adjustable voltages and currents.
MC78XXI is characterized for operation from −40°C to +125°C, and MC78XXC from 0°C to +125°C.



1: Input 2: GND 3: Output

## FEATURES

- **Output Current up to 1.5A**
- **Output voltages of 5; 6; 8; 9; 10; 11; 12; 15; 18; 24V**
- **Thermal Overload Protection**
- **Short Circuit Protection**
- **Output Transistor SOA Protection**
- **No external components required**
- **Output current in excess of 1A**
- **Industrial and commercial temperature range**

## ORDERING INFORMATION

| Device | Package | Operating Temperature |
|---|---|---|
| MC78XXCT | TO-220 | 0~ +125°C |
| MC78XXACT | TO-220 | |
| MC78XXIT | TO-220 | −40~ +125°C |

## BLOCK DIAGRAM

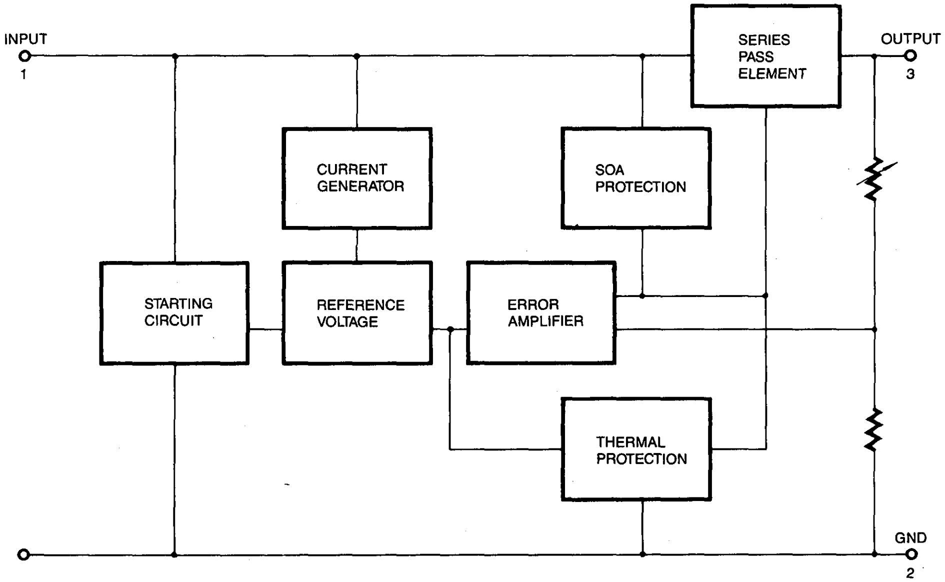


Fig. 1

## SCHEMATIC DIAGRAM

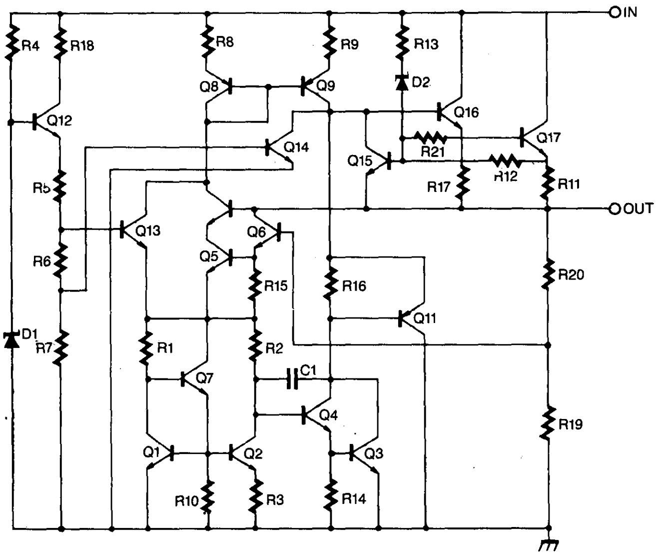


Fig. 2

## ABSOLUTE MAXIMUM RATINGS

| Characteristic | Symbol | Value | Unit |
|---|---|---|---|
| Input Voltage (for $V_O = 5V$ to 18V)<br>(for $V_O = 24V$) | $V_{IN}$<br>$V_{IN}$ | 35<br>40 | V<br>V |
| Thermal Resistance Junction-Cases | $\theta_{JC}$ | 5 | °C/W |
| Thermal Resistance Junction-Air | $\theta_{JA}$ | 65 | °C/W |
| Operating Temperature Range MC78XXC/AC<br>MC78XXI | $T_{opr}$ | 0 ~ +125<br>−40 ~ +125 | °C<br>°C |
| Storage Temperature Range | $T_{stg}$ | −65 ~ +150 | °C |

## ELECTRICAL CHARACTERISTICS MC7805

(Refer to test circuit, $T_{min} < T_j < T_{max}$, $I_o = 500mA$, $V_i = 10V$, $C_i = 0.33\mu F$, $C_o = 0.1\mu F$, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | | MC7805I | | | MC7805C | | | Unit |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Min | Typ | Max | Min | Typ | Max | |
| Output Voltage | $V_o$ | $T_j = 25°C$ | | 4.8 | 5.0 | 5.2 | 4.8 | 5.0 | 5.2 | V |
| | | $5.0mA \leq I_o \leq 1.0A$, $P_D \leq 15W$ | | | | | | | | |
| | | $V_i = 7V$ to 20V | | | | | 4.75 | 5.0 | 5.25 | |
| | | $V_i = 8V$ to 20V | | 4.75 | 5.0 | 5.25 | | | | |
| Line Regulation | $\triangle V_o$ | $T_j = 25°C$ | $V_i = 7V$ to 25V | | 5.0 | 100 | | 5.0 | 100 | mV |
| | | | $V_i = 8V$ to 12V | | 1.5 | 50 | | 1.5 | 50 | |
| Load Regulation | $\triangle V_o$ | $T_j = 25°C$ | $I_o = 5.0mA$ to 1.5A | | 9 | 100 | | 9 | 100 | mV |
| | | | $I_o = 250mA$ to 750mA | | 3 | 50 | | 3 | 50 | |
| Quiescent Current | $I_d$ | $T_j = 25°C$ | | | 5.0 | 8 | | 5.0 | 8 | mA |
| Quiescent Current Change | $\triangle I_d$ | $I_o = 5mA$ to 1.0A | | | | 0.5 | | | 0.5 | mA |
| | | $V_i = 7V$ to 25V | | | | | | | 1.3 | |
| | | $V_i = 8V$ to 25V | | | | 1.3 | | | | |
| Output Voltage Drift | $\triangle V_o / \triangle T$ | $I_o = 5mA$ | | | -0.8 | | | -0.8 | | mV/°C |
| Output Noise Voltage | $V_N$ | $f = 10Hz$ to 100KHz $T_j = 25°C$ | | | 40 | | | 40 | | $\mu V$ |
| Ripple Rejection | RR | $f = 120Hz$<br>$V_i = 8$ to 18V | | 62 | 78 | | 62 | 78 | | dB |
| Dropout Voltage | $V_D$ | $I_o = 1A$, $T_j = 25°C$ | | | 2 | | | 2 | | V |
| Output Resistance | $R_O$ | $f = 1KHz$ | | | 17 | | | 17 | | mΩ |
| Short Circuit Current | $I_{SC}$ | $V_i = 35V$, $T_j = 25°C$ | | | 250 | | | 250 | | mA |
| Peak Current | $I_{peak}$ | $T_j = 25°C$ | | | 2.2 | | | 2.2 | | A |

* $T_{min} < T_j < T_{max}$
MC78XXI: $T_{min} = -40°C$, $T_{max} = 125°C$
MC78XXC, $T_{min} = 0°C$, $T_{max} = 125°C$

* Load and line regulation are specified at constant junction temperature. Changes in $V_o$ due to heating effects must be taken into account separately. Pulse testing with low duty is used.

## ELECTRICAL CHARACTERISTICS MC7806

(Refer to test circuit, $T_{min}<T_j<T_{max}$, $I_o=500mA$, $V_i=11V$, $C_i=0.33\mu F$, $C_o=0.1\mu F$, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | | MC7806I | | | MC7806C | | | Unit |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Min | Typ | Max | Min | Typ | Max | |
| Output Voltage | $V_o$ | $T_j=25°C$ | | 5.75 | 6.0 | 6.25 | 5.75 | 6.0 | 6.25 | V |
| | | $5.0mA \leq I_o \leq 1.0A$, $P_D \leq 15W$ | | | | | | | | |
| | | $V_i=8.0V$ to 21V | | | | | 5.7 | 6.0 | 6.3 | |
| | | $V_i=9.0V$ to 21V | | 5.7 | 6.0 | 6.3 | | | | |
| Line Regulation | $\Delta V_o$ | $T_j=25°C$ | $V_i=8V$ to 25V | | 5 | 120 | | 5 | 120 | mV |
| | | | $V_i=9V$ to 13V | | 1.5 | 60 | | 1.5 | 60 | |
| Load Regulation | $\Delta V_o$ | $T_j=25°C$ | $I_o=5mA$ to 1.5A | | 9 | 120 | | 9 | 120 | mV |
| | | | $I_o=250mA$ to 750mA | | 3 | 60 | | 3 | 60 | |
| Quiescent Current | $I_d$ | $T_j=25°C$ | | | 5.0 | 8 | | 5.0 | 8 | mA |
| Quiescent Current Change | $\Delta I_d$ | $I_o=5mA$ to 1A | | | | 0.5 | | | 0.5 | mA |
| | | $V_i=8V$ to 25V | | | | | | | 1.3 | |
| | | $V_i=9V$ to 25V | | | | 1.3 | | | | |
| Output Voltage Drift | $\Delta V_o/\Delta T$ | $I_o=5mA$ | | | −0.8 | | | −0.8 | | mV/°C |
| Output Noise Voltage | $V_N$ | f = 10Hz to 100KHz $T_j=25°C$ | | | 45 | | | 45 | | $\mu V$ |
| Ripple Rejection | RR | f = 120Hz<br>$V_i=9$ to 19V | | 59 | 75 | | 59 | 75 | | dB |
| Dropout Voltage | $V_D$ | $I_o=1A$, $T_j=25°C$ | | | 2 | | | 2 | | V |
| Output Resistance | $R_O$ | f = 1KHz | | | 19 | | | 19 | | mΩ |
| Short Circuit Current | $I_{SC}$ | $V_i=35V$, $T_j=25°C$ | | | 250 | | | 250 | | mA |
| Peak Current | $I_{peak}$ | $T_j=25°C$ | | | 2.2 | | | 2.2 | | A |

* $T_{min}<T_j<T_{max}$
MC78XXI: $T_{min}=-40°C$, $T_{max}=125°C$
MC78XXC, $T_{min}=0°C$, $T_{max}=125°C$

* Load and line regulation are specified at constant junction temperature. Changes in $V_o$ due to heating effects must be taken into account separately. Pulse testing with low duty is used.

## ELECTRICAL CHARACTERISTICS MC7808

(Refer to test circuit, $T_{min} < T_j < T_{max}$, $I_o = 500mA$, $V_i = 14V$, $C_i = 0.33\mu F$, $C_o = 0.1\mu F$, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | | MC7808I | | | MC7808C | | | Unit |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Min | Typ | Max | Min | Typ | Max | |
| Output Voltage | $V_o$ | $T_j = 25°C$ | | 7.7 | 8.0 | 8.3 | 7.7 | 8.0 | 8.3 | V |
| | | $5.0mA \leq I_o \leq 1.0A$, $P_D \leq 15W$ | | | | | | | | |
| | | $V_i = 10.5V$ to $23V$ | | | | | 7.6 | 8.0 | 8.4 | |
| | | $V_i = 11.5V$ to $23V$ | | 7.6 | 8.0 | 8.4 | | | | |
| Line Regulation | $\triangle V_o$ | $T_j = 25°C$ | $V_i = 10.5V$ to $25V$ | | 6.0 | 160 | | 6.0 | 160 | mV |
| | | | $V_i = 11.5V$ to $17V$ | | 2.0 | 80 | | 2.0 | 80 | |
| Load Regulation | $\triangle V_o$ | $T_j = 25°C$ | $I_o = 5.0mA$ to $1.5A$ | | 12 | 160 | | 12 | 160 | mV |
| | | | $I_o = 250mA$ to $750mA$ | | 4.0 | 80 | | 4.0 | 80 | |
| Quiescent Current | $I_d$ | $T_j = 25°C$ | | | 5.0 | 8 | | 5.0 | 8 | mA |
| Quiescent Current Change | $\triangle I_d$ | $I_o = 5mA$ to $1.0A$ | | | | 0.5 | | | 0.5 | mA |
| | | $V_i = 10.5V$ to $25V$ | | | | | | | 1.0 | |
| | | $V_i = 11.5V$ to $25V$ | | | | 1.0 | | | | |
| Output Voltage Drift | $\triangle V_o/\triangle T$ | $I_o = 5mA$ | | | −0.8 | | | −0.8 | | mV/°C |
| Output Noise Voltage | $V_N$ | $f = 10Hz$ to $100KHz$ $T_j = 25°C$ | | | 52 | | | 52 | | $\mu V$ |
| Ripple Rejection | RR | $f = 120Hz$, $V_i = 11.5V$ to $21.5$ | | 56 | 72 | | 56 | 72 | | dB |
| Dropout Voltage | $V_D$ | $I_o = 1A$, $T_j = 25°C$ | | | 2 | | | 2 | | V |
| Output Resistance | $R_O$ | $f = 1KHz$ | | | 16 | | | 16 | | mΩ |
| Short Circuit Current | $I_{SC}$ | $V_i = 35V$, $T_j = 25°C$ | | | 250 | | | 250 | | mA |
| Peak Current | $I_{peak}$ | $T_j = 25°C$ | | | 2.2 | | | 2.2 | | A |

* $T_{min} < T_j < T_{max}$
MC78XXI: $T_{min} = -40°C$, $T_{max} = 125°C$
MC78XXC, $T_{min} = 0°C$, $T_{max} = 125°C$

* Load and line regulation are specified at constant junction temperature. Changes in $V_o$ due to heating effects must be taken into account separately. Pulse testing with low duty is used.

## ELECTRICAL CHARACTERISTICS MC7809

(Refer to test circuit, $T_{min} < T_j < T_{max}$, $I_o = 500mA$, $V_i = 15V$, $C_i = 0.33\mu F$, $C_o = 0.1\mu F$, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | | MC7809I | | | MC7809C | | | Unit |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Min | Typ | Max | Min | Typ | Max | |
| Output Voltage | $V_o$ | $T_j = 25°C$ | | 8.65 | 9 | 9.35 | 8.65 | 9 | 9.35 | V |
| | | $5.0mA \leq I_o \leq 1.0A$, $P_D \leq 15W$<br>$V_i = 11.5V$ to $24V$ | | | | | 8.6 | 9 | 9.4 | |
| | | $V_i = 12.5V$ to $24V$ | | 8.6 | 9 | 9.4 | | | | |
| Line Regulation | $\triangle V_o$ | $T_j = 25°C$ | $V_i = 11.5V$ to $25V$ | | 6 | 180 | | 6 | 180 | mV |
| | | | $V_i = 12V$ to $25V$ | | 2 | 90 | | 2 | 90 | |
| Load Regulation | $\triangle V_o$ | $T_j = 25°C$ | $I_o = 5mA$ to $1.5A$ | | 12 | 180 | | 12 | 180 | mV |
| | | | $I_o = 250mA$ to $750mA$ | | 4 | 90 | | 4 | 90 | |
| Quiescent Current | $I_d$ | $T_j = 25°C$ | | | 5.0 | 8 | | 5.0 | 8.0 | mA |
| Quiescent Current Change | $\triangle I_d$ | $I_o = 5mA$ to $1.0A$ | | | | 0.5 | | | 0.5 | mA |
| | | $V_i = 11.5V$ to $26V$ | | | | | | | 1.3 | |
| | | $V_i = 12.5V$ to $26V$ | | | | 1.3 | | | | |
| Output Voltage Drift | $\triangle V_o/\triangle T$ | $I_o = 5mA$ | | | −1 | | | −1 | | mV/°C |
| Output Noise Voltage | $V_N$ | $f = 10Hz$ to $100KHz$ $T_j = 25°C$ | | | 58 | | | 58 | | $\mu V$ |
| Ripple Rejection | RR | $f = 120Hz$<br>$V_i = 13V$ to $23V$ | | 56 | 71 | | 56 | 71 | | dB |
| Dropout Voltage | $V_D$ | $I_o = 1A$, $T_j = 25°C$ | | | 2 | | | 2 | | V |
| Output Resistance | $R_O$ | $f = 1KHz$ | | | 17 | | | 17 | | mΩ |
| Short Circuit Current | $I_{SC}$ | $V_i = 35V$, $T_j = 25°C$ | | | 250 | | | 250 | | mA |
| Peak Current | $I_{peak}$ | $T_j = 25°C$ | | | 2.2 | | | 2.2 | | A |

* $T_{min} < T_j < T_{max}$
MC78XXI: $T_{min} = -40°C$, $T_{max} = 125°C$
MC78XXC, $T_{min} = 0°C$, $T_{max} = 125°C$

* Load and line regulation are specified at constant junction temperature. Changes in $V_o$ due to heating effects must be taken into account separately. Pulse testing with low duty is used.

## ELECTRICAL CHARACTERISTICS MC7810

(Refer to test circuit, $T_{min} < T_i < T_{max}$, $I_o = 500mA$, $V_i = 16V$, $C_i = 0.33\mu F$, $C_o = 0.1\mu F$, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | | MC7810I | | | MC7810C | | | Unit |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Min | Typ | Max | Min | Typ | Max | |
| Output Voltage | $V_o$ | $T_j = 25°C$ | | 9.6 | 10 | 10.4 | 9.6 | 10 | 10.4 | V |
| | | $5.0mA \leq I_o \leq 1.0A$, $P_D \leq 15W$ | | | | | | | | |
| | | $V_i = 12.5V$ to 25V | | | | | 9.5 | 10 | 10.5 | |
| | | $V_i = 13.5V$ to 25V | | 9.5 | 10 | 10.5 | | | | |
| Line Regulation | $\triangle V_o$ | $T_j = 25°C$ | $V_i = 12.5V$ to 25V | | 10 | 200 | | 10 | 200 | mV |
| | | | $V_i = 13V$ to 20V | | 3 | 100 | | 3 | 100 | |
| Load Regulation | $\triangle V_o$ | $T_j = 25°C$ | $I_o = 5mA$ to 1.5A | | 12 | 200 | | 12 | 200 | mV |
| | | | $I_o = 250mA$ to 750mA | | 4 | 100 | | 4 | 100 | |
| Quiescent Current | $I_d$ | $T_j = 25°C$ | | | 5.1 | 8 | | 5.1 | 8 | mA |
| Quiescent Current Change | $\triangle I_d$ | $I_o = 5mA$ to 1.0A | | | | 0.5 | | | 0.5 | mA |
| | | $V_i = 12.5V$ to 29V | | | | | | | 1.0 | |
| | | $V_i = 13.5V$ to 29V | | | | 1.0 | | | | |
| Output Voltage Drift | $\triangle V_o/\triangle T$ | $I_o = 5mA$ | | | −1 | | | −1 | | mV/°C |
| Output Noise Voltage | $V_N$ | f = 10Hz to 100KHz $T_j = 25°C$ | | | 58 | | | 58 | | $\mu V$ |
| Ripple Rejection | RR | f = 120Hz<br>$V_i = 14V$ to 24V | | 56 | 71 | | 56 | 71 | | dB |
| Dropout Voltage | $V_D$ | $I_o = 1A$, $T_j = 25°C$ | | | 2 | | | 2 | | V |
| Output Resistance | $R_O$ | f = 1KHz | | | 17 | | | 17 | | mΩ |
| Short Circuit Current | $I_{SC}$ | $V_i = 35V$, $T_j = 25°C$ | | | 250 | | | 250 | | mA |
| Peak Current | $I_{peak}$ | $T_j = 25°C$ | | | 2.2 | | | 2.2 | | A |

* $T_{min} < T_j < T_{max}$
MC78XXI: $T_{min} = -40°C$, $T_{max} = 125°C$
MC78XXC, $T_{min} = 0°C$, $T_{max} = 125°C$

* Load and line regulation are specified at constant junction temperature. Changes in $V_o$ due to heating effects must be taken into account separately. Pulse testing with low duty is used.

## ELECTRICAL CHARACTERISTICS MC7811

(Refer to test circuit, $T_{min} < T_j < T_{max}$, $I_o$ = 500mA, $V_i$ = 18V, $C_i$ = 0.33μF, $C_o$ = 0.1μF, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | | MC7811I | | | MC7811C | | | Unit |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Min | Typ | Max | Min | Typ | Max | |
| Output Voltage | $V_o$ | $T_j$ = 25°C | | 10.6 | 11 | 11.4 | 10.6 | 11 | 11.4 | V |
| | | 5.0mA ≤ $I_o$ ≤ 1.0A, $P_D$ ≤ 15W<br>$V_i$ = 13.5V to 26V | | | | | 10.5 | 11 | 11.5 | |
| | | $V_i$ = 14.5V to 26V | | 10.5 | 11 | 11.5 | | | | |
| Line Regulation | $\Delta V_o$ | $T_j$ = 25°C | $V_i$ = 13.5 to 25V | | 10 | 220 | | 10 | 220 | mV |
| | | | $V_i$ = 14 to 21V | | 3.0 | 110 | | 3.0 | 110 | |
| Load Regulation | $\Delta V_o$ | $T_j$ = 25°C | $I_o$ = 5.0mA to 1.5A | | 12 | 220 | | 12 | 220 | mV |
| | | | $I_o$ = 250mA to 750mA | | 4 | 110 | | 4 | 110 | |
| Quiescent Current | $I_d$ | $T_j$ = 25°C | | | 5.1 | 8 | | 5.1 | 8 | mA |
| Quiescent Current Change | $\Delta I_d$ | $I_o$ = 5mA to 1A | | | | 0.5 | | | 0.5 | mA |
| | | $V_i$ = 13.5V to 29V | | | | | | | 1.0 | |
| | | $V_i$ = 14.5V to 29V | | | | 1.0 | | | | |
| Output Voltage Drift | $\Delta V_o / \Delta T$ | $I_o$ = 5mA | | | −1 | | | −1 | | mV/°C |
| Output Noise Voltage | $V_N$ | f = 10Hz to 100KHz $T_j$ = 25°C | | | 70 | | | 70 | | μV |
| Ripple Rejection | RR | f = 120Hz<br>$V_i$ = 14V to 24V | | 55 | 71 | | 55 | 71 | | dB |
| Dropout Voltage | $V_D$ | $I_o$ = 1A, $T_j$ = 25°C | | | 2 | | | 2 | | V |
| Output Resistance | $R_O$ | f = 1KHz | | | 18 | | | 18 | | mΩ |
| Short Circuit Current | $I_{SC}$ | $V_i$ = 35V, $T_j$ = 25°C | | | 250 | | | 250 | | mA |
| Peak Current | $I_{peak}$ | $T_j$ = 25°C | | | 2.2 | | | 2.2 | | A |

* $T_{min} < T_j < T_{max}$
MC78XXI: $T_{min}$ = −40°C, $T_{max}$ = 125°C
MC78XXC, $T_{min}$ = 0°C, $T_{max}$ = 125°C

* Load and line regulation are specified at constant junction temperature. Changes in $V_o$ due to heating effects must be taken into account separately. Pulse testing with low duty is used.

## ELECTRICAL CHARACTERISTICS MC7812

(Refer to test circuit, $T_{min} < T_j < T_{max}$, $I_o = 500mA$, $V_i = 19V$, $C_i = 0.33\mu F$, $C_o = 0.1\mu F$, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | | MC7812I | | | MC7812C | | | Unit |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Min | Typ | Max | Min | Typ | Max | |
| Output Voltage | $V_o$ | $T_j = 25°C$ | | 11.5 | 12 | 12.5 | 11.5 | 12 | 12.5 | V |
| | | $5.0mA \leq I_o \leq 1.0A$, $P_D \leq 15W$ | | | | | | | | |
| | | $V_{in} = 14.5V$ to 27V | | | | | 11.4 | 12 | 12.6 | |
| | | $V_i = 15.5V$ to 27V | | 11.4 | 12 | 12.6 | | | | |
| Line Regulation | $\triangle V_o$ | $T_j = 25°C$ | $V_i = 14.5$ to 30V | | 10 | 240 | | 10 | 240 | mV |
| | | | $V_i = 16$ to 22V | | 3.0 | 120 | | 3.0 | 120 | |
| Load Regulation | $\triangle V_o$ | $T_j = 25°C$ | $I_o = 5mA$ to 1.5A | | 12 | 240 | | 12 | 240 | mV |
| | | | $I_o = 250mA$ to 750mA | | 4.0 | 120 | | 4.0 | 120 | |
| Quiescent Current | $I_d$ | $T_j = 25°C$ | | | 5.1 | 8 | | 5.1 | 8 | mA |
| Quiescent Current Change | $\triangle I_d$ | $I_o = 5mA$ to 1.0A | | | | 0.5 | | | 0.5 | mA |
| | | $V_i = 14.5V$ to 30V | | | | | | | 1.0 | |
| | | $V_i = 15V$ to 30V | | | | 1.0 | | | | |
| Output Voltage Drift | $\triangle V_o/\triangle T$ | $I_o = 5mA$ | | | −1 | | | −1 | | mV/°C |
| Output Noise Voltage | $V_N$ | f = 10Hz to 100KHz $T_j = 25°C$ | | | 75 | | | 75 | | $\mu V$ |
| Ripple Rejection | RR | f = 120Hz<br>$V_i = 15V$ to 25V | | 55 | 71 | | 55 | 71 | | dB |
| Dropout Voltage | $V_D$ | $I_o = 1A$, $T_j = 25°C$ | | | 2 | | | 2 | | V |
| Output Resistance | $R_O$ | f = 1KHz | | | 18 | | | 18 | | mΩ |
| Short Circuit Current | $I_{SC}$ | $V_i = 35V$, $T_j = 25°C$ | | | 250 | | | 250 | | mA |
| Peak Current | $I_{peak}$ | $T_j = 25°C$ | | | 2.2 | | | 2.2 | | A |

* $T_{min} < T_j < T_{max}$
MC78XXI: $T_{min} = -40°C$, $T_{max} = 125°C$
MC78XXC, $T_{min} = 0°C$, $T_{max} = 125°C$

* Load and line regulation are specified at constant junction temperature. Changes in $V_o$ due to heating effects must be taken into account separately. Pulse testing with low duty is used.

## ELECTRICAL CHARACTERISTICS MC7815

(Refer to test circuit, $T_{min} < T_j < T_{max}$, $I_o = 500mA$, $V_i = 23V$, $C_i = 0.33\mu F$, $C_o = 0.1\mu F$, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | | MC7815I | | | MC7815C | | | Unit |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Min | Typ | Max | Min | Typ | Max | |
| Output Voltage | $V_o$ | $T_j = 25°C$ | | 14.4 | 15 | 15.6 | 14.4 | 15 | 15.6 | V |
| | | $5.0mA \leq I_o \leq 1.0A$, $P_D \leq 15W$<br>$V_i = 17.5V$ to 30V | | | | | 14.25 | 15 | 15.75 | |
| | | $V_i = 18.5V$ to 30V | | 14.25 | 15 | 15.75 | | | | |
| Line Regulation | $\Delta V_o$ | $T_j = 25°C$ | $V_i = 17.5$ to 30V | | 11 | 300 | | 11 | 300 | mV |
| | | | $V_i = 20$ to 26V | | 3 | 150 | | 3 | 150 | |
| Load Regulation | $\Delta V_o$ | $T_j = 25°C$ | $I_o = 5.0mA$ to 1.5A | | 12 | 300 | | 12 | 300 | mV |
| | | | $I_o = 250mA$ to 750mA | | 4 | 150 | | 4 | 150 | |
| Quiescent Current | $I_d$ | $T_j = 25°C$ | | | 5.2 | 8 | | 5.2 | 8 | mA |
| Quiescent Current Change | $\Delta I_d$ | $I_o = 5mA$ to 1.0A | | | | 0.5 | | | 0.5 | mA |
| | | $V_i = 17.5V$ to 30V | | | | | | | 1.0 | |
| | | $V_i = 18.5V$ to 30V | | | | 1.0 | | | | |
| Output Voltage Drift | $\Delta V_o/\Delta T$ | $I_o = 5mA$ | | | −1 | | | −1 | | mV/°C |
| Output Noise Voltage | $V_N$ | f = 10Hz to 100KHz $T_j = 25°C$ | | | 90 | | | 90 | | $\mu V$ |
| Ripple Rejection | RR | f = 120Hz<br>$V_i = 18.5V$ to 28.5V | | 54 | 70 | | 54 | 70 | | dB |
| Dropout Voltage | $V_D$ | $I_o = 1A$, $T_j = 25°C$ | | | 2 | | | 2 | | V |
| Output Resistance | $R_O$ | f = 1KHz | | | 19 | | | 19 | | mΩ |
| Short Circuit Current | $I_{SC}$ | $V_i = 35V$, $T_j = 25°C$ | | | 250 | | | 250 | | mA |
| Peak Current | $I_{peak}$ | $T_j = 25°C$ | | | 2.2 | | | 2.2 | | A |

* $T_{min} < T_j < T_{max}$
MC78XXI: $T_{min} = -40°C$, $T_{max} = 125°C$
MC78XXC, $T_{min} = 0°C$, $T_{max} = 125°C$

* Load and line regulation are specified at constant junction temperature. Changes in $V_o$ due to heating effects must be taken into account separately. Pulse testing with low duty is used.

## ELECTRICAL CHARACTERISTICS MC7818

(Refer to test circuit, $T_{min}<T_j<T_{max}$, $I_o=500mA$, $V_i=27V$, $C_i=0.33\mu F$, $C_o=0.1\mu F$, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | | MC7818I | | | MC7818C | | | Unit |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Min | Typ | Max | Min | Typ | Max | |
| Output Voltage | $V_o$ | $T_j=25°C$ | | 17.3 | 18 | 18.7 | 17.3 | 18 | 18.7 | V |
| | | $5.0mA \leq I_o \leq 1.0A$, $P_D \leq 15W$<br>$V_i=21V$ to $33V$ | | | | | 17.1 | 18 | 18.9 | |
| | | $V_i=22V$ to $33V$ | | 17.1 | 18 | 18.9 | | | | |
| Line Regulation | $\triangle V_o$ | $T_j=25°C$ | $V_i=21$ to $33V$ | | 15 | 360 | | 15 | 360 | mV |
| | | | $V_i=24$ to $30V$ | | 5 | 180 | | 5 | 180 | |
| Load Regulation | $\triangle V_o$ | $T_j=25°C$ | $I_o=5mA$ to $1.5A$ | | 15 | 360 | | 15 | 360 | mV |
| | | | $I_o=250mA$ to $750mA$ | | 5.0 | 180 | | 5.0 | 180 | |
| Quiescent Current | $I_d$ | $T_j=25°C$ | | | 5.2 | 8 | | 5.2 | 8 | mA |
| Quiescent Current Change | $\triangle I_d$ | $I_o=5mA$ to $1A$ | | | | 0.5 | | | 0.5 | mA |
| | | $V_i=21V$ to $33V$ | | | | | | | 1 | |
| | | $V_i=22V$ to $33V$ | | | | 1 | | | | |
| Output Voltage Drift | $\triangle V_o/\triangle T$ | $I_o=5mA$ | | | −1 | | | −1 | | mV/°C |
| Output Noise Voltage | $V_N$ | $f=10Hz$ to $100KHz$ $T_j=25°C$ | | | 110 | | | 110 | | $\mu V$ |
| Ripple Rejection | RR | $f=120Hz$<br>$V_i=22V$ to $32V$ | | 53 | 69 | | 53 | 69 | | dB |
| Dropout Voltage | $V_D$ | $I_o=1A$, $T_j=25°C$ | | | 2 | | | 2 | | V |
| Output Resistance | $R_O$ | $f=1KHz$ | | | 22 | | | 22 | | mΩ |
| Short Circuit Current | $I_{SC}$ | $V_i=35V$, $T_j=25°C$ | | | 250 | | | 250 | | mA |
| Peak Current | $I_{peak}$ | $T_j=25°C$ | | | 2.2 | | | 2.2 | | A |

* $T_{min}<T_j<T_{max}$
MC78XXI: $T_{min}=-40°C$, $T_{max}=125°C$
MC78XXC, $T_{min}=0°C$, $T_{max}=125°C$

* Load and line regulation are specified at constant junction temperature. Changes in $V_o$ due to heating effects must be taken into account separately. Pulse testing with low duty is used.

## ELECTRICAL CHARACTERISTICS MC7824

(Refer to test circuit, $T_{min} < T_j < T_{max}$, $I_o = 500mA$, $V_i = 33V$, $C_i = 0.33\mu F$, $C_o = 0.1\mu F$, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | | MC7824I | | | MC7824C | | | Unit |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Min | Typ | Max | Min | Typ | Max | |
| Output Voltage | $V_o$ | $T_j = 25°C$ | | 23 | 24 | 25 | 23 | 24 | 25 | V |
| | | $5.0mA \leq I_o \leq 1.0A$, $P_D \leq 15W$ | | | | | | | | |
| | | $V_i = 27V$ to $38V$ | | | | | 22.8 | 24 | 25.2 | |
| | | $V_i = 28V$ to $38V$ | | 22.8 | 24 | 25.2 | | | | |
| Line Regulation | $\Delta V_o$ | $T_j = 25°C$ | $V_i = 27V$ to $38V$ | | 18 | 480 | | 18 | 480 | mV |
| | | | $V_i = 30V$ to $36V$ | | 6 | 240 | | 6 | 240 | |
| Load Regulation | $\Delta V_o$ | $T_j = 25°C$ | $I_o = 5mA$ to $1.5A$ | | 15 | 480 | | 15 | 480 | mV |
| | | | $I_o = 250mA$ to $750mA$ | | 5.0 | 240 | | 5.0 | 240 | |
| Quiescent Current | $I_d$ | $T_j = 25°C$ | | | 5.2 | 8 | | 5.2 | 8 | mA |
| Quiescent Current Change | $\Delta I_d$ | $I_o = 5mA$ to $1A$ | | | | 0.5 | | | 0.5 | mA |
| | | $V_i = 27V$ to $38V$ | | | | | | | 1 | |
| | | $V_i = 28V$ to $38V$ | | | | 1 | | | | |
| Output Voltage Drift | $\Delta V_o/\Delta T$ | $I_o = 5mA$ | | | − 1.5 | | | − 1.5 | | mV/°C |
| Output Noise Voltage | $V_N$ | $f = 10Hz$ to $100KHz$ $T_j = 25°C$ | | | 170 | | | 170 | | $\mu V$ |
| Ripple Rejection | RR | $f = 120Hz$<br>$V_i = 28V$ to $38V$ | | 50 | 66 | | 50 | 66 | | dB |
| Dropout Voltage | $V_D$ | $I_o = 1A$, $T_j = 25°C$ | | | 2 | | | 2 | | V |
| Output Resistance | $R_O$ | $f = 1KHz$ | | | 28 | | | 28 | | mΩ |
| Short Circuit Current | $I_{SC}$ | $V_i = 35V$, $T_j = 25°C$ | | | 250 | | | 250 | | mA |
| Peak Current | $I_{peak}$ | $T_j = 25°C$ | | | 2.2 | | | 2.2 | | A |

* $T_{min} < T_j < T_{max}$
MC78XXI: $T_{min} = -40°C$, $T_{max} = 125°C$
MC78XXC, $T_{min} = 0°C$, $T_{max} = 125°C$

* Load and line regulation are specified at constant junction temperature. Changes in $V_o$ due to heating effects must be taken into account separately. Pulse testing with low duty is used.

## ELECTRICAL CHARACTERISTICS MC7805AC

(Refer to the test circuits, $T_j$=0 to 125°C, $I_o$=1A, $V_i$=10V, $C_i$=0.33$\mu$F, $C_o$=0.1$\mu$F unless otherwise specified)

| Characteristic | Symbol | Test Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Output Voltage | $V_o$ | $T_j$=25°C | 4.9 | 5 | 5.1 | V |
| | | $I_o$=5mA to 1A, $P_D \leq$15W<br>$V_i$=7.5 to 20V | 4.8 | 5 | 5.2 | |
| *Line Regulation | $\Delta V_o$ | $V_i$=7.5 to 25V,<br>$I_o$=500mA | | 5 | 50 | mV |
| | | $V_i$=8 to 12V | | 3 | 50 | |
| | | $T_j$=25°C $V_i$=7.3 to 25V | | 5 | 50 | |
| | | $V_i$=8 to 12V | | 1.5 | 25 | |
| *Load Regulation | $\Delta V_o$ | $T_j$=25°C<br>$I_o$=5mA to 1.5A | | 9 | 100 | mV |
| | | $I_o$=5mA to 1A | | 9 | 100 | |
| | | $I_o$=250 to 750mA | | 4 | 50 | |
| Quiescent Current | $I_d$ | $T_j$=25°C | | 5.0 | 6 | mA |
| Quiescent Current Change | $\Delta I_d$ | $I_o$=5mA to 1A | | | 0.5 | mA |
| | | $V_i$=8 to 25V, $I_o$=500mA | | | 0.8 | |
| | | $V_i$=7.5 to 20V, $T_j$=25°C | | | 0.8 | |
| Output Voltage Drift | $\frac{\Delta V_o}{\Delta T}$ | $I_o$=5mA | | −0.8 | | mV/°C |
| Output Noise Voltage | $V_N$ | f=10Hz to 100KHz:<br>$T_a$=25°C | | 10 | | $\frac{\mu V}{V_o}$ |
| Ripple Rejection | RR | f=120Hz, $I_o$=500mA<br>$V_i$=8 to 18V | | 68 | | dB |
| Dropout Voltage | $V_D$ | $I_o$=1A, $T_j$=25°C | | 2 | | V |
| Output Resistance | $R_o$ | f=1KHz | | 17 | | mΩ |
| Short Circuit Current | $I_{sc}$ | $V_i$=35V, $T_a$=25°C | | 250 | | mA |
| Peak Current | $I_{peak}$ | $T_j$=25°C | | 2.2 | | A |

* Load and line regulation are specified at constant junction temperature. Changes in $V_o$ due to heating effects must be taken into account separately. Pulse testing with low duty cycle is used.

## ELECTRICAL CHARACTERISTICS MC7806AC

(Refer to the test circuits, $T_j$=0 to 150°C, $I_o$=1A, $V_i$=11V, $C_i$=0.33µF, $C_o$=0.1µF unless otherwise specified)

| Characteristic | Symbol | Test Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| Output Voltage | $V_o$ | $T_j$=25°C | | 5.88 | 6 | 6.12 | V |
| | | $I_o$=5mA to 1A, $P_D \leq$15W<br>$V_i$=8.6 to 21V | | 5.76 | 6 | 6.24 | |
| *Line Regulation | $\Delta V_o$ | $V_i$=8.6 to 25V,<br>$I_o$=500mA | | | 5 | 60 | mV |
| | | $V_i$=9 to 13V | | | 3 | 60 | |
| | | $T_j$=25°C | $V_i$=8.3 to 21V | | 5 | 60 | |
| | | | $V_i$=9 to 13V | | 1.5 | 30 | |
| *Load Regulation | $\Delta V_o$ | $T_j$=25°C<br>$I_o$=5mA to 1.5A | | | 9 | 100 | mV |
| | | $I_o$=5mA to 1A | | | 4 | 100 | |
| | | $I_o$=250 to 750mA | | | 5.0 | 50 | |
| Quiescent Current | $I_d$ | $T_j$=25°C | | | 4.3 | 6 | mA |
| Quiescent Current Change | $\Delta I_d$ | $I_o$=5mA to 1A | | | | 0.5 | mA |
| | | $V_i$=9 to 25V, $I_o$=500mA | | | | 0.8 | |
| | | $V_i$=8.6 to 21V, $T_j$=25°C | | | | 0.8 | |
| Output Voltage Drift | $\frac{\Delta V_o}{\Delta T}$ | $I_o$=5mA | | | −0.8 | | mV/°C |
| Output Noise Voltage | $V_N$ | f=10Hz to 100KHz<br>$T_a$=25°C | | | 10 | | $\frac{\mu V}{V_o}$ |
| Ripple Rejection | RR | f=120Hz, $I_o$=500mA<br>$V_i$=9 to 19V | | | 65 | | dB |
| Dropout Voltage | $V_d$ | $I_o$=1A, $T_j$=25°C | | | 2 | | V |
| Output Resistance | $R_o$ | f=1KHz | | | 17 | | mΩ |
| Short Circuit Current | $I_{sc}$ | $V_i$=35V, $T_a$=25°C | | | 250 | | mA |
| Peak Current | $I_{peak}$ | $T_j$=25°C | | | 2.2 | | A |

* Load and line regulation are specified at constant junction temperature. Changes in $V_o$ due to heating effects must be taken into account separately. Pulse testing with low duty cycle is used.

## ELECTRICAL CHARACTERISTICS MC7808AC

(Refer to the test circuits, $T_j$=0 to 150°C, $I_o$=1 A, $V_i$=14V, $C_i$=0.33$\mu$F, $C_o$=0.1$\mu$F unless otherwise specified)

<table>
<tr><th>Characteristic</th><th>Symbol</th><th colspan="2">Test Conditions</th><th>Min</th><th>Typ</th><th>Max</th><th>Unit</th></tr>
<tr><td rowspan="2">Output Voltage</td><td rowspan="2">$V_o$</td><td colspan="2">$T_j$=25°C</td><td>7.84</td><td>8</td><td>8.16</td><td rowspan="2">V</td></tr>
<tr><td colspan="2">$I_o$=5mA to 1A, $P_D \leq$15W<br>$V_i$=10.6 to 23V</td><td>7.7</td><td>8</td><td>8.3</td></tr>
<tr><td rowspan="4">*Line Regulation</td><td rowspan="4">$\Delta V_o$</td><td colspan="2">$V_i$=10.6 to 25V,<br>$I_o$=500mA</td><td></td><td>6</td><td>80</td><td rowspan="4">mV</td></tr>
<tr><td colspan="2">$V_i$=11 to 17V</td><td></td><td>3</td><td>80</td></tr>
<tr><td rowspan="2">$T_j$=25°C</td><td>$V_i$=10.4 to 23V</td><td></td><td>6</td><td>80</td></tr>
<tr><td>$V_i$=11 to 17V</td><td></td><td>2</td><td>40</td></tr>
<tr><td rowspan="3">*Load Regulation</td><td rowspan="3">$\Delta V_o$</td><td colspan="2">$T_j$=25°C<br>$I_o$=5mA to 1.5A</td><td></td><td>12</td><td>100</td><td rowspan="3">mV</td></tr>
<tr><td colspan="2">$I_o$=5mA to 1A</td><td></td><td>12</td><td>100</td></tr>
<tr><td colspan="2">$I_o$=250 to 750mA</td><td></td><td>5</td><td>50</td></tr>
<tr><td>Quiescent Current</td><td>$I_d$</td><td colspan="2">$T_j$=25°C</td><td></td><td>5.0</td><td>6</td><td>mA</td></tr>
<tr><td rowspan="3">Quiescent Current Change</td><td rowspan="3">$\Delta I_d$</td><td colspan="2">$I_o$=5mA to 1A</td><td></td><td></td><td>0.5</td><td rowspan="3">mA</td></tr>
<tr><td colspan="2">$V_i$=11 to 25V, $I_o$=500mA</td><td></td><td></td><td>0.8</td></tr>
<tr><td colspan="2">$V_i$=10.6 to 23V, $T_j$=25°C</td><td></td><td></td><td>0.8</td></tr>
<tr><td>Output Voltage Drift</td><td>$\frac{\Delta V_o}{\Delta T}$</td><td colspan="2">$I_o$=5mA</td><td></td><td>−0.8</td><td></td><td>mV/°C</td></tr>
<tr><td>Output Noise Voltage</td><td>$V_N$</td><td colspan="2">f=10Hz to 100KHz<br>$T_a$=25°C</td><td></td><td>10</td><td></td><td>$\frac{\mu V}{V_o}$</td></tr>
<tr><td>Ripple Rejection</td><td>RR</td><td colspan="2">f=120Hz, $I_o$=500mA<br>$V_i$=11.5 to 21.5V</td><td></td><td>62</td><td></td><td>dB</td></tr>
<tr><td>Dropout Voltage</td><td>$V_D$</td><td colspan="2">$I_o$=1A, $T_j$=25°C</td><td></td><td>2</td><td></td><td>V</td></tr>
<tr><td>Output Resistance</td><td>$R_o$</td><td colspan="2">f=1KHz</td><td></td><td>18</td><td></td><td>mΩ</td></tr>
<tr><td>Short Circuit Current</td><td>$I_{sc}$</td><td colspan="2">$V_i$=35V, $T_a$=25°C</td><td></td><td>250</td><td></td><td>mA</td></tr>
<tr><td>Peak Current</td><td>$I_{peak}$</td><td colspan="2">$T_j$=25°C</td><td></td><td>2.2</td><td></td><td>A</td></tr>
</table>

* Load and line regulation are specified at constant junction temperature. Changes in $V_o$ due to heating effects must be taken into account separately. Pulse testing with low duty cycle is used.

## ELECTRICAL CHARACTERISTICS MC7809AC

(Refer to the test circuits, $T_j = 0$ to 125°C, $I_o = 1A$, $V_i = 15V$, $C_i = 0.33\mu F$, $C_o = 0.1\mu F$ unless otherwise specified)

| Characteristic | Symbol | Test Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Output Voltage | $V_o$ | $T_j = 25°C$ | 8.82 | 9.0 | 9.18 | V |
| | | $I_o = 5mA$ to 1.0A, $P_D \leq 15W$<br>$V_i = 11.2V$ to 24V | 8.65 | 9.0 | 9.35 | |
| Line Regulation | $\triangle V_o$ | $V_i = 11.7V$ to 25V<br>$I_o = 500mA$ | | 6 | 90 | mV |
| | | $V_i = 12.5V$ to 19V | | 4 | 45 | |
| | | $T_j = 25°C$ $V_i = 11.5V$ to 24V | | 6 | 90 | |
| | | $V_i = 12.5V$ to 19V | | 2 | 45 | |
| Load Regulation | $\triangle V_o$ | $T_j = 25°C$<br>$I_o = 5mA$ to 1.0A | | 12 | 100 | mV |
| | | $I_o = 5mA$ to 1.0A | | 12 | 100 | |
| | | $I_o = 250mA$ to 750mA | | 5 | 50 | |
| Quiescent Current | $I_d$ | $T_j = 25°C$ | | 5.0 | 6.0 | mA |
| Quiescent Current Change | $\triangle I_d$ | $V_i = 11.7V$ to 24V, $T_j = 25°C$ | | | 0.8 | mA |
| | | $V_i = 12V$ to 25V, $I_o = 500mA$ | | | 0.8 | |
| | | $I_o = 5mA$ to 1.0A | | | 0.5 | |
| Output Voltage Drift | $\triangle V_o/\triangle T$ | $I_o = 5mA$ | | −1.0 | | mV/°C |
| Output Noise Voltage | $V_N$ | f = 10Hz to 100KHz, Ta = 25°C | | 10 | | $\mu V/V_o$ |
| Ripple Rejection | RR | f = 120Hz, $V_i = 12V$ to 22V<br>$I_o = 500mA$ | | 62 | | dB |
| Dropout Voltage | $V_D$ | $I_o = 1.0A$, $T_j = 25°C$ | | 2.0 | | V |
| Output Resistance | $R_o$ | f = 1KHz | | 17 | | m |
| Short Circuit Current | $I_{short}$ | $V_i = 35V$, $T_j = 25°C$ | | 250 | | mA |
| Peak Current | $I_{peak}$ | $T_j = 25°C$ | | 2.2 | | A |

* Load and line regulation are specified at constant junction temperature. Changes in $V_o$ due to heating effects must be taken into account separately. Pulse testing with low duty cycle is used.

## ELECTRICAL CHARACTERISTICS MC7810AC

(Refer to the test circuits, $T_j = 0$ to 125°C, $I_o = 1A$, $V_i = 16V$, $C_i = 0.33\mu F$, $C_o = 0.1\mu F$, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| Output Voltage | $V_o$ | $T_j = 25°C$ | | 9.8 | 10 | 10.2 | V |
| | | $I_o = 5mA$ to 1.0A, $P_D \leq 15W$<br>$V_i = 12.8V$ to 25V | | 9.6 | 10 | 10.4 | |
| Line Regulation | $\triangle V_o$ | $V_i = 12.8V$ to 26V<br>$I_o = 500mA$ | | | 8 | 100 | mV |
| | | $V_i = 13V$ to 20V | | | 4 | 50 | |
| | | $T_j = 25°C$ | $V_i = 12.5V$ to 25V | | 8 | 100 | |
| | | | $V_i = 13V$ to 20V | | 3 | 50 | |
| Load Regulation | $\triangle V_o$ | $T_j = 25°C$<br>$I_o = 5mA$ to 1.5A | | | 12 | 100 | mV |
| | | $I_o = 5mA$ to 1.0A | | | 12 | 100 | |
| | | $I_o = 250mA$ to 750mA | | | 5 | 50 | |
| Quiescent Current | $I_d$ | $T_j = 25°C$ | | | 5.0 | 6.0 | mA |
| Quiescent Current Change | $\triangle I_d$ | $I_o = 5mA$ to 1.0A | | | | 0.5 | mA |
| | | $V_i = 13V$ to 26V, $I_o = 500mA$ | | | | 0.8 | |
| | | $V_i = 12.8V$ to 25V, $T_j = 25°C$ | | | | 0.8 | |
| Output Voltage Drift | $\triangle V_o/\triangle T$ | $I_o = 5mA$ | | | -1.0 | | mV/°C |
| Output Noise Voltage | $V_N$ | f = 10Hz to 100KHz, Ta = 25°C | | | 10 | | $\mu V/V_o$ |
| Ripple Rejection | RR | f = 120Hz, $V_i = 14V$ to 24V<br>$I_o = 500mA$ | | | 62 | | dB |
| Dropout Voltage | $V_D$ | $I_o = 1.0A$, $T_j = 25°C$ | | | 2.0 | | V |
| Output Resistance | $R_o$ | f = 1KHz | | | 17 | | m |
| Short Circuit Current | $I_{short}$ | $V_i = 35V$, $T_a = 25°C$ | | | 250 | | mA |
| Peak Current | $I_{peak}$ | $T_j = 25°C$ | | | 2.2 | | A |

* Load and line regulation are specified at constant junction temperature. Changes in $V_o$ due to heating effects must be taken into account separately. Pulse testing with low duty cycle is used.

## ELECTRICAL CHARACTERISTICS MC7811AC

(Refer to the test circuits, $T_j = 0$ to 125°C, $I_o = 1A$, $V_i = 18V$, $C_i = 0.33\mu F$, $C_o = 0.1\mu F$ unless otherwise specified)

| Characteristic | Symbol | Test Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| Output Voltage | $V_o$ | $T_j = 25°C$ | | 10.8 | 11.0 | 11.2 | V |
| | | $I_o = 5mA$ to 1.0A, $P_D \leq 15W$<br>$V_i = 13.8V$ to 26V | | 10.6 | 11.0 | 11.4 | |
| Line Regulation | $\triangle V_o$ | $V_i = 13.8V$ to 27V<br>$I_o = 500mA$ | | | 10 | 110 | mV |
| | | $V_i = 15V$ to 21V | | | 4 | 55 | |
| | | $T_j = 25°C$ | $V_i = 13.5V$ to 26V | | 10 | 110 | |
| | | | $V_i = 15V$ to 21V | | 3 | 55 | |
| Load Regulation | $\triangle V_o$ | $T_j = 25°C$<br>$I_o = 5mA$ to 1.5A | | | 12 | 100 | mV |
| | | $I_o = 5mA$ to 1.0A | | | 12 | 100 | |
| | | $I_o = 250mA$ to 750mA | | | 5 | 50 | |
| Quiescent Current | $I_d$ | $T_j = 25°C$ | | | 5.1 | 6.0 | mA |
| | | | | | | 6.0 | |
| Quiescent Current Change | $\triangle I_d$ | $V_i = 13.8V$ to 26V, $T_j = 25°C$ | | | | 0.8 | mA |
| | | $V_i = 14V$ to 27V, $I_o = 500mA$ | | | | 0.8 | |
| | | $I_o = 5mA$ to 1.0A | | | | 0.5 | |
| Output Voltage Drift | $\triangle V_o / \triangle T$ | $I_o = 5mA$ | | | - 1.0 | | mV/°C |
| Output Noise Voltage | $V_N$ | f = 10Hz to 100KHz, Ta = 25°C | | | 10 | | $\mu V/V_o$ |
| Ripple Rejection | RR | f = 120Hz, $V_i = 14V$ to 24V<br>$I_o = 500mA$ | | | 61 | | dB |
| Dropout Voltage | $V_D$ | $I_o = 1.0A$, $T_j = 25°C$ | | | 2.0 | | V |
| Output Resistance | $R_o$ | f = 1KHz | | | 18 | | m |
| Short Circuit Current | $I_{short}$ | $V_i = 35V$, $T_j = 25°C$ | | | 250 | | mA |
| Peak Current | $I_{peak}$ | $T_j = 25°C$ | | | 2.2 | | A |

* Load and line regulation are specified at constant junction temperature. Changes in $V_o$ due to heating effects must be taken into account separately. Pulse testing with low duty cycle is used.

## ELECTRICAL CHARACTERISTICS MC7812AC

(Refer to the test circuits, $T_j$=0 to 150°C, $I_o$=1A, $V_i$=19V, $C_i$=0.33μF, $C_o$=0.1μF unless otherwise specified)

| Characteristic | Symbol | Test Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| Output Voltage | $V_o$ | $T_j$=25°C | | 11.75 | 12 | 12.25 | V |
| | | $I_o$=5mA to 1A, $P_D \leq$15W<br>$V_i$=14.8 to 27V | | 11.5 | 12 | 12.5 | |
| *Line Regulation | $\Delta V_o$ | $V_i$=14.8 to 30V,<br>$I_o$=500mA | | | 10 | 120 | mV |
| | | $V_i$=16 to 22V | | | 4 | 120 | |
| | | $T_j$=25°C | $V_i$=14.5 to 27V | | 10 | 120 | |
| | | | $V_i$=16 to 22V | | 3 | 60 | |
| *Load Regulation | $\Delta V_o$ | $T_j$=25°C<br>$I_o$=5mA to 1.5A | | | 12 | 100 | mV |
| | | $I_o$=5mA to 1A | | | 12 | 100 | |
| | | $I_o$=250 to 750mA | | | 5 | 50 | |
| Quiescent Current | $I_d$ | $T_j$=25°C | | | 5.1 | 6 | mA |
| Quiescent Current Change | $\Delta I_d$ | $I_o$=5mA to 1A | | | | 0.5 | mA |
| | | $V_i$=15 to 30V, $I_o$=500mA | | | | 0.8 | |
| | | $V_i$=14.8 to 27V, $T_j$=25°C | | | | 0.8 | |
| Output Voltage Drift | $\frac{\Delta V_o}{\Delta T}$ | $I_o$=5mA | | | -1 | | mV/°C |
| Output Noise Voltage | $V_N$ | f=10Hz to 100KHz<br>$T_a$=25°C | | | 10 | | $\frac{\mu V}{V_o}$ |
| Ripple Rejection | RR | f=120Hz, $I_o$=500mA<br>$V_i$=15 to 25V | | | 60 | | dB |
| Dropout Voltage | $V_D$ | $I_o$=1A, $T_j$=25°C | | | 2 | | V |
| Output Resistance | $R_o$ | f=1KHz | | | 18 | | mΩ |
| Short Circuit Current | $I_{sc}$ | $V_i$=35V, $T_a$=25°C | | | 250 | | mA |
| Peak Current | $I_{peak}$ | $T_j$=25°C | | | 2.2 | | A |

* Load and line regulation are specified at constant junction temperature. Changes in $V_o$ due to heating effects must be taken into account separately. Pulse testing with low duty cycle is used.

## ELECTRICAL CHARACTERISTICS MC7815AC

(Refer to the test circuits, $T_j$=0 to 150°C, $I_o$=1A, $V_i$=23V, $C_i$=0.33μF, $C_o$=0.1μF unless otherwise specified)

| Characteristic | Symbol | Test Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Output Voltage | $V_o$ | $T_j$=25°C | 14.7 | 15 | 15.3 | V |
| | | $I_o$ = 5mA to 1A, $P_D \leq$ 15W<br>$V_i$ = 17.7 to 30V | 14.4 | 15 | 15.6 | |
| *Line Regulation | $\Delta V_o$ | $V_i$ = 17.9 to 30V,<br>$I_o$ = 500mA | | 10 | 150 | mV |
| | | $V_i$ =20 to 26V | | 5 | 150 | |
| | | $T_j$=25°C $V_i$=17.5 to 30V | | 11 | 150 | |
| | | $V_i$=20 to 26V | | 3 | 75 | |
| *Load Regulation | $\Delta V_o$ | $T_j$=25°C<br>$I_o$=5mA to 1.5A | | 12 | 100 | mV |
| | | $I_o$=5mA to 1A | | 12 | 100 | |
| | | $I_o$ = 250 to 750mA | | 5 | 50 | |
| Quiescent Current | $I_d$ | $T_j$=25°C | | 5.2 | 6 | mA |
| Quiescent Current Change | $\Delta I_d$ | $I_o$=5mA to 1A | | | 0.5 | mA |
| | | $V_i$=17.5 to 30V, $I_o$=500mA | | | 0.8 | |
| | | $V_i$=17.5 to 30V, $T_j$=25°C | | | 0.8 | |
| Output Voltage Drift | $\frac{\Delta V_o}{\Delta T}$ | $I_o$=5mA | | -1 | | mV/°C |
| Output Noise Voltage | $V_N$ | f =10Hz to 100KHz<br>$T_a$=25°C | | 10 | | $\frac{\mu V}{V_o}$ |
| Ripple Rejection | RR | f=120Hz, $I_o$=500mA<br>$V_i$=18.5 to 28.5V | | 58 | | dB |
| Dropout Voltage | $V_D$ | $I_o$=1A, $T_j$=25°C | | 2 | | V |
| Output Resistance | $R_o$ | f=1KHz | | 19 | | mΩ |
| Short Circuit Current | $I_{sc}$ | $V_i$ = 35V, $T_a$ = 25°C | | 250 | | mA |
| Peak Current | $I_{peak}$ | $T_j$=25°C | | 2.2 | | A |

* Load and line regulation are specified at constant junction temperature. Changes in $V_o$ due to heating effects must be taken into account separately. Pulse testing with low duty cycle is used.

## ELECTRICAL CHARACTERISTICS MC7818AC

(Refer to the test circuits, $T_j$=0 to 150°C, $I_o$=1A, $V_i$=27V, $C_i$=0.33μF, $C_o$=0.1μF unless otherwise specified)

| Characteristic | Symbol | Test Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Output Voltage | $V_o$ | $T_j$=25°C | 17.64 | 18 | 18.36 | V |
| | | $I_o$=5mA to 1A, $P_D \leq$15W<br>$V_i$=21 to 33V | 17.3 | 18 | 18.7 | |
| *Line Regulation | $\Delta V_o$ | $V_i$=21 to 33V,<br>$I_o$=500mA | | 15 | 180 | mV |
| | | $V_i$=24 to 30V | | 5 | 180 | |
| | | $T_j$=25°C $V_i$=20.6 to 33V | | 15 | 180 | |
| | | $V_i$=24 to 30V | | 5 | 90 | |
| *Load Regulation | $\Delta V_o$ | $T_j$=25°C<br>$I_o$=5mA to 1.5A | | 15 | 100 | mV |
| | | $I_o$=5mA to 1A | | 15 | 100 | |
| | | $I_o$=250 to 750mA | | 7 | 50 | |
| Quiescent Current | $I_d$ | $T_j$=25°C | | 5.2 | 6 | mA |
| Quiescent Current Change | $\Delta I_d$ | $I_o$=5mA to 1A | | | 0.5 | mA |
| | | $V_i$=21 to 33V, $I_o$=500mA | | | 0.8 | |
| | | $V_i$=21 to 33V, $T_j$=25°C | | | 0.8 | |
| Output Voltage Drift | $\frac{\Delta V_o}{\Delta T}$ | $I_o$=5mA | | −1 | | mV/°C |
| Output Noise Voltage | $V_N$ | f =10Hz to 100KHz<br>$T_a$=25°C | | 10 | | $\frac{\mu V}{V_o}$ |
| Ripple Rejection | RR | f=120Hz, $I_o$=500mA<br>$V_i$=22 to 32V | | 57 | | dB |
| Dropout Voltage | $V_D$ | $I_o$=1A, $T_j$=25°C | | 2 | | V |
| Output Resistance | $R_o$ | f=1KHz | | 19 | | mΩ |
| Short Circuit Current | $I_{sc}$ | $V_i$=35V, $T_a$=25°C | | 250 | | mA |
| Peak Current | $I_{peak}$ | $T_j$=25°C | | 2.2 | | A |

* Load and line regulation are specified at constant junction temperature. Changes in $V_o$ due to heating effects must be taken into account separately. Pulse testing with low duty cycle is used.

## ELECTRICAL CHARACTERISTICS MC7824AC

(Refer to the test circuits, $T_j$=0 to 150°C, $I_o$=1 A, $V_i$=33V, $C_i$=0.33$\mu$F, $C_o$=0.1$\mu$F unless otherwise specified)

| Characteristic | Symbol | Test Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Output Voltage | $V_o$ | $T_j$=25°C | 23.5 | 24 | 24.5 | V |
| | | $I_o$=5mA to 1A, $P_D \leq$15W<br>$V_i$=27.3 to 38V | 23 | 24 | 25 | |
| *Line Regulation | $\Delta V_o$ | $V_i$=27 to 38V,<br>$I_o$=500mA | | 18 | 240 | mV |
| | | $V_i$=30 to 36V | | 6 | 240 | |
| | | $T_j$=25°C, $V_i$=26.7 to 38V | | 18 | 240 | |
| | | $V_i$=30 to 36V | | 6 | 120 | |
| *Load Regulation | $\Delta V_o$ | $T_j$=25°C<br>$I_o$=5mA to 1.5A | | 15 | 100 | mV |
| | | $I_o$=5mA to 1A | | 15 | 100 | |
| | | $I_o$=250 to 750mA | | 7 | 50 | |
| Quiescent Current | $I_d$ | $T_j$=25°C | | 5.2 | 6 | mA |
| Quiescent Current Change | $\Delta I_d$ | $I_o$=5mA to 1A | | | 0.5 | mA |
| | | $V_i$=27.3 to 38V, $I_o$=500mA | | | 0.8 | |
| | | $V_i$=27.3 to 38V, $T_j$=25°C | | | 0.8 | |
| Output Voltage Drift | $\frac{\Delta V_o}{\Delta T}$ | $I_o$=1mA | | −1.5 | | mV/°C |
| Output Noise Voltage | $V_N$ | f=10Hz to 100KHz<br>$T_a$=25°C | | 10 | | $\frac{\mu V}{V_o}$ |
| Ripple Rejection | RR | f=120Hz, $I_o$=500mA<br>$V_i$=28 to 38V | | 54 | | dB |
| Dropout Voltage | $V_D$ | $I_o$=1A, $T_j$=25°C | | 2 | | V |
| Output Resistance | $R_o$ | f=1KHz | | 20 | | mΩ |
| Short Circuit Current | $I_{sc}$ | $V_i$=35V, $T_a$=25°C | | 250 | | mA |
| Peak Current | $I_{peak}$ | $T_j$=25°C | | 2.2 | | A |

* Load and line regulation are specified at constant junction temperature. Changes in $V_o$ due to heating effects must be taken into account separately. Pulse testing with low duty cycle is used.

## TEST CIRCUITS

Fig. 3 DC Parameters

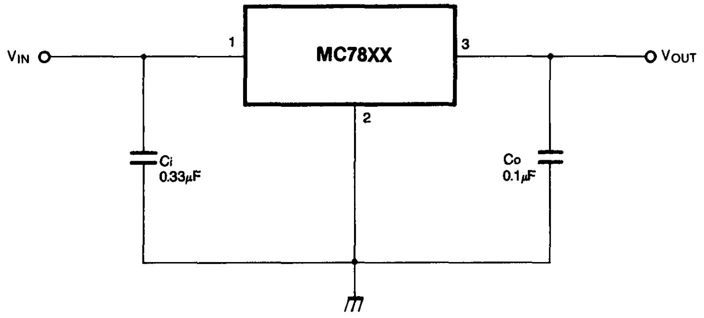


Fig. 4 Load Regulation

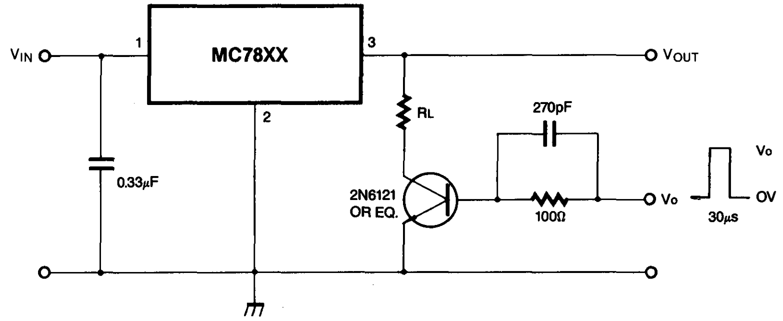
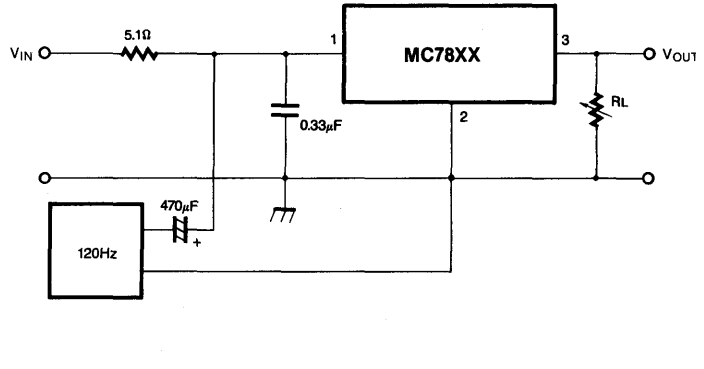


Fig. 5 Ripple Rejection



## APPLICATION CIRCUITS

**Fig. 6 Fixed Output Regulator**

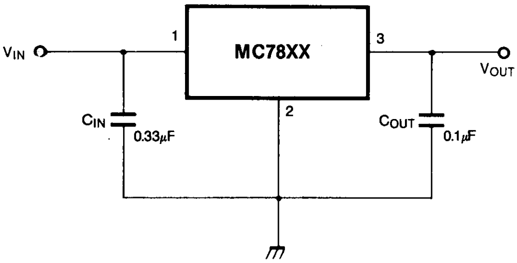
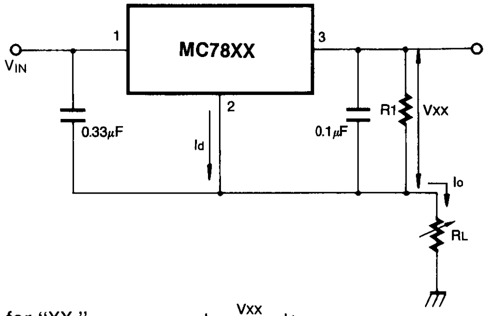


**Fig. 7 Constant Current Regulator**



$I_o = \frac{V_{XX}}{R_1} + I_d$

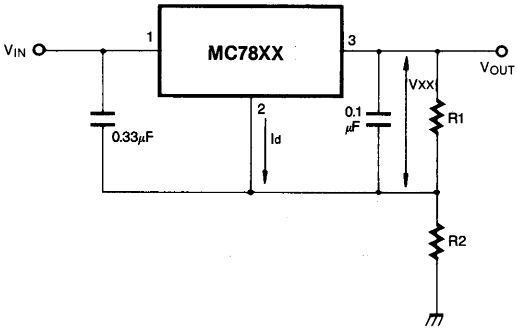
**Notes:**

(1) To specify an output voltage, substitute voltage value for "XX." A common ground is required between the input and the output voltage. The input voltage must remain typically 2.0V above the output voltage even during the low point on the input ripple voltage.

(2) $C_{IN}$ is required if regulator is located an appreciable distance from power supply filter.

(3) $C_{OUT}$ improves stability and transient response.

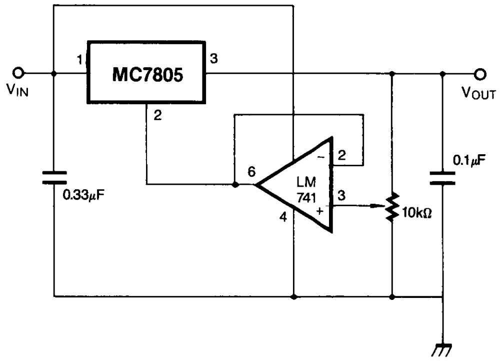
**Fig. 8 Circuit for Increasing Output Voltage**



$I_{R1} \geqslant 5I_d$

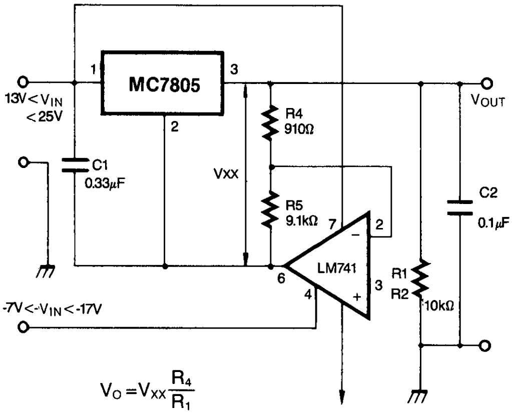
$V_O = V_{XX}(1 + R_2/R_1) + I_d R_2$

**Fig. 9 Adjustable Output Regulator (7 to 30V)**



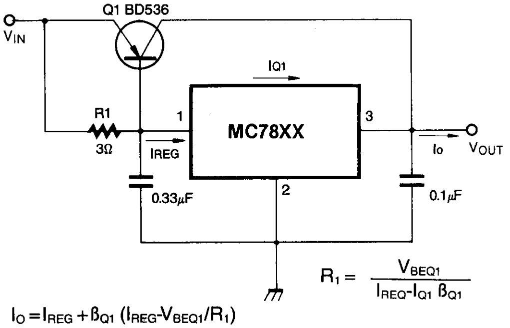
## APPLICATION CIRCUIT (continued)

**Fig. 10 0.5 to 10V Regulator**



$$V_O = V_{XX}\frac{R_4}{R_1}$$

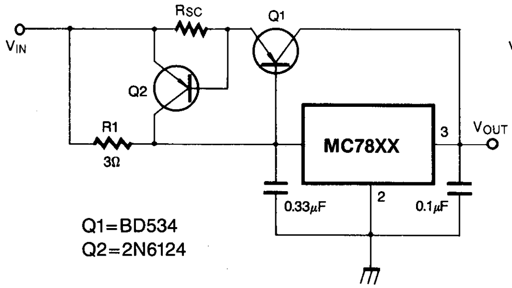
**Fig. 11 High Current Voltage Regulator**



$$R_1 = \frac{V_{BEQ1}}{I_{REQ}-I_{Q1}\,\beta_{Q1}}$$

$$I_O = I_{REG} + \beta_{Q1}\,(I_{REG}-V_{BEQ1}/R_1)$$

**Fig. 12 High Output Current with Short Circuit Protection**



Q1=BD534
Q2=2N6124

$$R_{SC} = \frac{V_{BEQ2}}{I_{SC}}$$

**Fig. 13 Tracking Voltage Regulator**

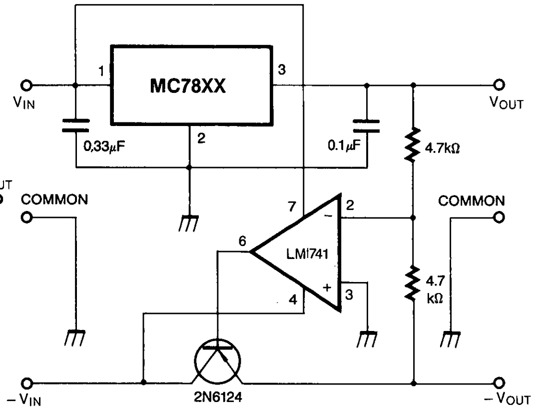


Fig. 14 Split Power Supply (± 15V – 1A)

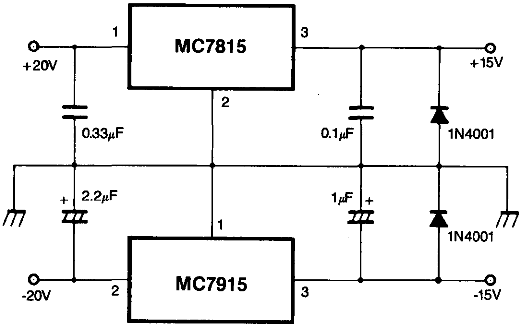


Fig. 15 Negative Output Voltage Circuit

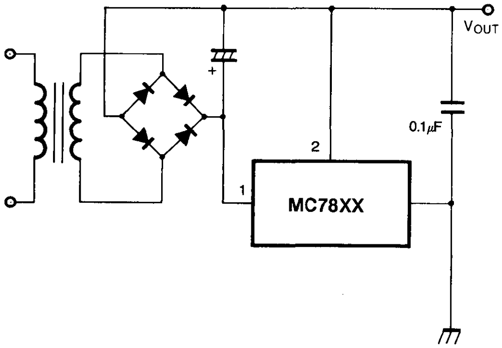


Fig. 16 Switching Regulator

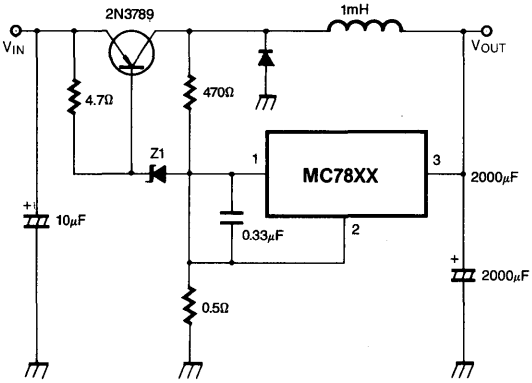
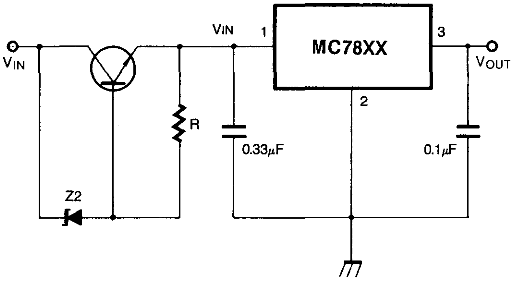


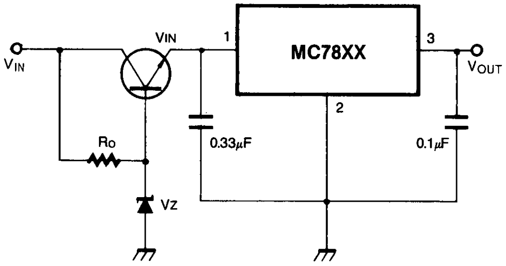
Fig. 17 High Input Voltage Circuit



$V_{IN} = V_i - (V_Z + V_{BE})$

## APPLICATION CIRCUITS (Continued)

**Fig. 18 High Input Voltage Circuit**



$V_{IN} = V_Z - V_{BE}$

**Fig. 19 Hiqh Output Voltage Regulator**

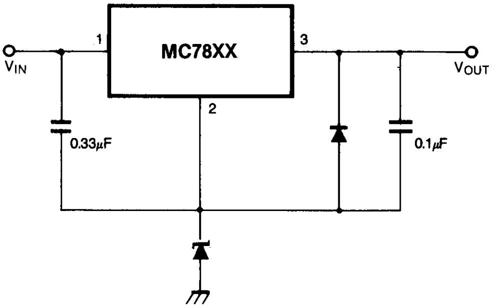
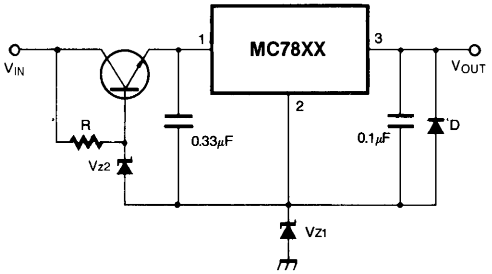
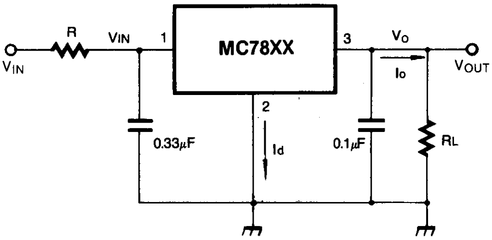


**Fig. 20 High Input and Output Voltage**



$V_O = V_{XX} + V_{Z1}$

**Fig. 21 Reducing Power Dissipation with Dropping Resitor**



$$R = \frac{V_{i\,(min)} - V_{XX} - V_{DROP\,(max)}}{I_{O\,(max)} + I_{O\,(max)}}$$

## APPLICATION CIRCUITS (Continued)

**Fig. 22 Remote Shuntdown**

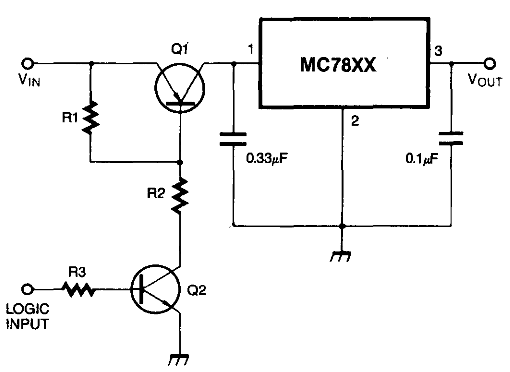
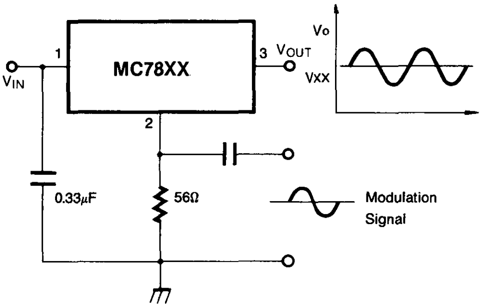
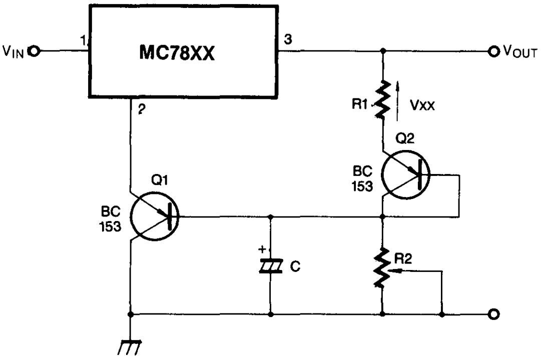


**Fig. 23 Power AM Modulator**



**Note:** The circuit performs well up to 100 KHz.

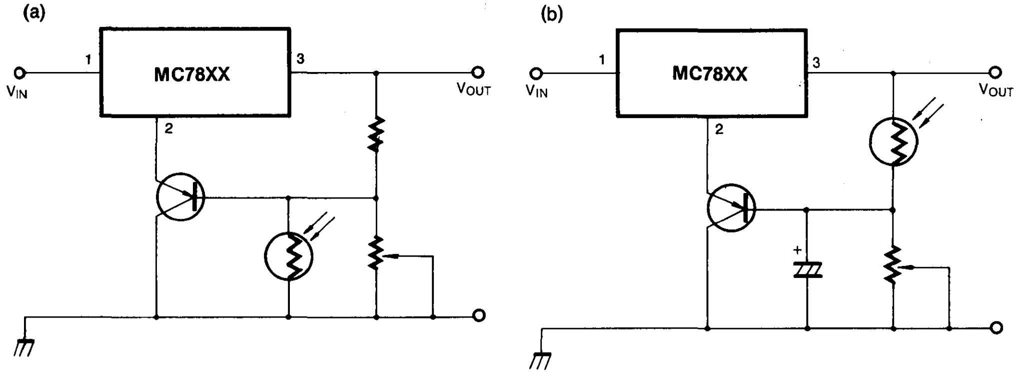
**Fig. 24 Adjustable Output Voltage with Temperature Compensation**



**Note:** Q2 is connected as a diode in order to compensate the variation of the Q1 $V_{BE}$ with the temperature. C allows a slow rise-time of the $V_O$

$$V_O = V_{XX} (1 + \frac{R_2}{R_1}) + V_{BE}$$

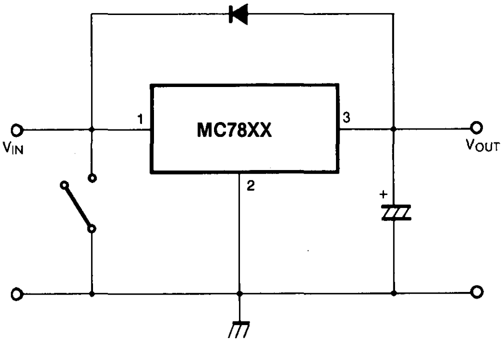
**Fig. 25 Light Controllers ($V_O$ min = $V_{XX} + V_{BE}$)**



$V_o$ falls when the light goes up

$V_o$ rises when the light goes up

**Fig. 26 Protection Against Input Short-Circuit with High Capacitance Loads**



Applications with high capacitance loads and an output voltage greater than 6 volts need an external diode (see fig. 26) to protect the device against input short circuit. In this case the input voltage falls rapidly while the output voltage decreases showly. The capacitance discharges by means of the Base-Emitter junction of the series pass transistor in the regulator. If the energy is sufficiently high, the transistor may be destroyed. The external diode by-passes the current from the IC to ground.

## TYPICAL PERFORMANCE CHARACTERISTICS

FIG. 27 QUIESCENT CURRENT

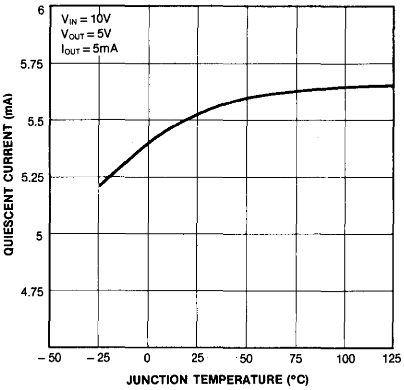


FIG. 28 PEAK OUTPUT CURRENT

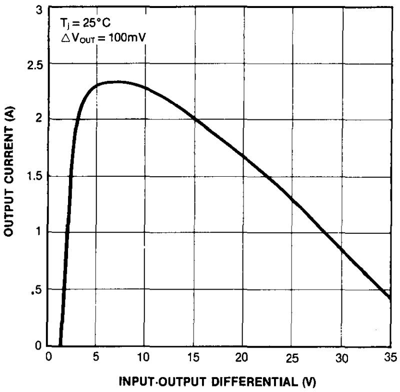


FIG. 29 OUTPUT VOLTAGE

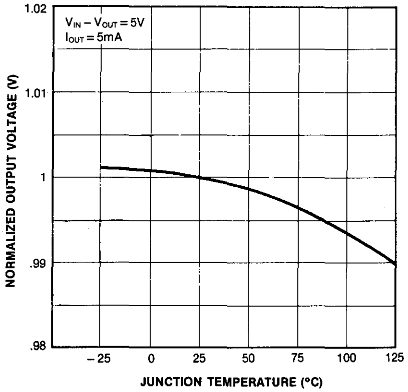
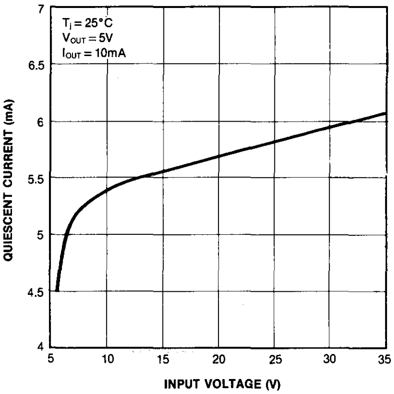


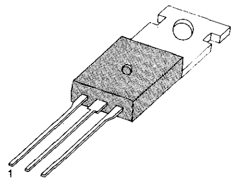
FIG. 30 QUIESCENT CURRENT



## 3-TERMINAL 0.5A POSITIVE VOLTAGE REGULATOR

The MC78MXXC/I series of three-terminal positive regulators are available in the TO-220 package with several fixed output voltages, making it useful in a wide range of applications. These regulators can provide local on-card regulation, eliminating the distribution problems associated with single point regulation. Each type employs internal current limiting, thermal shut-down and safe area protection, making it essentially indestructible. If adequate heat sinking is provided, they can deliver over 0.5 A output current. Although designed primarily as fixed voltage regulators, these devices can be used with external components to obtain adjustable voltages and currents. MC78MXXC is characterized for operation from 0°C to 125°C, and MC78MXXI from −40°C to 125°C.

TO-220



1: Input 2: GND 3: Output

## FEATURES

- **Output Current up to 0.5A**
- **Output Voltages of 5; 6; 8; 10; 12; 15; 18; 20; 24V**
- **Thermal Overload Protection**
- **Short Circuit Protection**
- **Output Transistor SOA Protection**
- **Industrial and commercial temperature range**

## ORDERING INFORMATION

| Device | Package | Operating Temperature |
|---|---|---|
| MC78MXXCT | TO-220 | 0~ +125°C |
| MC78MXXIT | TO-220 | −40~ +125°C |

## BLOCK DIAGRAM

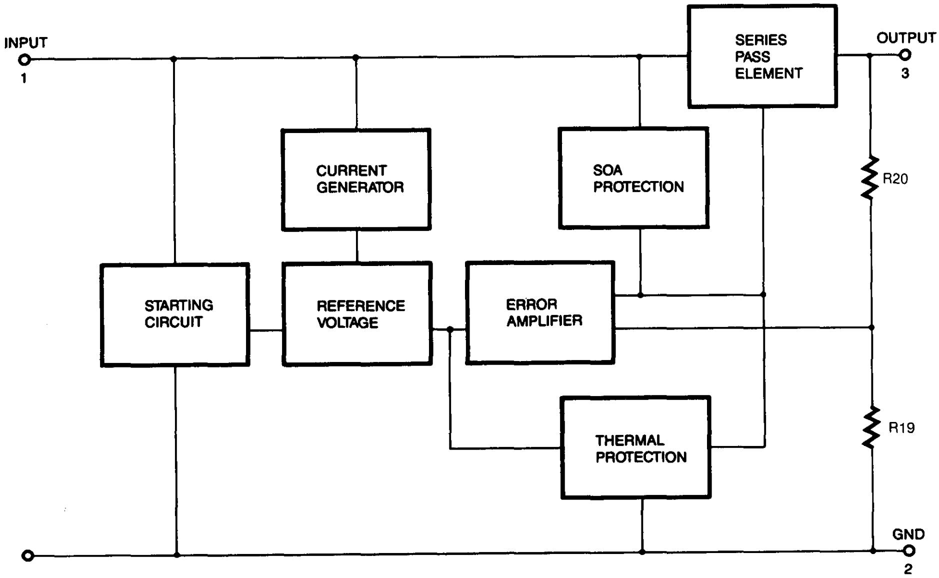


Fig. 1

## SCHEMATIC DIAGRAM

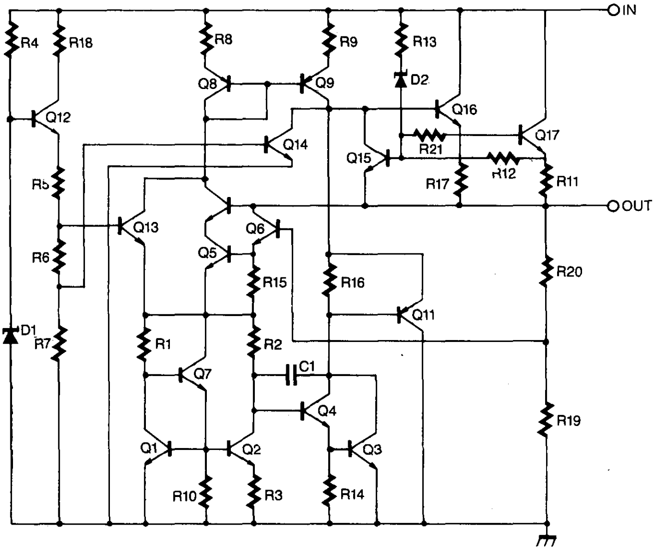


Fig. 2

## ABSOLUTE MAXIMUM RATINGS

| Characteristic | Symbol | Value | Unit |
|---|---|---|---|
| Input Voltage (for $V_O = 5V$ to 18V)<br>(for $V_O = 24V$) | $V_i$<br>$V_i$ | 35<br>40 | V<br>V |
| Thermal Resistance Junction-Cases | $0_{JC}$ | 5 | °C/W |
| Thermal Resistance Junction-Air | $0_{JA}$ | 65 | °C/W |
| Operating Temperature Range MC78XXI<br>MC78XXC/AC | $T_{opr}$ | − 40 ~ + 125<br>0 ~ + 125 | °C<br>°C |
| Storage Temperature Range | $T_{stg}$ | − 65 ~ + 150 | °C |

## ELECTRICAL CHARACTERISTICS MC78M05

(Refer to the test circuits, $T_{min} \leq T_j \leq 125°C$, $I_o = 350mA$, $V_i = 10V$, unless otherwise specified, $C_i = 0.33\mu F$, $C_o = 0.1\mu F$)

| Characteristic | Symbol | Test Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Output Voltage | $V_o$ | $T_j = 25°C$ | 4.8 | 5 | 5.2 | V |
| | | $I_o = 5$ to 350mA<br>$V_i = 7$ to 20V | 4.75 | 5 | 5.25 | |
| Line Regulation | $\Delta V_o$ | $I_o = 200mA$<br>$T_j = 25°C$<br>$V_i = 7$ to 25V | | | 100 | mV |
| | | $V_i = 8$ to 25V | | | 50 | |
| Load Regulation | $\Delta V_o$ | $I_o = 5mA$ to 0.5A, $T_j = 25°C$ | | | 100 | mV |
| | | $I_o = 5mA$ to 200mA, $T_j = 25°C$ | | | 50 | |
| Quiescent Current | $I_d$ | $T_j = 25°C$ | | 4.0 | 6 | mA |
| Quiescent Current Change | $\Delta I_d$ | $I_o = 5mA$ to 350mA | | | 0.5 | mA |
| | | $I_o = 200mA$<br>$V_i = 8$ to 25V | | | 0.8 | |
| Output Voltage Drift | $\frac{\Delta V_o}{\Delta T}$ | $I_o = 5mA$<br>$T_j = 0$ to 125°C | | −0.5 | | mV/°C |
| Output Noise Voltage | $V_N$ | f = 10Hz to 100KHz | | 40 | | $\mu V$ |
| Ripple Rejection | RR | f = 120Hz $I_o = 300mA$<br>$V_i = 8$ to 18V | 62 | | | dB |
| Dropout Voltage | $V_D$ | $T_j = 25°C, I_o = 500mA$ | | 2 | | V |
| Short Circuit Current | $I_{sc}$ | $T_j = 25°C$, $V_i = 35V$ | | 300 | | mA |
| Peak Current | $I_{peak}$ | $T_j = 25°C$ | | 700 | | mA |

* $T_{min}$
MC78MXXI: $T_{min} = -40°C$
MC78MXXC: $T_{min} = 0°C$

* Load and line regulation are specified at constant junction temperature. Change in $V_o$ due to heating effects must be taken into account separately. Pulse testing with low duty is used.

## ELECTRICAL CHARACTERISTICS MC78M06

(Refer to the test circuits, $T_{min} \leq T_j \leq 125°C$, $I_o = 350mA$, $V_i = 11V$, unless otherwise specified, $C_i = 0.33\mu F$, $C_o = 0.1\mu F$)

| Characteristic | Symbol | Test Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Output Voltage | $V_o$ | $T_j = 25°C$ | 5.75 | 6 | 6.25 | V |
| | | $I_o = 5$ to $350mA$<br>$V_i = 8$ to $21V$ | 5.7 | 6 | 6.3 | |
| Line Regulation | $\Delta V_o$ | $I_o = 200mA$, $T_j = 25°C$, $V_i = 8$ to $25V$ | | | 100 | mV |
| | | $I_o = 200mA$, $T_j = 25°C$, $V_i = 9$ to $25V$ | | | 50 | |
| Load Regulation | $\Delta V_o$ | $I_o = 5mA$ to $0.5A$, $T_j = 25°C$ | | | 120 | mV |
| | | $I_o = 5mA$ to $200mA$, $T_j = 25°C$ | | | 60 | |
| Quiescent Current | $I_d$ | $T_j = 25°C$ | | 4.0 | 6 | mA |
| Quiescent Current Change | $\Delta I_d$ | $I_o = 5mA$ to $350mA$ | | | 0.5 | mA |
| | | $I_o = 200mA$<br>$V_i = 9$ to $25V$ | | | 0.8 | |
| Output Voltage Drift | $\frac{\Delta V_o}{\Delta T}$ | $I_o = 5mA$<br>$T_j = 0$ to $125°C$ | | -0.5 | | mV/°C |
| Output Noise Voltage | $V_N$ | $f = 10Hz$ to $100KHz$ | | 45 | | $\mu V$ |
| Ripple Rejection | RR | $f = 120Hz$ $I_o = 300mA$<br>$V_i = 9$ to $19V$ | 59 | | | dB |
| Dropout Voltage | $V_D$ | $T_j = 25°C$, $I_o = 500mA$ | | 2 | | V |
| Short Circuit Current | $I_{sc}$ | $T_j = 25°C$, $V_i = 35V$ | | 300 | | mA |
| Peak Current | $I_{peak}$ | $T_j = 25°C$ | | 700 | | mA |

* $T_{min}$
MC78MXXI: $T_{min} = -40°C$
MC78MXXC: $T_{min} = 0°C$

* Load and line regulation are specified at constant junction temperature. Change in $V_o$ due to heating effects must be taken into account separately. Pulse testing with low duty is used.

## ELECTRICAL CHARACTERISTICS MC78M08

(Refer to the test circuits, $T_{min} \leq T_j \leq 125°C$, $I_o = 350mA$, $V_i = 14V$, unless otherwise specified, $C_i = 0.33\mu F$, $C_o = 0.1\mu F$)

| Characteristic | Symbol | Test Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| Output Voltage | $V_o$ | $T_j = 25°C$ | | 7.7 | 8 | 8.3 | V |
| | | $I_o = 5$ to 350mA<br>$V_i = 10.5$ to 23V | | 7.6 | 8 | 8.4 | |
| Line Regulation | $\triangle V_o$ | $I_o = 200mA$<br>$T_j = 25°C$ | $V_i = 10.5$ to 25V | | | 100 | mV |
| | | | $V_i = 11$ to 25V | | | 50 | |
| Load Regulation | $\triangle V_o$ | $I_o = 5mA$ to 0.5A, $T_j = 25°C$ | | | | 160 | mV |
| | | $I_o = 5mA$ to 200mA, $T_j = 25°C$ | | | | 80 | |
| Quiescent Current | $I_d$ | $T_j = 25°C$ | | | 4.0 | 6 | mA |
| Quiescent Current Change | $\triangle I_d$ | $I_o = 5mA$ to 350mA | | | | 0.5 | mA |
| | | $I_o = 200mA$<br>$V_i = 10.5$ to 25V | | | | 0.8 | |
| Output Voltage Drift | $\frac{\triangle V_o}{\triangle T}$ | $I_o = 5mA$<br>$T_j = 0$ to 125°C | | | -0.5 | | mV/°C |
| Output Noise Voltage | $V_N$ | f = 10Hz to 100KHz | | | 52 | | $\mu V$ |
| Ripple Rejection | RR | f = 120Hz $I_o = 300mA$<br>$V_i = 11.5$ to 21.5V | | 56 | | | dB |
| Dropout Voltage | $V_D$ | $T_j = 25°C$, $I_o = 500mA$ | | | 2 | | V |
| Short Circuit Current | $I_{sc}$ | $T_j = 25°C$, $V_i = 35V$ | | | 300 | | mA |
| Peak Current | $I_{peak}$ | $T_j = 25°C$ | | | 700 | | mA |

* $T_{min}$
MC78MXXI: $T_{min} = -40°C$
MC78MXXC: $T_{min} = 0°C$

* Load and line regulation are specified at constant junction temperature. Change in $V_o$ due to heating effects must be taken into account separately. Pulse testing with low duty is used.

## ELECTRICAL CHARACTERISTICS MC78M10

(Refer to the test circuits, $T_{min} \leq T_j \leq 125°C$, $I_o = 350mA$, $V_i = 17V$, unless otherwise specified, $C_i = 0.33\mu F$, $C_o = 0.1\mu F$)

| Characteristic | Symbol | Test Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Output Voltage | $V_o$ | $T_j = 25°C$ | 9.6 | 10 | 10.4 | V |
| | | $I_o = 5$ to 350mA<br>$V_i = 12.5$ to 25V | 9.5 | 10 | 10.5 | |
| Line Regulation | $\triangle V_o$ | $I_o = 200mA$, $T_j = 25°C$, $V_i = 12.5$ to 25V | | | 100 | mV |
| | | $I_o = 200mA$, $T_j = 25°C$, $V_i = 13$ to 25V | | | 50 | |
| Load Regulation | $\triangle V_o$ | $I_o = 5mA$ to 0.5A, $T_j = 25°C$ | | | 200 | mV |
| | | $I_o = 5mA$ to 200mA, $T_j = 25°C$ | | | 100 | |
| Quiescent Current | $I_d$ | $T_j = 25°C$ | | 4.1 | 6 | mA |
| Quiescent Current Change | $\triangle I_d$ | $I_o = 5mA$ to 350mA | | | 0.5 | mA |
| | | $I_o = 200mA$<br>$V_i = 12.5$ to 25V | | | 0.8 | |
| Output Voltage Drift | $\frac{\triangle V_o}{\triangle T}$ | $I_o = 5mA$<br>$T_j = 0$ to 125°C | | −0.5 | | mV/°C |
| Output Noise Voltage | $V_N$ | f = 10Hz to 100KHz | | 65 | | $\mu V$ |
| Ripple Rejection | RR | f = 120Hz, $I_o = 300mA$<br>$V_i = 13$ to 23V | 55 | | | dB |
| Dropout Voltage | $V_D$ | $T_j = 25°C$, $I_o = 500mA$ | | 2 | | V |
| Short Circuit Current | $I_{sc}$ | $T_j = 25°C$, $V_i = 35V$ | | 300 | | mA |
| Peak Current | $I_{peak}$ | $T_j = 25°C$ | | 700 | | mA |

* $T_{min}$
MC78MXXI: $T_{min} = -40°C$
MC78MXXC: $T_{min} = 0°C$

* Load and line regulation are specified at constant junction temperature. Change in $V_o$ due to heating effects must be taken into account separately. Pulse testing with low duty is used.

## ELECTRICAL CHARACTERISTICS MC78M12

(Refer to the test circuits, $T_{min} \leq T_j \leq 125°C$, $I_o = 350mA$, $V_i = 19V$, unless otherwise specified, $C_i = 0.33\mu F$, $C_o = 0.1\mu F$)

| Characteristic | Symbol | Test Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Output Voltage | $V_o$ | $T_j = 25°C$ | 11.5 | 12 | 12.5 | V |
| | | $I_o = 5$ to 350mA<br>$V_i = 14.5$ to 27V | 11.4 | 12 | 12.6 | |
| Line Regulation | $\Delta V_o$ | $I_o = 200mA$, $T_j = 25°C$, $V_i = 14.5$ to 30V | | | 100 | mV |
| | | $I_o = 200mA$, $T_j = 25°C$, $V_i = 16$ to 30V | | | 50 | |
| Load Regulation | $\Delta V_o$ | $I_o = 5mA$ to 0.5A, $T_j = 25°C$ | | | 240 | mV |
| | | $I_o = 5mA$ to 200mA, $T_j = 25°C$ | | | 120 | |
| Quiescent Current | $I_d$ | $T_j = 25°C$ | | 4.1 | 6 | mA |
| Quiescent Current Change | $\Delta I_d$ | $I_o = 5mA$ to 350mA | | | 0.5 | mA |
| | | $I_o = 200mA$<br>$V_i = 14.5$ to 30V | | | 0.8 | |
| Output Voltage Drift | $\frac{\Delta V_o}{\Delta T}$ | $I_o = 5mA$<br>$T_j = 0$ to 125°C | | −0.5 | | mV/°C |
| Output Noise Voltage | $V_N$ | f = 10Hz to 100KHz | | 75 | | $\mu$V |
| Ripple Rejection | RR | f = 120Hz, $I_o = 300mA$<br>$V_i = 15$ to 25V | 55 | | | dB |
| Dropout Voltage | $V_D$ | $T_j = 25°C$, $I_o = 500mA$ | | 2 | | V |
| Short Circuit Current | $I_{sc}$ | $T_j = 25°C$, $V_i = 35V$ | | 300 | | mA |
| Peak Current | $I_{peak}$ | $T_j = 25°C$ | | 700 | | mA |

* $T_{min}$
MC78MXXI: $T_{min} = -40°C$
MC78MXXC: $T_{min} = 0°C$

* Load and line regulation are specified at constant junction temperature. Change in $V_o$ due to heating effects must be taken into account separately. Pulse testing with low duty is used.

## ELECTRICAL CHARACTERISTICS MC78M15

(Refer to the test circuits, $T_{min} \leq T_j \leq 125°C$, $I_o = 350mA$, $V_i = 23V$, unless otherwise specified, $C_i = 0.33\mu F$, $C_o = 0.1\mu F$)

| Characteristic | Symbol | Test Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| Output Voltage | $V_o$ | $T_j = 25°C$ | | 14.4 | 15 | 15.6 | V |
| | | $I_o = 5$ to 350mA<br>$V_i = 17.5$ to 30V | | 14.25 | 15 | 15.75 | |
| Line Regulation | $\triangle V_o$ | $I_o = 200mA$<br>$T_j = 25°C$ | $V_i = 17.5$ to 30V | | | 100 | mV |
| | | | $V_i = 20$ to 30V | | | 50 | |
| Load Regulation | $\triangle V_o$ | $I_o = 5mA$ to 0.5A, $T_j = 25°C$ | | | | 300 | mV |
| | | $I_o = 5mA$ to 200mA, $T_j = 25°C$ | | | | 150 | |
| Quiescent Current | $I_d$ | $T_j = 25°C$ | | | 4.1 | 6 | mA |
| Quiescent Current Change | $\triangle I_d$ | $I_o = 5mA$ to 350mA | | | | 0.5 | mA |
| | | $I_o = 200mA$<br>$V_i = 17.5$ to 30V | | | | 0.8 | |
| Output Voltage Drift | $\frac{\triangle V_o}{\triangle T}$ | $I_o = 5mA$<br>$T_j = 0$ to 125°C | | | −1 | | mV/°C |
| Output Noise Voltage | $V_N$ | $f = 10Hz$ to 100KHz | | | 90 | | $\mu V$ |
| Ripple Rejection | RR | $f = 120Hz$ $I_o = 300mA$<br>$V_i = 18.5$ to 28.5V | | 54 | | | dB |
| Dropout Voltage | $V_D$ | $T_j = 25°C$, $I_o = 500mA$ | | | 2 | | V |
| Short Circuit Current | $I_{sc}$ | $T_j = 25°C$, $V_i = 35V$ | | | 300 | | mA |
| Peak Current | $I_{peak}$ | $T_j = 25°C$ | | | 700 | | mA |

* $T_{min}$
MC78MXXI: $T_{min} = -40°C$
MC78MXXC: $T_{min} = 0°C$

* Load and line regulation are specified at constant junction temperature. Change in $V_o$ due to heating effects must be taken into account separately. Pulse testing with low duty is used.

## ELECTRICAL CHARACTERISTICS MC78M18

(Refer to the test circuits, $T_{min} \leq T_j \leq 125°C$, $I_o = 350mA$, $V_i = 26V$, unless otherwise specified, $C_i = 0.33\mu F$, $C_o = 0.1\mu F$)

| Characteristic | Symbol | Test Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Output Voltage | $V_o$ | $T_j = 25°C$ | 17.3 | 18 | 18.7 | V |
| | | $I_o = 5$ to 350mA<br>$V_i = 20.5$ to 33V | 17.1 | 18 | 18.9 | |
| Line Regulation | $\Delta V_o$ | $I_o = 200mA$ $T_j = 25°C$, $V_i = 21$ to 33V | | | 100 | mV |
| | | $I_o = 200mA$ $T_j = 25°C$, $V_i = 24$ to 33V | | | 50 | |
| Load Regulation | $\Delta V_o$ | $I_o = 5mA$ to 0.5A, $T_j = 25°C$ | | | 360 | mV |
| | | $I_o = 5mA$ to 200mA, $T_j = 25°C$ | | | 180 | |
| Quiescent Current | $I_d$ | $T_j = 25°C$ | | 4.2 | 6 | mA |
| Quiescent Current Change | $\Delta I_d$ | $I_o = 5mA$ to 350mA | | | 0.5 | mA |
| | | $I_o = 200mA$<br>$V_i = 21$ to 33V | | | 0.8 | |
| Output Voltage Drift | $\frac{\Delta V_o}{\Delta T}$ | $I_o = 5mA$<br>$T_j = 0$ to 125°C | | - 1.1 | | mV/°C |
| Output Noise Voltage | $V_N$ | f = 10Hz to 100KHz | | 100 | | $\mu V$ |
| Ripple Rejection | RR | f = 120Hz $I_o = 300mA$<br>$V_i = 22$ to 32V | 53 | | | dB |
| Dropout Voltage | $V_D$ | $T_j = 25°C$, $I_o = 500mA$ | | 2 | | V |
| Short Circuit Current | $I_{sc}$ | $T_j = 25°C$, $V_i = 35V$ | | 300 | | mA |
| Peak Current | $I_{peak}$ | $T_j = 25°C$ | | 700 | | mA |

* $T_{min}$
MC78MXXI: $T_{min} = -40°C$
MC78MXXC: $T_{min} = 0°C$

* Load and line regulation are specified at constant junction temperature. Change in $V_o$ due to heating effects must be taken into account separately. Pulse testing with low duty is used.

## ELECTRICAL CHARACTERISTICS MC78M20

(Refer to the test circuits, $T_{min} \leq T_j \leq 125°C$, $I_o = 350mA$, $V_i = 29V$, unless otherwise specified, $C_i = 0.33\mu F$, $C_o = 0.1\mu F$)

| Characteristic | Symbol | Test Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Output Voltage | $V_o$ | $T_j = 25°C$ | 19.2 | 20 | 20.8 | V |
| | | $I_o = 5$ to 350mA<br>$V_i = 23$ to 35V | 19 | 20 | 21 | |
| Line Regulation | $\triangle V_o$ | $I_o = 200mA$, $T_j = 25°C$, $V_i = 23$ to 35V | | | 100 | mV |
| | | $I_o = 200mA$, $T_j = 25°C$, $V_i = 24$ to 35V | | | 50 | |
| Load Regulation | $\triangle V_o$ | $I_o = 5mA$ to 0.5A, $T_j = 25°C$ | | | 400 | mV |
| | | $I_o = 5mA$ to 200mA, $T_j = 25°C$ | | | 200 | |
| Quiescent Current | $I_d$ | $T_j = 25°C$ | | 4.2 | 6 | mA |
| Quiescent Current Change | $\triangle I_d$ | $I_o = 5mA$ to 350mA | | | 0.5 | mA |
| | | $I_o = 200mA$<br>$V_i = 23$ to 35V | | | 0.8 | |
| Output Voltage Drift | $\frac{\triangle V_o}{\triangle T}$ | $I_o = 5mA$<br>$T_j = 0$ to 125°C | | −1.1 | | mV/°C |
| Output Noise Voltage | $V_N$ | f = 10Hz to 100KHz | | 110 | | $\mu V$ |
| Ripple Rejection | RR | f = 120Hz $I_o = 300mA$<br>$V_i = 24$ to 34V | 53 | | | dB |
| Dropout Voltage | $V_D$ | $T_j = 25°C$, $I_o = 500mA$ | | 2 | | V |
| Short Circuit Current | $I_{sc}$ | $T_j = 25°C$, $V_i = 35V$ | | 300 | | mA |
| Peak Current | $I_{peak}$ | $T_j = 25°C$ | | 700 | | mA |

* $T_{min}$
MC78MXXI: $T_{min} = -40°C$
MC78MXXC: $T_{min} = 0°C$

* Load and line regulation are specified at constant junction temperature. Change in $V_o$ due to heating effects must be taken into account separately. Pulse testing with low duty is used.

## ELECTRICAL CHARACTERISTICS MC78M24

(Refer to the test circuits, $T_{min} \leq T_j \leq 125°C$, $I_o = 350mA$, $V_i = 33V$, unless otherwise specified, $C_i = 0.33\mu F$, $C_o = 0.1\mu F$)

| Characteristic | Symbol | Test Conditions | Min | Typ | Max | |
|---|---|---|---|---|---|---|
| Output Voltage | $V_o$ | $T_j = 25°C$ | 23 | 24 | 25 | V |
| | | $I_o = 5$ to 350mA<br>$V_i = 27$ to 38V | 22.8 | 24 | 25.2 | |
| Line Regulation | $\Delta V_o$ | $I_o = 200mA$<br>$T_j = 25°C$<br>$V_i = 27$ to 38V | | | 100 | mV |
| | | $V_i = 28$ to 38V | | | 50 | |
| Load Regulation | $\Delta V_o$ | $I_o = 5mA$ to 0.5A, $T_j = 25°C$ | | | 480 | mV |
| | | $I_o = 5mA$ to 200mA, $T_j = 25°C$ | | | 240 | |
| Quiescent Current | $I_d$ | $T_j = 25°C$ | | 4.2 | 6 | mA |
| Quiescent Current Change | $\Delta I_d$ | $I_o = 5mA$ to 350mA | | | 0.5 | mA |
| | | $I_o = 200mA$<br>$V_i = 27$ to 38V | | | 0.8 | |
| Output Voltage Drift | $\frac{\Delta V_o}{\Delta T}$ | $I_o = 5mA$<br>$T_j = 0$ to 125°C | | −1.2 | | mV/°C |
| Output Noise Voltage | $V_N$ | f = 10Hz to 100KHz | | 170 | | $\mu V$ |
| Ripple Rejection | RR | f = 120Hz $I_o = 300mA$<br>$V_i = 28$ to 38V | 50 | | | dB |
| Dropout Voltage | $V_D$ | $T_j = 25°C$, $I_o = 500mA$ | | 2 | | V |
| Short Circuit Current | $I_{sc}$ | $V_i = 35V$ | | 300 | | mA |
| Peak Current | $I_{peak}$ | $T_j = 25°C$ | | 700 | | mA |

* $T_{min}$
MC78MXXI: $T_{min} = -40°C$
MC78MXXC: $T_{min} = 0°C$

* Load and line regulation are specified at constant junction temperature. Change in $V_o$ due to heating effects must be taken into account separately. Pulse testing with low duty is used.

## APPLICATION CIRCUIT

**Fig. 1 Fixed output regulator**

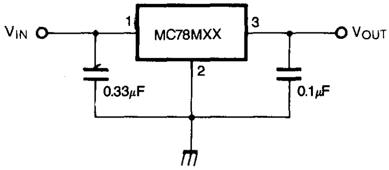
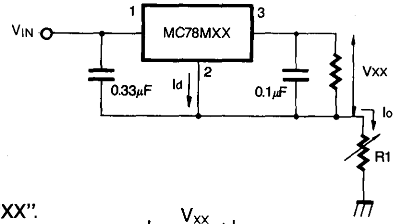


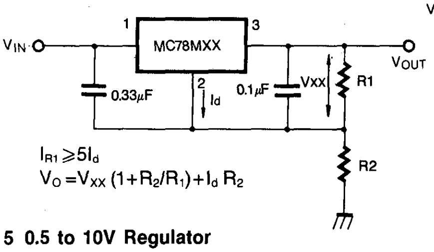
**Fig. 2 Constant current regulator**



$$I_O = \frac{V_{XX}}{R_1} + I_d$$

**Notes:**
(1) To specify an output voltage, substitute voltage value for "XX".
(2) Although no output capacitor is needed for stability, it does improve transient response.
(3) Required if regulator is located an appreciable distance from power supply filter.

**Fig. 3 Circuit for increasing output voltage**



$I_{R1} \geqslant 5I_d$
$V_O = V_{XX}(1+R_2/R_1)+I_d R_2$

**Fig. 4 Adjustable output regulator (7 to 30V)**

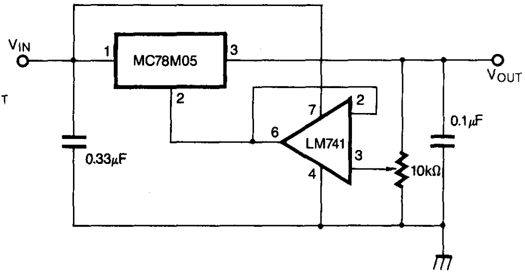
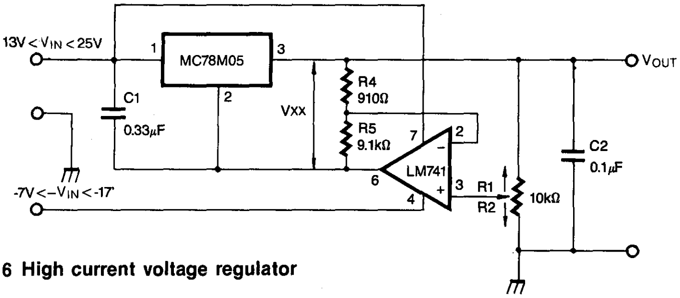
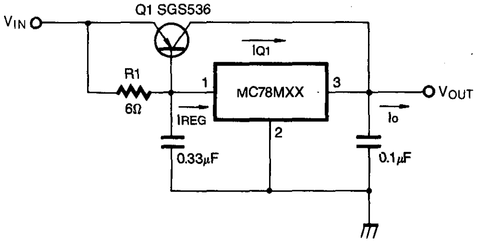


**Fig. 5 0.5 to 10V Regulator**



$$V_O = V_{XX}\frac{R_4}{R_1}$$

**Fig. 6 High current voltage regulator**

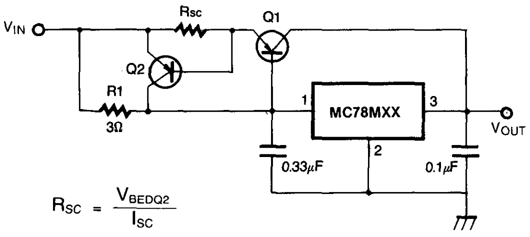


$$R_1 = \frac{V_{BEQ1}}{I_{REG} - \frac{I_{Q1}}{\beta_{Q1}}}$$

$$I_O = I_{REG} + \beta_{Q1}\left(I_{REG} - \frac{V_{BEQ1}}{R_{R1}}\right)$$

## APPLICATION CIRCUIT (continued)

**Fig. 7 High output current with short circuit protection**



$$R_{SC} = \frac{V_{BEDQ2}}{I_{SC}}$$

**Fig. 8 Tracking voltage regulator**

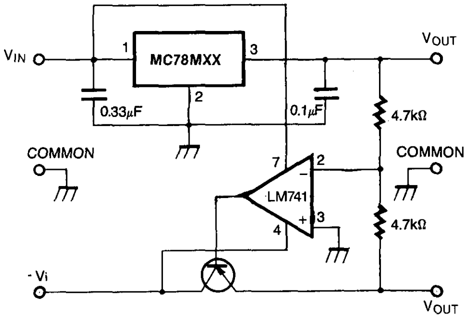
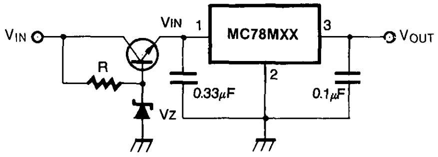
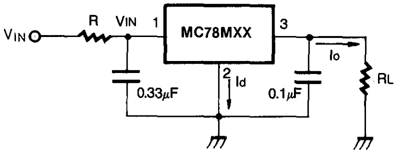


**Fig. 9 High input voltage circuit**



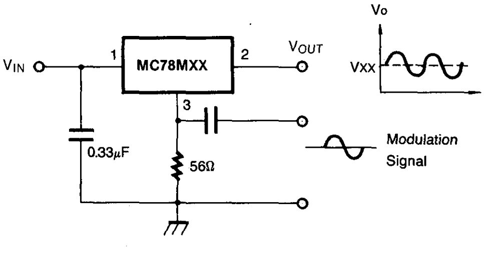
$$V_{IN} = V_Z - V_{BE}$$

**Fig. 10 Reducing power dissipation with dropping resistor**



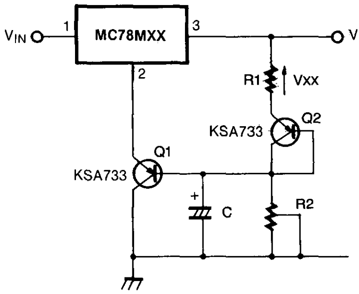
$$R = \frac{V_i\,(\min) - V_{XX} - V_{DROP}\,(\max)}{I_O\,(\max) + I_d\,(\max)}$$

**Fig. 11**
**(unity voltage gain, $I_O \leq 0.5$)**



**Note:** *The circuit performs well up to 100 KHz.*

**Fig. 12 Adjustable output voltage with temperature compensation**



**Note:** Q2 is connected as a diode in order to compensate the variation of the Q1 $V_{BE}$ with the temperature. C allows a slow rise-time of the $V_O$

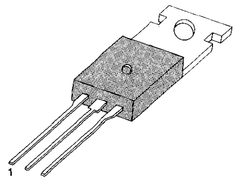
$$V_O = V_{XX}\left(1 + \frac{R_2}{R_1}\right) + V_{BE}$$

## 3-TERMINAL NEGATIVE VOLTAGE REGULATOR

The MC79XXC series of three-terminal negative regulators are available in the TO-220 package and with several output voltages. They can provide local on-card regulation, eliminating the distribution problems associated with single point regulation; furthermore, having the same voltage options as the MC78XXC positive standard series, they are particularly suited for split power supplies.

If adequate heat sinking is provided, the MC79XXC series can deliver an output current in excess of 1.5A. Although designed primarily as fixed voltage regulators, these devices can be used with external components to obtain adjustable voltages and currents.

TO-220



1: GND 2: Input 3: Output

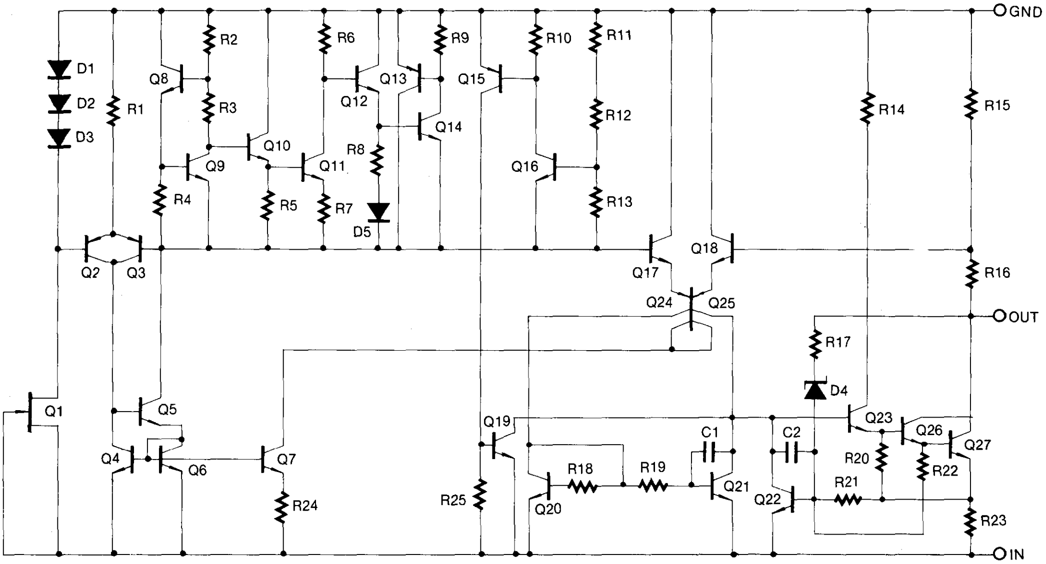
## FEATURES

- **Output current in excess of 1A**
- **Output voltages of −5V, −6V, −8V, −12V, −15V, −18V, −24V**
- **Internal thermal overload protection**
- **Short circuit protection**
- **Output transistor safe-area compensation**

## ORDERING INFORMATION

| Device | Package | Operating Temperature |
|---|---|---|
| MC79XXCT | TO-220 | 0 ~ 125°C |

## SCHEMATIC DIAGRAM



## ABSOLUTE MAXIMUM RATINGS

| Characteristic | Symbol | Value | Unit |
|---|---|---|---|
| Input Voltage (for $V_o = -2$ to $-18V$)<br>(for $V_o = -24V$) | $V_{IN}$ | $-35$<br>$-40$ | V<br>V |
| Thermal Resistance Junction-Case<br>Junction-Air | $0_{JC}$<br>$0_{JA}$ | 5<br>65 | °C/W<br>°C/W |
| Operating Temperature Range | $T_{opr}$ | $0 \sim +125$ | °C |
| Storage Temperature Range | $T_{stg}$ | $-65 \sim +150$ | °C |

## ELECTRICAL CHARACTERISTICS MC7905C

($C_i = 2.2\mu F$, $C_o = 1\mu F$, $T_j = 0$ to 125°C, $I_o = 500mA$, $V_i = 10V$, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Output Voltage | $V_o$ | $T_j=25°C$ | $-4.8$ | $-5$ | $-5.2$ | V |
| | | $I_o=5mA$ to 1A, $P_o \leq 15W$<br>$V_i = -8$ to $-20V$ | $-4.75$ | $-5$ | $-5.25$ | |
| Line Regulation | $\triangle V_o$ | $T_j = 25°C$<br>$V_i = -7$ to $-25V$ | | 10 | 100 | mV |
| | | $V_i = -8$ to $-12V$ | | 5 | 50 | |
| Load Regulation | $\triangle V_o$ | $T_j = 25°C$<br>$I_o=5mA$ to 1.5A | | 10 | 100 | mV |
| | | $T_j=25°C$<br>$I_o=250$ to 750mA | | 3 | 50 | |
| Quiescent Current | $I_d$ | $T_j=25°C$ | | 3 | 6 | mA |
| Quiescent Current Change | $\triangle I_d$ | $I_o=5mA$ to 1A | | | 0.5 | mA |
| | | $V_i = -8$ to $-25V$ | | | 1.3 | |
| Output Voltage Drift | $\frac{\triangle V_o}{\triangle T}$ | $I_o = 5mA$ | | $-0.4$ | | mV/°C |
| Output Noise Voltage | $V_N$ | $f = 10Hz$ to 100KHz<br>$T_j=25°C$ | | 100 | | $\mu V$ |
| Ripple Rejection | RR | $f=120Hz$<br>$\triangle V_i=10V$ | 54 | 60 | | dB |
| Dropout Voltage | $V_D$ | $T_j=25°C$<br>$I_o=1A$ | | 2 | | V |
| Short Circuit Current | $I_{sc}$ | $T_j = 25°C$, $V_i = -35V$ | | 300 | | mA |
| Peak Current | $I_{peak}$ | $T_j=25°C$ | | 2.2 | | A |

* Load and line regulation are specified at constant junction temperature. Change in $V_o$ due to heating effects must be taken into account separately. Pulse testing with low duty is used.

## ELECTRICAL CHARACTERISTICS MC7906C

($C_i = 2.2\mu F$, $C_o = 1\mu F$, $T_j = 0$ to 125°C, $I_o = 500mA$, $V_i = 11V$, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Output Voltage | $V_o$ | $T_j = 25°C$ | −5.75 | −6 | −6.25 | V |
| | | $I_o = 5mA$ to 1A, $P_o \leq 15W$ $V_i = -9$ to $-21V$ | −5.7 | −6 | −6.3 | |
| Line Regulation | $\Delta V_o$ | $T_j = 25°C$, $V_i = -8$ to $-25V$ | | 10 | 120 | mV |
| | | $T_j = 25°C$, $V_i = -9$ to $-13V$ | | 5 | 60 | |
| Load Regulation | $\Delta V_o$ | $T_j = 25°C$ $I_o = 5mA$ to 1.5A | | 10 | 120 | mV |
| | | $T_j = 25°C$ $I_o = 250$ to 750mA | | 3 | 60 | |
| Quiescent Current | $I_d$ | $T_j = 25°C$ | | 3 | 6 | mA |
| Quiescent Current Change | $\Delta I_d$ | $I_o = 5mA$ to 1A | | | 0.5 | mA |
| | | $V_i = -9$ to $-25V$ | | | 1.3 | |
| Output Voltage Drift | $\frac{\Delta V_o}{\Delta T}$ | $I_o = 5mA$ | | −0.5 | | mV/°C |
| Output Noise Voltage | $V_N$ | f = 10Hz to 100KHz $T_j = 25°C$ | | 130 | | μV |
| Ripple Rejection | RR | f=120Hz $\Delta V_i = 10V$ | 54 | 60 | | dB |
| Dropout Voltage | $V_D$ | $T_j = 25°C$ $I_o = 1A$ | | 2 | | V |
| Short Circuit Current | $I_{sc}$ | $T_j = 25°C$, $V_i = -35V$ | | 300 | | mA |
| Peak Current | $I_{peak}$ | $T_j = 25°C$ | | 2.2 | | A |

* Load and line regulation are specified at constant junction temperature. Change in $V_o$ due to heating effects must be taken into account separately. Pulse testing with low duty is used.

## ELECTRICAL CHARACTERISTICS MC7908C

($C_i = 2.2\mu F$, $C_o = 1\mu F$, $T_j = 0$ to 125°C, $I_o = 500mA$, $V_i = 14V$, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Output Voltage | $V_o$ | $T_j$=25°C | -7.7 | -8 | -8.3 | V |
| | | $I_o$=5mA to 1A, $P_o \leq$ 15W<br>$V_i$ = -11.5 to -23V | -7.6 | -8 | -8.4 | |
| Line Regulation | $\triangle V_o$ | $T_j$=25°C, $V_i$ = -10.5 to -25V | | 10 | 160 | mV |
| | | $T_j$=25°C, $V_i$ = -11 to -17V | | 5 | 80 | |
| Load Regulation | $\triangle V_o$ | $T_j$=25°C<br>$I_o$=5mA to 1.5A | | 12 | 160 | mV |
| | | $T_j$=25°C<br>$I_o$=250 to 750mA | | 4 | 80 | |
| Quiescent Current | $I_d$ | $T_j$=25°C | | 3 | 6 | mA |
| Quiescent Current Change | $\triangle I_d$ | $I_o$=5mA to 1A | | | 0.5 | mA |
| | | $V_i$ = -11.5 to -25V | | | 1 | |
| Output Voltage Drift | $\frac{\triangle V_o}{\triangle T}$ | $I_o$ = 5mA | | -0.6 | | mV/°C |
| Output Noise Voltage | $V_N$ | f = 10Hz to 100KHz<br>$T_j$=25°C | | 175 | | $\mu V$ |
| Ripple Rejection | RR | f=120Hz<br>$\triangle V_i$=10V | 54 | 60 | | dB |
| Dropout Voltage | $V_D$ | $T_j$=25°C<br>$I_o$=1A | | 2 | | V |
| Short Circuit Current | $I_{sc}$ | $T_j$=25°C, $V_i$ = -35V | | 300 | | mA |
| Peak Current | $I_{peak}$ | $T_j$=25°C | | 2.2 | | A |

* Load and line regulation are specified at constant junction temperature. Change in $V_o$ due to heating effects must be taken into account separately. Pulse testing with low duty is used.

## ELECTRICAL CHARACTERISTICS MC7912C

($C_i = 2.2\mu F$, $C_o = 1\mu F$, $T_j = 0$ to 125°C, $I_o = 500mA$, $V_i = 18V$, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Output Voltage | $V_o$ | $T_j = 25°C$ | $-11.5$ | $-12$ | $-12.5$ | V |
| | | $I_o = 5mA$ to 1A, $P_o \leq 15W$<br>$V_i = -15.5$ to $-27V$ | $-11.4$ | $-12$ | $-12.6$ | |
| Line Regulation | $\triangle V_o$ | $T_j = 25°C$, $V_i = -14.5$ to $-30V$ | | 12 | 240 | mV |
| | | $T_j = 25°C$, $V_i = -16$ to $-22V$ | | 6 | 120 | |
| Load Regulation | $\triangle V_o$ | $T_j = 25°C$<br>$I_o = 5mA$ to 1.5A | | 12 | 240 | mV |
| | | $T_j = 25°C$<br>$I_o = 250$ to 750mA | | 4 | 120 | |
| Quiescent Current | $I_d$ | $T_j = 25°C$ | | 3 | 6 | mA |
| Quiescent Current Change | $\triangle I_d$ | $I_o = 5mA$ to 1A | | | 0.5 | mA |
| | | $V_i = -15$ to $-30V$ | | | 1 | |
| Output Voltage Drift | $\frac{\triangle V_o}{\triangle T}$ | $I_o = 5mA$ | | $-0.8$ | | mV/°C |
| Output Noise Voltage | $V_N$ | f = 10Hz to 100KHz<br>$T_j = 25°C$ | | 200 | | $\mu V$ |
| Ripple Rejection | RR | f=120Hz<br>$\triangle V_i = 10V$ | 54 | 60 | | dB |
| Dropout Voltage | $V_D$ | $T_j = 25°C$<br>$I_o = 1A$ | | 2 | | V |
| Short Circuit Current | $I_{sc}$ | $T_j = 25°C$, $V_i = -35V$ | | 300 | | mA |
| Peak Current | $I_{peak}$ | $T_j = 25°C$ | | 2.2 | | A |

* Load and line regulation are specified at constant junction temperature. Change in $V_o$ due to heating effects must be taken into account separately. Pulse testing with low duty is used.

## ELECTRICAL CHARACTERISTICS MC7915C

($C_i = 2.2\mu F$, $C_o = 1\mu F$, $T_j = 0$ to 125°C, $I_o = 500mA$, $V_i = 23V$, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Output Voltage | $V_o$ | $T_j = 25°C$ | −14.4 | −15 | −15.6 | V |
| | | $I_o = 5mA$ to 1A, $P_o \leq 15W$<br>$V_i = -18$ to $-30V$ | −14.25 | −15 | −15.75 | |
| Line Regulation | $\Delta V_o$ | $T_j = 25°C$<br>$V_i = -17.5$ to $-30V$ | | 12 | 300 | mV |
| | | $V_i = -20$ to $-26V$ | | 6 | 150 | |
| Load Regulation | $\Delta V_o$ | $T_j = 25°C$<br>$I_o = 5mA$ to 1.5A | | 12 | 300 | mV |
| | | $T_j = 25°C$<br>$I_o = 250$ to 750mA | | 4 | 150 | |
| Quiescent Current | $I_d$ | $T_j = 25°C$ | | 3 | 6 | mA |
| Quiescent Current Change | $\Delta I_d$ | $I_o = 5mA$ to 1A | | | 0.5 | mA |
| | | $V_i = -18.5$ to $-30V$ | | | 1 | |
| Output Voltage Drift | $\frac{\Delta V_o}{\Delta T}$ | $I_o = 5mA$ | | −0.9 | | mV/°C |
| Output Noise Voltage | $V_N$ | f = 10Hz to 100KHz<br>$T_j = 25°C$ | | 250 | | $\mu V$ |
| Ripple Rejection | RR | f=120Hz<br>$\Delta V_i = 10V$ | 54 | 60 | | dB |
| Dropout Voltage | $V_D$ | $T_j = 25°C$<br>$I_o = 1A$ | | 2 | | V |
| Short Circuit Current | $I_{sc}$ | $T_j = 25°C$, $V_i = -35V$ | | 300 | | mA |
| Peak Current | $I_{peak}$ | $T_j = 25°C$ | | 2.2 | | A |

* Load and line regulation are specified at constant junction temperature. Change in $V_o$ due to heating effects must be taken into account separately. Pulse testing with low duty is used.

## ELECTRICAL CHARACTERISTICS MC7918C

($C_i = 2.2\mu F$, $C_o = 1\mu F$, $T_j = 0$ to 125°C, $I_o = 500mA$, $V_i = 27V$, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Output Voltage | $V_o$ | $T_j = 25°C$ | -17.3 | -18 | -18.7 | V |
| | | $I_o = 5mA$ to 1A, $P_o \leq 15W$<br>$V_i = -22.5$ to $-33V$ | -17.1 | -18 | -18.9 | |
| Line Regulation | $\Delta V_o$ | $T_j = 25°C$, $V_i = -21$ to $-33V$ | | 15 | 360 | mV |
| | | $T_j = 25°C$, $V_i = -24$ to $-30V$ | | 8 | 180 | |
| Load Regulation | $\Delta V_o$ | $T_j = 25°C$<br>$I_o = 5mA$ to 1.5A | | 15 | 360 | mV |
| | | $T_j = 25°C$<br>$I_o = 250$ to 750mA | | 5 | 180 | |
| Quiescent Current | $I_d$ | $T_j = 25°C$ | | 3 | 6 | mA |
| Quiescent Current Change | $\Delta I_d$ | $I_o = 5mA$ to 1A | | | 0.5 | mA |
| | | $V_i = -22$ to $-33V$ | | | 1 | |
| Output Voltage Drift | $\frac{\Delta V_o}{\Delta T}$ | $I_o = 5mA$ | | -1 | | mV/°C |
| Output Noise Voltage | $V_N$ | f = 10Hz to 100KHz<br>$T_j = 25°C$ | | 300 | | $\mu V$ |
| Ripple Rejection | RR | f=120Hz<br>$\Delta V_i = 10V$ | 54 | 60 | | dB |
| Dropout Voltage | $V_D$ | $T_j = 25°C$<br>$I_o = 1A$ | | 2 | | V |
| Short Circuit Current | $I_{sc}$ | $T_j = 25°C$, $V_i = -35V$ | | 300 | | mA |
| Peak Current | $I_{peak}$ | $T_j = 25°C$ | | 2.2 | | A |

* Load and line regulation are specified at constant junction temperature. Change in $V_o$ due to heating effects must be taken into account separately. Pulse testing with low duty is used.

## ELECTRICAL CHARACTERISTICS MC7924C

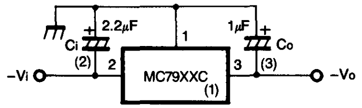
($C_i = 2.2\mu F$, $C_o = 1\mu F$, $T_j = 0$ to 125°C, $I_o = 500mA$, $V_i = 33V$, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| Output Voltage | $V_o$ | $T_j = 25°C$ | | -23 | -24 | -25 | V |
| | | $I_o = 5mA$ to 1A, $P_o \leq 15W$<br>$V_i = -27$ to $-38V$ | | -22.8 | -24 | -25.2 | |
| Line Regulation | $\triangle V_o$ | $T_j = 25°C$ | $V_i = -27$ to $-38V$ | | 15 | 480 | mV |
| | | | $V_i = -30$ to $-36V$ | | 8 | 240 | |
| Load Regulation | $\triangle V_o$ | $T_j = 25°C$<br>$I_o = 5mA$ to 1.5A | | | 15 | 480 | mV |
| | | $T_j = 25°C$<br>$I_o = 250$ to 750mA | | | 5 | 240 | |
| Quiescent Current | $I_d$ | $T_j = 25°C$ | | | 3 | 6 | mA |
| Quiescent Current Change | $\triangle I_d$ | $I_o = 5mA$ to 1A | | | | 0.5 | mA |
| | | $V_i = -27$ to $-38V$ | | | | 1 | |
| Output Voltage Drift | $\frac{\triangle V_o}{\triangle T}$ | $I_o = 5mA$ | | | -1 | | mV/°C |
| Output Noise Voltage | $V_N$ | f = 10Hz to 100KHz<br>$T_j = 25°C$ | | | 400 | | $\mu V$ |
| Ripple Rejection | RR | f=120Hz<br>$\triangle V_i = 10V$ | | 54 | 60 | | dB |
| Dropout Voltage | $V_D$ | $T_j = 25°C$<br>$I_o = 1A$ | | | 2 | | V |
| Short Circuit Current | $I_{sc}$ | $T_j = 25°C$, $V_i = -35V$ | | | 300 | | mA |
| Peak Current | $I_{peak}$ | $T_j = 25°C$ | | | 2.2 | | A |

* Load and line regulation are specified at constant junction temperature. Change in $V_o$ due to heating effects must be taken into account separately. Pulse testing with low duty is used.

## APPLICATION INFORMATION

Fig. 1 — Fixed output regulator



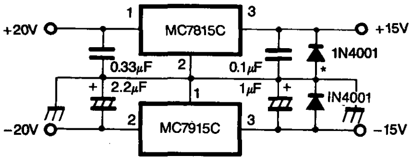
**Notes:**

(1) To specify an output voltage, substitute voltage value for "XXC".

(2) Required for stability. For value given, capacitor must be solid tantalum. If aluminium electrolitics are used, at least ten times value shown should be selected. Ci is required if regulator is located an appreciable distance from power supply filter.

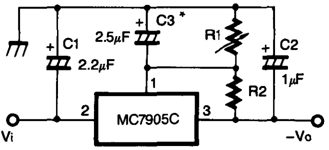
(3) To improve transient response. If large capacitors are used, a high current diode from input to output (1N4001 or similar) should be introduced to protect the device from momentary input short circuit.

Fig. 2 — Split power supply (±15V/1A)



* Against potential latch-up problems.

Fig. 3 — Circuit for increasing output voltage

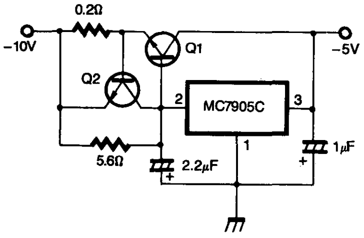


$$V_o = V_{XX} \cdot \frac{R_1 + R_2}{R_2}$$

$V_{XX}/R_2 > 3\, I_d$

* C3 optional for improved transient response and ripple rejection.

Fig. 4 — High current negative regulator (−5V/4A with 5A current limiting)

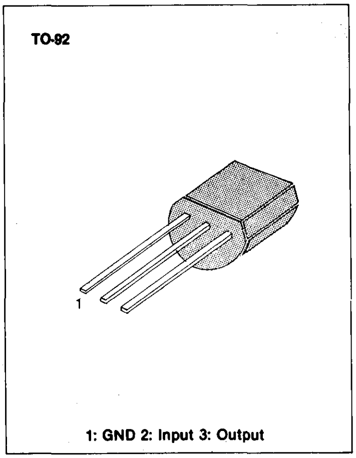


## 3-TERMINAL NEGATIVE VOLTAGE REGULATOR

These regulators employ internal current limiting and thermal—shutdown, making them essentially indestructible. The are intended as fixed voltage regulators in a wide range of applications including local regulator for elimination of noise and distribution problems associated with single—point regulation.

## FEATURES

- **Output current up to 100mA**
- **No external components**
- **Internal thermal over load protection**
- **Internal short circuit current limiting**
- **Available in JEDEC TO-92**
- **Mass production: MC79L05**
- **Under development: −12, −15, −18, −24V**



## ORDERING INFORMATION

| Device | Package | Operating Temperature |
|---|---|---|
| MC79LXXACZ | TO-92 | 0 ~ 125°C |

## SCHEMATIC DIAGRAM

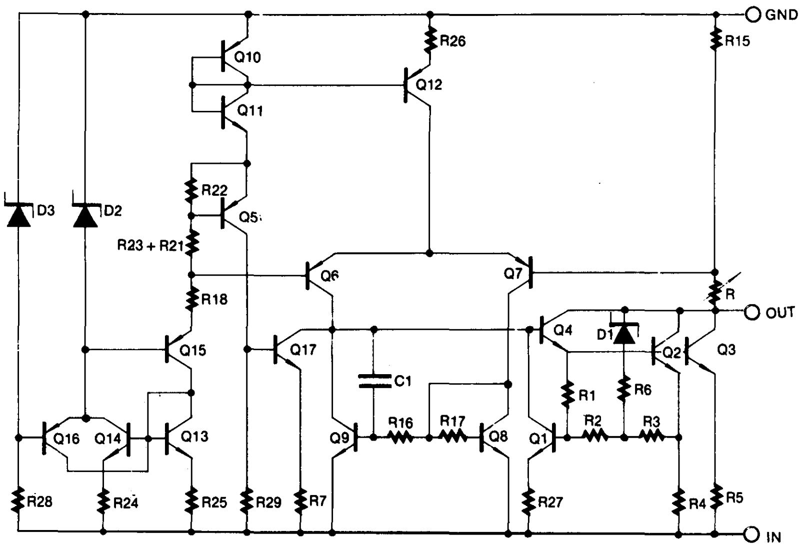


**Fig. 1**

## ABSOLUTE MAXIMUM RATINGS ($T_a = 25°C$)

| Characteristic | Symbol | Value | Unit |
|---|---|---|---|
| Input Voltage ($-5V$)<br>($-12V$ to $-18V$)<br>($-24V$) | $V_I$ | $-30$<br>$-35$<br>$-40$ | $V_{DC}$ |
| Operating Temperature Range | $T_{opr}$ | $0 \sim +125$ | °C |
| Storage Temperature Range | $T_{stg}$ | $-65 \sim +150$ | °C |

## MC79L05AC ELECTRICAL CHARACTERISTICS

($V_i = -10V$, $I_o = 40mA$, $C_i = 0.33\mu F$, $C_o = 0.1\mu F$, $0°C \leq T_j \leq +125°C$, unless otherwise specified)

| Characteristic | | Symbol | Test Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|---|
| Output Voltage | | $V_o$ | $T_j = 25°C$ | | $-4.8$ | $-5.0$ | $-5.2$ | V |
| Line Regulation | | $\triangle V_o$ | $T_j = 25°C$ | $-7.0V \geq V_i \geq -20V$ | | | 150 | mV |
| | | | | $-8.0V \geq V_i \geq -20V$ | | | 100 | |
| Load Regulation | | $\triangle V_o$ | $T_j = 25°C$ | $1.0mA \leq I_o \leq 100mA$ | | | 60 | mV |
| | | | | $1.0mA \leq I_o \leq 40mA$ | | | 30 | |
| Output Voltage | | $V_o$ | $-7.0V > V_i > -20V$, $1.0mA \leq I_o \leq 40mA$ | | $-4.75$ | | $-5.25$ | V |
| | | | $V_i = -1.0V$, $1.0mA \leq I_o \leq 70mA$ | | $-4.75$ | | $-5.25$ | |
| Quiescent Current | | $I_d$ | $T_j = +25°C$ | | | | 6.0 | mA |
| | | | $T_j = +125°C$ | | | | 5.5 | |
| Quiescent Current Change | With Line | $I_d$ | $-8V \geq V_i \geq -20V$ | | | | 1.5 | mA |
| | With Load | | $1.0mA \leq I_o \leq 40mA$ | | | | 0.1 | |
| Output Noise Voltage | | $V_N$ | $T_a = 25°C$, $10Hz \leq f \leq 100KHz$ | | | 40 | | $\mu V$ |
| Ripple Rejection | | RR | $f = 120Hz$, $-8.0 \geq V_i \geq -18V$<br>$T_j = 25°C$ | | 41 | 49 | | dB |
| Dropout Voltage | | $V_D$ | $T_j = 25°C$ | | | 1.7 | | V |

* Load and line regulation are specified at constant junction temperature. Change in $V_o$ due to heating effects must be taken into account separately. Pulse testing with low duty is used.

## MC79L12AC ELECTRICAL CHARACTERISTICS

($V_i$ = -19V, $I_o$=40mA, $C_i$=0.33μF, $C_o$=0.1μF, 0°C≤$T_j$≤+125°C, unless otherwise specified)

| Characteristic | | Symbol | Test Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|---|
| Output Voltage | | $V_o$ | $T_j$=25°C | | -11.5 | -12.0 | -12.5 | V |
| Line Regulation | | $\Delta V_o$ | $T_j$=25°C | $-14.5V \geq V_i \geq -27V$ | | | 250 | mV |
| | | | | $-16V \geq V_i \geq -27V$ | | | 200 | |
| Load Regulation | | $\Delta V_o$ | $T_j$=25°C | 1.0mA≤$I_o$≤100mA | | | 100 | mV |
| | | | | 1.0mA≤$I_o$≤40mA | | | 50 | |
| Output Voltage | | $V_o$ | $-14.5V > V_i > -27V$, 1.0mA≤$I_o$≤40mA | | -11.4 | | -12.6 | V |
| | | | $V_i = -19V$, 1.0mA≤$I_o$≤70mA | | -11.4 | | -12.6 | |
| Quiescent Current | | $I_d$ | $T_j$=+25°C | | | | 6.5 | mA |
| | | | $T_j$=+125°C | | | | 6.0 | |
| Quiescent Current Change | With Line | $I_d$ | $-16V \geq V_i \geq -27V$ | | | | 1.5 | mA |
| | With Load | | 1.0mA≤$I_o$≤40mA | | | | 0.1 | |
| Output Noise Voltage | | $V_N$ | Ta=25°C, 10Hz≤f≤100KHz | | | 80 | | μV |
| Ripple Rejection | | RR | f=120Hz, $-15V \geq V_i \geq -25V$<br>$T_j$=25°C | | 37 | 42 | | dB |
| Dropout Voltage | | $V_D$ | $T_j$=25°C | | | 1.7 | | V |

* Load and line regulation are specified at constant junction temperature. Change in $V_o$ due to heating effects must be taken into account separately. Pulse testing with low duty is used.

## MC79L15AC ELECTRICAL CHARACTERISTICS

($V_i$ = -23V, $I_o$=40mA, $C_i$=0.33μF, $C_o$=0.1μF, 0°C≤$T_j$≤+125°C, unless otherwise specified)

| Characteristic | | Symbol | Test Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|---|
| Output Voltage | | $V_o$ | $T_j$=25°C | | -14.4 | -15.0 | -15.6 | V |
| Line Regulation | | $\Delta V_o$ | $T_j$=25°C | $-17.5V \geq V_i \geq -30V$ | | | 300 | mV |
| | | | | $-27V \geq V_i \geq -30V$ | | | 250 | |
| Load Regulation | | $\Delta V_o$ | $T_j$=25°C | 1.0mA≤$I_o$≤100mA | | | 150 | mV |
| | | | | 1.0mA≤$I_o$≤40mA | | | 75 | |
| Output Voltage | | $V_o$ | $-17.5V > V_i > -30V$, 1.0mA≤$I_o$≤40mA | | -14.25 | | -15.75 | V |
| | | | $V_i = -23V$, 1.0mA≤$I_o$≤70mA | | -14.25 | | -15.75 | |
| Quiescent Current | | $I_d$ | $T_j$=+25°C | | | | 6.5 | mA |
| | | | $T_j$=+125°C | | | | 6.0 | |
| Quiescent Current Change | With Line | $I_d$ | $-20V \geq V_i \geq -30V$ | | | | 1.5 | mA |
| | With Load | | 1.0mA≤$I_o$≤40mA | | | | 0.1 | |
| Output Noise Voltage | | $V_N$ | Ta=25°C, 10Hz≤f≤100KHz | | | 90 | | μV |
| Ripple Rejection | | RR | f=120Hz, $-18.5V \geq V_i \geq -28.5V$<br>$T_j$=25°C | | 34 | 39 | | dB |
| Dropout Voltage | | $V_D$ | $T_j$=25°C | | | 1.7 | | V |

* Load and line regulation are specified at constant junction temperature. Change in $V_o$ due to heating effects must be taken into account separately. Pulse testing with low duty is used.

## MC79L18AC ELECTRICAL CHARACTERISTICS

($V_i = -27V$, $I_o = 40mA$, $C_i = 0.33\mu F$, $C_o = 0.1\mu F$, $0°C \leq T_j \leq +125°C$, unless otherwise specified)

| Characteristic | | Symbol | Test Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|---|
| Output Voltage | | $V_o$ | $T_j = 25°C$ | | - 17.3 | - 18.0 | - 18.7 | V |
| Line Regulation | | $\triangle V_o$ | $T_j = 25°C$ | $-20.7V \geq V_i \geq -33V$ | | | 325 | mV |
| | | | | $-21V \geq V_i \geq -33V$ | | | 275 | |
| Load Regulation | | $\triangle V_o$ | $T_j = 25°C$ | $1.0mA \leq I_o \leq 100mA$ | | | 170 | mV |
| | | | | $1.0mA \leq I_o \leq 40mA$ | | | 85 | |
| Output Voltage | | $V_o$ | $-20.7V > V_i > -33V$, $1.0mA \leq I_o \leq 40mA$ | | - 17.1 | | - 18.9 | V |
| | | | $V_i = -27V$, $1.0mA \leq I_o \leq 70mA$ | | - 17.1 | | - 18.9 | |
| Quiescent Current | | $I_d$ | $T_j = +25°C$ | | | | 6.5 | mA |
| | | | $T_j = +125°C$ | | | | 6.0 | |
| Quiescent Current Change | With Line | $I_d$ | $-21V \geq V_i \geq -33V$ | | | | 1.5 | mA |
| | With Load | | $1.0mA \leq I_o \leq 40mA$ | | | | 0.1 | |
| Output Noise Voltage | | $V_N$ | $Ta = 25°C$, $10Hz \leq f \leq 100KHz$ | | | 150 | | $\mu V$ |
| Ripple Rejection | | RR | $f = 120Hz$, $-23V \geq V_i \geq -33V$<br>$T_j = 25°C$ | | 33 | 48 | | dB |
| Dropout Voltage | | $V_D$ | $T_j = 25°C$ | | | 1.7 | | V |

* Load and line regulation are specified at constant junction temperature. Change in $V_o$ due to heating effects must be taken into account separately. Pulse testing with low duty is used.

## MC79L24AC ELECTRICAL CHARACTERISTICS

($V_i = -33V$, $I_o = 40mA$, $C_i = 0.33\mu F$, $C_o = 0.1\mu F$, $0°C \leq T_j \leq +125°C$, unless otherwise specified)

| Characteristic | | Symbol | Test Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|---|
| Output Voltage | | $V_o$ | $T_j = 25°C$ | | - 23 | - 24 | - 25 | V |
| Line Regulation | | $\triangle V_o$ | $T_j = 25°C$ | $-27V \geq V_i \geq -38V$ | | | 350 | mV |
| | | | | $-28V \geq V_i \geq -38V$ | | | 300 | |
| Load Regulation | | $\triangle V_o$ | $T_j = 25°C$ | $1.0mA \leq I_o \leq 100mA$ | | | 200 | mV |
| | | | | $1.0mA \leq I_o \leq 40mA$ | | | 100 | |
| Output Voltage | | $V_o$ | $-27V > V_i > -38V$, $1.0mA \leq I_o \leq 40mA$ | | - 22.8 | | - 25.2 | V |
| | | | $V_i = -33V$, $1.0mA \leq I_o \leq 70mA$ | | - 22.8 | | - 25.2 | |
| Quiescent Current | | $I_d$ | $T_j = +25°C$ | | | | 6.5 | mA |
| | | | $T_j = +125°C$ | | | | 6.0 | |
| Quiescent Current Change | With Line | $I_d$ | $-28V \geq V_i \geq -38V$ | | | | 1.5 | mA |
| | With Load | | $1.0mA \leq I_o \leq 40mA$ | | | | 0.1 | |
| Output Noise Voltage | | $V_N$ | $Ta = 25°C$, $10Hz \leq f \leq 100KHz$ | | | 200 | | $\mu V$ |
| Ripple Rejection | | RR | $f = 120Hz$, $-29V \geq V_i \geq -35V$<br>$T_j = 25°C$ | | 31 | 47 | | dB |
| Dropout Voltage | | $V_D$ | $T_j = 25°C$ | | | 1.7 | | V |

* Load and line regulation are specified at constant junction temperature. Change in $V_o$ due to heating effects must be taken into account separately. Pulse testing with low duty is used.

# TYPICAL APPLICATION

**Design Considerations**

The MC79LXXAC Series of fixed voltage regulators are designed with Thermal Overload Protection that shuts down the circuit when subjected to an excessive power overload condition. Internal Short-Circuit Protection that limits the maximum current the circuit will pass.

In many low current applications, compensation capacitors are not required. However, it is recommended that the regulator input be bypassed with a capacitor if the regulator is connected to the power supply filter with long wire lengths, or if the output load capacitance is large. An input bypass capacitor should be selected to provide good high-frequency characteristics to insure stable operation under all load conditions. A 0.33μF or larger tantalum, mylar, or other capacitor having low internal impedance at high frequencies should be chosen. The bypass capacitor should be mounted with the shortest possible leads directly across the regulator's input terminals. Normally good construction techniques should be used to minimize ground loops and lead resistance drops since the regulator has no external sense lead. Bypassing the output is also recommended.

**Fig. 1 POSITIVE AND NEGATIVE REGULATOR FIG.**

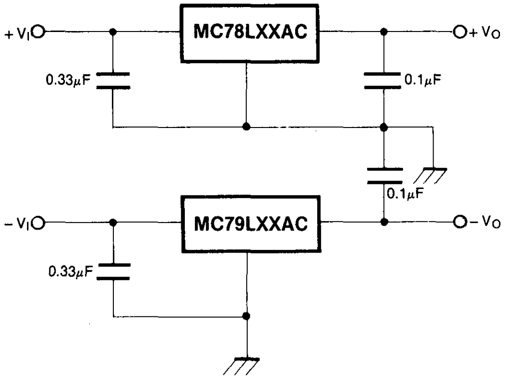
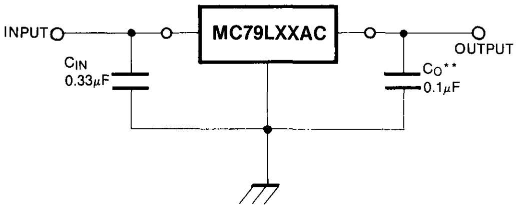


**Fig. 2 TYPICAL APPLICATION**



A common ground is required between the input and the output voltages. The input voltage must remain typically 2.0V above the output voltage even during the low point on the input ripple voltage.

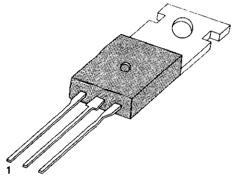
* = $C_{IN}$ is required if regulator is located an appreciable distance from power supply filter.

** = $C_O$ improves stability and transient response.

# 3-TERMINAL 0.5A NEGATIVE VOLTAGE REGULATOR

The MC79MXX series of 3-Terminal medium current negative voltage regulators are monolithic integrated circuits designed as fixed voltage regulators. These regulators employ internal current limiting, thermal shutdown and safe-area compensation making them essentially indestructible. If adequate heat sinking is provided, they can deliver up to 500mA output current. They are intended as fixed voltage regulators in a wide range of applications including local (on-card) regulation for elimination of noise and distribution problems associated with single point regulation. In addition to use as fixed voltage regulators, these devices can be used with external components to obtain adjustable output voltages and currents.

TO-220



**1: GND 2: Input 3: Output**

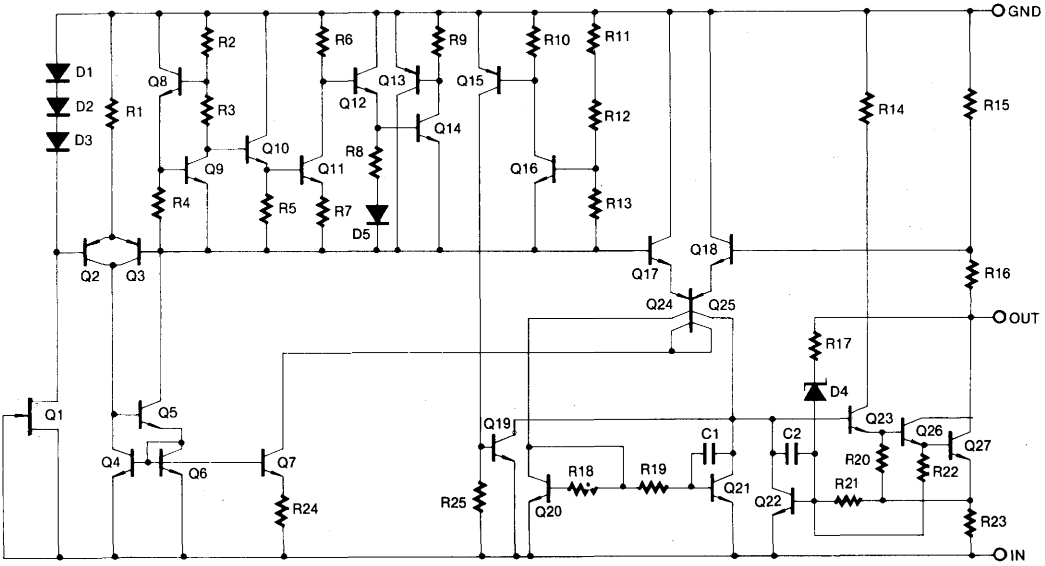
## FEATURES

- **No external components required**
- **Output current in excess of 0.5A**
- **Internal thermal-overload protection**
- **Internal short circuit current limiting**
- **Output transistor safe-area compensation**
- **Available in JEDEC TO-220**
- **Output voltages of −5V, −6V, −8V, −12V, −15V, −18V, −24V**

## ORDERING INFORMATION

| Device | Package | Operating Temperature |
|---|---|---|
| MC79MXXCT | TO-220 | 0 ~ 125°C |
| **MC79MXXIT | TO-220 | −40 ~ 125°C |

## SCHEMATHIC DIAGRAM



## ABSOLUTE MAXIMUM RATINGS

| Characteristic | Symbol | Value | Unit |
|---|---|---|---|
| Input Voltage (for $V_o = -5$ to $-1.8V$)<br>(for $V_o = 24V$) | $V_{IN}$ | −35<br>−40 | V<br>V |
| Thermal Resistance Junction-Case<br>Junction-Air | $\Theta_{JC}$<br>$\Theta_{JA}$ | 5<br>65 | °C/W<br>°C/W |
| Operating Temperature Range MC79MXXC<br>MC79MXXI | $T_{opr}$ | 0～+125<br>−40～+125 | °C<br>°C |
| Storage Temperature Range | $T_{stg}$ | −65～+150 | °C |

## ELECTRICAL CHARACTERISTICS MC79M05C

(Refer to test circuit, $T_{min} \leq T_j \leq 125°C$, $I_O = 350mA$, $V_i = -10V$, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| Output Voltage | $V_o$ | $T_j = 25°C$ | | −4.8 | −5.0 | −5.2 | V |
| | | $5.0mA \leq I_o \leq 350mA$<br>$V_i = -7V$ to $-25V$ | | −4.75 | −5.0 | −5.25 | |
| Line Regulation | $\Delta V_o$ | $T_j = 25°C$ | $V_i = -7V$ to $-25V$ | | 7.0 | 50 | mV |
| | | | $V_i = -8V$ to $-18V$ | | 2.0 | 30 | |
| Load Regulation | $\Delta V_o$ | $T_j = 25°C$ | $I_o = 5.0mA$ to $500mA$ | | 30 | 100 | mV |
| Quiescent Current | $I_d$ | $T_j = 25°C$ | | | 3 | 6 | mA |
| Quiescent Current Change | $\Delta I_d$ | $I_o = 5.0mA$ to $350mA$ | | | | 0.4 | mA |
| | | $V_i = -8V$ to $-25V$ | | | | 0.4 | |
| Output Voltage Drift | $\Delta V_o/\Delta T$ | $I_o = 5mA$ | | | 0.2 | | mV/°C |
| Output Noise Voltage | $V_N$ | $f = 10Hz$ to $100KHz$ $T_j = 25°C$ | | | 40 | | μV |
| Ripple Rejection | RR | $f = 120Hz$, $V_i = -8$ to $-18V$ | | 54 | 60 | | dB |
| Dropout Voltage | $V_D$ | $I_o = 500mA$, $T_j = 25°C$ | | | 1.1 | | V |
| Short Circuit Current | $I_{SC}$ | $V_i = -35V$, $T_j = 25°C$ | | | 140 | | mA |
| Peak Current | $I_{peak}$ | $T_j = 25°C$ | | | 650 | | mA |

* Load and line regulation are specified at constant junction temperature. Change in $V_o$ due to heating effects must be taken into account separately. Pulse testing with low duty is used.

## ELECTRICAL CHARACTERISTICS MC79M06C

(Refer to test circuit, $T_{min} \leq T_j \leq 125°C$, $I_O = 350mA$, $V_I = -11V$, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| Output Voltage | $V_o$ | $T_j = 25°C$ | | −5.75 | −6.0 | −6.25 | V |
| | | $5.0mA \leq I_o \leq 350mA$<br>$V_i = -8.0V$ to $-25V$ | | −5.7 | −6.0 | −6.3 | |
| Line Regulation | $\Delta V_o$ | $T_j = 25°C$ | $V_i = -8V$ to $-25V$ | | 7.0 | 60 | mV |
| | | | $V_i = -9V$ to $-19V$ | | 2.0 | 40 | |
| Load Regulation | $\Delta V_o$ | $T_j = 25°C$ | $I_o = 5.0mA$ to $500mA$ | | 30 | 120 | mV |
| Quiescent Current | $I_d$ | $T_j = 25°C$ | | | 3 | 6 | mA |
| Quiescent Current Change | $\Delta I_d$ | $I_o = 5.0mA$ to $350mA$ | | | | 0.4 | mA |
| | | $V_i = -8.0V$ to $-25V$ | | | | 0.4 | |
| Output Voltage Drift | $\Delta V_o / \Delta T$ | $I_o = 5mA$ | | | 0.4 | | mV/°C |
| Output Noise Voltage | $V_N$ | f = 10Hz to 100KHz $T_j = 25°C$ | | | 50 | | μV |
| Ripple Rejection | RR | f = 120Hz, $V_i = -9$ to $-19V$ | | 54 | 60 | | dB |
| Dropout Voltage | $V_D$ | $I_o = 500mA$, $T_j = 25°C$ | | | 1.1 | | V |
| Short Circuit Current | $I_{SC}$ | $V_i = -35V$, $T_j = 25°C$ | | | 140 | | mA |
| Peak Current | $I_{peak}$ | $T_j = 25°C$ | | | 650 | | mA |

* Load and line regulation are specified at constant junction temperature. Change in $V_o$ due to heating effects must be taken into account separately. Pulse testing with low duty is used.

## ELECTRICAL CHARACTERISTICS MC79M08C

(Refer to test circuit, $T_{min} \leq T_j \leq 125°C$, $I_O = 350mA$, $V_I = -14V$, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| Output Voltage | $V_o$ | $T_j = 25°C$ | | −7.7 | −8.0 | −8.3 | V |
| | | $5.0mA \leq I_o \leq 350mA$<br>$V_i = -10.5V$ to $-25V$ | | −7.6 | −8.0 | −8.4 | |
| Line Regulation | $\Delta V_o$ | $T_j = 25°C$ | $V_i = -10.5V$ to $-25V$ | | 7.0 | 80 | mV |
| | | | $V_i = -11V$ to $-21V$ | | 2.0 | 50 | |
| Load Regulation | $\Delta V_o$ | $T_j = 25°C$ | $I_o = 5.0mA$ to $500mA$ | | 30 | 160 | mV |
| Quiescent Current | $I_d$ | $T_j = 25°C$ | | | 3 | 6 | mA |
| Quiescent Current Change | $\Delta I_d$ | $I_o = 5.0mA$ to $350mA$ | | | | 0.4 | mA |
| | | $V_i = -10.5V$ to $-25V$ | | | | 0.4 | |
| Output Voltage Drift | $\Delta V_o / \Delta T$ | $I_o = 5mA$ | | | −0.6 | | mV/°C |
| Output Noise Voltage | $V_N$ | f = 10Hz to 100KHz $T_j = 25°C$ | | | 60 | | μV |
| Ripple Rejection | RR | f = 120Hz, $V_i = -11.5V$ to $-21.5V$ | | 54 | 59 | | dB |
| Dropout Voltage | $V_D$ | $I_o = 500mA$, $T_j = 25°C$ | | | 1.1 | | V |
| Short Circuit Current | $I_{SC}$ | $V_i = -35V$, $T_j = 25°C$ | | | 140 | | mA |
| Peak Current | $I_{peak}$ | $T_j = 25°C$ | | | 650 | | mA |

* Load and line regulation are specified at constant junction temperature. Change in $V_o$ due to heating effects must be taken into account separately. Pulse testing with low duty is used.

## ELECTRICAL CHARACTERISTICS MC79M12C

(Refer to test circuit, $T_{min} \le T_j \le 125°C$, $I_o = 350mA$, $V_i = -19V$, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| Output Voltage | $V_o$ | $T_j = 25°C$ | | −11.5 | −12 | −12.5 | V |
| | | $5.0mA \le I_o \le 350mA$<br>$V_i = -14.5V$ to $-30V$ | | −11.4 | −1.2 | −12.6 | |
| Line Regulation | $\Delta V_o$ | $T_j = 25°C$ | $V_i = -14.5V$ to $-30V$ | | 8.0 | 80 | mV |
| | | | $V_i = -15V$ to $-25V$ | | 3.0 | 50 | |
| Load Regulation | $\Delta V_o$ | $T_j = 25°C$ | $I_o = 5.0mA$ to 500mA | | 30 | 240 | mV |
| Quiescent Current | $I_d$ | $T_j = 25°C$ | | | 3 | 6 | mA |
| Quiescent Current Change | $\Delta I_d$ | $I_o = 5.0mA$ to 350mA | | | | 0.4 | mA |
| | | $V_i = -14.5V$ to $-30V$ | | | | 0.4 | |
| Output Voltage Drift | $\Delta V_o/\Delta T$ | $I_o = 5mA$ | | | −0.8 | | mV/°C |
| Output Noise Voltage | $V_N$ | f = 10Hz to 100KHz $T_j = 25°C$ | | | 75 | | μV |
| Ripple Rejection | RR | f = 120Hz, $V_i = -15V$ to $-25V$ | | 54 | 60 | | dB |
| Dropout Voltage | $V_D$ | $I_o = 500mA$, $T_j = 25°C$ | | | 1.1 | | V |
| Short Circuit Current | $I_{SC}$ | $V_i = -35V$, $T_j = 25°C$ | | | 140 | | mA |
| Peak Current | $I_{peak}$ | $T_j = 25°C$ | | | 650 | | mA |

* Load and line regulation are specified at constant junction temperature. Change in $V_o$ due to heating effects must be taken into account separately. Pulse testing with low duty is used.

## ELECTRICAL CHARACTERISTICS MC79M15C

(Refer to test circuit, $T_{min} \le T_j \le 125°C$, $I_O = 350mA$, $V_i = -23V$, *unless otherwise specified*)

| Characteristic | Symbol | Test Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| Output Voltage | $V_o$ | $T_j = 25°C$ | | −14.4 | −15 | −15.6 | V |
| | | $5.0mA \le I_o \le 350mA$<br>$V_i = -17.5V$ to $-30V$ | | −14.25 | −15 | −15.75 | |
| Line Regulation | $\Delta V_o$ | $T_j = 25°C$ | $V_i = -17.5V$ to $-30V$ | | 9.0 | 80 | mV |
| | | | $V_i = -18V$ to $-28V$ | | 5.0 | 50 | |
| Load Regulation | $\Delta V_o$ | $T_j = 25°C$ | $I_o = 5.0mA$ to 500mA | | 30 | 240 | mV |
| Quiescent Current | $I_d$ | $T_j = 25°C$ | | | 3 | 6 | mA |
| Quiescent Current Change | $\Delta I_d$ | $I_o = 5.0mA$ to 350mA | | | | 0.4 | mA |
| | | $V_i = -17.5V$ to $-28V$ | | | | 0.4 | |
| Output Voltage Drift | $\Delta V_o/\Delta T$ | $I_o = 5mA$ | | | −1.0 | | mV/°C |
| Output Noise Voltage | $V_N$ | f = 10Hz to 100KHz $T_j = 25°C$ | | | 90 | | μV |
| Ripple Rejection | RR | f = 120Hz, $V_i = -18.5V$ to $-28.5V$ | | 54 | 59 | | dB |
| Dropout Voltage | $V_D$ | $I_o = 500mA$, $T_j = 25°C$ | | | 1.1 | | V |
| Short Circuit Current | $I_{SC}$ | $V_i = -35V$, $T_j = 25°C$ | | | 140 | | mA |
| Peak Current | $I_{peak}$ | $T_j = 25°C$ | | | 650 | | mA |

* Load and line regulation are specified at constant junction temperature. Changes in $V_o$ due to heating effects must be taken into account separately. Pulse testing with low duty is used.

## ELECTRICAL CHARACTERISTICS MC79M18C

(Refer to test circuit, $T_{min} \leq T_j \leq 125°C$, $I_O = 350mA$, $V_I = -27V$, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| Output Voltage | $V_o$ | $T_j = 25°C$ | | −17.3 | −18 | −18.7 | V |
| | | $5.0mA \leq I_o \leq 350mA$<br>$V_i = -21V$ to $-33V$ | | −17.1 | −18 | −18.9 | |
| Line Regulation | $\Delta V_o$ | $T_j = 25°C$ | $V_i = -21V$ to $-33V$ | | 9.0 | 80 | mV |
| | | | $V_i = -24V$ to $-30V$ | | 5.0 | 60 | |
| Load Regulation | $\Delta V_o$ | $T_j = 25°C$ | $I_o = 5.0mA$ to $500mA$ | | 30 | 360 | mV |
| Quiescent Current | $I_d$ | $T_j = 25°C$ | | | 3 | 6 | mA |
| Quiescent Current Change | $\Delta I_d$ | $I_o = 5.0mA$ to $350mA$ | | | | 0.4 | mA |
| | | $V_i = -21V$ to $-33V$ | | | | 0.4 | |
| Output Voltage Drift | $\Delta V_o/\Delta T$ | $I_o = 5mA$ | | | −1.0 | | mV/°C |
| Output Noise Voltage | $V_N$ | $f = 10Hz$ to $100KHz$ $T_j = 25°C$ | | | 110 | | μV |
| Ripple Rejection | RR | $f = 120Hz$, $V_i = -22V$ to $-32V$ | | 54 | 59 | | dB |
| Dropout Voltage | $V_D$ | $I_o = 500mA$, $T_j = 25°C$ | | | 1.1 | | V |
| Short Circuit Current | $I_{SC}$ | $V_i = -35V$, $T_j = 25°C$ | | | 140 | | mA |
| Peak Current | $I_{peak}$ | $T_j = 25°C$ | | | 650 | | mA |

* Load and line regulation are specified at constant junction temperature. Changes in $V_o$ due to heating effects must be taken into account separately. Pulse testing with low duty is used.

## ELECTRICAL CHARACTERISTICS MC79M24C

(Refer to test circuit, $T_{min} \leq T_j \leq 125°C$, $I_O = 350mA$, $V_I = -33V$, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| Output Voltage | $V_o$ | $T_j = 25°C$ | | −23 | −24 | −25 | V |
| | | $5.0mA \leq I_o \leq 350mA$<br>$V_i = -27V$ to $-38V$ | | −22.8 | −24 | −25.2 | |
| Line Regulation | $\Delta V_o$ | $T_j = 25°C$ | $V_i = -27V$ to $-38V$ | | 9.0 | 80 | mV |
| | | | $V_i = -30V$ to $-36V$ | | 5.0 | 70 | |
| Load Regulation | $\Delta V_o$ | $T_j = 25°C$ | $I_o = 5.0mA$ to $500mA$ | | 30 | 300 | mV |
| Quiescent Current | $I_d$ | $T_j = 25°C$ | | | 3 | 6 | mA |
| Quiescent Current Change | $\Delta I_d$ | $I_o = 5.0mA$ to $350mA$ | | | | 0.4 | mA |
| | | $V_i = -27V$ to $-38V$ | | | | 0.4 | |
| Output Voltage Drift | $\Delta V_o/\Delta T$ | $I_o = 5mA$ | | | −1.0 | | mV/°C |
| Output Noise Voltage | $V_N$ | $f = 10Hz$ to $100KHz$ $T_j = 25°C$ | | | 180 | | μV |
| Ripple Rejection | RR | $f = 120Hz$, $V_i = -28V$ to $-38V$ | | 54 | 58 | | dB |
| Dropout Voltage | $V_D$ | $I_o = 500mA$, $T_j = 25°C$ | | | 1.1 | | V |
| Short Circuit Current | $I_{SC}$ | $V_i = -35V$, $T_j = 25°C$ | | | 140 | | mA |
| Peak Current | $I_{peak}$ | $T_j = 25°C$ | | | 650 | | mA |

* Load and line regulation are specified at constant junction temperature. Changes in $V_o$ due to heating effects must be taken into account separately. Pulse testing with low duty is used.

## TYPICAL APPLICATION

Bypass capacitors are recommended for stable operation of the MC79MXX series of regulators over the input voltage and output current ranges. Output bypass capacitors will improve the transient response of the regulator.

The bypass capacitors, (2μF on the input, 1μF on the output) should be ceramic or solid tantalum which have good high frequency characteristics. If aluminum electrolytics are used, their values should be 10μF or larger. The bypass capacitors should be mounted with the shortest shortest leads, and if possible, directly across the regulator terminals.

**Fig. 1 Fixed Output Regulator**

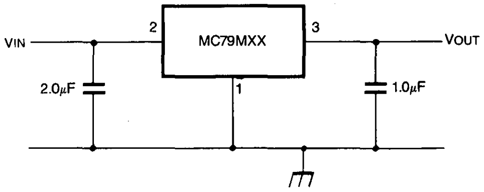
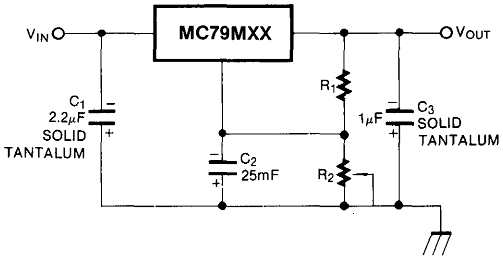


**Fig. 2 Variable Output**



**Note**

1. Required for stability. For value given, capacitor must be solid tantalum. 25μF aluminum electrolytic may be substituted.
2. $C_2$ improves transient response and ripple rejection. Do not increase beyond 50μF.

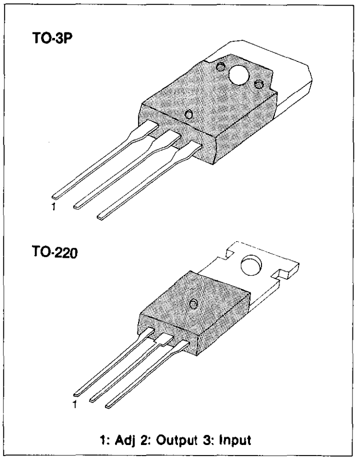
$$V_{OUT} = V_{SET} \left(\frac{R_1 + R_2}{R_1}\right)$$

Select $R_2$ as follows

MC79M05: 300Ω, MC79M12: 750Ω, MC79M15: 11Ω

# 3A ADJUSTABLE POSITIVE VOLTAGE REGULATOR

The KA350 is an adjustable 3-terminal positive voltage regulator capable of supplying in excess of 3.0 A over an output voltage range of 1.2 V to 33 V. This voltage regulator is exceptionally easy to use and requires only two external resistors to set the output voltage. Further, it employs internal current limiting, thermal shutdown and safe area compensation, making them essentially blow-out proof. All overload protection circuitry remains fully functional even if the adjustment terminal is accidentially disconnected.



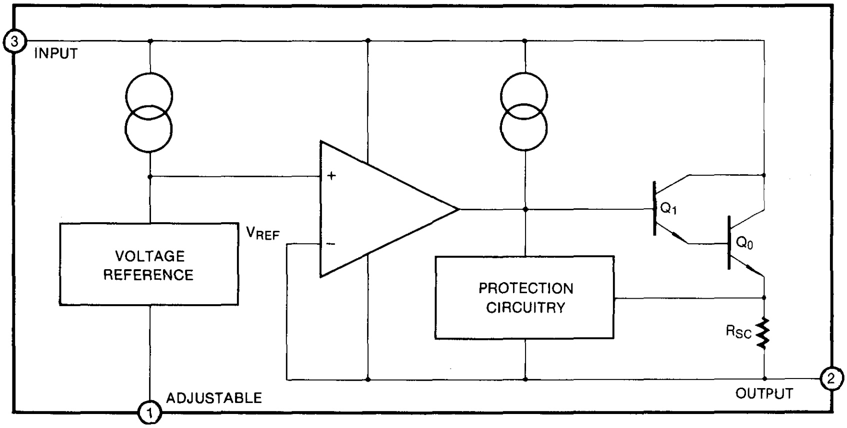
1: Adj 2: Output 3: Input

| Device | Package | Operating Temperature |
|---|---|---|
| KA350H | TO-3P | 0 ~ 125°C |
| KA350T | TO-220 | |

## FEATURES

- **Output adjustable between 1.2V and 33V**
- **Guaranteed 3A output current**
- **Internal thermal overload protection**
- **Load regulation typically 0.1%**
- **Line regulation typically 0.005%/V**
- **Internal short-circuit current limiting constant with temperature.**
- **Output transistor safe-area compensation**
- **Floating operation for high voltage application**
- **Standard 3-lead transistor package**
- **Eliminates stocking many fixed voltages**

## BLOCK DIAGRAM



## ABSOLUTE MAXIMUM RATINGS

| Characteristic | Symbol | Value | Unit |
|---|---|---|---|
| Input-Output Voltage Differential | $V_{IN} - V_{OUT}$ | 35 | $V_{DC}$ |
| Lead Temperature (Soldering, 10 sec) | $T_{lead}$ | 300 | °C |
| Power Dissipation | $P_D$ | Internally limited | |
| Operating Junction Temperature Range | $T_{opr}$ | 0 ~ +125 | °C |
| Storage Temperature Range | $T_{stg}$ | −65 ~ +150 | °C |

## ELECTRICAL CHARACTERISTICS

($V_{IN} - V_{OUT} = 5V$, $I_{OUT} = 1.5A$, $T_j = 0°C$ to 125°C; $P_{max}$, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Line Regulation | $\triangle V_o$ | Ta = 25°C, $3V \leq V_I\text{-}V_o \leq 35V$ (Note 1) | | 0.005 | 0.03 | %/V |
| Load Regulation | $\triangle V_o$ | Ta = 25°C, $10mA \leq I_o \leq 3A$<br>$V_o \leq 5V$ (Note 1)<br>$V_o \geq 5V$ (Note 1) | | <br>5<br>0.1 | <br>25<br>0.5 | <br>mV<br>% |
| Adjustment Pin Current | $I_{adj}$ | | | 50 | 100 | μA |
| Adjustment Pin Current Change | $\triangle I_{adj}$ | $3V \leq V_I - V_o \leq 35V$,<br>$10mA \leq I_L \leq 3A$, $P_D \leq P_{MAX}$ | | 0.2 | 5.0 | μA |
| Thermal Regulation | $REG_{therm}$ | Pulse = 20mS, Ta = 25°C | | 0.002 | | %/W |
| Reference Voltage | $V_{REF}$ | $3V \leq V_I - V_o \leq 35V$, $10mA \leq I_o \leq 3A$, $P \leq 30W$ | 1.2 | 1.25 | 1.30 | V |
| Line Regulation | $\triangle V_o$ | $3.0V \leq V_I - V_o \leq 35V$ | | 0.02 | 0.07 | %/V |
| Load Regulation | $\triangle V_o$ | $10mA \leq I_O \leq 3.0A$<br>$V_o \leq 5.0V$<br>$V_O \geq 5.0V$ | | <br>20<br>0.3 | <br>70<br>1.5 | <br>mV<br>% |
| Temperature Stability | $T_S$ | $T_j = 0°C$ to 125°C | | 1.0 | | % |
| Maximum Output Current | $I_{MAX}$ | $V_I - V_o \leq 10V$, $P_D \leq P_{MAX}$ | 3.0 | 4.5 | | A |
| | | $V_I - V_o = 30V$, $P_D \leq P_{MAX}$, Ta = 25°C | 0.25 | 1.0 | | A |
| Minimum Load Current | $I_{MIN}$ | $V_I - V_o = 35V$ | | 3.5 | 10 | mA |
| RMS Noise, % of $V_{OUT}$ | $V_N$ | $10Hz \leq f \leq 10KHz$, Ta = 25°C | | 0.003 | | % |
| Ripple Rejection | RR | $V_o = 10V$, $f = 120Hz$,<br>$C_{adj} = 0$<br>$C_{adj} = 10\mu F$ | <br><br>66 | <br>65<br>80 | | <br>dB<br>dB |
| Long-Term Stability | S | $T_j = 125°C$ | | 0.3 | 1 | %/1000HR |

Note 1: Regulation is measured at constant junction temperature. Changes in output voltage due to heating effects must be taken into account separately. Pulse testing with low duty cycle is used.

## TYPICAL PERFORMANCE CHARACTERISTICS

Fig. 1 LOAD REGULATION

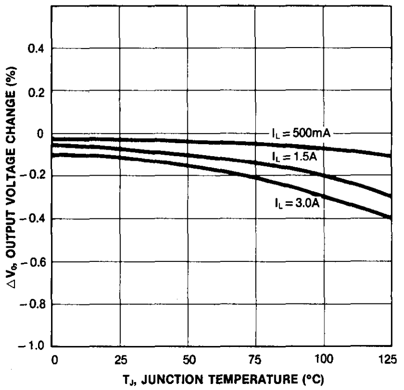


Fig. 2 CURRENT LIMIT

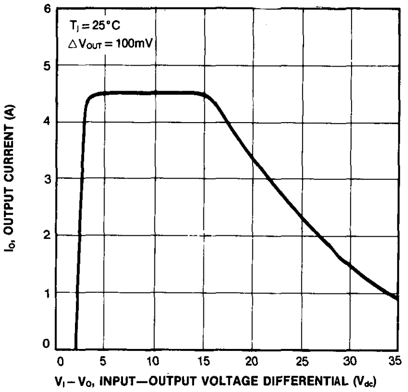


Fig. 3 ADJUSTMENT PIN CURRENT

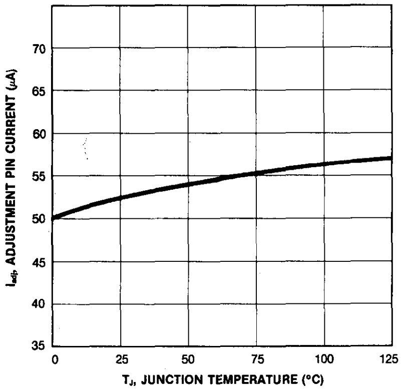


Fig. 4 DROPOUT VOLTAGE

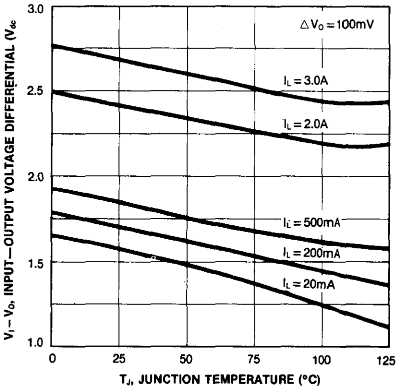


Fig. 5 TEMPERATURE STABILITY

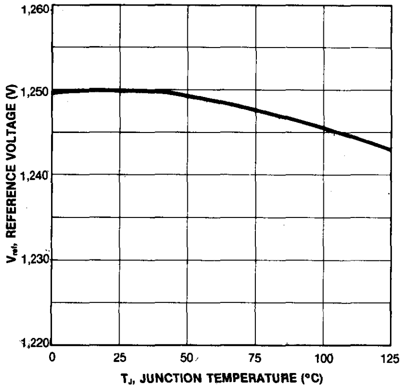
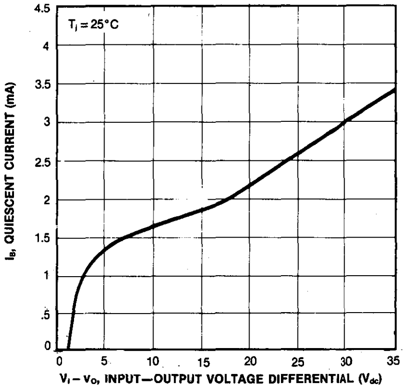


Fig. 6 MINIMUM LOAD CURRENT



## TYPICAL PERFORMANCE CHARACTERISTICS

Fig. 7 RIPPLE REJECTION vs $V_{OUT}$

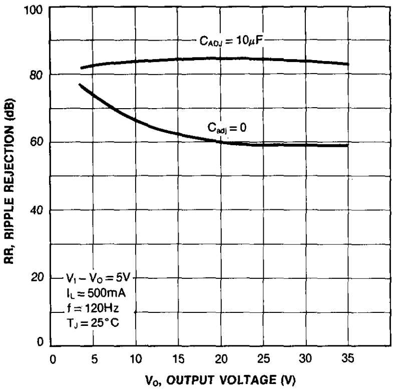


Fig. 8 RIPPLE REJECTION vs $I_{OUT}$

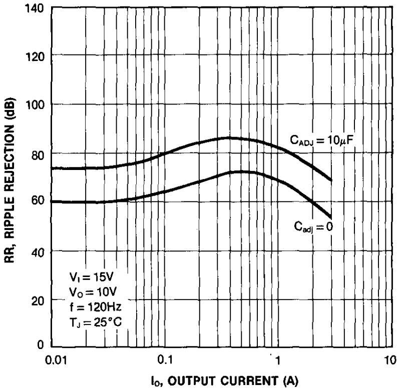


Fig. 9 RIPPLE REJECTION vs FREQUENCY

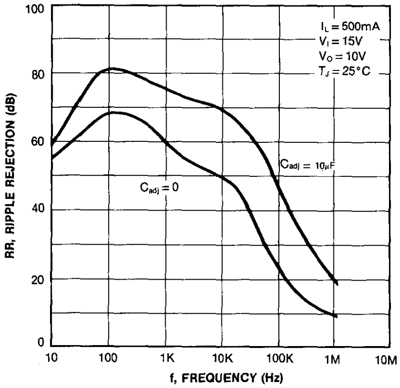


Fig. 10 OUTPUT IMPEDANCE

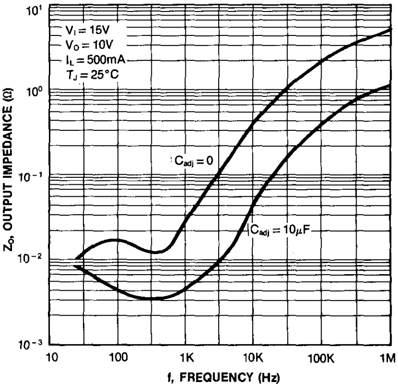


Fig. 11 LINE TRANSIENT RESPONSE

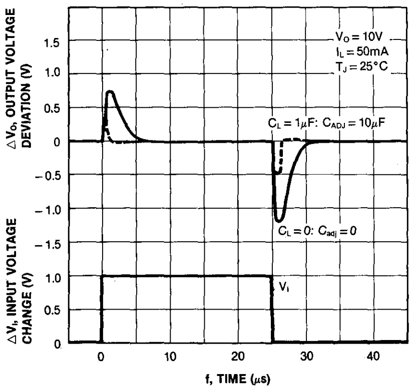
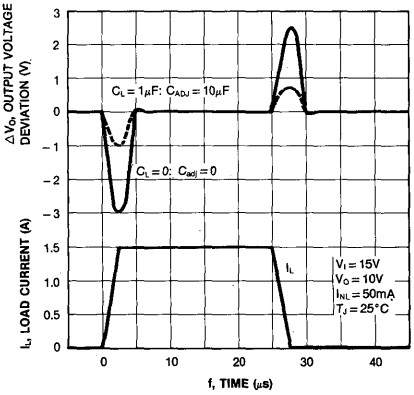


Fig. 12 LOAD TRANSIENT RESPONSE



# APPLICATION INFORMATION

## STANDARD APPLICATION

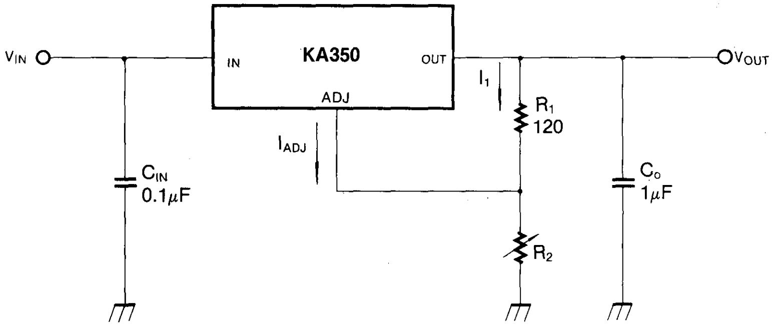


Fig. 13

$C_{in}$: $C_{in}$ is required if the regulator is located an appreciable distance from power supply filter.
$C_o$: Output capacitors in the range of 1 μF to 100 μF of aluminum or tantalum electronic are commonly used to provide improved output impedance and rejection of transients.

In operation, the KA350 develops a nominal 1.25 V reference voltage, $V_{ref}$, between the output and adjustment terminal. The reference voltage is impressed across program resistor $R_1$ and, since the voltage is constant, a constant current $I_1$ then flows through the output set resistor $R_2$, giving an output voltage of

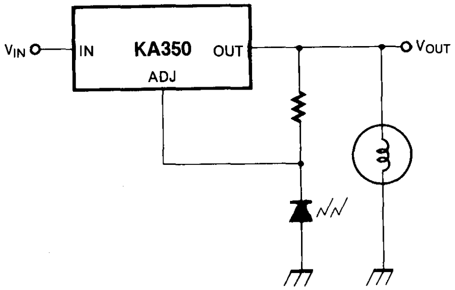
$$V_{out} = 1.25V\ (1 + \frac{R_2}{R_1}) + I_{ADJ}\ R_2$$

Since $I_{ADJ}$ current (less than 100μA) from the adjustment terminal represents an error term, the KA350 was designed to minimize $I_{ADJ}$ and make it very constant with line and load changes. To do this, all quiescent operating current is returned to the output establishing a minimum load current requirement. If there is insufficient load on the output, the output voltage will rise.

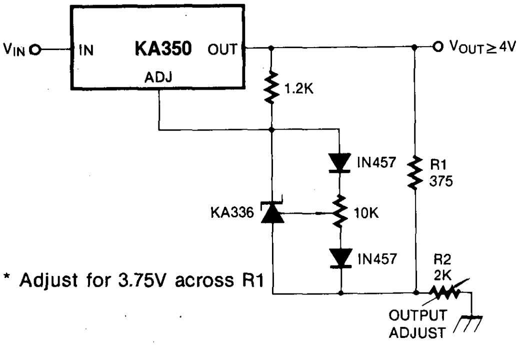
Since the KA350 is a floating regulator, it is only the voltage differential across the circuit which is important to performance, and operation at high voltage with respect to ground is possible.

## TYPICAL APPLICATIONS

### Fig. 14 LIGHT CONTROLLER

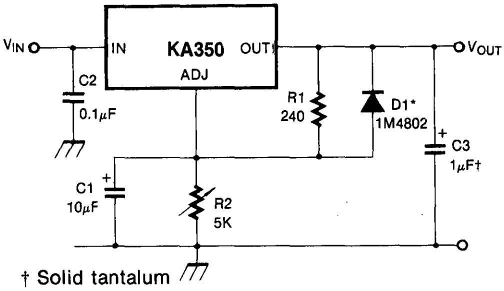


### Fig. 15 PRECISION POWER REGULATOR WITH LOW TEMPERATURE COEFFICIENT



* Adjust for 3.75V across R1

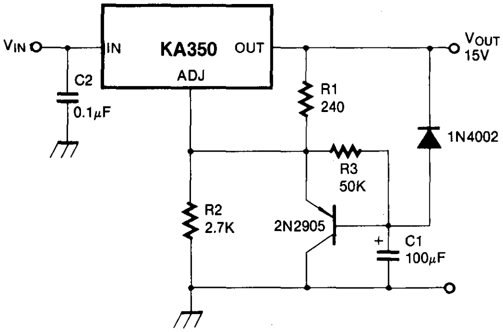
### Fig. 16 ADJUSTABLE REGULATOR WITH IMPROVED RIPPLE REJECTION



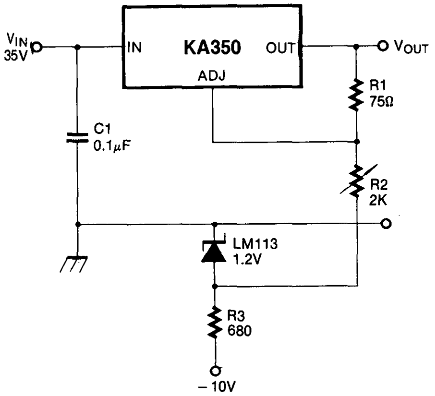
† Solid tantalum

* Discharges C1 if output is shorted to ground

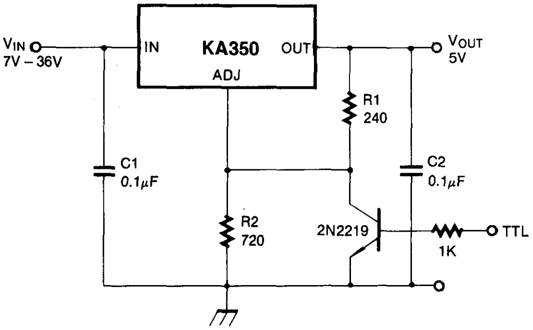
### Fig. 17 SLOW TURN-ON 15V REGULATOR



### Fig. 18 0 TO 30V REGULATOR



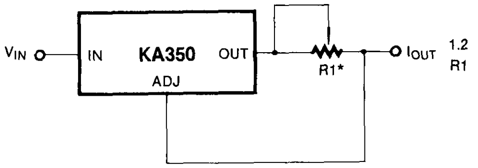
### Fig. 19 5V LOGIC REGULATOR WITH ELECTRONIC SHUTDOWN*



* Min output = 1.2V

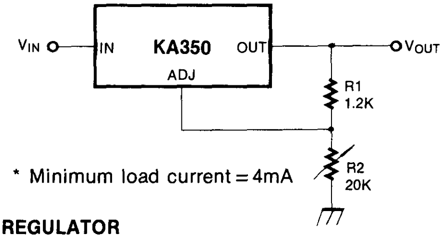
## TYPICAL APPLICATIONS (Continued)

### Fig. 20 PRECISION CURRENT LIMITER



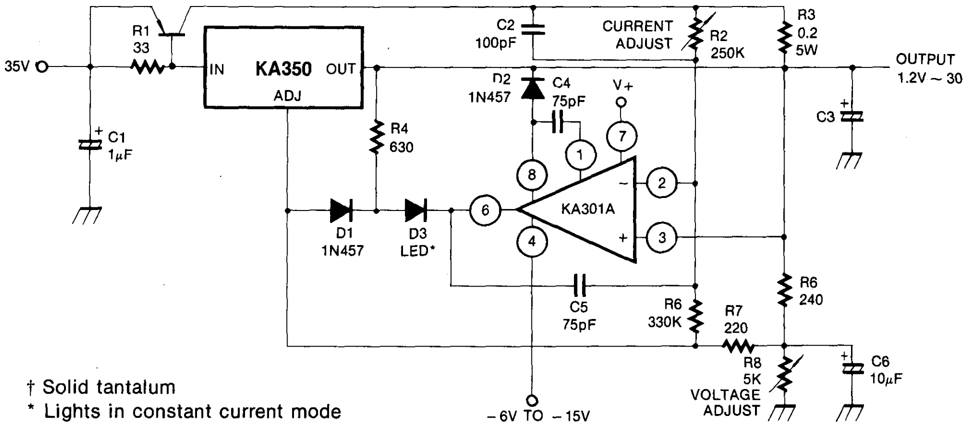
* 0.4≤R1≤120Ω

### Fig. 21 1.2V – 20V REGULATOR WITH MINIMUM PROGRAM CURRENT



* Minimum load current = 4mA

### Fig. 22 5A CONSTANT VOLTAGE/CONSTANT CURRENT REGULATOR



† Solid tantalum

* Lights in constant current mode

### Fig. 23 12V BATTERY CHARGER

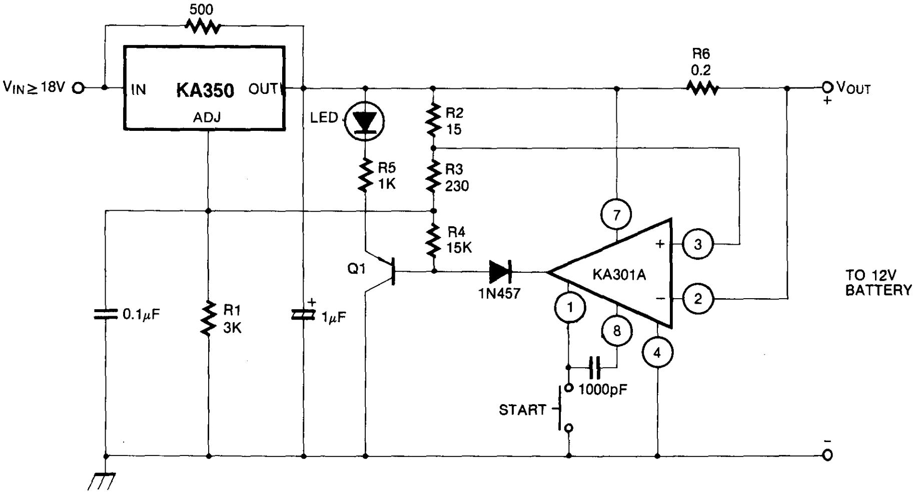


**Fig. 24 TRACKING PREREGULATOR**

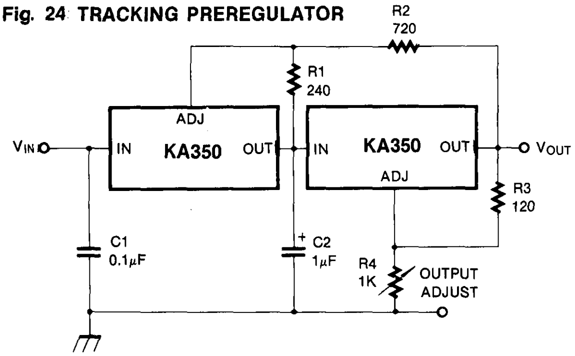


**Fig. 25 3A CURRENT REGULATOR**

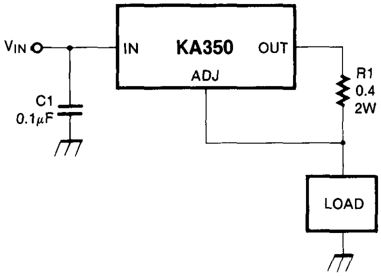
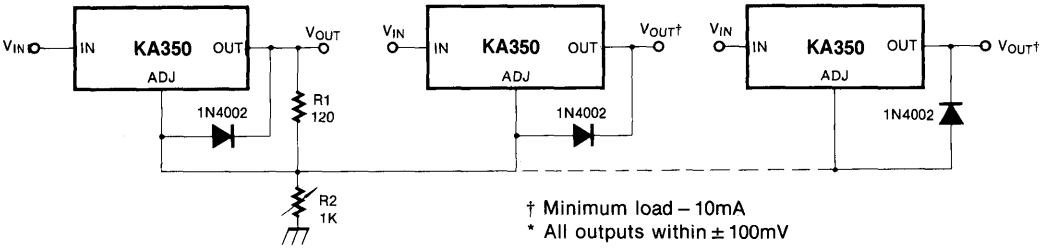


**Fig. 26 ADJUSTING MULTIPLE ON-CARD REGULATORS WITH SINGLE CONTROL***



† Minimum load – 10mA

* All outputs within ± 100mV

**Fig. 27 AC VOLTAGE REGULATOR**

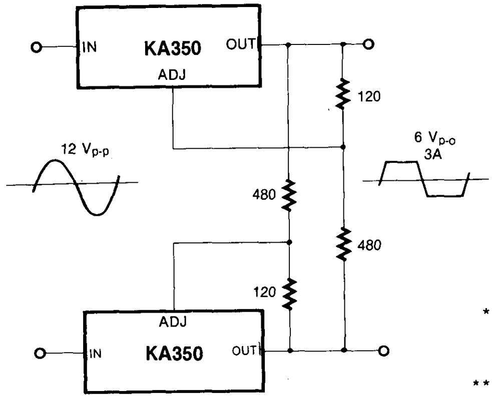
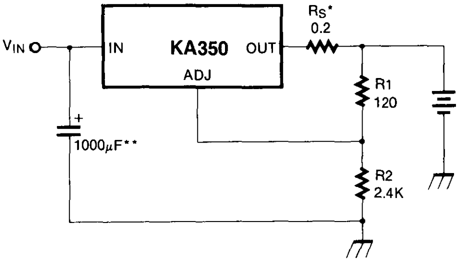


**Fig. 28 SIMPLE 12V BATTERY CHARGER**



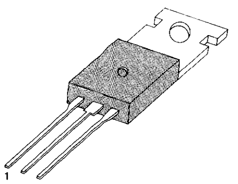
* $R_S$ – sets output impedance of charger $Z_{OUT} = R_S\ (1 + \frac{R_2}{R_1})$ Use of $R_S$ allows low charging rates with fully charged battery.

** 1000μF is recommended to filter out any input transients.

# 3-TERMINAL POSITIVE ADJUSTABLE REGULATOR

The LM317 is a 3-terminal adjustable positive voltage regulator capable of supplying in excess of 1.5A over an output voltage range of 1.2V to 37V. This voltage regulator is exceptionally easy to use and requires only two external resistors to set the output voltage. Further, it employs internal current-limiting, thermal-shutdown and safe area compensation, making it essentially blow-out proof. The LM317 serves a wide variety of applications including local, on-card regulation. This device also makes an especially simple adjustable switching regulator, and a programmable output regulator, or by connecting a fixed resistor between the adjustment and output, the LM317 can be used as a precision current regulator.

TO-220



1: Adj 2: Output 3: Input

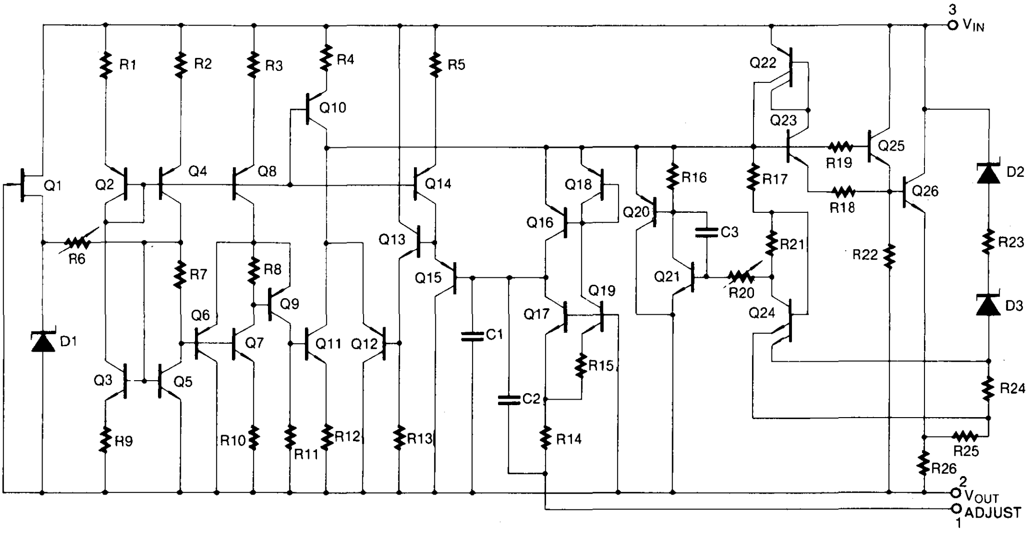
## FEATURE

- **Output current in excess of 1.5A**
- **Output adjustable between 1.2V and 37V**
- **Internal thermal-overload protection**
- **Internal short-circuit current-limiting constant with temperature**
- **Output transistor safe-area compensation**
- **Floating operation for high-voltage applications**
- **Standard 3-pin transistor packages**

## ORDERING INFORMATION

| Device | Package | Operating Temperature |
|---|---|---|
| KA337T | TO-220 | 0 ~ +125°C |

## SCHEMATIC DIAGRAM



## ABSOLUTE MAXIMUM RATINGS

| Characteristic | Symbol | Value | Unit |
|---|---|---|---|
| Input-Output Voltage Differential | $V_{IN} - V_{OUT}$ | 40 | $V_{DC}$ |
| Lead Temperature | $T_{lead}$ | 230 | °C |
| Power Dissipation | $P_D$ | Internally limited | — |
| Operating Temperature Range | $T_{opr}$ | 0 ~ +125 | °C |
| Storage Temperature Range | $T_{stg}$ | −65 ~ +150 | °C |

## ELECTRICAL CHARACTERISTICS

($V_{IN} - V_{OUT} = 5V$, $I_{OUT} = 0.5A$, $0°C \leq T_j \leq 125°C$, $I_{max} = 1.5A$, $P_{max} = 20W$, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Line Regulation | $\triangle V_o$ | Ta = 25°C, $3V \leq V_{IN} - V_{OUT} \leq 40V$ | | 0.01 | 0.04 | %/V |
| | | $3V \leq V_{IN} - V_{OUT} \leq 40V$ | | 0.02 | 0.07 | %/V |
| Load Regulation | $\triangle V_o$ | Ta = 25°C, $10mA \leq I_{OUT} \leq I_{MAX}$<br>$V_{OUT} \leq 5V$<br>$V_{OUT} \geq 5V$ | | <br>5<br>0.1 | <br>25<br>0.5 | <br>mV<br>$\%V_o$ |
| | | $10mA \leq I_{OUT} \leq I_{MAX}$<br>$V_{OUT} \leq 5V$<br>$V_{OUT} \geq 5V$ | | <br>20<br>0.3 | <br>70<br>1.5 | <br>mV<br>$\%V_o$ |
| Adjustable Pin Current | $I_{adj}$ | | | 50 | 100 | μA |
| Adjustable Pin Current Change | $\triangle I_{adj}$ | $2.5V \leq V_{IN} - V_{OUT} \leq 40V$<br>$10mA \leq I_{OUT} \leq I_{MAX}$<br>$P \leq P_{MAX}$ | | 0.2 | 5 | μA |
| Reference Voltage | $V_{REF}$ | $3V \leq V_{IN} - V_{OUT} \leq 40V$<br>$10mA \leq I_{OUT} \leq I_{MAX}$<br>$P_D \leq P_{MAX}$ | 1.20 | 1.25 | 1.30 | V |
| Temperature Stability | $T_S$ | | | 0.7 | | $\%V_o$ |
| Minimum Load Current to Maintain Regulation | $I_{MIN}$ | $V_{IN} - V_{OUT} = 40V$ | | 3.5 | 10 | mA |
| Maximum Output Current | $I_{MAX}$ | $V_{IN} - V_{OUT} \leq 15V$, $P_D \leq P_{MAX}$<br>$V_{IN} - V_{OUT} = 40V$, $P_D \leq P_{MAX}$ | 1.5<br>0.15 | 2.2<br>0.4 | | A |
| RMS Noise, % of $V_{OUT}$ | $e_N$ | Ta = 25°C, $10Hz \leq f \leq 10KHz$ | | 0.003 | | $\%V_o$ |
| Ripple Rejection | RR | $V_{OUT} = 10V$, f = 120Hz<br>without $C_{ADJ}$<br>$C_{ADJ} = 10\mu F$ | <br><br>66 | <br>65<br>80 | | dB |
| Long-Term Stability, $T_j = T_{high}$ | S | Ta = 25°C for end point measurements, 1000HR | | 0.3 | 1 | % |
| Thermal Resistance Junction to Case | $R_{\theta JC}$ | | | 5 | | °C/W |

* Load and line regulation are specified at constant junction temperature. Change in $V_o$ due to heating effects must be taken into account separately. Pulse testing with low duty is used.

## TYPICAL PERFORMANCE CHARACTERISTICS

Fig. 1 LOAD REGULATION

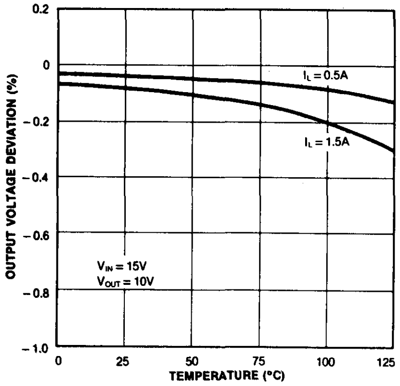


Fig. 2 ADJUSTMENT CURRENT

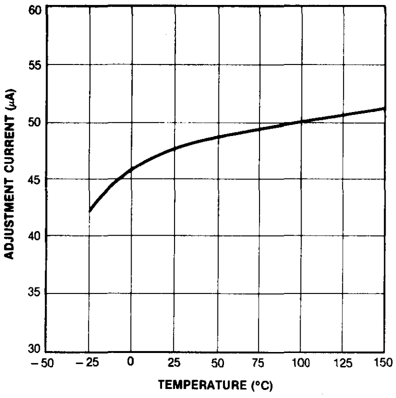


Fig. 3 DROPOUT VOLTAGE

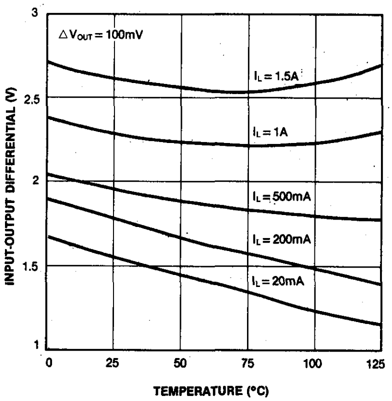


Fig. 4 TEMPERATURE STABILITY

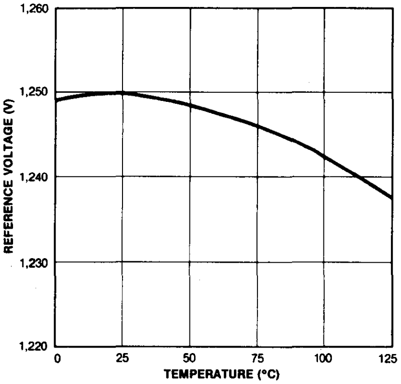


Fig. 5 RIPPLE REJECTION

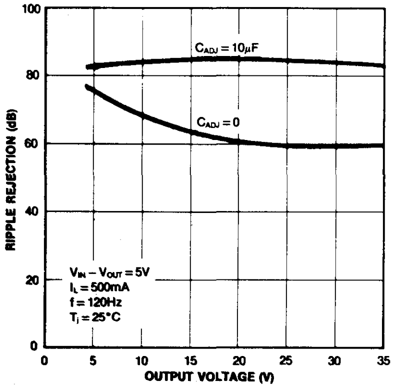


Fig. 6 RIPPLE REJECTION

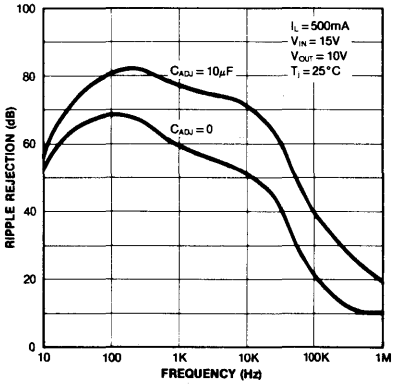


**Fig. 7 RIPPLE REJECTION**

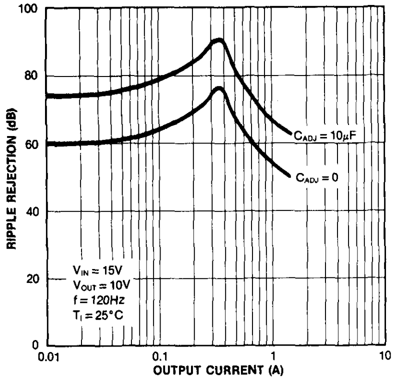


**Fig. 8 OUTPUT IMPEDANCE**

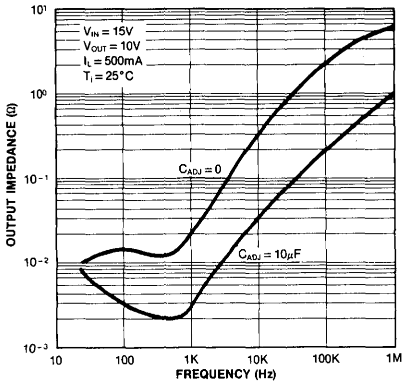


**Fig. 9 LINE TRANSIENT RESPONSE**

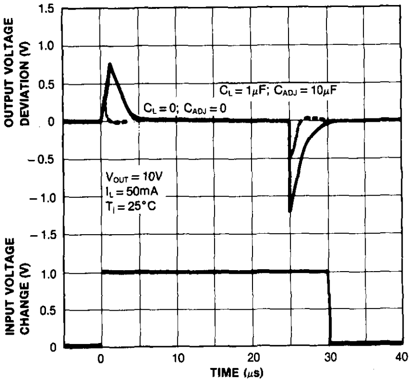


**Fig. 10 LOAD TRANSIENT RESPONSE**

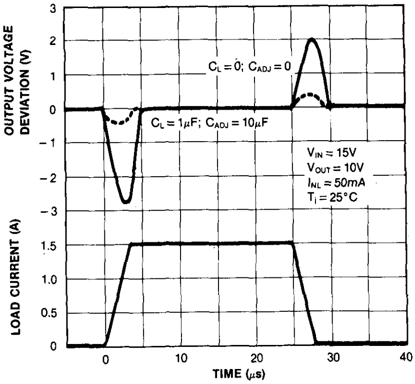
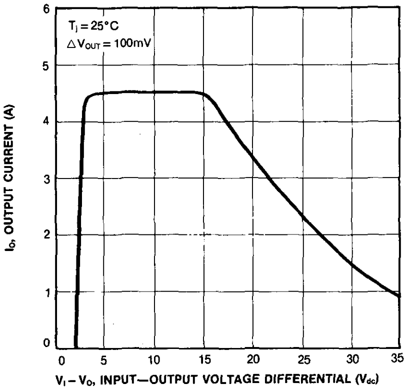


**Fig. 11 MAXIMUM OUTPUT CURRENT**



## TYPICAL APPLICATIONS

**Fig. 12 AC Voltage Regulator**

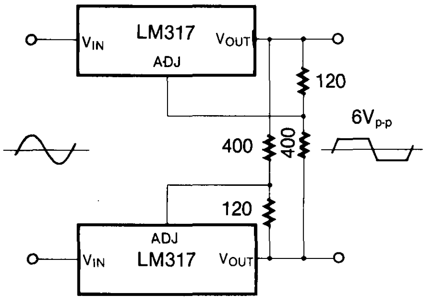
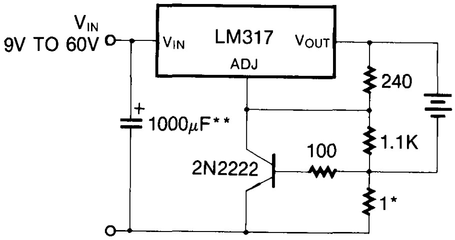


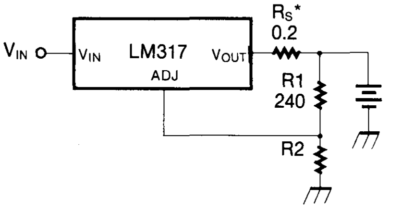
**Fig. 13 Current Limited 6V Charger**



* Sets peak current (0.6A for 1Ω)

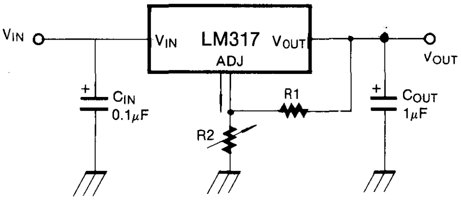
** The 1000μF is recommended to filter out input transients

**Fig. 14 12V Battery Charger**



* $R_S$—sets output impedance of charger $Z_{OUT} = R_S\ (1 + \frac{R2}{R1})$ Use of $R_S$ allows low charging rates with fully charged battery.

**Fig. 15 Programmable Regulator**

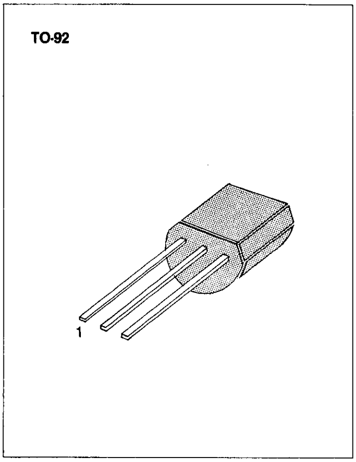


$$V_{OUT} = 1.25V\ (1 + \frac{R_2}{R_1}) + I_{adj}\ R_2$$

$C_{IN}$ is required when regulator is located an appreciable distance from power supply filter. $C_{OUT}$ is not needed for stability, however, it does improve transient response.
Since $I_{adj}$ is controlled to less than 100μA, the error associated with this term is negligible in most applications.

# 3-TERMINAL POSITIVE ADJUSTABLE REGULATOR

The KA317L is a 3-terminal adjustable positive voltage regulator capable of supplying in excess of 100mA over an output voltage range of 1.2V to 37V. This voltage regulator is exceptionally easy to use and requires only two external resistors to set the output voltage. Further, it employs internal current-limiting, thermal-shutdown and safe area compensation, making it essentially simple adjustable switching regulator, a programmable output regulator, or by connecting a fixed resistor between the adjustment and output, the KA317L can be used as a precision current regulator.



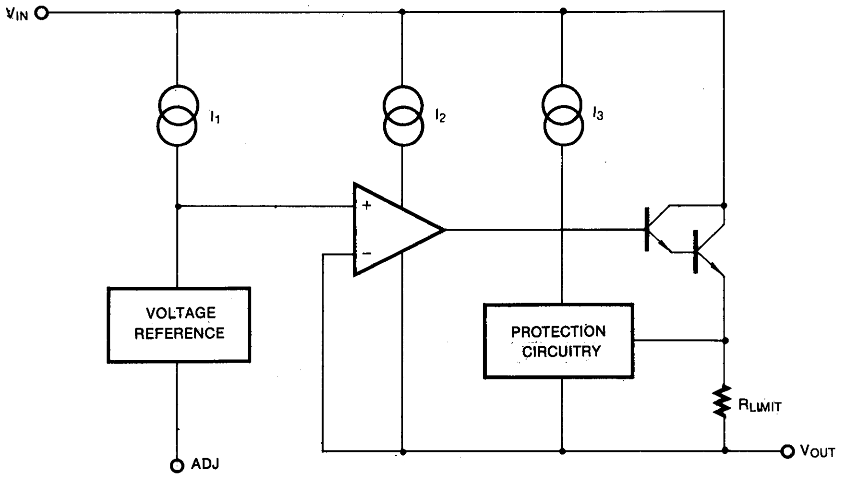
## FEATURES

- Output current in excess of 100mA
- Output adjustable between 1.2V and 37V
- Internal thermal-overload protection
- Internal short-circuit current-limiting
- Output transistor safe-area compensation
- Floating operation for high-voltage applications

## ORDERING INFORMATION

| Device | Package | Operating Temperature |
|---|---|---|
| KA317LZ | TO-92 | 0~125°C |

## BLOCK DIAGRAM



## ABSOLUTE MAXIMUM RATINGS

| Characteristic | Symbol | Value | Unit |
|---|---|---|---|
| Input-Output Voltage Differential | $V_{IN}-V_{OUT}$ | 40 | V |
| Power Dissipation | $P_D$ | Internally Limited | |
| Operating Temperature | $T_{opr}$ | 0 ~ +125 | °C |
| Storage Temperature | $T_{stg}$ | −65 ~ +150 | °C |

## ELECTRICAL CHARACTERISTICS

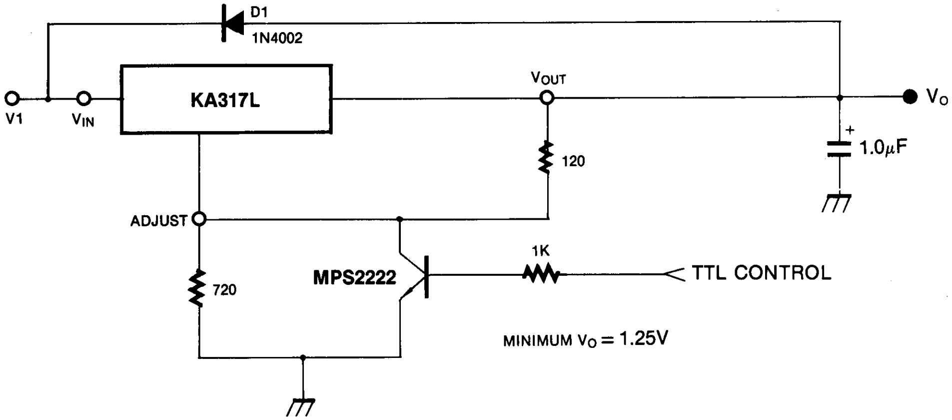
**($V_{IN}-V_{OUT}=5V$, $I_{OUT}=40mA$, $0°C<T_J<125°C$** $P_{DMAX}=625mW$, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| *Line Regulation | $\triangle V_O$ | $T_a=25°C$<br>$3V\leq V_{IN}-V_{OUT}\leq 40V$ | | 0.01 | 0.04 | %/V |
| | | $3V\leq V_{IN}-V_{OUT}\leq 40V$ | | 0.02 | 0.07 | |
| *Load Regulation | $\triangle V_O$ | $T_a=25°C$<br>$10mA\leq I_{OUT}\leq 100mA$<br>$V_{OUT}\leq 5V$<br>$V_{OUT}\geq 5V$ | | 5<br>0.1 | 25<br>0.5 | mV<br>$\%V_O$ |
| | | $10mA\leq I_{OUT}\leq 100mA$<br>$V_{OUT}\leq 5V$<br>$V_{OUT}\geq 5V$ | | 20<br>0.3 | 70<br>1.5 | mV<br>$\%V_O$ |
| Adjustment Pin Current | $I_{Adj}$ | | | 50 | 100 | μA |
| Adjustment Pin Current Change | $\triangle I_{Adj}$ | $3V\leq V_{IN}-V_{OUT}\leq 40V$<br>$10mA\leq I_{OUT}\leq 100mA$<br>$P_D<P_{DMAX}$ | | 0.2 | 5 | μA |
| Reference Voltage | $V_{REF}$ | $3V<V_{IN}-V_{OUT}<40V$<br>$10mA\leq I_{OUT}\leq 100mA$<br>$P_D\leq P_{DMAX}$ | 1.20 | 1.25 | 1.30 | V |
| Temperature Stability | $T_S$ | | | 0.7 | | $\%V_O$ |
| Minimum Load Current to Maintain Regulation | $I_{MIN}$ | $V_{IN}-V_{OUT}=40V$ | | 3.5 | 10 | mA |
| Maximum Output Current | $I_{MAX}$ | $V_{IN}-V_{OUT}=5V$<br>$P_D<P_{DMAX}$ | 100 | 200 | | mA |
| | | $V_{IN}-V_{OUT}=40V$<br>$P_D<P_{DMAX}$, $T_a=25°C$ | (25i | (50 | | |
| RMS Noise, % of $V_{OUT}$ | $e_N$ | $T_a=25°C$<br>$10Hz<f<10KHz$ | | 0.003 | | $\%V_O$ |
| Ripple Rejection | RR | $V_{OUT}=10V$, $f=120Hz$<br>without $C_{Adj}$<br>$C_{Adj}=10\mu F$ | 66 | 65<br>80 | | dB |
| Long-Term Stability | S | $T_j=125°C$, 1000 Hours | | 0.3 | 1 | %/1000Hrs |

* Load and Line regulation are specified at constant junction temperature. Change in $V_O$ due to heating effects must be taken into account separately. Pulse testing with low duty cycle is used.

## TYPICAL APPLICATIONS

**Fig. 1 5V Electronic Shutdown Regulator**



D1 protects the device during an input short circuit.

**Fig. 2 Slow Turn-On Regulator**

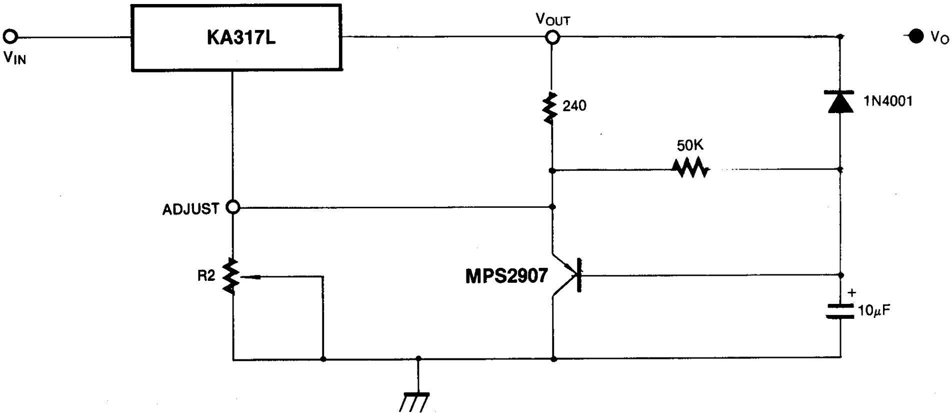
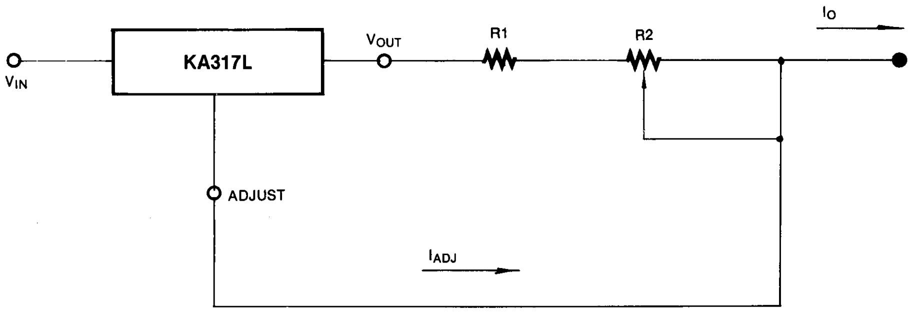


**Fig. 3 Current Regulator**



$$I_{OMAX} = \left(\frac{V_{REF}}{R1}\right) + I_{ADJ} \cong \frac{1.25V}{R1}$$

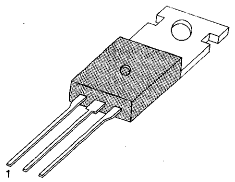
$$I_{OMIN} = \left(\frac{V_{REF}}{R1 + R2}\right) + I_{ADJ} \cong \frac{1.25V}{R1 + R2}$$

$$5mA < I_{OUT} < 100mA$$

## 3-TERMINAL POSITIVE ADJUSTABLE REGULATOR

The KA317M is a 3-terminal adjustable positive voltage regulator capable of supplying in excess of 500mA over an output voltage range of 1.2V to 37V. This voltage regulator is exceptionally easy to use and requires only two external resistors to set the output voltage. **Further, it employs internal current-limiting, thermal-shutdown and safe area compensation, making it essentially simple adjustable switching regulator, a programmable output regulator, or by connecting a fixed resistor between the adjustment and output, the KA317M can be used as a precision current regulator.**

TO-220



1: Adj 2: Output 3: Input

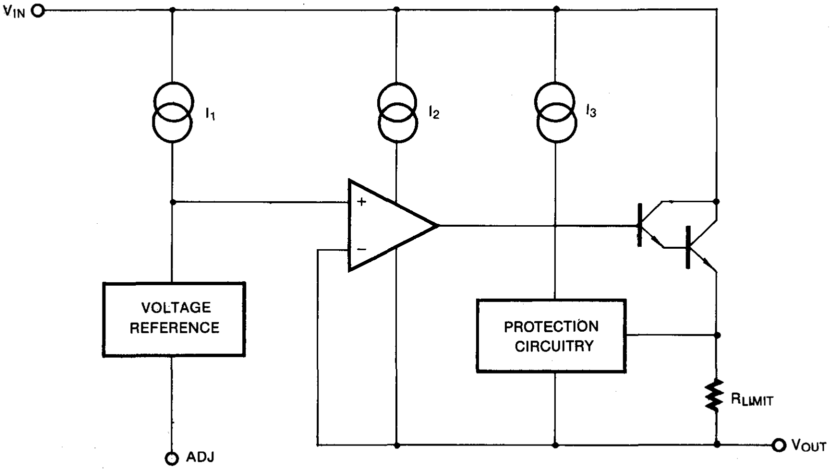
## FEATURES

- Output current in excess of 500mA
- Output adjustable between 1.2V and 37V
- Internal thermal-overload protection
- Internal short-circuit current-limiting
- Output transistor safe-area compensation
- Floating operation for high-voltage applications

## ORDERING INFORMATION

| Device | Package | Operating Temperature |
|---|---|---|
| KA317MT | TO-220 | 0 ~ 125°C |

## BLOCK DIAGRAM



## ABSOLUTE MAXIMUM RATINGS

| Characteristic | Symbol | Value | Unit |
|---|---|---|---|
| Input-Output Voltage Differential | $V_{IN}-V_{OUT}$ | 40 | V |
| Power Dissipation | $P_D$ | Internally Limited | |
| Operating Temperature | $T_{opr}$ | 0~+125 | °C |
| Storage Temperature | $T_{stg}$ | −65~+150 | °C |

## ELECTRICAL CHARACTERISTICS

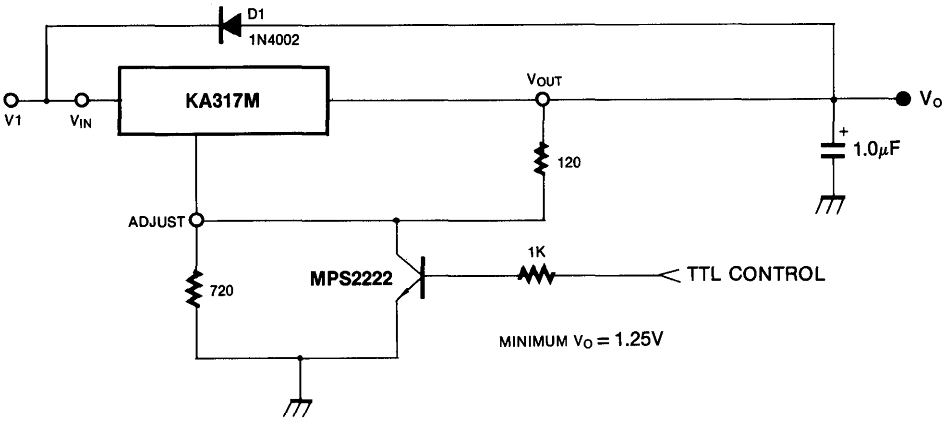
($V_{IN}-V_{OUT}=5V$, $I_{OUT}=0.1A$, $0°C<T_j<125°C$ $P_{DMAX}=7.5W$, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| *Line Regulation | $\triangle V_O$ | $T_a=25°C$<br>$3V\leq V_{IN}-V_{OUT}\leq 40V$ | | 0.01 | 0.04 | %/V |
| | | $3V\leq V_{IN}-V_{OUT}\leq 40V$ | | 0.02 | 0.07 | |
| *Load Regulation | $\triangle V_O$ | $T_a=25°C$<br>$10mA\leq I_{OUT}\leq 0.5A$<br>$V_{OUT}\leq 5V$<br>$V_{OUT}\geq 5V$ | | 5<br>0.1 | 25<br>0.5 | mV<br>%$V_O$ |
| | | $10mA\leq I_{OUT}\leq 0.5A$<br>$V_{OUT}\leq 5V$<br>$V_{OUT}\geq 5V$ | | 20<br>0.3 | 70<br>1.5 | mV<br>%$V_O$ |
| Adjustment Pin Current | $I_{Adj}$ | | | 50 | 100 | μA |
| Adjustment Pin Current Change | $\triangle I_{Adj}$ | $3V\leq V_{IN}-V_{OUT}\leq 40V$<br>$10mA\leq I_{OUT}\leq 0.5A$<br>$P_D<P_{DMAX}$ | | 0.2 | 5 | μA |
| Reference Voltage | $V_{REF}$ | $3V<V_{IN}-V_{OUT}<40V$<br>$10mA\leq I_{OUT}\leq 0.5A$<br>$P_D\leq P_{DMAX}$ | 1.20 | 1.25 | 1.30 | V |
| Temperature Stability | $T_S$ | | | 0.7 | | %$V_O$ |
| Minimum Load Current to Maintain Regulation | $I_{MIN}$ | $V_{IN}-V_{OUT}=40V$ | | 3.5 | 10 | mA |
| Maximum Output Current | $I_{MAX}$ | $V_{IN}-V_{OUT}\leq 15V$<br>$P_D<P_{DMAX}$ | 0.5 | 0.9 | | A |
| | | $V_{IN}-V_{OUT}=5V$<br>$P_D<P_{DMAX}$, $T_a=25°C$ | 0.15 | 0.25 | | |
| RMS Noise, % of $V_{OUT}$ | $e_N$ | $T_a=25°C$<br>$10Hz<f<10KHz$ | | 0.003 | | %$V_O$ |
| Ripple Rejection | RR | $V_{OUT}=10V$, $f=120Hz$<br>without $C_{Adj}$<br>$C_{Adj}=10\mu F$ | 66 | 65<br>80 | | dB |
| Long-Term Stability | S | $T_j=125°C$, 1000 Hours | | 0.3 | 1 | %/1000Hrs |

* Load and Line regulation are specified at constant junction temperature. Change in $V_O$ due to heating effects must be taken into account separately. Pulse testing with low duty cycle is used.

## TYPICAL APPLICATIONS

**Fig. 1 5V Electronic Shutdown Regulator**



D1 protects the device during an input short circuit.

**Fig. 2 Slow Turn-On Regulator**

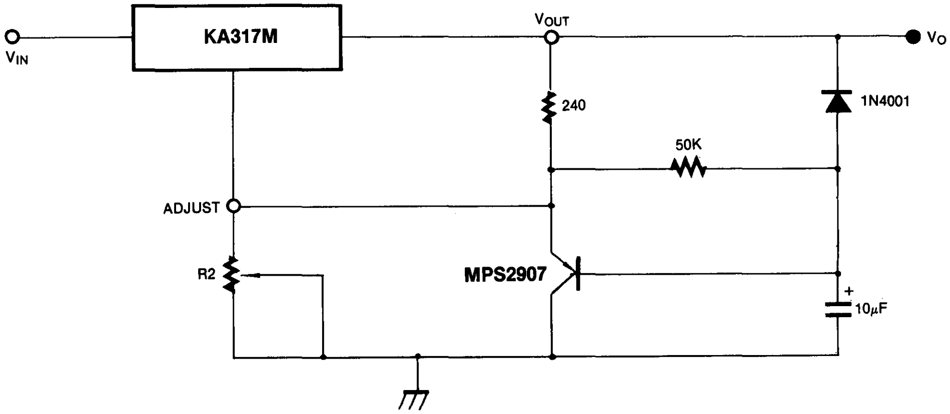
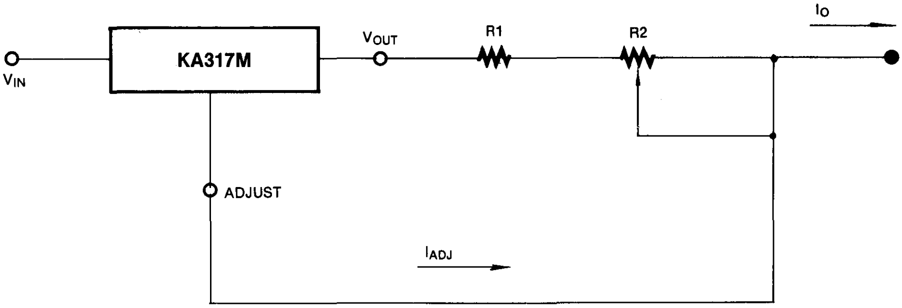


**Fig. 3 Current Regulator**



$$I_{OMAX} = (\frac{V_{REF}}{R1}) + I_{ADJ} \cong \frac{1.25V}{R1}$$

$$I_{OMIN} = (\frac{V_{REF}}{R1 + R2}) + I_{ADJ} \cong \frac{1.25V}{R1 + R2}$$

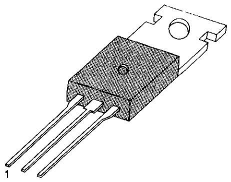
$$5mA < I_{OUT} < 500mA$$

## 3-TERMINAL NEGATIVE ADJUSTABLE REGULATOR

The KA337 is a 3-terminal negative adjustable regulator. It supply in excess of 1.5A over an output voltage range of −1.2V to −37V.

This regulator requires only two external resistors to set an output voltage and 1 capacitor to compensate frequency.

TO-220



1: Adj 2: Input 3: Output

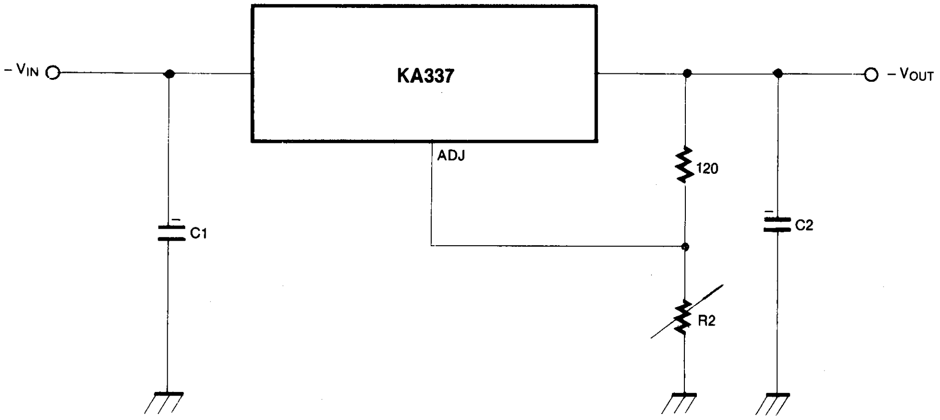
## FEATURES

- **Output current in excess of −1.5A**
- **Output voltage adjustable between −1.2V & −37V**
- **Internal thermal-overload protection**
- **Internal short-circuit current-limiting constant with temperature**
- **Output transistor safe-area compensation**
- **Floating operation for high-voltage applications**
- **Standard 3-pin, TO-220 package**

## ORDERING INFORMATION

| Device | Package | Operating Temperature |
|---|---|---|
| KA337T | TO-220 | 0 ~ +125°C |

## APPLICATION CIRCUIT



* $-V_{OUT} = -1.25V\ (1 + R2/120\Omega) + (-I_{adj} * R2)$

* Output current depends on maximum power dissipation

## ABSOLUTE MAXIMUM RATINGS

| Characteristic | Symbol | Value | Unit |
|---|---|---|---|
| Input-Output Voltage Differential | $V_{IN}$-$V_{OUT}$ | 40 | V |
| Power Dissipation | $P_D$ | Internally limited | |
| Operating Temperature Range | $T_{opr}$ | 0 ~ +125 | °C |
| Storage Temperature Range | $T_{stg}$ | −65 ~ +150 | °C |

## ELECTRICAL CHARACTERISTICS

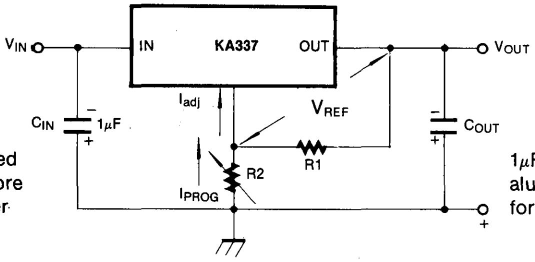
($V_{in} - V_{out} = 5V$, $I_{out} = 0.5A$, $0°C \leq T_j \leq 125°C$, $P_{max} = 20W$, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Line Regulation | $V_O$ | Ta = 25°C<br>$-40V \leq V_{OUT} - V_{IN} \leq -3V$ | | 0.01 | 0.04 | %/V |
| | | $-40V < V_{OUT} - V_{IN} \leq -3V$ | | 0.02 | 0.07 | |
| Load Regulation | $V_O$ | Ta = 25°C<br>$10mA \leq I_{OUT} \leq 1.5A$ | | 15 | 50 | mV |
| | | $10mA \leq I_{OUT} \leq 1.5A$ | | 15 | 150 | |
| Adjustable Pin Current | $I_{adj}$ | | | 50 | 100 | μA |
| Adjustable Pin Current Change | | Ta = 25°C<br>$10mA \leq I_{OUT} \leq 1.5A$<br>$-40V \leq V_{OUT} - V_{IN} \leq -3V$ | | 2 | 5 | μA |
| Reference Voltage | $V_{ref}$ | Ta = 25°C | −1.213 | −1.250 | −1.287 | V |
| | | $-40V \leq V_{OUT} - V_{IN} \leq -3V$<br>$10mA \leq I_{OUT} \leq 1.5A$ | −1.200 | −1.250 | −1.300 | |
| Temperature Stability | $T_S$ | | | 0.6 | | % |
| Minimum Load Current to Maintain Rejection | $I_l$ (min) | $-40V \leq V_{OUT} - V_{IN} \leq -3V$ | | 2.5 | 10 | mA |
| | | $-10V \leq V_{OUT} - V_{IN} \leq -3V$ | | 1.5 | 6 | |
| Output Noise | en | Ta = 25°C<br>$10Hz \leq f \leq 10KHz$ | | $30 \times V_{OUT}$ | | $V/10^6$ |
| Ripple Rejection | RR | $V_{OUT} = -10V$, f = 120Hz | | 60 | | dB |
| | | $C_{adj} = 10\mu F$ | 66 | 77 | | |
| Long Term Stability | | $T_j = 125°C$, 1000 hours | | 0.3 | 1 | % |
| Thermal Resistance Junction to Case | $R_{\theta JC}$ | | | 4 | | °C/W |

* Load and line regulation are specified at constant junction temperature. Change in $V_o$ due to heating effects must be taken into account separately. Pulse testing with low duty is used.

## TYPICAL APPLICATION

### ADJUSTABLE VOLTAGE REGULATOR



1μF solid tantalum required only if the regulator is more than 10cm from the power supply filter capacitor

1μF solid tantalum or 10μF aluminum electrolytic required for stability

R1 is 120Ω Typical

$R2 = R1 (\frac{V_{OUT}}{V_{REF}} - 1)$ where $V_{REF} = -1.25V$ Typical

The KA337 is a 3-terminal floating regulator. In operation, the KA337 develops and maintains a nominal −1.25 volt reference $V_{REF}$ between its output and adjustment terminals. This reference voltage is converted to a programming current ($I_{PROG}$) by R1 (see FIG. 2), and this constant current flows through R2 from ground. The regulated output voltage is given by:

$$V_{OUT} = V_{REF} (1 + \frac{R2}{R1}) + I_{adj} R2$$

Since the current into the adjustment terminal ($I_{adj}$) represents an error term in the equation, the KA337 was designed to control $I_{adj}$ to less than 100μA and keep it constant. To do this, all quiescent operating current is returned to the output terminal. This imposes the requirement for a minimum load current. If the load current is less than this minimum, the output voltage will increase.

Since the KA337 is a floating regulator, it is only the voltage differential across the circuit that is important to performance, and operation at high voltages with respect to ground is possible.

### LOAD REGULATION

The KA337 is capable of providing extremely good load regulation, but a few precautions are needed to obtain maximum performance. For best performance the programming resistor (R1) should be connected as close to the regulator as possible to minimize line drops which effectively appear in series with the reference, thereby degrading regulation. The ground end of R2 can be returned near the load ground to provide remote ground sensing and improve load regulation.

## TYPICAL PERFORMANCE CHARACTERISTICS

**Fig. 3 ADJUSTMENT CURRENT**

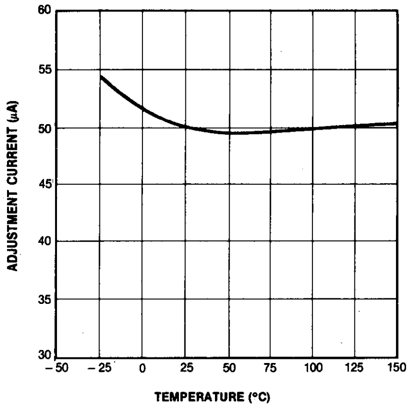


**Fig. 4 CURRENT LIMIT**

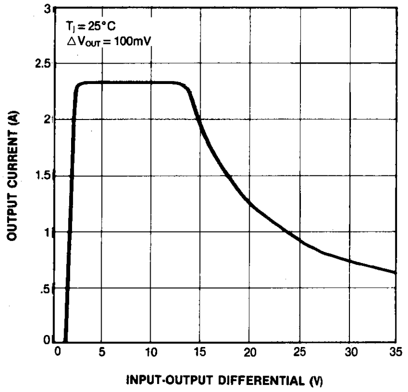


**Fig. 5 LOAD REGULATION**

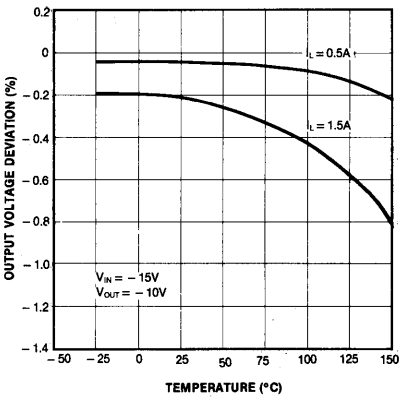
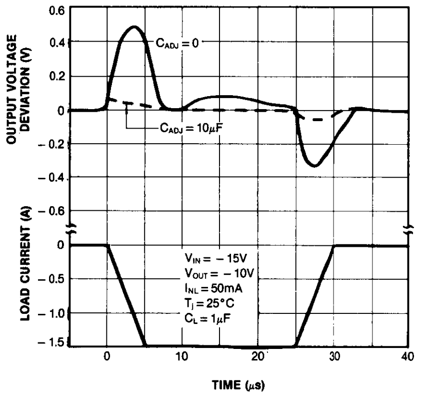


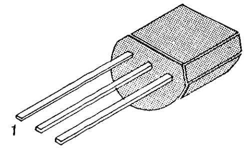
**Fig. 6 LOAD TRANSIENT RESPONSE**



# 3-TERMINAL NEGATIVE ADJUSTABLE REGULATOR

The KA337L is a 3-terminal negative adjustable regulator. It supply in excess of −0.1A over an output voltage range of −1.2V to −37V. This regulator requires only two external resistor to set the output voltage. Included on the chip are current limiting, thermal overload protection and safe area compensation.

**TO-92**



**1: Adj 2: Output 3: Input**

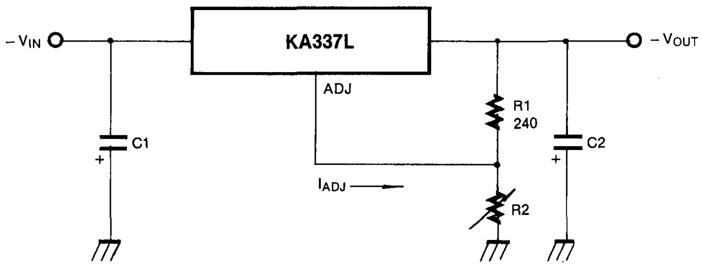
## FEATURES

- **Output current in excess of 0.1A**
- **Output voltage adjustable between −1.2V and −37V**
- **Internal thermal-overload protection**
- **Internal short-circuit current limiting**
- **Output transistor safe-area compensation**
- **Floating operation for high-voltage applications**
- **Standard 3-pin TO-92 package**

## ORDERING INFORMATION

| Device | Package | Operating Temperature |
|---|---|---|
| KA337LZ | TO-92 | 0~ +125°C |

## APPLICATION CIRCUIT



* $-V_{OUT} = -1.25V \left(1 + \frac{R2}{240}\right) + (-I_{adj} \times R_2)$

*C1: 1μF solid tantalum or 10μF aluminum electrolytic (for optimum stability)

*C2: 1μF solid tantalum (for transient response)

## ABSOLUTE MAXIMUM RATINGS

| Characteristic | Symbol | Value | Unit |
|---|---|---|---|
| Input-Output Voltage Differential | $V_{IN}-V_{OUT}$ | 40 | V |
| Power Dissipation | $P_D$ | Internally Limited | |
| Operating Temperature | $T_{opr}$ | 0 ~ + 125 | °C |
| Storage Temperature | $T_{stg}$ | − 65 ~ + 150 | °C |

## ELECTRICAL CHARACTERISTICS

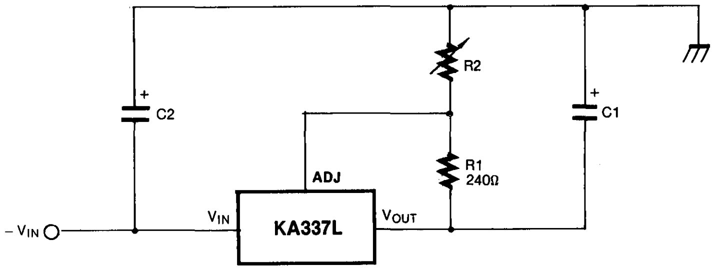
($V_{IN}-V_{out}=5V$, $I_{OUT}=40mA$, $0°C \leq T_j \leq 125°C$, $P_{DMAX}=625mW$, $I_{MAX}=100mA$, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| *Line Regulation | $\triangle V_O$ | $T_a=25°C$<br>$3V \leq \lvert V_{IN}-V_{OUT}\rvert \leq 40V$ | | 0.01 | 0.04 | %/V |
| | | $3V \leq \lvert V_{IN}-V_{OUT}\rvert \leq 40V$ | | 0.02 | 0.07 | |
| *Load Regulation | $\triangle V_O$ | $T_a=25°C$<br>$5mA \leq I_O \leq 0.1A$ | | 0.1 | 0.5 | % |
| | | $5mA \leq I_O \leq 0.1A$ | | 0.3 | 1.5 | |
| Adjustment Pin Current | $I_{Adj}$ | | | 50 | 100 | μA |
| Adjustment Pin Current Change | $\triangle I_{Adj}$ | $3V \leq \lvert V_{IN}-V_{OUT}\rvert \leq 40V$<br>$5mA \leq I_O \leq 0.1A$ | | 0.2 | 5 | μA |
| Reference Voltage | $V_{REF}$ | $3V \leq \lvert V_{IN}-V_{OUT}\rvert \leq 40V$<br>$10mA \leq I_{OUT} \leq 0.1A$, $P_D \leq 625mW$ | 1.2 | 1.25 | 1.3 | V |
| Temperature Stability | $T_S$ | | | 0.65 | 1.5 | % |
| Minimum Load Current to Maintain Regulation | $I_L(min)$ | $3V \leq \lvert V_{IN}-V_{OUT}\rvert \leq 15V$<br>$\lvert V_{IN}-V_{OUT}\rvert \leq 40V$ | | 2.2<br>3.5 | 3.5<br>5 | mA |
| Current Limit | $I_{MAX}$ | $3V \leq \lvert V_{IN}-V_{OUT}\rvert \leq 13V$<br>$\lvert V_{IN}-V_{OUT}\rvert = 40V$ | 100<br>25 | 200<br>50 | 320<br>120 | mA |
| Output Noise | $V_N$ | $T_a=25°C$, $10Hz \leq f \leq 10KHz$ | | 0.003 | 0.01 | % |
| Ripple Rejection Ratio | RR | $V_{OUT}=-10V$, $f=120Hz$ | | 65 | | dB |
| | | $C_{Adj}=10\mu F$ | 66 | 80 | | |
| Long Term Stability | | $T_j=125°C$, 1000 hours | | 0.3 | 1 | % |

* Regulation is measured at constant junction temperature, using pulse testing with a low duty cycle.

## TYPICAL APPLICATIONS

### 1.2V – 25V Adjustable Regulator

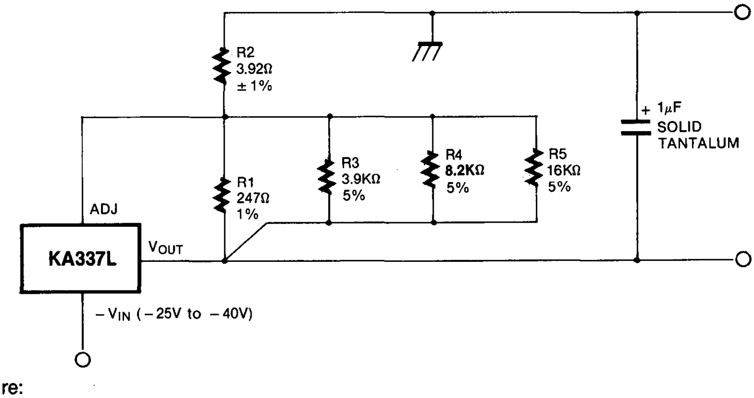


Full output current not available at high input-output voltages

$$-V_{OUT} = -1.25V\left(1 + \frac{R2}{240\Omega}\right)$$

†C1 = 1μF solid tantalum or 10μF aluminum electrolytic required for stability
*C2 = 1μF solid tantalum is required only if regulator is more than 4" from power supply filter capacitor

### Regulator with Trimmable Output Voltage



Trim Procedure:
—If $V_{OUT}$ is –23.08V or bigger, cut out R3 (if smaller, don't cut it out).
—Then if $V_{OUT}$ is –22.47V or bigger, cut out R4 (if smaller, don't).
—Then if $V_{OUT}$ is –22.16V or bigger, cut out R5 (if smaller, don't).
This will trim the output to well within 1% of –22.00 $V_{DC}$, without any of the expense or trouble of a trim pot. Of course, this technique can be used at any output voltage level.

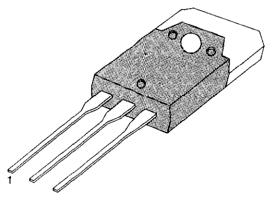
## 3-TERMINAL POSITIVE VOLTAGE REGULATOR

The LM323 is a three-terminal positive regulator with a preset 5V output and a load driving capability of 3 Amps.

New circuit design and processing techniques are used to provide the high output current without sacrificing the regulation characteristics of lower current devices.

The LM323 can be used with a external transistor to supply up to 15A at 5 Volts.

**TO-3P**



1: Input 2: GND 3: Output

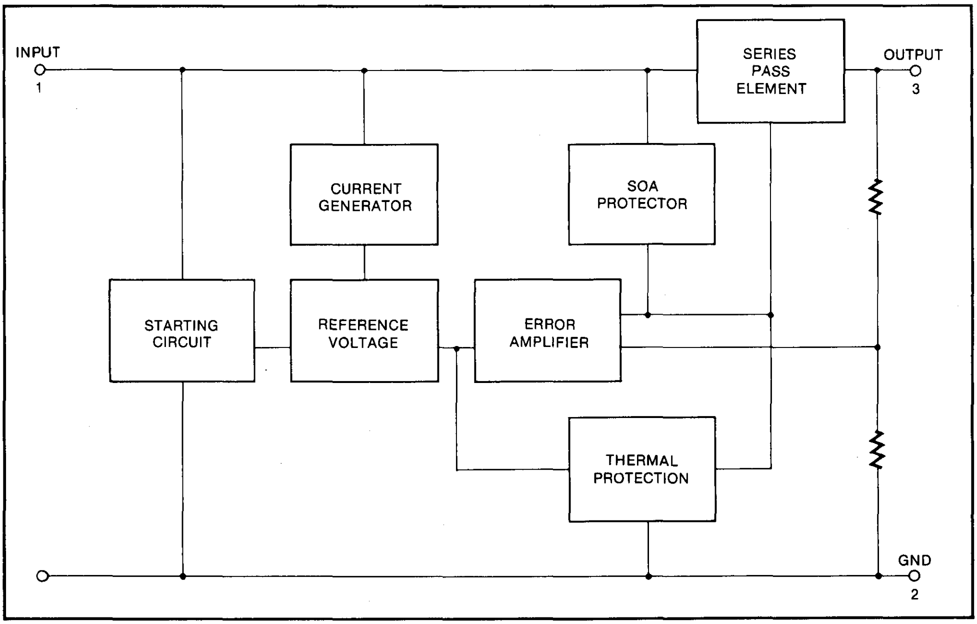
## FEATURES

- **3 Amp output current**
- **Internal current and thermal limiting**
- **0.01Ω typical output impedance**
- **7.5V minimum input voltage**
- **Output transistor safe area compensation**

## ORDERING INFORMATION

| Device | Package | Operating Temperature |
|---|---|---|
| LM323H | TO-3P | 0 ~ 125°C |

## SCHEMATIC DIAGRAM



## ABSOLUTE MAXIMUM RATINGS

| Characteristic | Symbol | Value | Unit |
|---|---|---|---|
| Input Voltage | $V_{IN}$ | 20 | V |
| Operating Temperature Range | $T_{opr}$ | 0 ~ + 125 | °C |
| Storage Temperature Range | $T_{stg}$ | − 65 ~ + 150 | °C |

## ELECTRICAL CHARACTERISTICS

**($0°C \leq T_J \leq 125°C$ unless otherwise specified)**

| Characteristic | Symbol | Test Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Output Voltage | $V_O$ | $T_J = 25°C$<br>$V_{IN} = 7.5V$, $I_{OUT} = 0$ | 4.8 | 5 | 5.2V | |
| | | $7.5V \leq V_{IN} \leq 15V$<br>$0 \leq I_{OUT} \leq 3A$, $P \leq 30W$ | 4.75 | | 5.25 | V |
| Line Regulation | $\Delta V_O$ | $T_J = 25°C$<br>$7.5V \leq V_{IN} \leq 15V$ | | 5 | 25 | mV |
| Load Regulation | $\Delta V_O$ | $T_J = 25°C$, $V_{IN} = 7.5V$<br>$0 \leq I_{OUT} \leq 3A$ | | 25 | 100 | mV |
| Quiescent Current | $I_d$ | $7.5V \leq V_{IN} \leq 15V$<br>$0 \leq I_{OUT} \leq 3A$ | | 3 | 20 | mA |
| Output Noise Voltage | $V_N$ | $T_J = 25°C$,<br>$10Hz \leq f \leq 100KHz$ | | 40 | | $\mu V_{rms}$ |
| Short Circuit Current | $I_{SC}$ | $T_J = 25°C$, $V_{IN} = 15V$ | | 4.5 | | A |
| | | $T_J = 25°C$, $V_{IN} = 7.5V$ | | 5.5 | | A |
| Thermal Resistance Junction to Case | $\Theta_{JC}$ | | | 3 | | °C/W |

* Load and line regulation are specified at constant junction temperature. Change in $V_o$ due to heating effects must be taken into account separately. Pulse testing with low duty is used.

## TYPICAL PERFORMANCE CHARACTERISTICS

Fig. 1 **MAXIMUM AVERAGE POWER DISSIPATION**

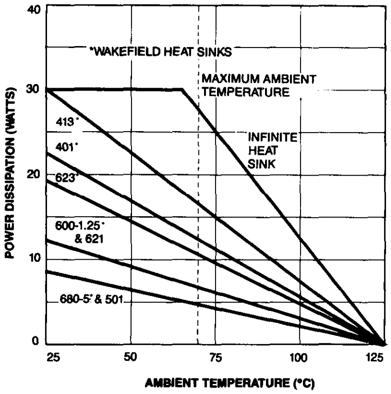


Fig. 2 **OUTPUT IMPEDANCE**

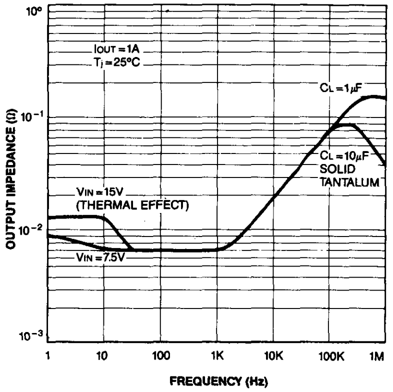


Fig. 3 **SHORT CIRCUIT CURRENT**

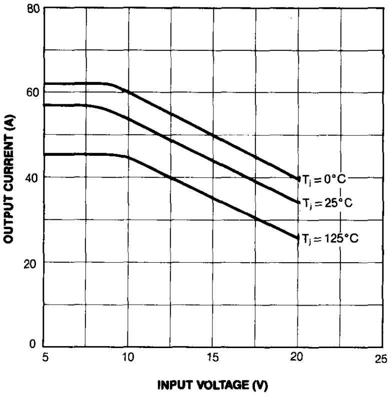


Fig. 4 **RIPPLE REJECTION**

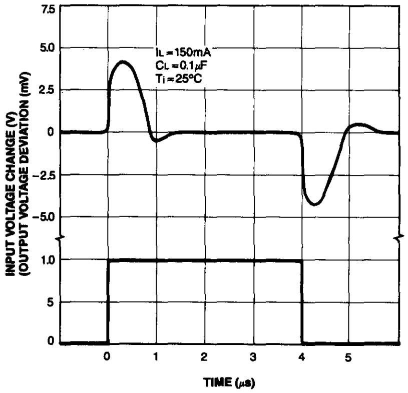


Fig. 5 **DROPOUT VOLTAGE**

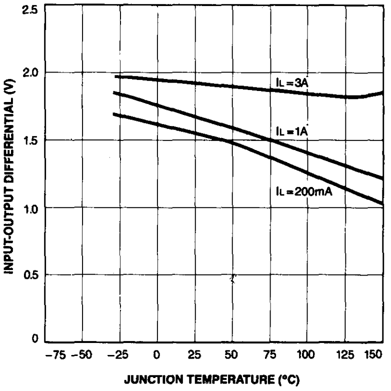


Fig. 6 **LINE TRANSIENT RESPONSE**

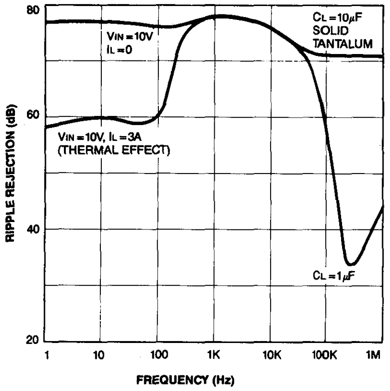


**Fig. 7** OUTPUT VOLTAGE

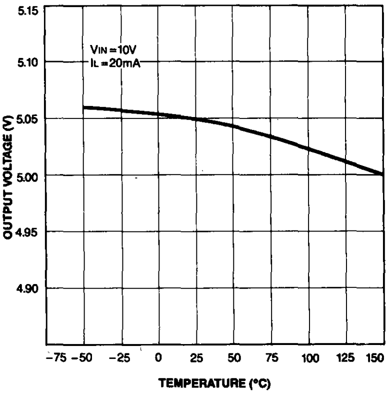


**Fig. 8** QUIESCENT CURRENT

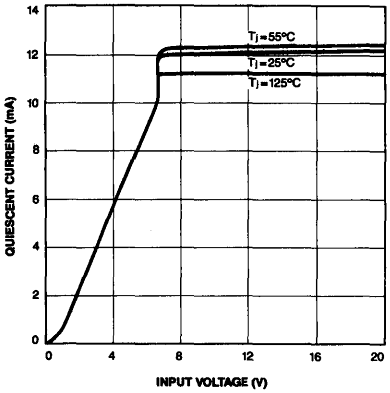


**Fig. 9** LOAD TRANSIENT RESPONSE

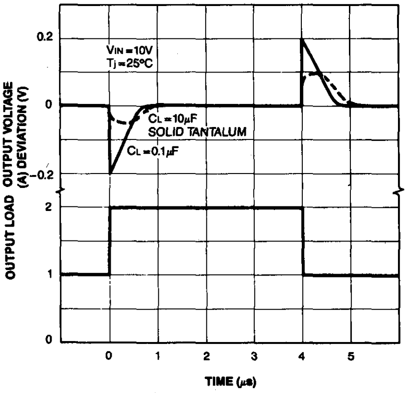
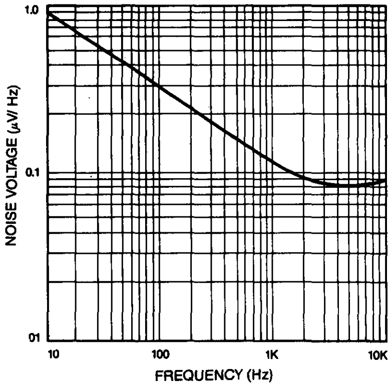


**Fig. 10** OUTPUT NOISE VOLTAGE

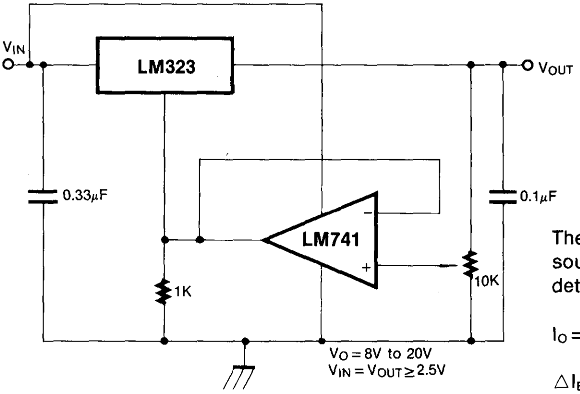


## TYPICAL APPLICATIONS

The LM323 fixed voltage regulator is designed with Thermal Overload Protection that shuts down the circuit when subjected to an excessive power overload condition. Internal Short-Circuit Protection that limits the maximum current the circuit will pass, and Output Transistor Safe-Area Compensation that reduces the output short-circuit current as the voltage across the pass transistor is increased.

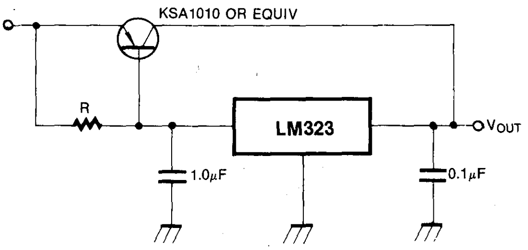
In many low current applications, compensation capacitors are not required. However, it is recommended that the regulator input be bypassed with a capacitor if the regulator is connected to the power supply filter with long wire lengths, or if the output load capacitance is large. An input bypass capacitor should be selected to provide good high-frequency characteristics to insure stable operation under all load conditions. A $0.33\mu F$ or larger tantalum, mylar, or other capacitor having low internal impedance at high frequencies should be chosen. The bypass capacitor should be mounted with the shortest possible leads directly across the regulator's input terminals. Normally good construction techniques should be used to minimize ground loops and lead resistance drops since the regulator has no external sense lead.

### FIG. 11 ADJUSTABLE OUTPUT REGULATOR

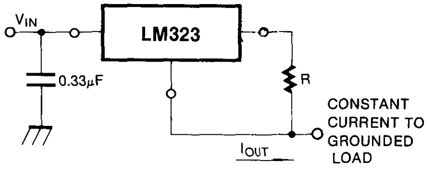


The addition of an operational amplifier allows adjustment to higher or intermediate values while retaining regulation characteristics. The minimum voltage obtainable with this arrangement is 3.0 volts greater than the regulator voltage.

### FIG. 13 CURRENT BOOST REGULATOR



### FIG. 12 CURRENT REGULATOR



The LM323 regulator can also be used as a current source when connected as above. Resistor R determines the current as follows:

$$I_O = \frac{5.0V}{R} + I_B$$

$\Delta I_B = 0.7mA$ over line, load and temperature changes
$I_B = 3.5mA$

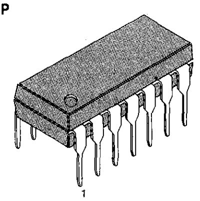
For example, a 2-ampere current source would require R to be a 2.5 ohm, 15W resistor and the output voltage compliance would be the input voltage less 7.5 volts.

The LM323 can be current boosted with a PNP transistor. The KSA1010 provides current to 15 amperes. Resistor R in conjunction with the $V_{BE}$ of the PNP determines when the pass transistor begins conducting; this circuit is not short-circuit proof. The input-output differential voltage minimum is increased by the $V_{BE}$ of the pass transistor.

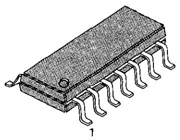
## PRECISION VOLTAGE REGULATOR

The LM723C/LM723I are monolithic integrated circuit voltage regulators featuring high ripple rejection, excellent output and load regulation, excellent temperature stability, and low standby current. The LM723C/LM723I are also useful in a wide range of other applications such as a shunt regulator, a current regulator or a temperature controller. The LM723C is characteristized for operation from 0°C to 70°C, and the LM723I from −25°C to +85°C.

14 DIP



14 SOP



## FEATURES

- **Positive or Negative Supply Operation.**
- **0.01% line and load regulation**
- **Output voltage adjustable from 2 to 37 volts.**
- **Output current to 150mA without external pass transistor**

## ORDERING INFORMATION

| Device | Package | Operating Temperature |
|---|---|---|
| LM723CN | 14 DIP | 0∼+70°C |
| LM723CD | 14 SOP | |
| LM723IN | 14 DIP | −25∼+85°C |
| LM723ID | 14 SOP | |

## BLOCK DIAGRAM

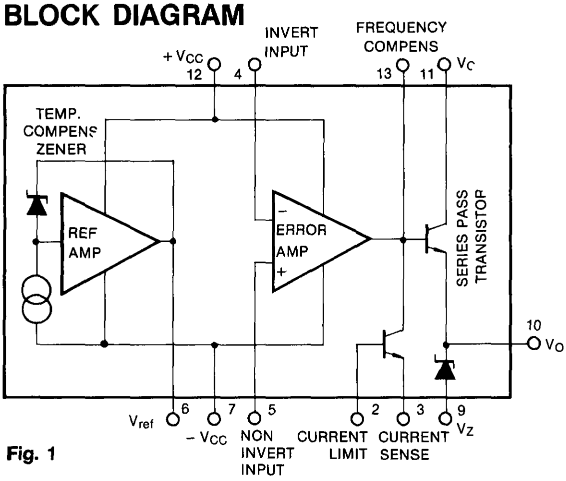


**Fig. 1**

## SCHEMATIC DIAGRAM

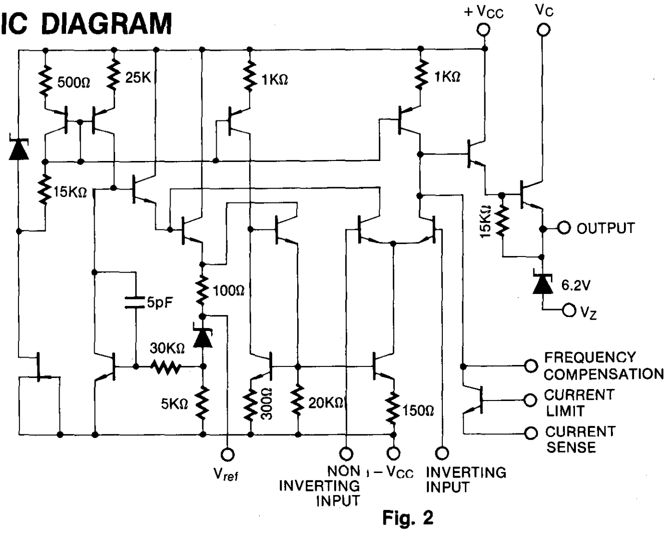


**Fig. 2**

## ABSOLUTE MAXIMUM RATINGS

| Characteristic | Symbol | Value | Unit |
|---|---|---|---|
| Pulse Voltage from V+ to V− (50ms) | $V_{IN(P)}$ | 50 | $V_{peak}$ |
| Continuous Voltage from V+ to V− | $V_{IN}$ | 40 | V |
| Input-Output Voltage Differential | $V_{IN}-V_{OUT}$ | 40 | V |
| Maximum Output Current | $I_O$ | 150 | mA |
| Differential Input Voltage | $V_{ID}$ | ±5 | V |
| Voltage Between Non-Inverting Input and V− | $V_{IE}$ | 8 | V |
| Current from $V_Z$ | $I_Z$ | 25 | mA |
| Current from $V_{REF}$ | $I_{REF}$ | 15 | mA |
| Power Dissipation | $P_D$ | 1000 | mW |
| Operating Temperature Range LM723C<br>LM723I | $T_{opr}$ | 0 ~ +70<br>−25 ~ +85 | °C<br>°C |
| Storage Temperature Range | $T_{stg}$ | −65 ~ +150 | °C |

## ELECTRICAL CHARACTERISTICS

(unless otherwise specified, $Ta=25°C$, $V_I=V_{CC}=V_C=12V$, $V_O=+5V$, $I_L=1.0mA$, $R_{SC}=0$, $C_I=100pF$, $C_{ref}=0$ and devider impedance as seen by error Amplifier≤10KΩ connected as shown in figure 3)

| Characteristic | Symbol | Test Conditions | LM723I/LM723C | | | Unit |
|---|---|---|---|---|---|---|
| | | | Min | Typ | Max | |
| Line Regulation | $\triangle V_O$ | $V_I=12V$ to 15V<br>$V_I=12V$ to 40V | | 0.01<br>0.1 | 0.1<br>0.5 | % |
| | | $T_{MIN}\leq T_A\leq T_{MAX}$<br>$V_I=12V$ to 15V | | | 0.3 | |
| Load Regulation | $\triangle V_O$ | $I_O=1mA$ to 50mA | | 0.03 | 0.2 | % |
| | | $T_{MIN}\leq T_A\leq T_{MAX}$<br>$I_O=1$ to 50mA | | | 0.6 | |
| Ripple Rejection | RR | f=100Hz to 10KHz, $C_{REF}=0$ | | 74 | | dB |
| | | f=100Hz to 10KHz, $C_{REF}=5\mu F$ | | 86 | | |
| Average Temperature Coefficient of Output Voltage | $\triangle V_O/\triangle T$ | $T_{MIN}\leq T_A\leq T_{MAX}$ | | 0.003 | 0.015 | %/°C |
| Short Circuit Current Limit | $I_{SC}$ | $R_{SC}=10\Omega$, $V_O=0$ | | 65 | | mA |
| Reference Voltage | $V_{REF}$ | | 6.80 | 7.15 | 7.50 | V |
| Output Noise Voltage | $V_N$ | f=100Hz to 10KHz, $C_{REF}=0$ | | 20 | | $\mu V_{rms}$ |
| | | f=100Hz to 10KHz, $C_{REF}=5\mu F$ | | 2.5 | | |
| Long-term Stability | $V_O/T$ | | | 0.1 | | %/1000HR |
| Standby Current Drain | $I_D$ | $I_L=0$, $V_{IN}=30V$ | | 2.0 | 4.0 | mA |
| Input Voltage Range | $V_I$ | | 9.5 | | 40 | V |
| Output Voltage Range | $V_O$ | | 2.0 | | 37 | V |
| Input-Output Voltage Differential | $V_D$ | | 3.0 | | 38 | V |

* Note: $T_{MIN}=0°C$ for LM723C $T_{MAX}=70°C$ for LM723C
= −25°C for LM723I =85°C for LM723I

**Table 1 — Resistor values (KΩ) for standard output voltage**

| Output Voltage | Applicable Figures | Fixed Output ±5% | | Output Adjustable ±10% | | | Output Voltage | Applicable Figures | Fixed Output ±5% | | Output Adjustable ±10% | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $R_1$ | $R_2$ | $R_1$ | $P_1$ | $R_2$ | | | $R_1$ | $R_2$ | $R_1$ | $P_1$ | $R_2$ |
| +3 | 3, 6 | 4.12 | 3.01 | 1.8 | 0.5 | 1.2 | −6* | 5 | 3.57 | 2.43 | 1.2 | 0.5 | 0.75 |
| +5 | 3, 6 | 2.15 | 4.99 | 0.75 | 0.5 | 2.2 | −9 | 5 | 3.48 | 5.36 | 1.2 | 0.5 | 2 |
| +6 | 3, 6 | 1.15 | 6.04 | 0.5 | 0.5 | 2.7 | −12 | 5 | 3.57 | 8.45 | 1.2 | 0.5 | 3.3 |
| +9 | 4, 6 | 1.87 | 7.15 | 0.75 | 1 | 2.7 | −15 | 5 | 3.65 | 11.5 | 1.2 | 0.5 | 4.3 |
| +12 | 4, 6 | 4.87 | 7.15 | 2 | 2 | 3 | −28 | 5 | 3.57 | 24.3 | 1.2 | 0.5 | 10 |
| +15 | 4, 6 | 7.87 | 7.15 | 3.3 | 1 | 3 | | | | | | | |
| +28 | 4, 6 | 21 | 7.15 | 5.6 | 1 | 2 | | | | | | | |

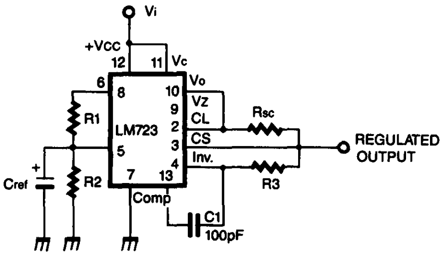
Note: *$V_{CC}$ must be connected to a +3V or greater supply.

**Table II — Formulae for intermediate output voltages**

| | | |
|---|---|---|
| Outputs from +2 to +7 volts<br>Fig. 3<br>$V_o = [\, V_{ref} \times \frac{R_2}{R_1 + R_2} \,]$ | Foldback Current Limiting<br>$I_{KNEE} = [\, \frac{V_o \; R_3}{R_{sc} \; R_4} + \frac{V_{SENSE} \, (R_3 + R_4)}{R_{sc} \; R_4} \,]$<br>$I_{SHORT\,CKT} = [\, \frac{V_{SENSE}}{R_{sc}} \times \frac{R_3 + R_4}{R_4} \,]$ | Current Limiting<br>$I_{LIMIT} = \frac{V_{SENSE}}{R_{sc}}$ |
| Outputs from +7 to +37 volts<br>Fig. 4, 6<br>$V_o = [V_{ref} \times \frac{R_1 + R_2}{R_2}]$ | Output from −6 to −250 volts<br>Fig. 5<br>$V_o = [\frac{V_{ref}}{2} \times \frac{R_1 + R_2}{R_1}];\ R_3 = R_4$ | |

## APPLICATION INFORMATION

Fig. 3 Basic low voltage regulator ($V_O = 2$ to 7V)

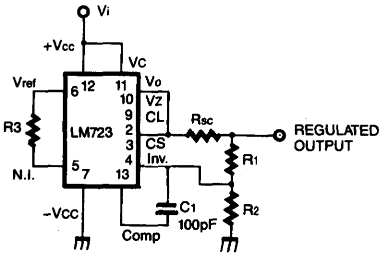


**Note:** R3=R1 • R2/(R1+R2) for minimum temperature drift.
R3 may be eliminated for minimum component count.

**Typical performance**

| | |
|---|---|
| Regulated Output Voltage | 5V |
| Line Regulation (ΔVi =3V) | 0.5mV |
| Load Regulation (ΔIo =50mA) | 1.5mV |

Fig. 4 Basic high voltage regulator ($V_O = 7$ to 37V)

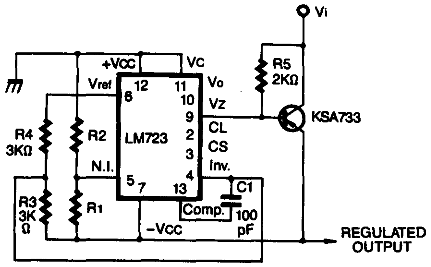


**Note:** R1•R2/(R1+R2)for minimum temperature drift.
R3 may be eliminated for minimum component count.

**Typical performance**

| | |
|---|---|
| Regulated Output Voltage | 15V |
| Line Regulation (ΔVi =3V) | 1.5mV |
| Load Regulation (ΔIo =50mA) | 4.5mV |

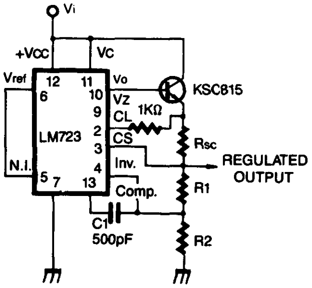
Fig. 5 Negative voltage regulator



**Typical performance**

| | |
|---|---|
| Regulated output Voltage | -15V |
| Line Regulation (ΔVi =3V) | 1mV |
| Load Regulation (ΔIo =100mA) | 2mV |

Fig. 6 Positive voltage regulator
(External NPN Pass Transistor)



**Typical performance**

| | |
|---|---|
| Regulated Output Voltage | +15V |
| Line Regulation (ΔVi =3V) | 1.5mV |
| Load Regulation (ΔIo =1A) | 15mV |

Fig. 7 MAXIMUM OUTPUT CURRENT VS. VOLTAGE DROP

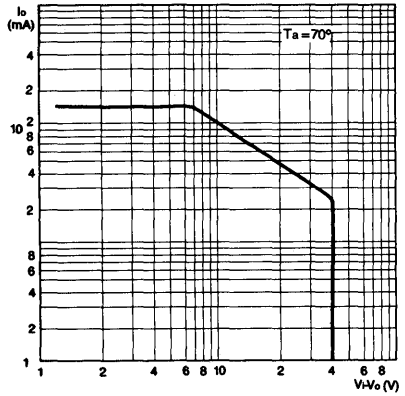


Fig. 8 CURRENT LIMITING CHARACTERISTICS

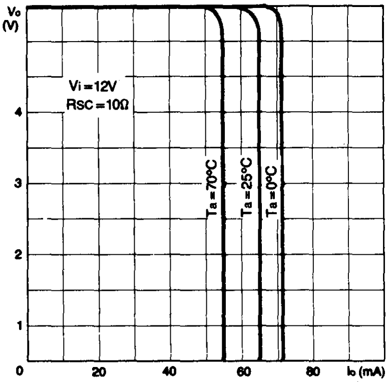


Fig. 9 CURRENT LIMITING CHARACTERISTICS VS. JUNCTION TEMPERATURE

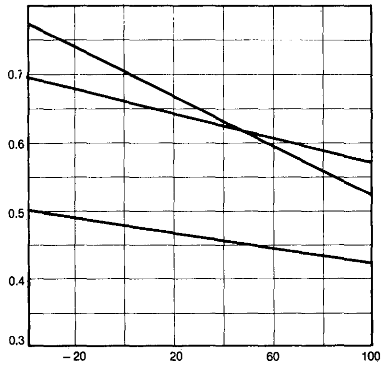


Fig. 10 LOAD REGULATION CHARACTERISTICS WITHOUT CURRENT LIMITING

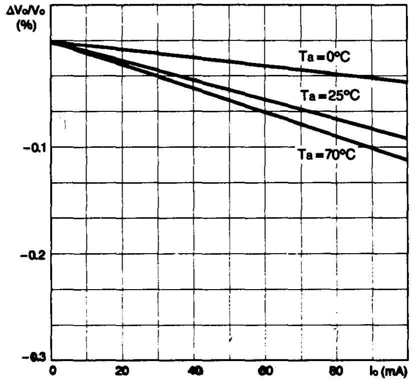


Fig. 11 LOAD REGULATION CHARACTERISTICS WITH CURRENT LIMITING

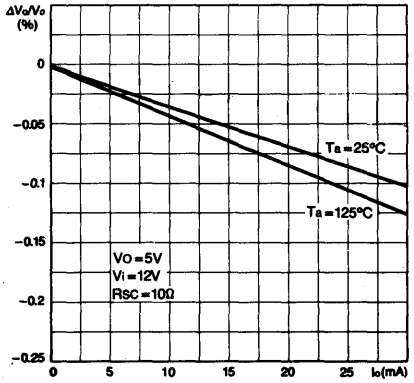
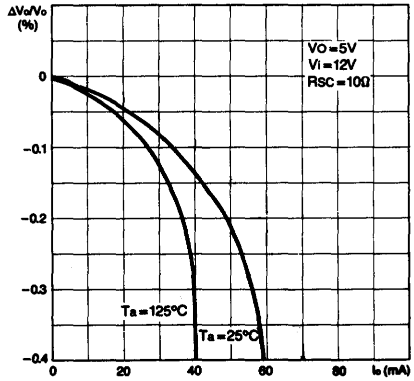


Fig. 12 LOAD REGULATION CHARACTERISTIC WITH CURRENT LIMITING



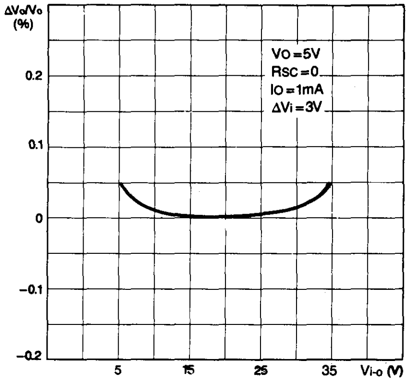


Fig. 13 LINE REGULATION—VOLTAGE DROP

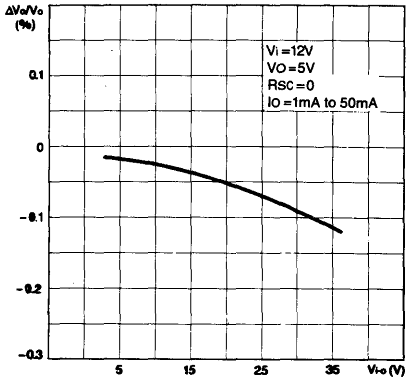


Fig. 14 LOAD REGULATION—VOLTAGE DROP

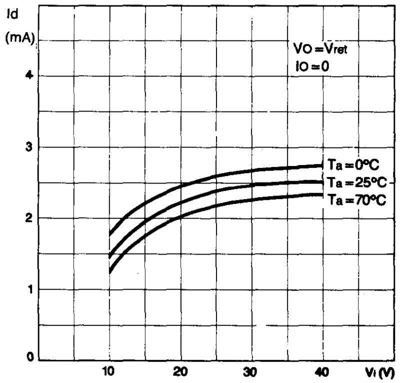


Fig. 15 QUIESCENT DRAIN CURRENT VS. INPUT VOLTAGE

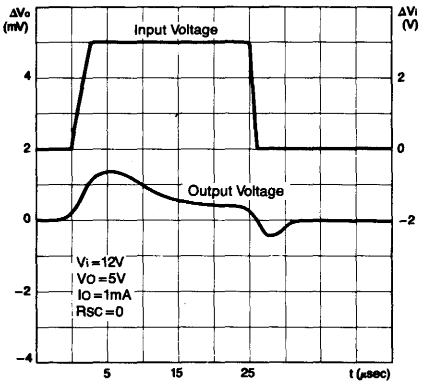


Fig. 16 LINE TRANSIENT RESPONSE

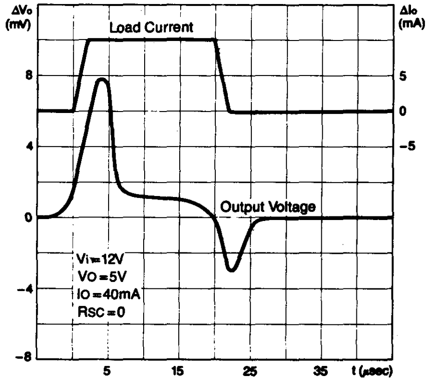


Fig. 17 LOAD TRANSIENT RESPONSE

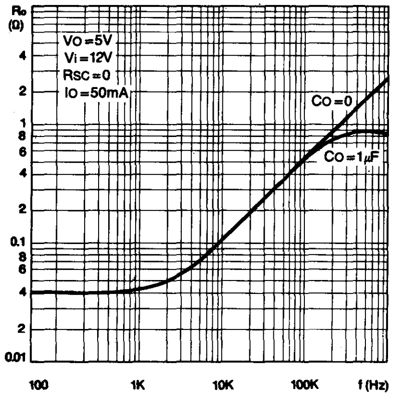
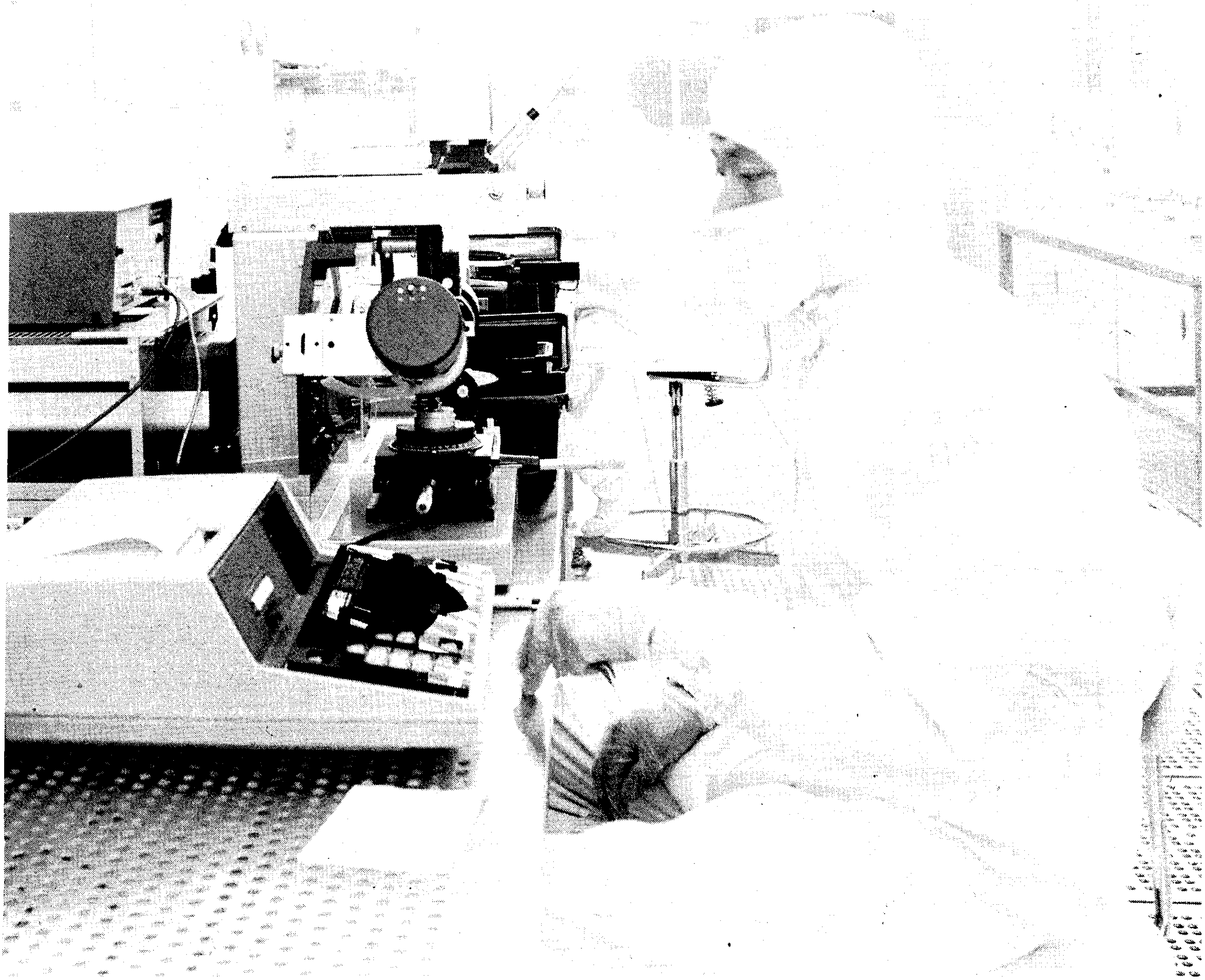


Fig. 18 OUTPUT IMPEDANCE VS. FREQUENCY

# NOTES

# PWM CONTROLLERS 4



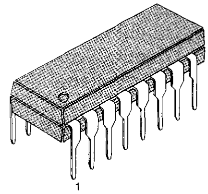
## REGULATOR PULSE WIDTH MODULATOR

The KA7500 is used for the control circuit of the pulse width modulation switching regulator. The KA7500 consists of a 5 V reference voltage circuit two error amplifiers, flip-floop, an output control circuit a PWM comparator a dead time comparator and an oscillator. This device can be operated in the of switching frequency range, of 1 KHz to 300 KHz.

## FEATURES

- **Internal regulator provides a stable 5V reference supply trimmed to 1%**
- **Uncommitted output TR for 200mA sink or source current**
- **Output control for push-pull or single-ended operation**
- **Variable duty cycle by dead time control (pin 4)**
- **Complete PWM control circuitry**
- **On-chip oscillator with master or slave operation**
- **Internal circuitry prohibits double pulse at either output**

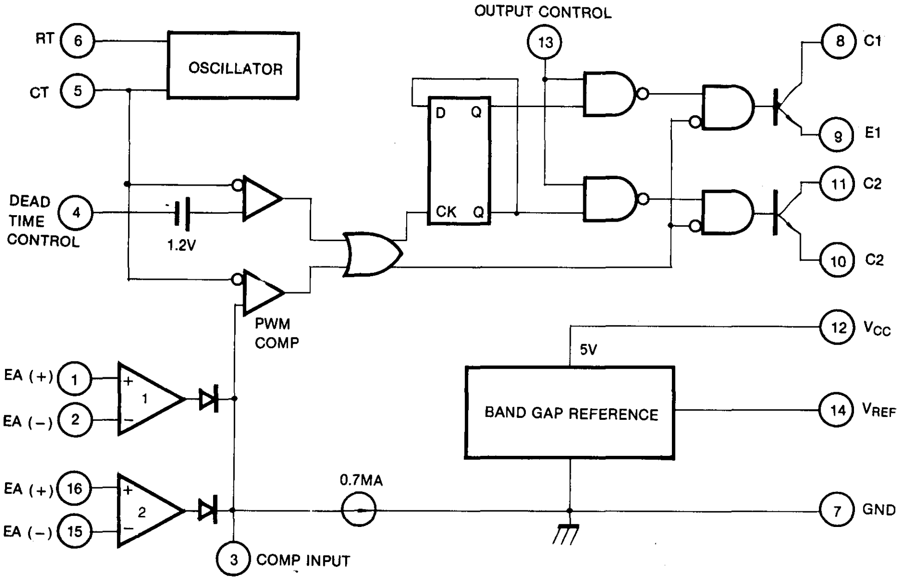
**16 DIP**



## ORDERING INFORMATION

| Device | Package | Operating Temperature |
|---|---|---|
| KA7500 | 16 DIP | 0 ~ 70°C |

## BLOCK DIAGRAM



## ABSOLUTE MAXIMUM RATINGS (Ta = 25°C)

| Characteristic | Symbol | Value | Unit |
|---|---|---|---|
| Supply Voltage | $V_{CC}$ | 42 | V |
| Collector Output Voltage | $V_{CO}$ | 42 | V |
| Collector Output Current | $I_{CO}$ | 250 | mA |
| Amplifier Input Voltage | $V_{IN}$ | $V_{CC}+0.3$ | V |
| Power Dissipation | $P_d$ | 1 | W |
| Operating Temperature Range | $T_{opr}$ | 0 ~ +70 | °C |
| Storage Temperature Range | $T_{stg}$ | −65 ~ +150 | °C |

## ELECTRICAL CHARACTERISTICS

($V_{CC}=20V$, f = 10KHz, Ta = 25°C, unless otherwise specified)

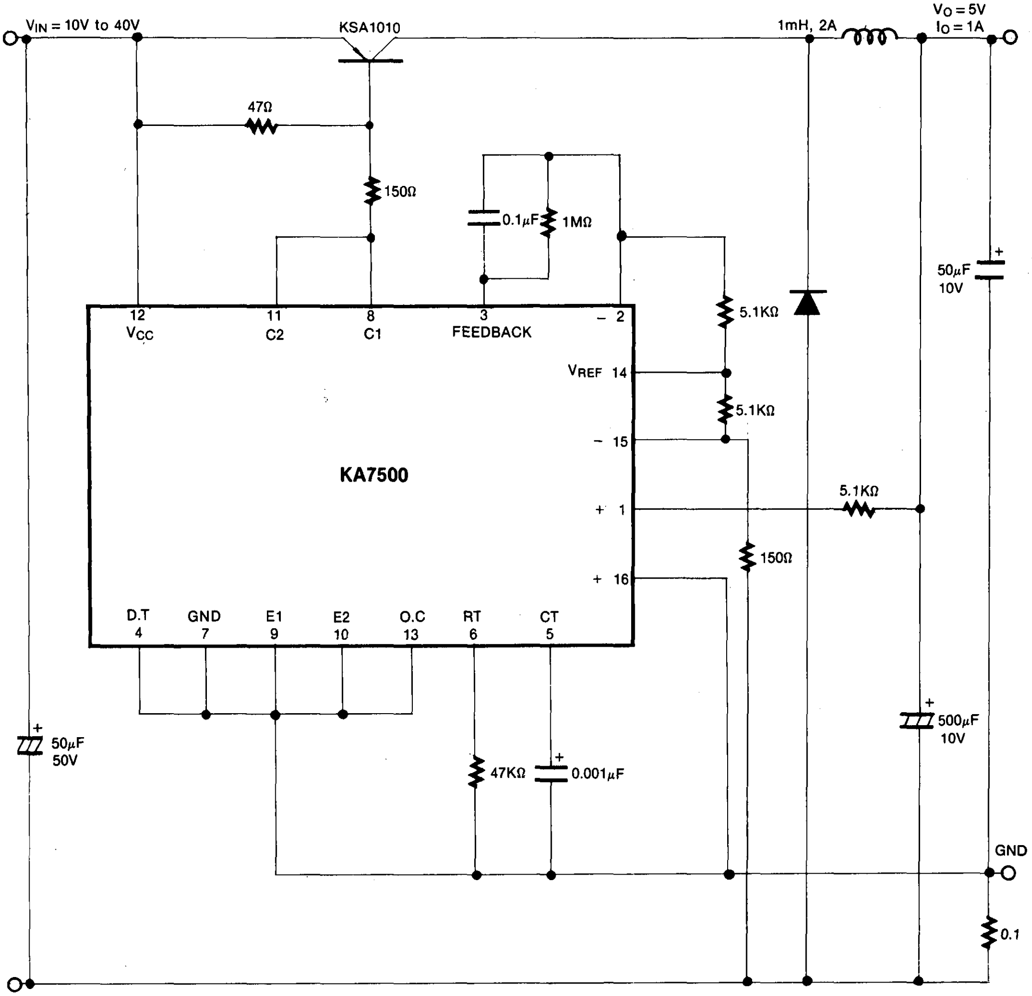
| Characteristic | Symbol | Test Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| **REFERENCE SECTION** | | | | | | |
| Reference Output Voltage | $V_O$ | $I_{ref}=1mA$ | 4.75 | 5.0 | 5.25 | V |
| Line Regulation | $\triangle V_O$ | $V_{CC}=7V$ to 40V | | 2.0 | 25 | mV |
| Temperature Coefficient | | Ta = 0°C to 70°C | | 0.01 | 0.03 | %/°C |
| Load Regulation | $\triangle V_O$ | $I_{ref}=1mA$ to 10mA | | 1.0 | 15 | mV |
| Short-Circuit Output Current | $I_{SC}$ | $V_{ref}=0$ | 10 | 35 | 50 | mA |
| **OSCILLATOR SECTION** | | | | | | |
| Oscillation Frequency | $F_{OSC}$ | $C_T=0.01\mu F$, $R_T=12K$ | | 10 | | KHz |
| Frequency Change with Temperature | $F_{OSC}/T$ | $C_T=0.01\mu F$, $R_T=12K$ | | | 2 | % |
| **DEAD TIME CONTROL SECTION** | | | | | | |
| Input Bias Current | $I_B$ | $V_{CC}=15V$, $0<V_4<5.25V$ | | −2.0 | −10 | μA |
| Maximum Duty Cycle | $DC_{max}$ | $V_{CC}=15V$, Pin 4 = 0V<br>O.C Pin = $V_{ref}$ | 45 | | | % |
| Input Threshold Voltage | $V_{TH}$ | Zero Duty Cycle | | 3.0 | 3.3 | V |
| | | Max. Duty Cycle | 0 | | | |
| **ERROR AMP SECTION** | | | | | | |
| Input Offset Voltage | $V_{IO}$ | $V_3=2.5V$ | | 2.0 | 10 | mV |
| Input Offset Current | $I_{IO}$ | $V_3=2.5V$ | | 25 | 250 | mA |
| Input Bias Current | $I_B$ | $V_3=2.5V$ | | 0.2 | 1.0 | μA |
| Common Mode Input Voltage | $V_{OR}$ | $7V<V_{CC}<40V$ | −0.3 | | $V_{CC}$ | V |
| Open-Loop Voltage Gain | $A_{VO}$ | $0.5V<V_3<3.5V$ | 70 | 95 | | dB |
| Unit-Gain Bandwidth | BW | | | 650 | | KHz |

## ELECTRICAL CHARACTERISTICS (Continued)

| Characteristic | Symbol | Test Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| **PWM COMPARATOR SECTION** | | | | | | |
| Input Threshold Voltage | $V_{TH}$ | Zero Duty Cycle | | 4 | 4.5 | V |
| Input Sink Current | $I_{IS}$ | $V_3 = 0.7V$ | −0.3 | −0.7 | | mA |
| **OUTPUT CONTROL SECTION** | | | | | | |
| Single-Ended Operation | $V_{OCL}$ | | | | 0.4 | V |
| Push-Pull Operation | $V_{OCH}$ | | 2.4 | | | |
| **OUTPUT SECTION** | | | | | | |
| Output Saturation Voltage Common Emitter | $V_{CE}(sat)$ | $V_E = 0$, $I_C = 200mA$ | | 1.1 | 1.3 | V |
| Common Collector | $V_{CC}(sat)$ | $V_C = 15V$, $I_E = -200mA$ | | 1.5 | 2.5 | |
| Collector Off-State Current | $I_C(off)$ | $V_{CC} = 40V$, $V_{CE} = 40V$ | | 2 | 100 | μA |
| Emitter Off-State Current | $I_E(off)$ | $V_{CC} = V_C = 40V$, $V_E = 0$ | | | −100 | |
| **TOTAL DEVICE** | | | | | | |
| Standby Supply Current | $I_{CC}$ | Pin 6 = $V_{ref}$, $V_{CC} = 15V$ | | 6 | 10 | mA |
| **OUTPUT SWITCHING CHARACTERISTIC** | | | | | | |
| Rise Time | $T_R$ | | | | | |
| Common Emitter | | | | 100 | 200 | nS |
| Common Collector | | | | 100 | 200 | |
| Fall Time | $T_F$ | | | | | |
| Common Emitter | | | | 25 | 100 | nS |
| Common Collector | | | | 40 | 100 | |

## TYPICAL APPLICATION

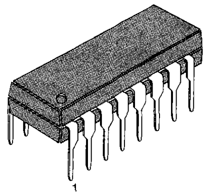
**Fig. 1 PULSE WIDTH MODULATED STEP-DOWN CONVERTER**



# REGULATOR PULSE WIDTH MODULATOR

The KA3524 regulating pulse width modulator contains all of the control circuitry necessary to implement switching regulators of either polarity, transformer coupled DC to DC converters, transformerless polarity converters and voltage doublers, as well as other power control applications. This device includes a 5V voltage regulator capable of supplying up to 50mA to external circuitry, a control amplifier, an oscillator, a pulse width modulator, a phase splitting flip-flop, dual alternating output switch transistors, and current limiting and shut-down circuitry. Both the regulator output transistor and each output switch are internally current limiting and, to limit junction temperature, an internal thermal shutdown circuit is employed.

16 DIP



## FEATURES

- **Complete PWM power control circuitry**
- **Operation beyond 100KHz**
- **2% frequency stability with temperature**
- **Total quiescent current less than 10mA**
- **Single ended or push-pull outputs**
- **Current limit amplifier provides external component protection**
- **On-chip protection against excessive junction temperature and output current**
- **5V, 50mA linear regulator output available to user**

## ORDERING INFORMATION

| Device | Package | Operating Temperature |
|---|---|---|
| KA3524N | 16 DIP | 0~70°C |

## BLOCK DIAGRAM

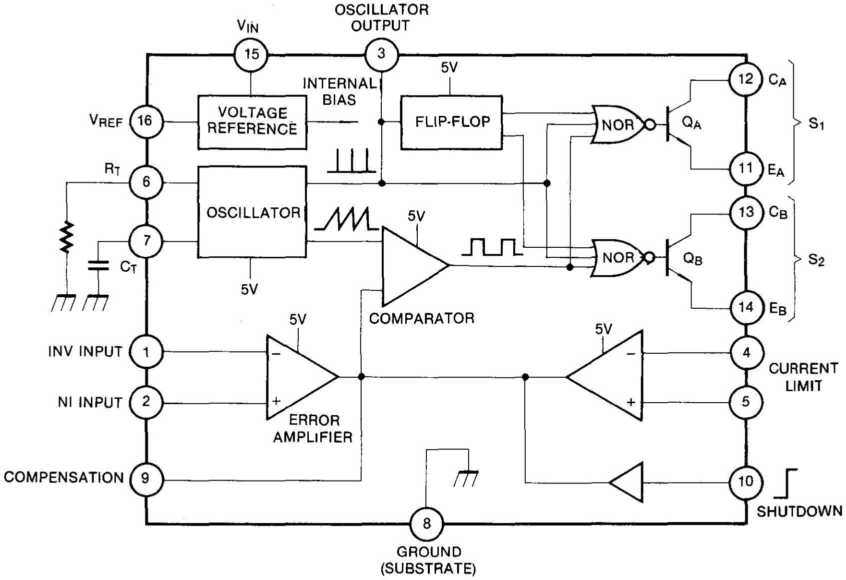


Fig. 1

## ABSOLUTE MAXIMUM RATINGS

| Characteristic | Symbol | Value | Unit |
|---|---|---|---|
| Power Supply Voltage | $V_{CC}$ | 40 | V |
| Reference Output Current | $I_{REF}$ | 50 | mA |
| Output Current (Each Output) | $I_O$ | 100 | mA |
| Oscillator Changing Current (pin 6 or 7) | $I_{charge}$ | 5 | mA |
| Lead Temperature (Soldering, 10 sec) | $T_{lead}$ | 300 | °C |
| Power Dissipation | $P_D$ | 1000 | mW |
| Operating Temperature | $T_{opr}$ | 0 ~ +70 | °C |
| Storage Temperature | $T_{stg}$ | −65 ~ +150 | °C |

## ELECTRICAL CHARACTERISTICS

($V_{IN}$ = 20V, f = 20KHz, Ta = 0 to 70°C unless otherwise specified)

| Characteristic | Symbol | Test Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| **REFERENCE SECTION** | | | | | | |
| Output Voltage | $V_O$ | | 4.6 | 5.0 | 5.4 | V |
| Line Regulation | $\triangle V_O$ | $V_{IN}$ = 8 ~ 40V | | 10 | 30 | mV |
| Load Regulation | $\triangle V_O$ | $I_L$ = 0 ~ 20mA | | 20 | 50 | mV |
| Ripple Rejection | RR | f = 120Hz, Ta = 25°C | | 66 | | dB |
| Short-Circuit Output Current | $I_{SC}$ | $V_{ref}$ = 0, Ta = 25°C | | 100 | | mA |
| Temperature Stability | $T_S$ | | | 0.3 | 1 | % |
| Long Term Stability | S | Ta = 25°C | | 20 | | mV/Khr |
| **OSCILLATOR SECTION** | | | | | | |
| Maximum Frequency | $f_{MAX}$ | CT = 0.001μF, RT = 2KΩ | | 350 | | KHz |
| Initial Accuracy | | RT and CT constant | | 5 | | % |
| Frequency Change with Voltage | $\triangle f$ | $V_{IN}$ = 8 ~ 40V, Ta = 25°C | | | 1 | % |
| Frequency Change with Temperature | $\triangle f$ | Over operating temperature range | | | 2 | % |
| Output Amplitude (Pin 3) | VA3 | Ta = 25°C | | 3.5 | | V |
| Output Pulse Width (Pin 3) | V3PW | CT = 0.01μF, Ta = 25°C | | 0.5 | | μs |
| **ERROR AMPLIFIER SECTION** | | | | | | |
| Input Offset Voltage | $V_{IO}$ | VCM = 2.5V | | 2 | 10 | mV |
| Input Bias Current | $I_{IB}$ | VCM = 2.5V | | 2 | 10 | μA |
| Open Loop Voltage Gain | $A_{VO}$ | | 60 | 80 | | dB |
| Common-Mode Input Voltage Range | $V_{CR}$ | Ta = 25°C | 1.8 | | 3.4 | V |
| Common-Mode Rejection Ratio | CMRR | Ta = 25°C | | 70 | | dB |
| Small Signal Bandwidth | BW | $A_V$ = 0dB, Ta = 25°C | | 3 | | MHz |
| Output Voltage Swing | $V_{OSW}$ | Ta = 25°C | 0.5 | | 3.8 | V |

## ELECTRICAL CHARACTERISTICS (Continued)

($V_{IN} = 20V$, $f = 20KHz$, $Ta = 0 \sim 70°C$ unless otherwise specified)

| Characteristic | Symbol | Test Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| **COMPARATOR SECTION** | | | | | | |
| Maximum Duty Cycle | $DC_{max}$ | % Each output on | 45 | | | % |
| Input Threshold (Pin 9) | $V_{TH1}$ | Zero duty cycle | | 1 | | V |
| Input Threshold (Pin 9) | $V_{TH2}$ | Maximum duty cycle | | 3.5 | | V |
| Input Bias Current | $I_B$ | | | 1 | | μA |
| **CURRENT LIMITING SECTION** | | | | | | |
| Sense Voltage | $V_{sense}$ | V(Pin 2) − V(Pin 1) ≥ 50mV<br>Pin 9 = 2V, Ta = 25°C | 180 | 200 | 220 | mV |
| Sense Voltage T.C. | | | | 0.2 | | mV/°C |
| Common-Mode Voltage | | | 0.7 | | 1 | V |
| **OUTPUT SECTION (EACH OUTPUT)** | | | | | | |
| Collector-Emitter Voltage | $V_{CEO}$ | | 40 | | | V |
| Collector Leakage Current | $I_{LKg}$ | $V_{CE} = 40V$ | | 0.1 | 50 | μA |
| Saturation Voltage | $V_{SAT}$ | IC = 50mA | | 1 | 2 | V |
| Emitter Output Voltage | $V_E$ | $V_{IN} = 20V$, | 17 | 18 | | V |
| Rise Time (10% to 90%) | $t_r$ | RC = 2KΩ, Ta = 25°C | | 0.2 | | μs |
| Fall Time (90% to 10%) | $t_f$ | RC = 2KΩ, Ta = 25°C | | 0.1 | | μs |
| Total Standby Current | $I_{STD}$ | $V_{IN} = 40V$, PINS 1, 4, 7, 8, 11 and 14 are grounded, Pin 2 = 2V All other inputs and outputs open | | 5 | 10 | mA |

# APPLICATION INFORMATION

## Voltage Reference

An internal series regulator provides a nominal 5 volt output which is used both to generate a reference voltage and is the regulated source for all the internal timing and controlling circuitry. This regulator may be bypassed for operation from a fixed 5 volt supply by connecting pins 15 and 16 together to the input voltage. In this configuration, the maximum input voltage is 6.0 volts.

This reference regulator may be used as a 5 volt source for other circuitry. It will provide up to 50mA of current itself and can easily be expanded to higher current with an external PNP as shown in Figure 2.

**EXPANDED REFERENCE CURRENT CAPABILITY**

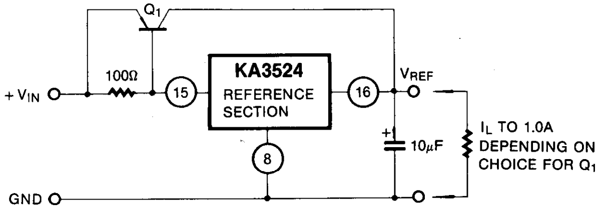


**Fig. 2**

## Oscillator

The oscillator in the KA3524 uses an external resistor ($R_T$) to establish a constant charging current into an external capacitor ($C_T$). While this uses more current than a series connected RC, it provides a linear ramp voltage on the capacitor which is also used as a reference for the comparator. The charging current is equal to $3.6V \div R_T$ and should be kept within the range of approximately 30μA to 2mA, i.e., $1.8K < R_T < 100K$. The range of values for $C_T$ also has limits as the discharge time of $C_T$ determines the pulse width of the oscillator output pulse. This pulse is used (among other things) as a blanking pulse to both outputs to insure that there is no possibility of having both outputs on simultaneously during transitions. This output dead time relationship is shown in Figure 6. A pulse width below approximately 0.5 microseconds may allow false triggering of one output by removing he blanking pulse prior to the flip-flops reaching a stable state. If small values of $C_T$ must be used, the pulse width may still be expanded by adding a shunt capacitance (= 100pF) to ground at the oscillator output. (Note: Although the oscillator output is a convenient oscilloscope sync input, the cable and input capacitance may increase the blanking pulse width slightly.) Obviously, the upper limit of the pulse width is determined by the maximum duty cycle acceptable. Practical values of $C_T$ fall between .001 and 0.1 microfarad.

The oscillator period is approximately $t = R_TC_T$ where t is in microseconds when $R_T$ = ohms and $C_T$ = microfarads. The selection of $R_T$ and $C_T$ can be made for a wide range of operating frequencies by using Fig. 7. Note that for series regulator applications, the two outputs can be connected in parallel for an effective 0-90% duty cycle and the frequency of the oscillator is the frequency of the output. For push-pull applications, the outputs are separated and the flip-flop divides the frequency such that each output duty cycle is 0-45% and the overall frequency is one-half that of the oscillator.

## External Synchronization

If it is desired to synchronize the KA3524 to an external clock, a pulse of = +3 volts may be applied to the oscillator output terminal with $R_TC_T$ set slightly greater than the clock period. The same considerations of pulse width apply. The impedance to ground at this point is approximately 2K ohms.

If two or more KA3524s must be synchronized together, one must be designated as the master with its $R_TC_T$ set for the correct period. The slaves should each have an $R_TC_T$ set for an approximately 10% longer period than the master with the added requirement that $C_T$ (slave) = one-half $C_T$ (master). Then connecting Pin 3 on all units together will insure that the master output pulse—which occurs first and has a wider pulse width—will reset the slave units.

## Error Amplifier

This circuit is a simple differential-input, transconductance amplifier. The output is the compensation terminal pin 9, which is a high impedance node ($R_L = 5M\Omega$). The gain is

$$A_V = gmR_L = \frac{8I_CR_L}{2K_T} = .002\ R_L$$

and can easily be reduced from a nominal of 10,000 by an external shunt resistance from pin 9 to ground, as shown in Figure 8,

In addition to DC gain control, the compensation terminal is also the place for AC phase compensation. The frequency response curves of Figure 5 show the uncompensated amplifier with a single pole at approximately 200Hz and a unity gain cross-over at 5MHz.

Typically, most output filter designs will introduce one or more additional poles at a significantly higher power frequency. Therefore, the best stabilizing network is a series R-C combination between pin 9 and ground which introduces a zero to cancel one of the output filter poles. A good starting point is 50KΩ plus .001 microfarad.

One final point on the compensation terminal is that this is also a convenient place to insert any programming signal which is to override the error amplifier. Internal shutdown and current limit circuits are connected here, but any other circuit which can sink 200 μA can pull this point to ground, thus shutting off both outputs.

While feedback is normally applied around the entire regulator, the error amplifier can be used with conventional operational amplifier feedback and is stable in either the inverting or non-inverting mode. Regardless of the connections, however, input common-mode limits must be observed or output signal inversions may result. For conventional regulator applications, the 5 volt reference voltage must be divided down as shown in Figure 3. The error amplifier may also be used in fixed duty cycle applications by using the unity gain configuration shown in the open loop test circuit.

## Current Limiting

The current limiting circuitry of the KA3524 is shown in Figure 4.

By matching the base-emitter voltages of Q1 and Q2, and assuming negligible voltage drop across $R_1$:

$$\begin{aligned}\text{Threshold} &= V_{BE}(Q1) + I_1R_2 - V_{BE}(Q2)\\ &= I_1R_2 = 200\text{mV}\end{aligned}$$

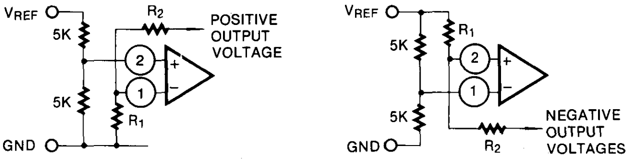
Although this circuit provides a relatively small threshold with a negligible temperature coefficient, there are some limitations to its use, the most important of which is the ± 1 volt common mode range which requires sensing in the ground line. Another factor to consider is that the frequency compensation provided by $R_1C_1$ and Q1 provides a roll-off pole at approximately 300Hz.

Since the gain of this circuit is relatively low, there is a transition region as the current limit amplifier takes over pulse width control from the error amplifier. For testing purposes, the threshold is defined as the input voltage to get 25% duty cycle with the error amplifier signaling maximum duty cycle.

In addition to constant current limiting, pins 4 and 5 may also be used in transformer-coupled circuits to sense primary current and shorten an output pulse, should transformer saturation occur. Another application is to ground pin 5 and use pin 4 as an additional shutdown terminal: i.e., the output will be off with pin 4 open and on when it is grounded. Finally, foldback current limitting can be provided with the network of Figure 5. This circuit can reduce the shortcircuit current ($I_{SC}$ to approximately one third the maximum available outpu current ($I_{MAX}$).

**Fig. 3 ERROR AMPLIFIER BIASING CIRCUITS**

$$V_O = \frac{2.5V(R_1 + R_2)}{R_1}$$



$$\frac{R_1R_2}{R_1 + R_2} = 2.5K\Omega$$

Note change in input connections for opposite polarity outputs.

**Fig. 4 CURRENT LIMITING CIRCUITRY OF THE KA3524**

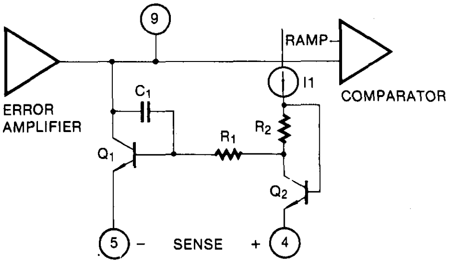
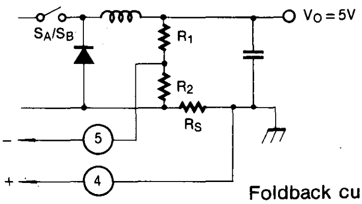


**Fig. 5 FOLDBACK CURRENT LIMITING**



$$I_{MAX} = \frac{1}{R_S}\quad V_{TH} + \frac{V_0R_2}{R_1 + R_2}$$

$I_{SC} = \frac{V_{TH}}{R_S}$ where

$V_{TH} = 200\text{mV}$

Foldback current limiting can be used to reduce power dissipation under shorted output conditions

## TYPICAL PERFORMANCE CHARACTERISTICS

**Fig. 6** OUTPUT STAGE DEAD TIME AS A FUNCTION OF THE TIMING CAPACITOR VALUE

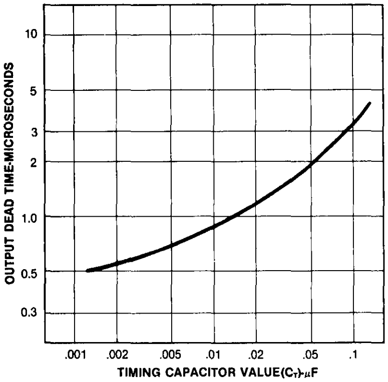


**Fig. 7** OSCILLATOR PERIOD AS A FUNCTION OF $R_T$ AND $C_T$

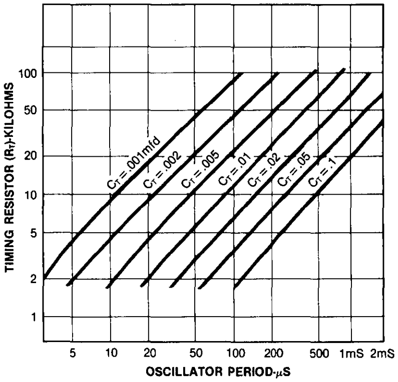
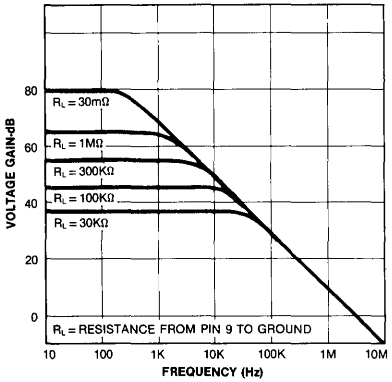
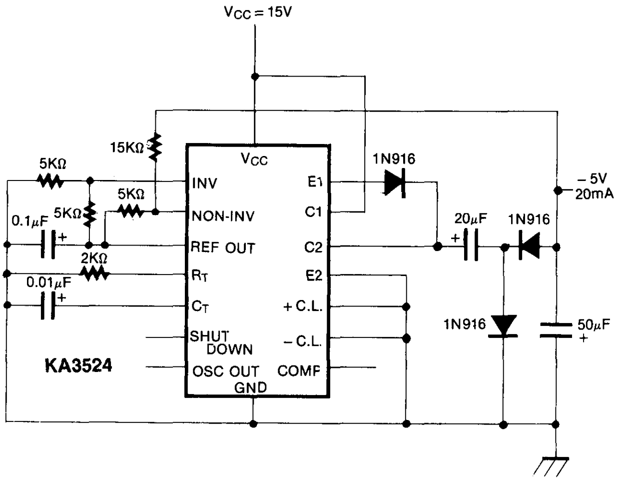


**Fig. 8** AMPLIFIES OPEN-LOOP GAIN AS A FUNCTION OF FREQUENCY AND LOADING ON PIN 9

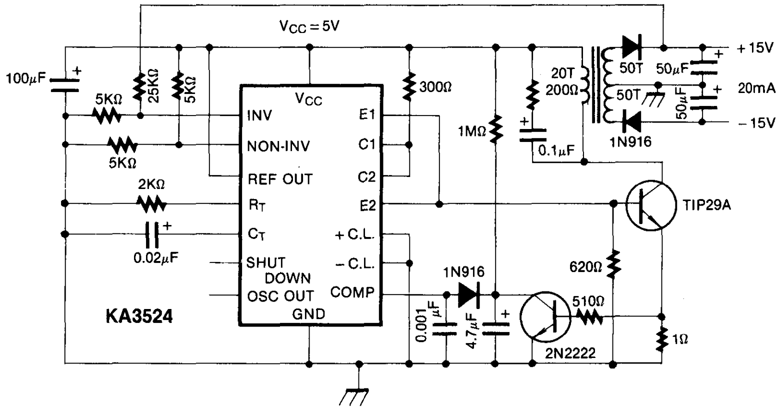


## TYPICAL APPLICATIONS

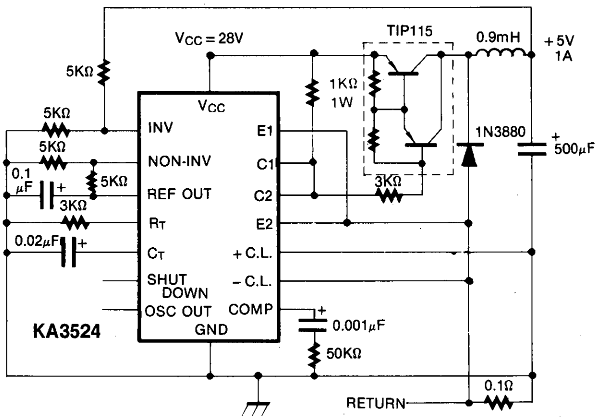
### Fig. 9 CAPACITOR-DIODE OUTPUT CIRCUIT



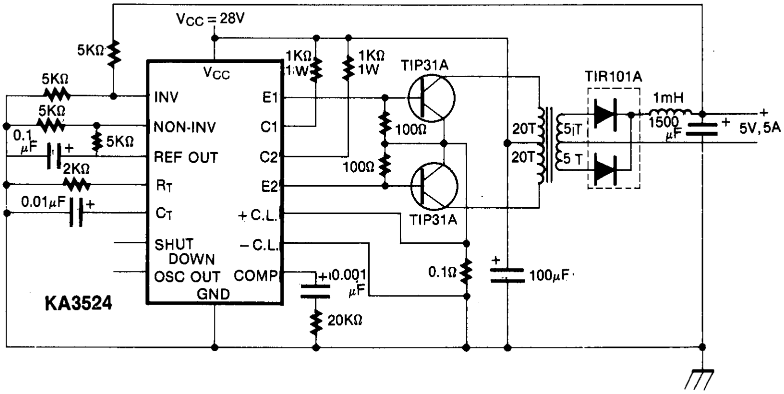
### Fig. 10 FLYBACK CONVERTER CIRCUIT



## Fig. 11 SINGLE-ENDED LC CIRCUIT



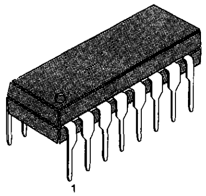
## Fig. 12 PUSH-PULL TRANSFORMER-COUPLED CIRCUIT



## REGULATOR PULSE WIDTH MODULATOR

The KA3525A of pulse width modulator integrated circuit is designed to offer improved performance and lowered external parts count when used in designing all types of switching power supplies.
The on-chip +5.1 volt reference is trimmed to ±1% and the error amplifier has an input common-mode voltage range that includes the reference voltage, eliminating the need for external divider resistors.
A sync input to the oscillator allows multiple units to be slaved together or a single unit to be synchronized to an external system clock.
A single resistor between the $C_T$ and the discharge terminals provides a wide range of dead time adjustment.
This device also features built-in soft-start circuitry, requiring only an external timing capacitor.
A shutdown pin controls both the soft-start circuitry and the output stages, providing instantaneous turn off through the PWM latch with pulsed shutdown, as well as soft-start recycle with longer shutdown commands.
These functions are also controlled by an undervoltage lockout which keeps the outputs off and the soft-start capacitor discharged for subnormal input voltages.
Another feature of this PWM circuit is a latch following the comparator. Once a PWM pulse has been terminated for any reason, the outputs will remain off for the duration of the period.
The latch is reset with each clock pulse.
The output stages are totem-pole designs capable of sourcing or sinking in excess of 200mA.
The output stage of the KA3525A features NOR logic, giving a LOW output for an OFF state.

**16 DIP**



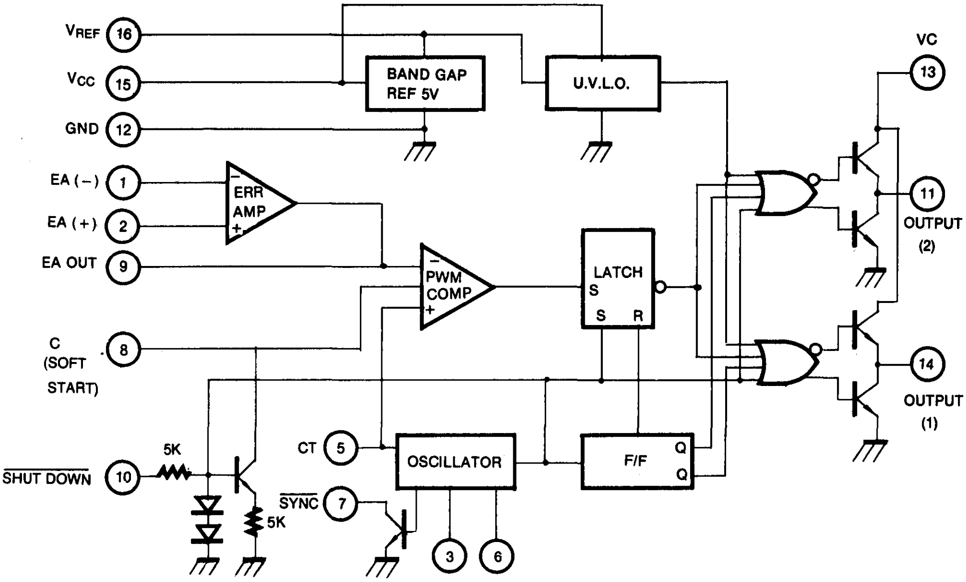
## ORDERING INFORMATION

| Device | Package | Operating Temperature |
|---|---|---|
| KA3525AN | 16 DIP | 0~+70°C |

## FEATURES

- **8.0 to 35V Operation**
- **5.1V±1.0% Trimmed Reference**
- **100Hz to 500KHz Oscillator Range**
- **Separate Oscillator Sync Pin**
- **Adjustable Dead Time Control**
- **Input Undervoltage Lockout with Hysteresis**
- **Latching PWM to Prevent Multiple Pulses**
- **Pulse-by-Pulse Shutdown**
- **Dual Source/Sink Output Drivers**
- **Internal Soft-Start**

## BLOCK DIAGRAM



## ABSOLUTE MAXIMUM RATINGS

| Characteristic | Symbol | Value | Unit |
|---|---|---|---|
| Power Supply Voltage | $V_{CC}$ | 40 | V |
| Collector Supply Voltage | $V_C$ | 40 | V |
| Output Current, Sink or Source | $I_O$ | 500 | mA |
| Reference Output Current | $I_{REF}$ | 50 | mA |
| Oscillator Charging Current | $I_{charge}$ | 5 | mA |
| Power Dissipation | $P_D$ | 1000 | mW |
| Operating Temperature | $T_{opr}$ | 0 ~ +70 | °C |
| Storage Temperature | $T_{stg}$ | −65 ~ +150 | °C |
| Lead Temperature (Soldering, 10 sec) | $T_{lead}$ | +300 | °C |

## ELECTRICAL CHARACTERISTICS

($V_{CC}$ = 20V, Ta = 0 ~ +70°C, unless otherwise specified)

| Characteristic | Symbol | Test Condition | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| **REFERENCE SECTION** | | | | | | |
| Reference Output Voltage | $V_{REF}$ | Tj = 25°C | 5.0 | 5.1 | 5.2 | V |
| Line Regulation | $\Delta V_{REF}$ | $V_{CC}$ = 8 to 35V | | 10 | 20 | mV |
| Load Regulation | $\Delta V_{REF}$ | $I_L$ = 0 to 20mA | | 20 | 50 | mV |
| Short Circuit Current | $I_{SC}$ | $V_{REF}$ = 0, Tj = 25°C | | 80 | 100 | mA |
| Total Output Variation (Note 1) | $\Delta V_{REF}$ | Line, Load and Temperature | 4.95 | | 5.25 | V |
| Temperature Stability (Note 1) | $\Delta V_{REF}/\Delta T$ | | | 20 | 50 | mV |
| Long Term Stability (Note 1) | $T_L$ | $T_j$ = 125°C, 1 KHrs | | 20 | 50 | mV |
| **OSCILLATOR SECTION** | | | | | | |
| Initial Accuracy (Note 1, 2) | | $T_j$ = 25°C | | ±2 | ±6 | % |
| Voltage Stability (Note 1, 2) | $\Delta f/\Delta V_{CC}$ | $V_{CC}$ = 8 to 35V | | ±1 | ±2 | % |
| Maximum Frequency | $f_{MAX}$ | $R_T$ = 2KΩ, $C_T$ = 470pF | 400 | | | KHz |
| Minimum Frequency | $f_{MIN}$ | $R_T$ = 200KΩ, $C_T$ = 0.1μF | | | 120 | Hz |
| Clock Amplitude (Note 1, 2) | | | 3 | 3.5 | | V |
| Clock Width (Note 1, 2) | | Tj = 25°C | 0.3 | 0.5 | 1 | μS |
| Sync Threshold | | | 1.2 | 2 | 2.8 | V |
| Sync Input Current | | Sync = 3.5V | | 1 | 2.5 | mA |

## ELECTRICAL CHARACTERISTICS

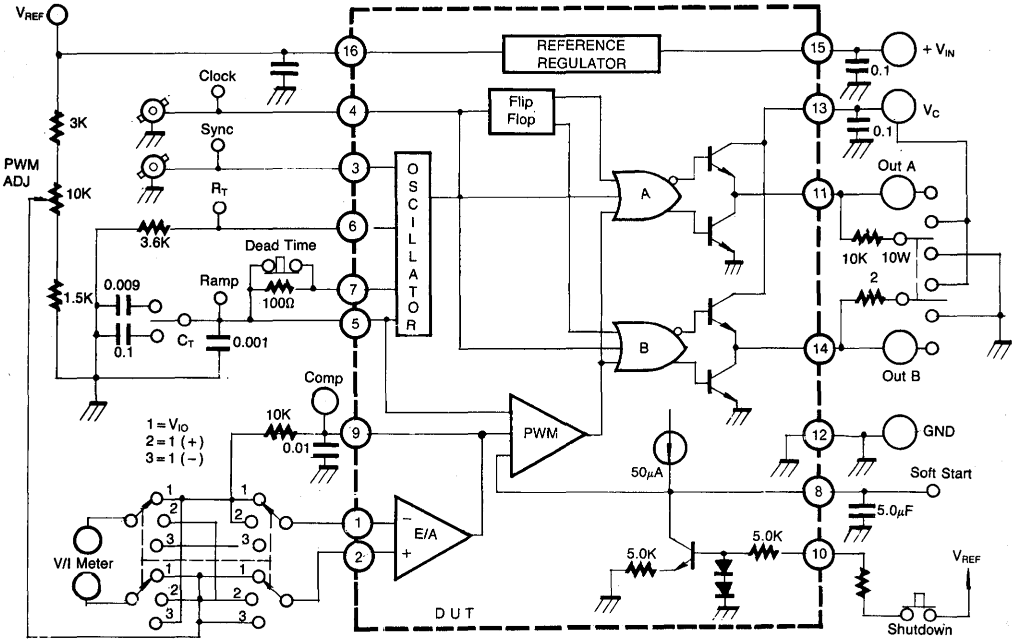
($V_{CC}=20V$, $Ta=0\sim+70°C$, unless otherwise specified)

| Characteristic | Symbol | Test Condition | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| **ERROR AMPLIFIER SECTION** ($V_{CM}=5.1V$) | | | | | | |
| Input Offset Voltage | $V_{IO}$ | | | 2 | 10 | mV |
| Input Bias Current | $I_{IB}$ | | | 1 | 10 | μA |
| Input Offset Current | $I_{IO}$ | | | | 1 | μA |
| DC Open Loop Gain | $A_{VO}$ | $R_L \geq 10M\Omega$ | 60 | 75 | | dB |
| Common Mode Rejection Ratio | CMRR | $V_{CM}=1.5$ to 5.2V | 60 | 75 | | dB |
| Power Supply Rejection Ratio | PSRR | $V_{CC}=8$ to 3.5V | 50 | 60 | | dB |
| **PWM COMPARATOR SECTION** | | | | | | |
| Minimum Duty Cycle | $D_{min}$ | | | | 0 | % |
| Maximum Duty Cycle | $D_{max}$ | | 45 | 49 | | % |
| Input Threshold Voltage (Note 2) | $V_{TH1}$ | Zero Duty Cycle | 0.7 | 0.9 | | V |
| Input Threshold Voltage (Note 2) | $V_{TH2}$ | Max Duty Cycle | | 3.3 | 3.6 | V |
| **SOFT-START SECTION** | | | | | | |
| Soft Start Current | $I_{soft}$ | $V_{SD}=0V$, $V_{SS}=0V$ | 25 | 50 | 80 | μA |
| Soft Start Low Level Voltage | | $V_{SD}=25V$ | | 0.4 | 0.7 | V |
| Shutdown Threshold Voltage | $Th_{SD}$ | | 0.6 | 0.8 | 1 | V |
| Shutdown Input Current | | $V_{SD}=2.5V$ | | 0.4 | 1 | mA |
| **OUTPUT SECTION** | | | | | | |
| Low Output Voltage I | $V_{OL\ I}$ | $I_{sink}=20mA$ | | 0.2 | 0.4 | V |
| Low Output Voltage II | $V_{OL\ II}$ | $I_{sink}=100mA$ | | 1 | 2 | V |
| High Output Voltage I | $V_{OH\ I}$ | $I_{source}=20mA$ | 18 | 19 | | V |
| High Output Voltage II | $V_{OH\ II}$ | $I_{source}=100mA$ | 17 | 18 | | V |
| Under Voltage Lockout | $V_{UV}$ | $V_8$ and $V_9=$ High | 6 | 7 | 8 | V |
| Collector Leakage Current | $I_{LKG}$ | $V_{CC}=35V$ | | | 200 | μA |
| Rise Time (Note 1) | $T_r$ | $C_L=1\mu F$, $T_j=25°C$ | | 100 | 600 | nS |
| Fall Time (Note 1) | $T_f$ | $C_L=1\mu F$, $T_j=25°C$ | | 50 | 300 | nS |
| **STANDBY CURRENT** | | | | | | |
| Supply Current | $I_S$ | $V_{CC}=35V$ | | 14 | 20 | mA |

(Note)

1. These parameters, although guaranteed over the recommended operating conditions, are not 100% tested in production
2. Tested at $f_{OSC}=40$ KHz ($R_T=3.6K$, $C_T=0.01\mu F$, $R_D=0\Omega$)

## Fig. 1. TEST CIRCUIT



## Fig. 2. KA3525AN OSCILLATOR

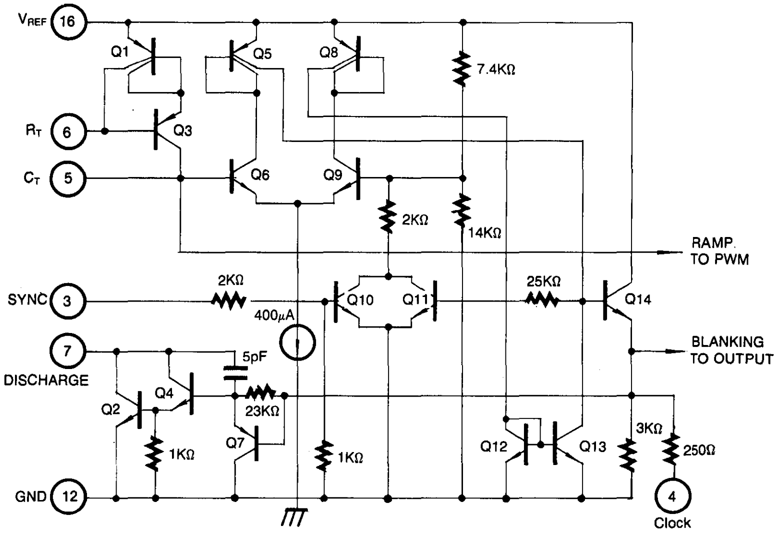
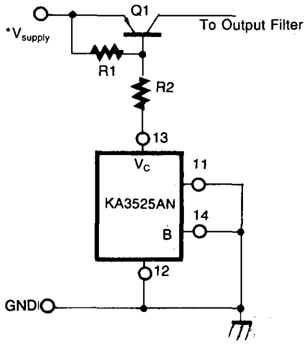
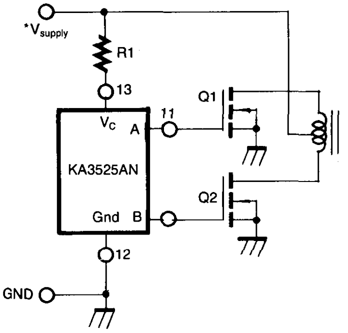


**Fig. 3 SINGLE ENDED SUPPLY**



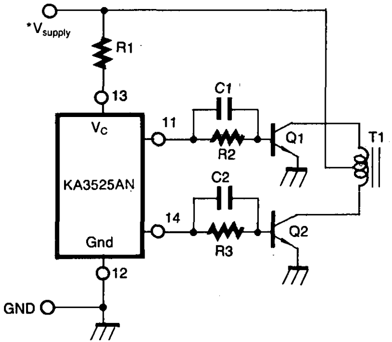
For single-ended supplies, the driver outputs are grounded. The $V_C$ terminal is switched to ground by the totem-pole source transistors on alternate oscillator cycles.

**Fig. 5 DRIVING POWER MOSFETS**



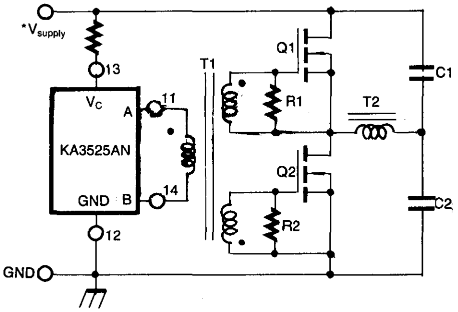
The low source impedance of the output drivers provides rapid charging of power FET input capacitance while minimizing external components.

**Fig. 4 PUSH-PULL CONFIGURATION**



In conventional push-pull bipolar designs, forward base drive is controlled by R1-R3. Rapid turn-off times for the power devices are achieved with speed-up capacitors C1 and C2.

**Fig. 6 DRIVING TRANSFORMER IN A HALF-BRIDGE CONFIGURATION**



Low power transformers can be driven directly by the KA3525A. Automatic reset occurs during deadtime, when both ends of the primary winding are switched to ground.

## PRINCIPLES OF OPERATION

### SHUTDOWN OPTIONS (See Block Diagram)

Since both the compensation and soft-start terminals (Pins 9 and 8) have current source pull-ups, either can readily accept a pull-down signal which only has to sink a maximum of 100$\mu$A to turn off the outputs. This is subject to the added requirement of discharging whatever external capacitance may be attached to these pins.

An alternate approach is the use of the shutdown circuitry of Pin 10 which has been improved to enhance the available shutdown options. Activating this circuit by applying a positive signal on Pin 10 performs two functions: the PWM latch is immediately set providing the fastest turn-off signal to the outputs; and a 150$\mu$A current sink begins to discharge the external soft-start capacitor. If the shutdown command is short, the PWM signal is terminated without significant discharge of the soft-start capacitor, thus, allowing, for example, a convenient implementation of pulse-by-pulse current limiting. Holding Pin 10 high for a longer duration, however, will ultimately discharge this external capacitor, recycling slow turn-on upon release.

Pin 10 should not be left floating as noise pickup could conceivably interrupt normal operation.

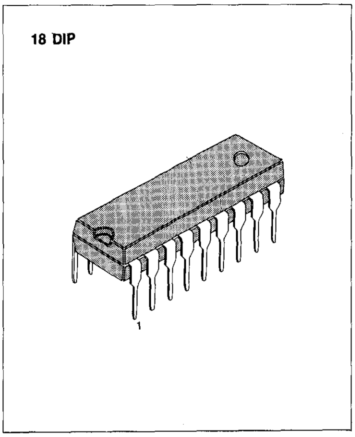
## REGULATOR PULSE WIDTH MODULATOR

The KA3526B is a high performance pulse width modulator integrated circuit intended for fixed frequency switching regulators and other power control applications.

Functions included in this IC are temperature compensated voltage reference, sawtooth oscillator, error amplifier, pulse width modulator, pulse metering and steering logic, and two low impedance power drivers.

Also included are protective features such as soft-start and under-voltage lockout, digital current limiting, double pulse inhibit, a data latch for single pulse metering, adjustable deadtime, and provision for symmetry correction inputs.

All digital control parts are TTL and B-series CMOS compatible. Active low logic design allows easy wired-OR connections for maximum flexibility. This versatible device can be used to implement single-ended or push-pull switching regulator of either polarity, both transformerless and transformer coupled. The KA3526B is characterized for operation from 0°C to +70°C.



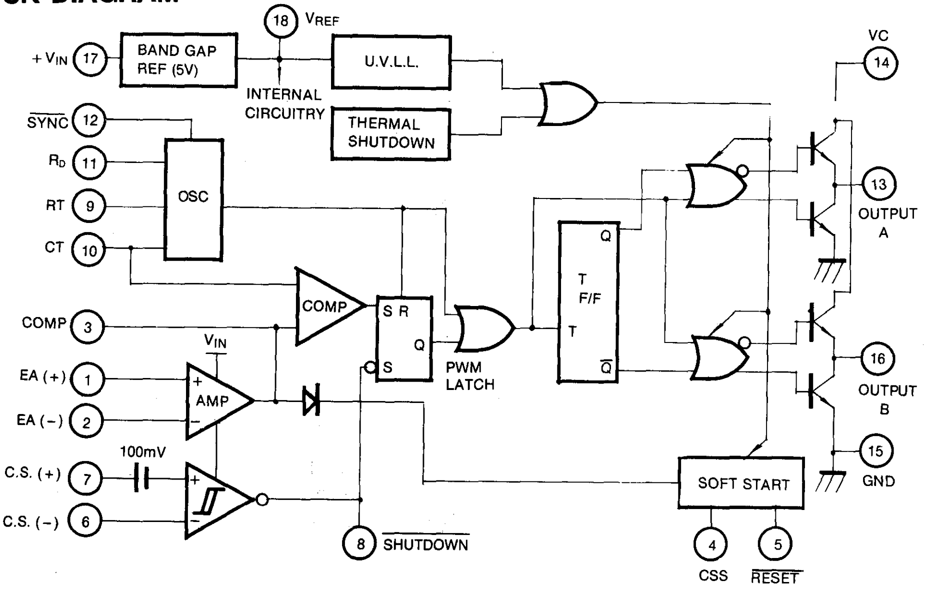
## FEATURES

- **8 to 35V Operation**
- **5V Bandgap Reference Trimmed to ±1%**
- **1Hz to 650KHz Oscillator Range**
- **Dual 100mA Source/Sink Outputs**
- **Programmable Dead Time**
- **Under-Voltage Lockout**
- **Single Pulse Metering**
- **Programmable Soft-Start**
- **Wide Current Limit Common Mode Range**
- **TTL/CMOS Compatible Logic Parts**
- **Symmetry Correction Capability**
- **Digital Current Limiting**

## ORDERING INFORMATION

| Device | Package | Operating Temperature |
|---|---|---|
| KA3526BN | 18 DIP | 0~+70°C |

## BLOCK DIAGRAM



## ABSOLUTE MAXIMUM RATINGS

| Characteristic | Symbol | Value | Unit |
|---|---|---|---|
| Power supply voltage | $V_{CC}$ | 40 | V |
| Collector Supply Voltage | $V_C$ | 40 | V |
| Output Current, Sink or Source | $I_O$ | 200 | mA |
| Reference Load Current | $I_{REF}$ | 50 | mA |
| Power Dissipation | $P_D$ | 1000 | mW |
| Operating Temperature | $T_{opr}$ | 0 ~ +70 | °C |
| Storage Temperature | $T_{stg}$ | −65 ~ +150 | °C |
| Lead Temperature (Soldering, 10 sec) | $T_{lead}$ | +300 | °C |

## ELECTRICAL CHARACTERISTICS

($V_{CC}$ = 15V, Ta = 0 ~ +70°C, unless otherwise specified)

| Characteristic | Symbol | Test Condition | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| **REFERENCE SECTION ($I_L$ = 0mA)** | | | | | | |
| Reference Output Voltage | $V_{REF}$ | $T_j$ = 25°C | 4.9 | 5.0 | 5.1 | V |
| Line Regulation | $\Delta V_{REF}$ | $V_{CC}$ = 7 to 35V | | 2.0 | 15 | mV |
| Load Regulation | $\Delta V_{REF}$ | $I_L$ = 0 to 20mA | | 5.0 | 20 | mV |
| Temperature Stability (Note) | $\Delta V_{REF}/\Delta Tj$ | $T_j$ = 0 to +70°C | | 15 | 50 | mV |
| Output Voltage Range(Note) | $\Delta V_{REF}$ | | 4.85 | 5.0 | 5.15 | V |
| Short-Circuit Output Current | $I_{SC}$ | $V_{REF}$ = 0V | 25 | 50 | 100 | mA |
| **UNDER-VOLTAGE LOCKOUT SECTION** | | | | | | |
| $\overline{\text{RESET}}$ Output Voltage | $V_{\overline{RESET}}$ | $V_{REF}$ = 3.8V | | 0.2 | 0.4 | V |
| $\overline{\text{RESET}}$ Output Voltage | $V_{\overline{RESET}}$ | $V_{REF}$ = 4.7V | 2.4 | 4.8 | | V |
| **OSCILLATOR SECTION ($f_{osc}$ = 40KHz; $R_T$ = 4.12KΩ ± 1%, $C_T$ = 0.01μF ± 1%, $R_D$ = 0Ω)** | | | | | | |
| Initial Accuracy | | $T_j$ = 25°C | | ±3 | ±8 | % |
| Frequency Change with Voltage | $\Delta f/\Delta V_{CC}$ | $V_{CC}$ = 7 to 35V | | 0.5 | 1.0 | % |
| Frequency Change with Temperature (Note) | $\Delta f/\Delta T_j$ | $T_j$ = 0 to 70°C | | 1.0 | 3.0 | % |
| Minimum Frequency | $f_{min}$ | $R_T$ = 150KΩ, $C_T$ = 20μF | | | 1.0 | Hz |
| Maximum Frequency | $f_{max}$ | $R_T$ = 2KΩ, $C_T$ = 470pF | 550 | 650 | | KHz |
| Sawtooth Peak Voltage | $V_p$ | $V_{CC}$ = 35V | | 3.0 | 3.5 | V |
| Sawtooth Valley Voltage | $V_V$ | $V_{IN}$ = 7V | 0.5 | 1.0 | | V |
| SYNC Pulse Width | PW | $R_L$ = 2.7KΩ to $V_{ref}$, $T_j$ = 25°C | | 1.1 | | μS |

## ELECTRICAL CHARACTERISTICS ($V_{IN}=15V$, $T_a=0\sim+70°C$, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| **ERROR AMPLIFIER SECTION ($V_{CM}=0$ to 5.2V)** | | | | | | |
| Input Offset Voltage | $V_{IO}$ | $R_S \leq 2K\Omega$ | | 2.0 | 10 | mV |
| Input Bias Current | $V_{IB}$ | | | -350 | -2000 | nA |
| Input Offset Current | $I_{IO}$ | | | 35 | 200 | nA |
| DC Open Loop Gain | $A_V$ | $R1 \geq 10M\Omega$, $T_j=25°C$ | 60 | 72 | | dB |
| High Output Voltage | $V_{OH}$ | $V_{pin1}-V_{pin2} \geq 0.15V$<br>$I_{source}=100\mu A$ | 3.6 | 4.2 | | V |
| Low Output Voltage | $V_{OL}$ | $V_{pin2}-V_{pin1} \geq 0.15V$<br>$I_{sink}=100\mu A$ | | 0.2 | 0.4 | V |
| Common Mode Rejection Ratio | CMRR | $R_S \leq 2K\Omega$ | 70 | 94 | | dB |
| Supply Voltage Rejection Ratio | PSRR | $V_{CC}=12$ to 18V | 66 | 80 | | dB |
| **PWM COMPARATOR SECTION ($f_{OSC}=40KHz$; $R_T=4.12K\Omega \pm 1\%$, $C_T=0.01\mu F \pm 1\%$, $R_D=0\Omega$)** | | | | | | |
| Minimum Duty Cycle | $D_{min}$ | $V_{pin3}=0.4V$ | | | 0 | % |
| Maximum Duty Cycle | $D_{max}$ | $V_{pin3}=3.6V$ | 45 | 49 | | % |
| **DIGITAL PORTS (SYNC, SHUTDOWN and RESET)** | | | | | | |
| High Output Voltage | $V_{OH}$ | $I_{source}=40\mu A$ | 2.4 | 4.0 | | V |
| Low Output Voltage | $V_{OL}$ | $I_{sink}=3.6mA$ | | 0.2 | 0.4 | V |
| High Input Current | $I_{IH}$ | $V_{IH}=2.4V$ | | -125 | -200 | μA |
| Low Input Current | $I_{IL}$ | $V_{IL}=0.4V$ | | -225 | -360 | μA |
| Shutdown Delay | $S_D$ | From Pin 8, $T_j=25°C$ | | 160 | | ns |
| **CURRENT LIMIT COMPARATOR SECTION ($V_{CM}=0$ to 12V)** | | | | | | |
| Sense Voltage | $V_S$ | $R_S \leq 50\Omega$, $T_j=25°C$ | 80 | 100 | 120 | mV |
| Input Bias Current | $I_{IB}$ | | | -3.0 | -10 | μA |
| **SOFT-START SECTION** | | | | | | |
| Error Clamp Voltage | $V_{EC}$ | $V_{pin5}=0.4V$ | | 0.1 | 0.4 | V |
| $C_S$ Charging Current | $I_{CS}$ | $V_{pin5}=2.4V$ | 50 | 100 | 150 | μA |
| **OUTPUT DRIVERS (Each Output) ($V_C=15V$)** | | | | | | |
| High Output Voltage I | $V_{OH}I$ | $I_{source}=20mA$ | 12.5 | 13.5 | | V |
| High Output Voltage II | $V_{OH}II$ | $I_{source}=100mA$ | 12 | 13 | | V |
| Low Output Voltage I | $V_{OL}I$ | $I_{sink}=20mA$ | | 0.2 | 0.3 | V |
| Low Output Voltage II | $V_{OL}II$ | $I_{sink}=100mA$ | | 1.2 | 2.0 | V |
| Collector Leakage Current | $I_{LKG}$ | $V_C=40V$ | | 50 | 150 | μA |
| Rise Time | $T_R$ | $C_L=1nF$ | | 0.3 | 0.6 | μS |
| Fall Time | $T_F$ | $C_L=1nF$ | | 0.1 | 0.2 | μS |
| Cross Conduction Charge | $C_C$ | Per Cycle, $T_j=25°C$ | | 8 | | nC |
| **POWER CONSUMPTION SECTION ($V_{CC}=35V$, $T_T=4.12K\Omega$)** | | | | | | |
| Standby Current | $I_{CC}$ | $V_{pin8}=0.4V$ | | 14 | 25 | mA |

NOTE

•These parameters although guaranteed over the recommended operating conditions are not 100% tested in production.

# APPLICATION INFORMATION

## VOLTAGE REFERENCE

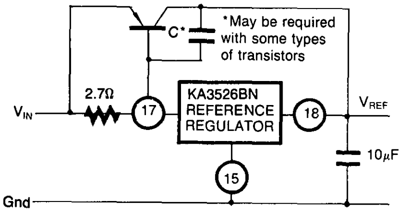
The reference regulator of the KA3526B is based on a temperature compensated zener diode. The circuitry is fully active at supply voltages above +8 volts, and provides up to 20mA of load current to external circuitry at +5.0 volts.

In systems where additional current is required, an external PNP transistor can be used to boost the available current. A rugged low frequency audio-type transistor should be used, and lead lengths between the PWM and transmitter should be as short as possible to minimize the risk of oscillations.

Even so, some types of transistors may require collector-base capacitance for stability.

Up to 1 amp of load current can be obtained with excellent regulation if the device selected maintains high current gain.

Fig. 1
EXTENDING REFERENCE OUTPUT CURRENT



## UNDER-VOLTAGE LOCKOUT

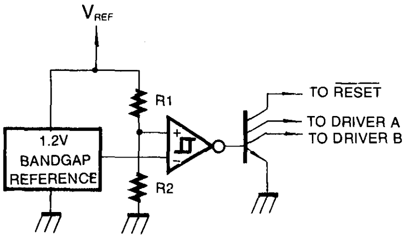
The under-voltage lockout circuit protects the KA3526B and the power devices it controls from inadequate supply voltage. If $+V_{IN}$ is too low, the circuit disables the output drivers and hold $\overline{\text{RESET}}$ pin LOW. This prevents spurious output pulses while the control circuitry is stabilizing, and holds the soft-start timing capacitor in a discharged state.

The circuit consists of a +1.2 volt bandgap reference and comparator circuit which is active when the reference voltage has risen to 3 $B_{BE'}$ or +1.8 volts at 25°C. When the reference voltage rises to approximately +4.4 volts, the circuit enables the output drivers and release the $\overline{\text{RESET}}$ pin, allowing a normal soft-start. The comparator has 200mV of hysteresis to minimize oscillation at the trip point.

When $+V_{IN}$ to the PWM is removed and the reference drops to +4.2 volts, the under-voltage circuit pulls $\overline{\text{RESET}}$ Low gain.

The soft-start capacitor is immediately discharged, and the PWM is ready for another soft-start cycle. The KA3526B can operate from a +5 volt supply by connecting the $V_{ref}$ pin to the $+V_{IN}$ pin and maintaining the supply between +4.8 and +5.2 volts.

Fig. 2
SIMPLIFIED UNDER-VOLTAGE LOCKOUT

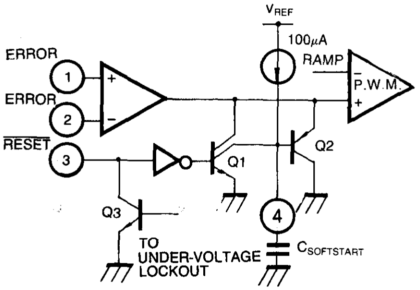


## SOFT-START CIRCUIT

The soft-start circuit protects the power transistors and rectifier diodes from high current surges during power supply turn-on. When supply voltage is first applied to the KA3526B, the under-voltage lockout circuit holds $\overline{\text{RESET}}$ LOW with Q3. Q1 is turned on, which holds the soft-start capacitor voltage at zero.

The second collector of Q1 clamps the output of the error amplifier to ground, guaranteeing zero duty cycle at the driver outputs. When the supply voltage reaches normal operating range, $\overline{\text{RESET}}$ will go high. Q1 turn off, allowing the internal 100μA current source to charge $C_S$. Q2 clamps the error amplifier output $IV_{BE}$ above the voltage on $C_S$. As the soft-start voltage ramps up to +5V, the duty cycle of the PWM linearly increases to whatever value the voltage regulation loop requires for an error rull.

Fig. 3
SOFT-START CIRCUIT SCHEMATIC



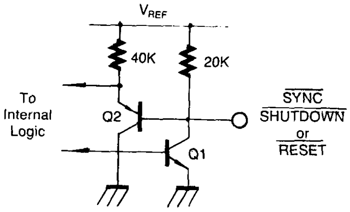
## DIGITAL CONTROL PARTS

The three digital control ports of the KA3526B are bi-directional. Each pin can drive TTL and 5V CMOS logic directly, up to a fan-out of 10 low-power schottky gates. Each pin can also be directly driven by open-collector TTL, open-drain CMOS, and open-collector voltage comparators; fan-in is equivalent to 1 low-power schottky gate. Each port is normally HIGH; the pin is pulled LOW to activate the particular function.

Driving $\overline{\text{SYNC}}$ LOW initiates a discharge cycle in the oscillator. Pulling $\overline{\text{SHUTDOWN}}$ LOW immediately inhibits all PWM output pulses. Holding $\overline{\text{RESET}}$ LOW discharges the soft-start capacitor. The logic threshold + 1.1 volts at + 25°C. Noise immunity can be gained at the expense of fan-out with an external 2K pull-up resistor to + 5 volts.

Fig. 4

DIGITAL CONTROL PORT SCHEMATIC



## OSCILLATOR

The oscillator is programmed for frequency and dead time with three components: $R_T$, $C_T$ and $R_D$. Two waveforms are generated: a sawtooth waveform at pin 10 for pulse width modulation, and a logic clock at pin 12.

The following procedure is recommended for choosing timing values:

1. Remember that the frequency at each driver output is half the oscillator frequency, and the frequency at the $+V_C$ terminal is the same as the oscillator frequency.
2. If more dead time is required, select a large value of $R_D$. At 40KHz dead time increases by 400nS/Ω.
3. Increasing the dead time will cause the oscillator frequency to decrease slightly.
   Go back and decrease the value of $R_T$ slightly to bring the frequency back to the design value.

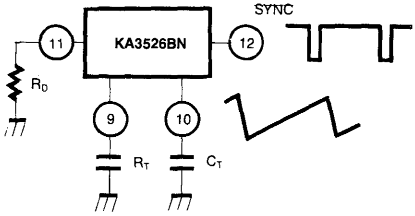
The KA3526B can be synchronized to an external logic clock by programming the oscillator to free-run at a frequency 10% slower than the sync frequency. A periodic LOW logic pulse approximately 0.5μS wide at the $\overline{\text{SYNC}}$ pin will then lock the oscillator to the external frequency.

Multiple devices can be synchronized together by programming one master unit for the desired frequency, and then sharing its sawtooth and clock waveforms with the slave units.

All $C_T$ terminals are connected to the $\overline{\text{SYNC}}$ pin of the master, and all $\overline{\text{SYNC}}$ terminals are likewise connected to the $\overline{\text{SYNC}}$ pin of the master. Slave $R_T$ terminals are left open or connected to $V_{REF}$. Slave $R_D$ terminals may be either left open or grounded.

Fig. 5

OSCILLATOR CONNECTIONS AND WAVEFORMS

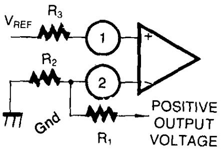


## ERROR AMPLIFIER

The error amplifier is a transconductance design, with an output impedance of 2 megaohms. Since all voltage gain takes places at the output pin, the open-loop gain/frequency characteristics can be controlled with shunt reactance to ground. When compensated for unity-gain stability with 100pF, the amplifier has an open-loop pole at 400Hz. The input connections to the error amplifier are determined by the polarity of the switching supply output voltage. For positive supplies, the common-mode voltage is + 5.0 volts and the feedback connections in Fig. 6A are used. With negative supplies, the common-mode voltage is ground and the feedback divider is connected between the negative output and + 5.0 volt reference voltages, as shown in Fig. 6B.

Fig. 6 A

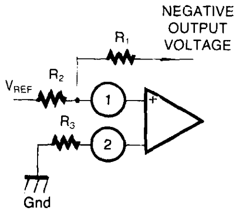
ERROR AMPLIFIER CONNECTIONS



$V_{OUT} = V_{REF}\ \frac{R_1 + R_2}{R_2}$

$R_3 = \frac{R_1 R_2}{R_1 + R_2}$

Fig. 6B



$V_{OUT} = V_{REF}\ \frac{R_1}{R_2}$

$R_3 = \frac{R_1 R_2}{R_1 + R_2}$

## OUTPUT DRIVERS

The totem-pole output drivers of the KA3526B are designed to source and sink 100mA continuously and 200mA peak. Loads can be driven either from the output pins 13 and 16, or from the +V_C pin, as required.
Since the bottom transistor of the totem-pole is allowed to saturate, there is momentary conduction path from the +V_C terminal to ground during switching. To limit the resulting current spikes a small resistor in series with pin 14 is always recommended. The resistor value is determined by the driver supply voltage, and should be chosen for 200mA peak currents, as shown in Fig. 9.

Fig. 7. PUSH-PULL CONFIGURATION

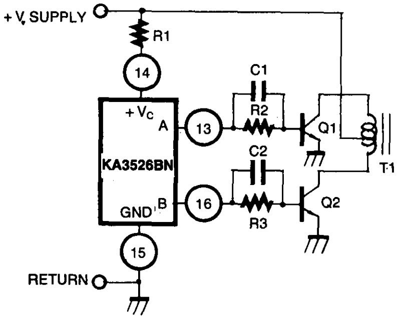


Fig. 8. SINGLE-ENDED CONFIGURATION

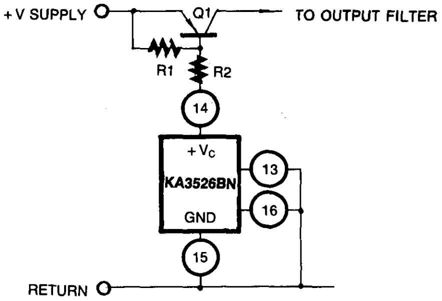
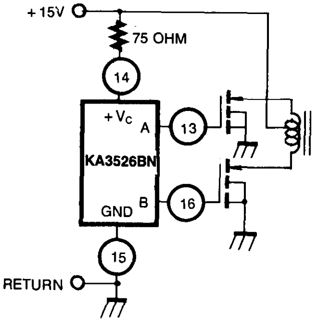


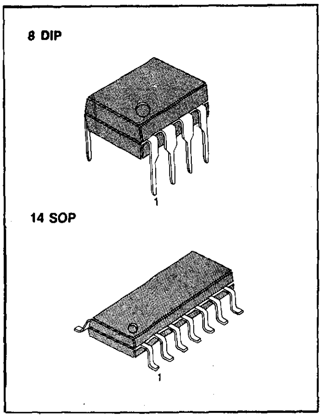
Fig. 9. DRIVING N-CHANNEL POWER MOSFETS



## CURRENT MODE PWM CONTROLLER

The KA3842 is fixed frequency current-mode PWM controller. It is specially designed for Off-Line and DC-to-DC converter applications with minimal external components. This integrated circuit features a trimmed oscillator for precise duty cycle control, a temperature compensated reference, high gain error amplifier, current sensing comparator, and a high current totempole output ideally suited for driving a power MOSFET.

Protection circuitry includes built in under-voltage lockout and current limiting.



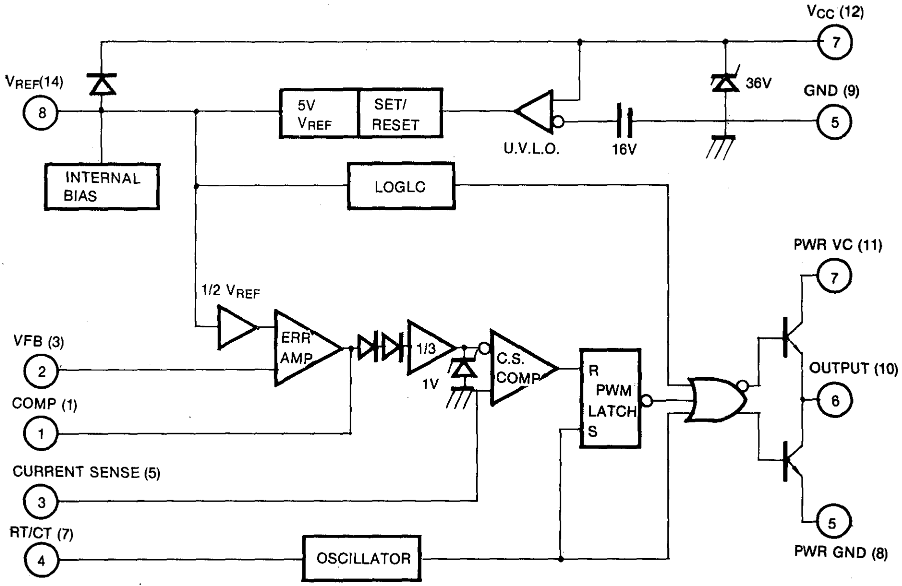
## FEATURES

- **Automatic feed forward compensation**
- **Optimized for off-line converter**
- **Double pulse suppression**
- **Current mode operation to 500KHz**
- **High gain totempole output**
- **Internally trimmed bandgap reference**
- **Undervoltage lockout with hysteresis**
- **Low start up current**

## ORDERING INFORMATION

| Device | Package | Operating Temperature |
|---|---|---|
| KA3842N | 8 DIP | 0~ +70°C |
| KA3842D | 14 SOP | 0~ +70°C |

## BLOCK DIAGRAM



* ( ) IS 14SOIC PIN NO

## ABSOLUTE MAXIMUM RATINGS

| Characteristic | Symbol | Value | Unit |
|---|---|---|---|
| Supply Voltage | $V_{CC}$ | 30 | V |
| Output Current | $I_O$ | ±1 | A |
| Analog Inputs | $V_{IN}$ | $-0.3$ to $V_{CC}$ | V |
| Error Amp Output Sink Current | $I_{sink}$ | 10 | mA |
| Power Dissipation | $P_D$ | 1 | W |

## ELECTRICAL CHARACTERISTICS

(*$V_{CC} = 15V$, $R_T = 10K\Omega$, $C_T = 3.3nF$, $0 \leq T_A \leq 70°C$, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| **REFERENCE SECTION** | | | | | | |
| Output Voltage | $V_{REF}$ | $T_j = 25°C$, $I_O = 1mA$ | 4.90 | 5.00 | 5.10 | V |
| Line Regulation | $\triangle V_O$ | $12V \leq V_{CC} \leq 25V$ | | 6 | 20 | mV |
| Load Regulation | $\triangle V_O$ | $1mA \leq I_O \leq 20mA$ | | 6 | 25 | mV |
| Output Short Circuit | $I_{OSC}$ | $T_A = 25°C$ | | −85 | −180 | mA |
| **OSCILLATOR SECTION** | | | | | | |
| Nominal Frequency | $F_{OSC}$ | $T_j = 25°C$ | 47 | 52 | 57 | KHz |
| Voltage Stability | $S_V$ | $12V \leq V_{CC} \leq 25V$ | | 0.2 | 1 | % |
| Amplitude | $V_{OSC}$ | | | 1.7 | | $V_{p\text{-}p}$ |
| **ERROR AMPLIFIER SECTION** | | | | | | |
| Input Bias Current | $I_{BI}$ | | | −0.3 | −2 | μA |
| Input Voltage | $V_{IN}$ | $V_{PIN1} = 2.5V$ | 2.42 | 2.50 | 2.58 | V |
| Open Loop Gain | $A_{VOL}$ | $2V \leq V_O \leq 4V$ | 65 | 90 | | dB |
| Power Supply Rejection Ratio | $PSRR_{EA}$ | $12V \leq V_{CC} \leq 25V$ | 60 | 70 | | dB |
| Output Sink Current | $I_{SI}$ | $V_{PIN2} = 2.7V$, $V_{PIN1} = 1.1V$ | 2 | 6 | | mA |
| Output Source Current | $I_{SO}$ | $V_{PIN2} = 2.3V$, $V_{PIN1} = 5V$ | −0.5 | −0.8 | | mA |
| V Out High | $V_{OH}$ | $V_{PIN2} = 2.3V$, $R_L = 15K\Omega$ to GND | 5 | 6 | | V |
| V Out Low | $V_{OL}$ | $V_{PIN2} = 2.7V$, $R_L = 15K\Omega$ to Pin 8 | | 0.8 | 1.1 | V |
| **CURRENT SENSE SECTION** | | | | | | |
| Gain | G | (Note 1 & 2) | 2.85 | 3 | 3.15 | V/V |
| Maximum Input Signal | $V_{MAX}$ | $V_{PIN1} = 5V$ (Note 1) | 0.9 | 1 | 1.1 | V |
| Power Supply Rejection Ratio | $PSRR_{SC}$ | $12V \leq V_{CC} \leq 25V$ (Note 1) | | 70 | | dB |
| Input Bias Current | $I_{B2}$ | | | −2 | −10 | μA |

## ELECTRICAL CHARACTERISTICS (Continued)

| Characteristic | Symbol | Test Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| **OUTPUT SECTION** | | | | | | |
| Output Low Level | $V_{OL}$ | $I_{sink} = 20mA$ | | 0.1 | 0.4 | V |
| | | $I_{sink} = 200mA$ | | 1.5 | 2.2 | V |
| Output High Level | $V_{OH}$ | $I_{source} = 20mA$ | 13 | 13.5 | | V |
| | | $I_{source} = 200mA$ | 12 | 13.5 | | V |
| Rise Time | $T_r$ | $T_j = 25°C$, $C_L = 1nF$ (Note 3) | | 50 | 150 | nS |
| Fall Time | $T_f$ | $T_j = 25°C$, $C_L = 1nF$ (Note 3) | | 50 | 150 | nS |
| **UNDER-VOLTAGE LOCKOUT SECTION** | | | | | | |
| Start Threshold | $V_{thH}$ | | 14.5 | 16 | 17.5 | V |
| Minimum Operating Voltage | $V_{thL}$ | After Turn On | 8.5 | 10 | 11.5 | V |
| **TOTAL STANDBY CURRENT** | | | | | | |
| Start-Up Current | $I_{st}$ | | | 0.5 | 1 | mA |
| Operating Supply Current | $I_{CC}$ | $V_{PIN2} = V_{PIN3} = 0V$ | | 11 | 17 | mA |
| Zener Voltage | $V_Z$ | $I_{CC} = 25mA$ | 30 | 36 | | V |

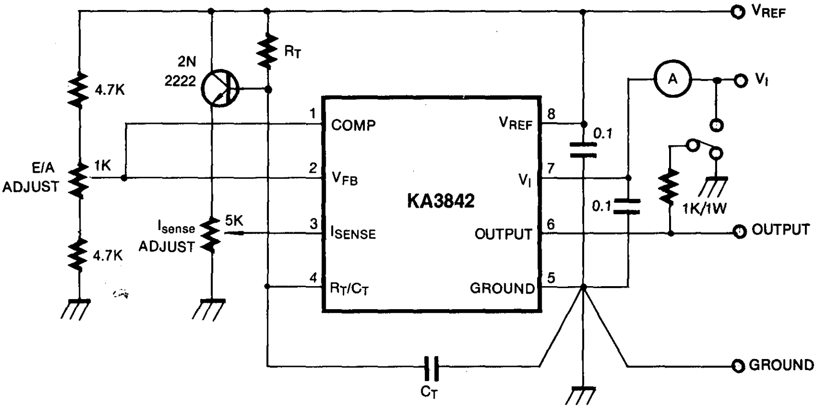
* Adjust $V_{CC}$ above the start threshold before setting at 15V

Note 1. Parameter measured at trip point of latch with $V_{PIN2} = 0$

2. Gain defined as: $A = \frac{\triangle V_{PIN1}}{\triangle V_{PIN3}}$; $0 \leq V_{PIN3} \leq 0.8V$

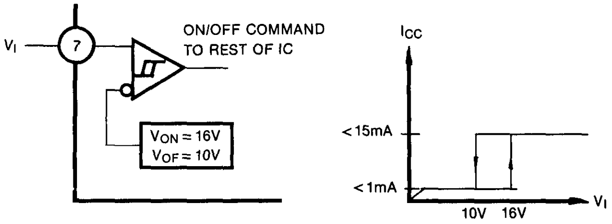
3. These parameters, although guaranteed, are not 100% tested in production.

**Fig. 1 Open Loop Test Circuit**



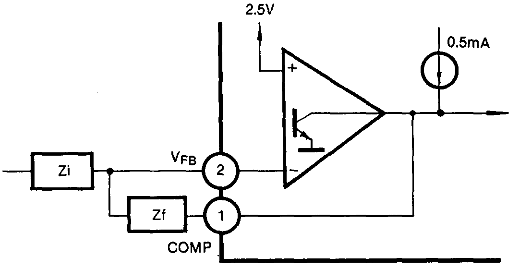
High peak currents associated with capacitive loads necessitate careful grounding techniques Timing and bypass capacitors should be connected close to pin 5 in a single point ground. The transistor and 5KΩ potentiometer are used to sample the oscillator waveform and apply an adjustable ramp to pin 3.

**Fig. 2 Under Voltage Lockout**



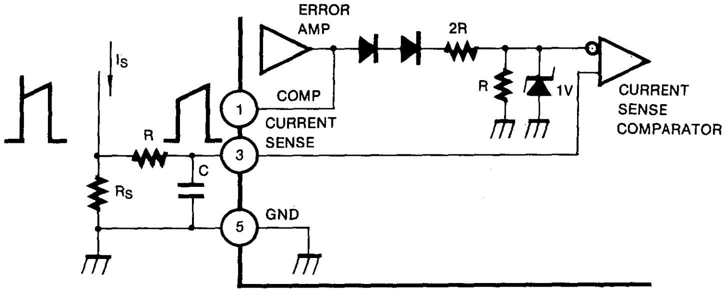
During Under-Voltage Lock-Out, the output driver is biased to a high impedance state. Pin 6 should be shunted to ground with a bleeder resistor to prevent activating the power switch with output leakage current.

**Fig. 3 Error Amp Configuration**



Error amp can source or sink up to 0.5mA

Fig. 4 Current Sense Circuit

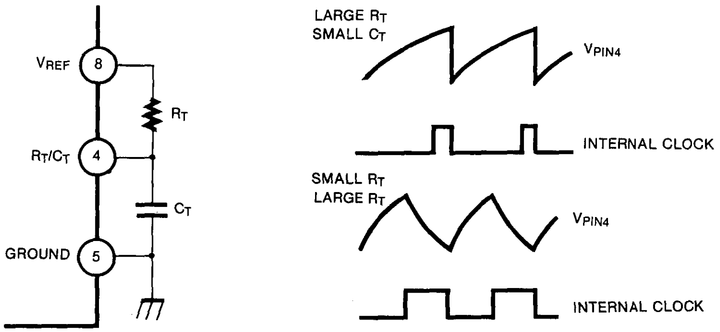


Peak current ($I_S$) is determined by the formula:

$$I_{Smax} \approx \frac{1.0V}{R_S}$$

A small RC filter may be required to suppress switch transients.

**Fig. 5 Oscillator Waveforms and Maximum Duty Cycle**



Oscillator timing capacitor, $C_T$, is charged by $V_{REF}$ through $R_T$, and discharged by an internal current source. During the discharge time, the internal clock signal blanks the output to the low state. Selection of $R_T$ and $C_T$ therefore determines both oscillator frequency and maximum duty cycle. Charge and discharge times are determined by the formulas:

$$t_c \approx 0.55\ R_T\ C_T$$

$$t_d \approx R_T\ C_T\ ln(\frac{0.0063\ R_T - 2.7}{0.0063\ R_T - 4})$$

Frequency, then, is: $f = (t_c + t_d)^{-1}$

For $R_T > 5K\Omega$, $f \approx \frac{1.8}{R_T\ C_T}$

**Fig. 6 Oscillator Dead Time & Frequency**

DEADTIME vs $C_T$ ($R_T$>5K)

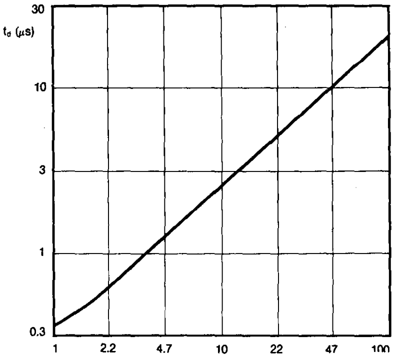


**Fig. 7 Timing Resistance vs Frequency**

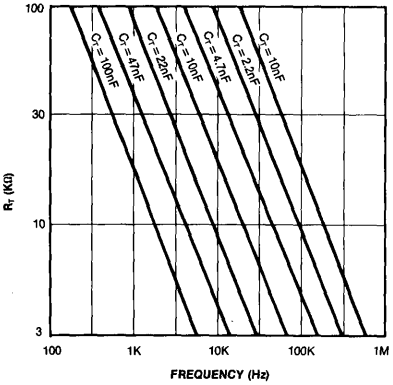
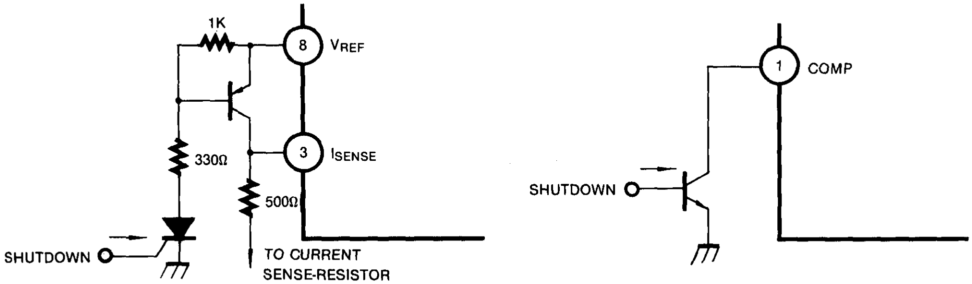
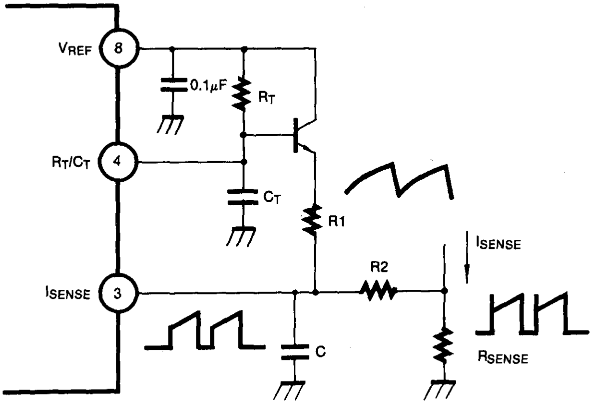


**Fig. 8 Shutdown Techniques**



Shutdown of the KA3842 can be accomplished by two methods; either raise pin 3 above 1V or pull pin 1 below a voltage two diode drops above ground. Either method causes the output of the PWM comparator to be high (refer to block diagram). The PWM latch is reset dominant so that the output will remain low until the next clock cycle after the shutdown condition at pins 1 and/or 3 is removed. In one example, an externally latched shutdown may be accomplished by adding an SCR which will be reset by cycling $V_{CC}$ below the lower UVLO threshold. At this point the reference turns off, allowing the SCR to reset.

**Fig. 9 Slope Compensation**



A fraction of the oscillator ramp can be resistively summed with the current sense signal to provide slope compensation for converters requiring duty cycles over 50%.

Note that capacitor, C, forms a filter with R2 to suppress the leading edge switch spikes.

**Fig. 10 Output Saturation Characteristics**

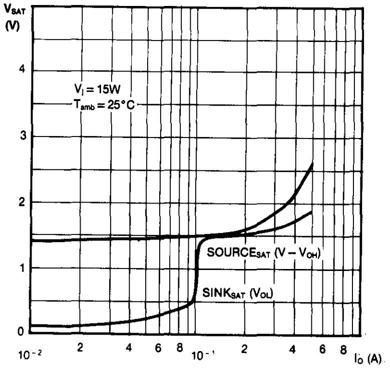


**Fig. 11 Error Amplifier Open Loop Frequency Response**

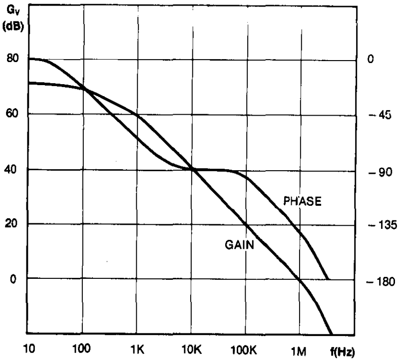
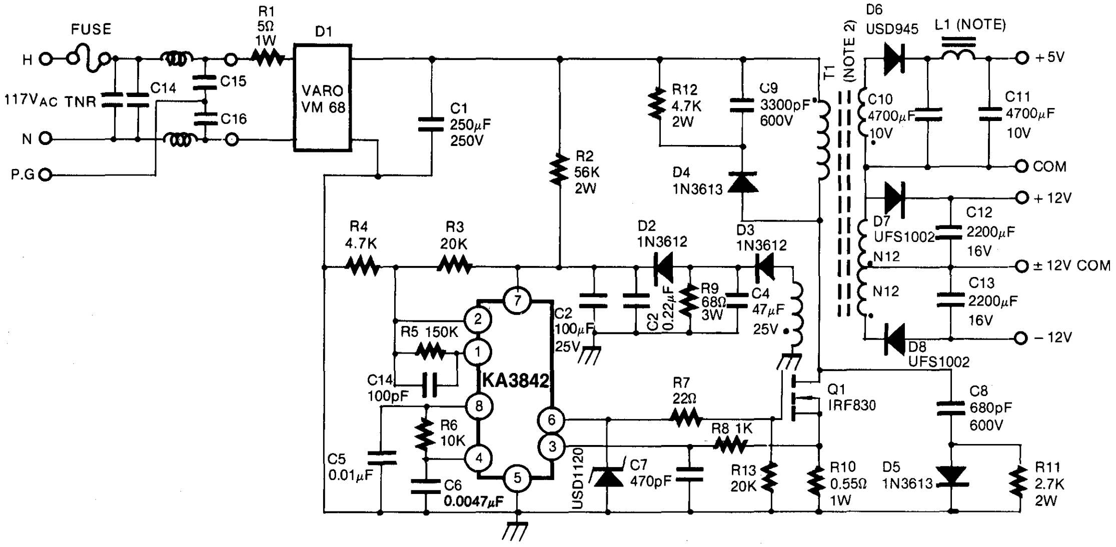


**Fig. 12 25W Off-Line Flyback Converter**



Power Supply Specifications

| | |
|---|---|
| 1. Input Voltage: | 95VAC to 130VAC (50Hz/60Hz) |
| 2. Line Isolation: | 3750V |
| 3. Switching Frequency: | 40KHz |
| 4. Efficiency @ Full Load: | 70% |

Note: T1-Primary: 35 Turns #26 AWG
Secondary ±12V: 7 turns #30 AWG (2 strands)
Bifiliar wound
Secondary 5.0V: 3 turns (six strands)
#26 Hexfiliar wound
Secondary Feedback: 8 turns #30 AWG
(2 strands) Bifliar wound
Core: TDK EI-28
Bobbin: TDK EI-28
Gap: 0.2mm for a primary
inductance of 1.0mH
L1-15μH

5. Output Voltage:
A. +5V, ±5%: 1A to 4A load
Ripple voltage: 50mV P-P Max.
B. +12V, ±3%: 0.1A to 0.3A load
Ripple voltage: 100mV P-P Max.
C. −12V, ±3%: 0.1A to 0.3A load
Ripple voltage: 100mV P-P Max.

## CURRENT MODE PWM CONTROLLER

The KA3846 control IC provides all of the necessary features to implement fixed frequency, current mode control schemes while maintaining a minimum external parts count.

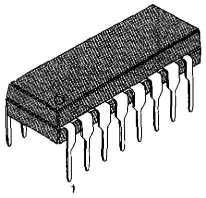
The superior performance of this technique can be measured in improved line regulation, enhanced load response characteristics, and a simpler, easier-to-design control loop. Topological advantages include inherent pulse-by-pulse current limiting capability, automatic symmetry correction for push-pull converters, and the ability to parallel "power module" while maintaining equal current sharing.

Protection circuitry includes built-in-under-voltage lockout and programmable current limit in addition to soft-start capability. A shutdown function is also available which can initiate either a complete shutdown with automatic restart or latch the supply off.

Other features include fully latched operation, double pulse suppression, deadtime adjust capability, and ±1% trimmed bandgap reference.

The KA3846 features low outputs in the OFF state.

16 DIP



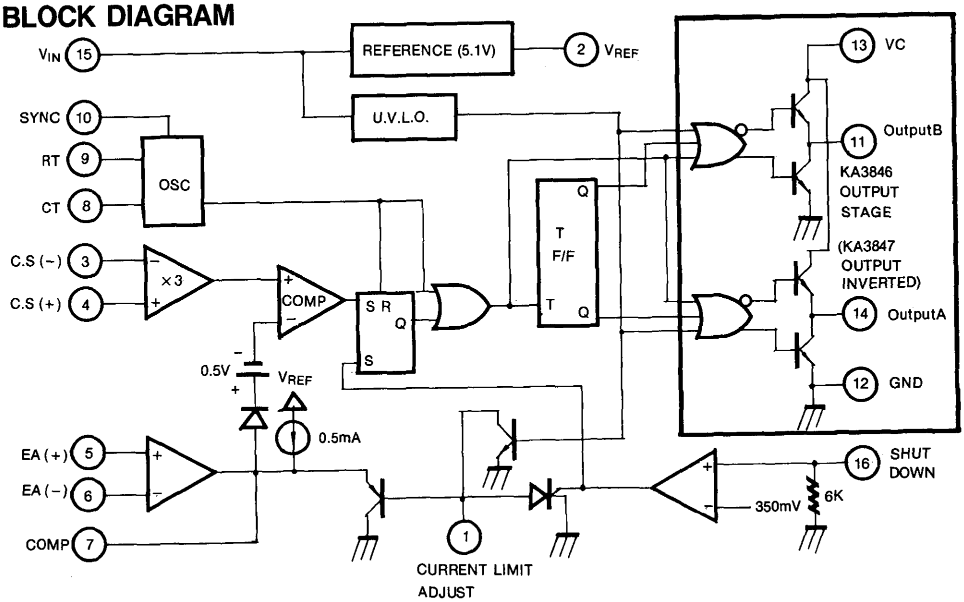
## FEATURES

- **Automatic Feed Forward Compensation**
- **Programmable Pulse by Pulse Current Limiting**
- **Automatic Symmetry Correction in Push-Pull Configuration**
- **Enhanced Load Response Characteristics**
- **Parallel Operation Capability for Modulator Power Systems**
- ***Differential Current Sense Amplifier with Common Mode Range***
- **Double Pulse Suppression**
- **200mA Totem-Pole Outputs**
- **±1% Bandgap Reference**
- **Under-Voltage Lockout**
- **Soft-Start Capability**
- **Shutdown Terminal**
- **500KHz Operation**

## ORDERING INFORMATION

| Device | Package | Operating Temperature |
|---|---|---|
| KA3846N | 16 DIP | 0~+70°C |

## BLOCK DIAGRAM



## ABSOLUTE MAXIMUM RATINGS

| Characteristic | Symbol | Value | Unit |
|---|---|---|---|
| Power Supply Voltage | $V_{CC}$ | 40 | V |
| Collector Supply Voltage | $V_C$ | 40 | V |
| Output Current, Sink or Source (Peak) | $I_O$ | 500 | mA |
| Reference Load Current | $I_{REF}$ | 30 | mA |
| Soft Start Sink Current | $I_{SOFT}$ | 50 | mA |
| Sync Output Current | $I_{SYNC}$ | 5 | mA |
| Error Amplifier Output Current | $I_{Error}$ | 5 | mA |
| Oscillator Changing Current | $I_{OSC}$ | 5 | mA |
| Power Dissipation | $P_D$ | 1000 | mW |
| Operating Temperature | $T_{opr}$ | 0 ~ +70 | °C |
| Storage Temperature | $T_{stg}$ | −65 ~ +150 | °C |
| Lead Temperature (Soldering, 10 sec) | $T_{lead}$ | +300 | °C |

## ELECTRICAL CHARACTERISTICS

($V_{CC}$ = 15V, Ta = 0 ~ +70°C, unless otherwise specified)

| Characteristic | Symbol | Test Condition | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| **REFERENCE SECTION** | | | | | | |
| Reference Output Voltage | $V_{REF}$ | $T_j = 25°C$, $I_O = 1mA$ | 5.00 | 5.10 | 5.20 | V |
| Line Regulation | $\Delta V_{REF}$ | $V_{CC}$ = 8 to 40V | | 5 | 20 | mV |
| Load Regulation | $\Delta V_{REF}$ | $I_L$ = 1 to 10mA | | 3 | 15 | mV |
| Temperature Stability (Note 6) | $\Delta V_{REF}/\Delta T_j$ | | | 0.4 | 1.0 | mV/°C |
| Output Voltage Range (Note 6) | | | 4.95 | | 5.25 | V |
| Short-Circuit Current | $I_{SC}$ | $V_{REF} = 0V$ | −10 | −45 | | mA |
| Output Noise Voltage (Note 6) | $V_{NV}$ | f = 10Hz to 10KHz, $T_j = 25°C$ | | 100 | | μV |
| Long-Term Stability (Note 6) | $T_L$ | $T_j = 125°C$, 1KHrs | 2 | 5 | 8 | mV |

## ELECTRICAL CHARACTERISTICS

($V_{CC}$ = 15V, Ta = 0 ~ +70°C, unless otherwise specified)

| Characteristic | Symbol | Test Condition | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| **OSCILLATOR SECTION** (Note 2) | | | | | | |
| Initial Accuracy | | $T_j = 25°C$ | 39 | 43 | 47 | KHz |
| Frequency Change with Voltage | $\Delta f/V_{CC}$ | $V_{CC}$ = 8 to 40V | | −1 | 2 | % |
| Frequency Change with Temperature (Note 6) | $\Delta f/\Delta T_j$ | | | −1 | | % |
| Sync Output High Level | $V_{OH}$ | | 3.9 | 4.35 | | V |
| Sync Output Low Level | $V_{OL}$ | | | 2.3 | 2.5 | V |
| Sync Input High Level | $V_{IH}$ | Pin 8 = 0V | 3.9 | | | V |
| Sync Input Low Level | $V_{IL}$ | Pin 8 = 0V | | | 2.5 | V |
| Sync Input Current | $I_I$ | Sync Voltage = 3.9V, Pin 8 = 0V | | 1.3 | 1.5 | mA |
| **ERROR AMPLIFIER SECTION** | | | | | | |
| Input Offset Voltage | $V_{IO}$ | | | 0.5 | 5 | mV |
| Input Bias Current | $I_{IB}$ | | | −0.6 | −1 | μA |
| Input Offset Current | $I_{IO}$ | | | 40 | 250 | nA |
| Common-Mode Range | $V_{CMR}$ | $V_{in}$ = 8 to 40V | 0 | | $V_{CC}$-2 | V |
| Open Loop Voltage Gain | $A_V$ | $V_O$ = 1.2 to 3V, $V_{CM}$ = 2V | 80 | 105 | | dB |
| Unity Gain Bandwidth (Note 6) | GBW | $T_j = 25°C$ | 0.7 | 1.0 | | MHz |
| Common Mode Rejection Ratio | CMRR | $V_{CM}$ = 0 to 38V, $V_{CC}$ = 40V | 75 | 100 | | dB |
| Supply Voltage Rejection Ratio | PSRR | $V_{CC}$ = 8 to 40V | 80 | 105 | | dB |
| Output Sink Current | $I_{sink}$ | $V_{IO}$ = −15mV to 5V, $V_{pin}7$ = 1.2V | 2 | 6 | | mA |
| Output Source Current | $I_{source}$ | $V_{IO}$ = 15mV to 5V, $V_{pin}7$ = 2.5V | −0.4 | −0.5 | | mA |
| High Level Output Voltage | $V_{OH}$ | $R_L$ = 15KΩ | 4.3 | 4.6 | | V |
| Low Level Output Voltage | $V_{OL}$ | $R_L$ = 15KΩ | | 0.7 | 1 | V |
| **CURRENT SENSE AMPLIFIER SECTION** | | | | | | |
| Amplifier Gain (Note 1, 3) | $G_V$ | $V_{pin3}$ = 0V, Pin 1 open | 2.5 | 2.75 | 3.0 | V |
| Maximum Differential Input Signal ($V_{pin4}$-$V_{pin3}$) (Note 1) | $V_{DM}$ | $R_L$ = 15KΩ, Pin 1 open | 1.1 | 1.2 | | V |
| Input Offset Voltage (Note 1) | $V_{IO}$ | $V_{pin1}$ = 0.5V, Pin 7 open | | 5 | 25 | mV |
| Common Mode Rejection Ratio | CMRR | $V_{CM}$ = 1 to 12V | 60 | 83 | | dB |
| Supply Voltage Rejection Ratio | PSRR | $V_{in}$ = 8 to 40V | 60 | 84 | | dB |
| Input Bias Current (Note 1) | $I_{IB}$ | $V_{pin1}$ = 0.5V, pin 7 open | | −2.5 | −10 | μA |
| Input Offset Current (Note 1) | $I_{IO}$ | $V_{pin1}$ = 0.5V, Pin 7 open | | 0.08 | 1 | μA |
| Delay to Outputs (Note 6) | $T_d$ | $T_j = 25°C$ | | 200 | 500 | nS |

## ELECTRICAL CHARACTERISTICS

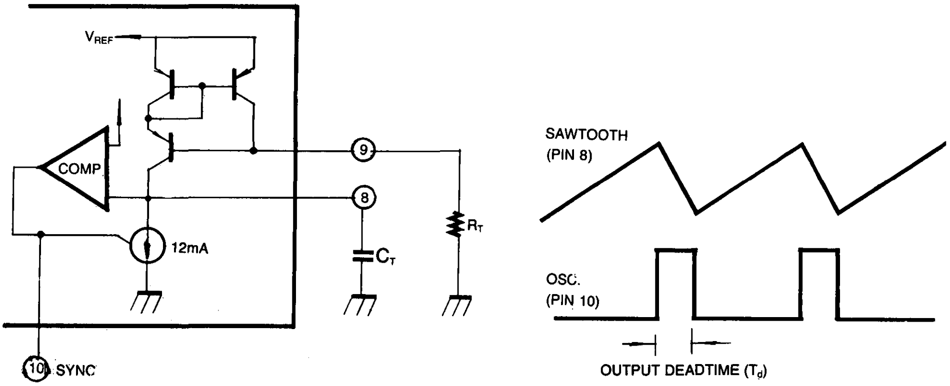
($V_{CC}=15V$, $Ta=0\sim+70°C$, unless otherwise specified)

| Characteristic | Symbol | Test Condition | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| **CURRENT LIMIT ADJUST SECTION** | | | | | | |
| Current Limit Offset Voltage (Note 1) | $V_{CL}$ | $V_{pin3}=0V$<br>$V_{pin4}=0V$, Pin 7 open | 0.45 | 0.5 | 0.55 | V |
| Input Bias Current | $I_{IS}$ | $V_{pin5}=V_{ref}$, $V_{pin6}=0V$ | | −10 | −30 | μA |
| **SHUTDOWN TERMINAL SECTION** | | | | | | |
| Threshold Voltage | $V_{TH}$ | | 250 | 350 | 400 | mV |
| Input Voltage Range | $V_{CM}$ | | 0 | | $V_{in}$ | V |
| Minimum Latching Current (Note 4) | $I_{L,\ Min}$ | | 3.0 | 1.5 | | mA |
| Maximum Non-Latching Current (Note 5) | $I_{L,\ Max}$ | | | 1.5 | 0.8 | mA |
| **UNDER-VOLTAGE LOCKOUT SECTION** | | | | | | |
| Start-up Threshold | $V_{STH}$ | | 7 | 7.7 | 8.4 | V |
| Threshold Hysteresis | $V_{HYS}$ | | 0.45 | 0.75 | 1.05 | V |
| **OUTPUT SECTION** | | | | | | |
| Collector-Emitter Voltage | $V_C$ | | 40 | | | V |
| Collector Leakage Current | $I_{Leak}$ | $V_C=40V$ | | | 200 | μA |
| Low Output Voltage I | $V_{OLI}$ | $I_{sink}=20mA$ | | 0.1 | 0.4 | V |
| Low Output Voltage II | $V_{OLII}$ | $I_{sink}=100mA$ | | 0.4 | 2.1 | V |
| High Output Voltage I | $V_{OHI}$ | $I_{source}=20mA$ | 13 | 13.5 | | V |
| High output Voltage II | $V_{OHII}$ | $I_{source}=100mA$ | 12 | 13.5 | | V |
| Rise Time (Note 6) | $T_r$ | $C_L=1nF$, $T_j=25°C$ | | 50 | 300 | μS |
| Fall Time (Note 6) | $T_f$ | $C_L=1nF$, $T_j=25°C$ | | 50 | 300 | μS |
| **TOTAL STANDBY CURRENT** | | | | | | |
| Supply Current | $I_S$ | | | 17 | 21 | mA |

(Notes)

1. Parameter measured at trip point of latch with $V_{pin5}=V_{REF}$, $V_{pin6}=0V$
2. $R_T=10K\Omega$, $C_T=4.7nF$
3. Amplifier gain defined as: $G=\frac{\Delta V_{pin7}}{\Delta V_{pin4}}$ ; $\Delta V_{pin4}=0$ to 1.0V
4. Current into Pin 1 guaranteed to latch circuit in shutdown state.
5. Current into Pin 1 guaranteed not to latch circuit in shutdown state.
6. These parameters, although guaranteed over the recommended operating conditions, are not 100% tested in production.

## Fig. 1. KA3846N OSCILLATOR CIRCUIT

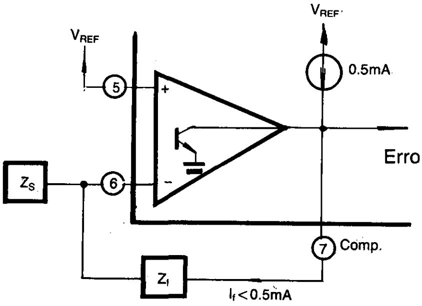


Output deadtime is determined by the external capacitor, $C_T$, according to the formula: $T_d\ (\mu S) = 145C_T\ (\mu F) \left( \frac{12}{12 - \frac{3.6}{R_T(K\Omega)}} \right)$

For large values of $R_T$: $T_d\ (\mu S) = 145C_T\ (\mu F)$

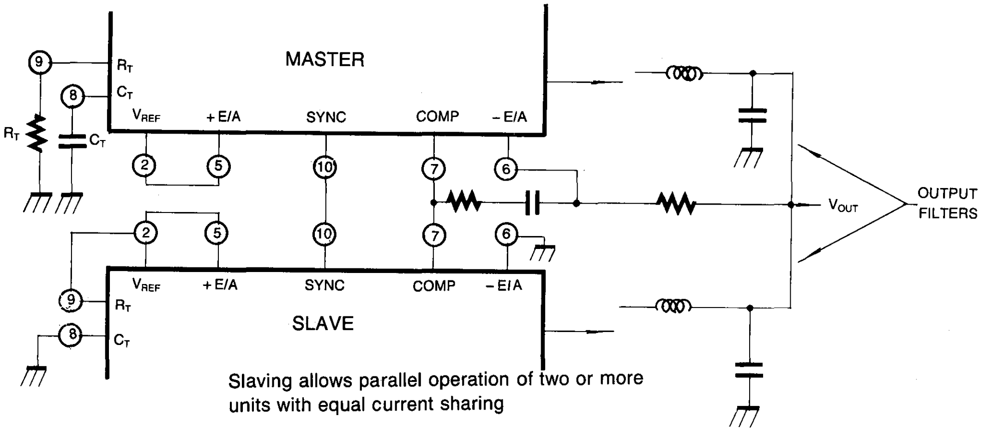
Oscillator frequency is approximately by the formula: $f_T\ (kHz) = \frac{2.2}{R_T(K\Omega)\ C_T(\mu F)}$

## Fig. 2. ERROR AMPLIFIER OUTPUT CONFIGURATION



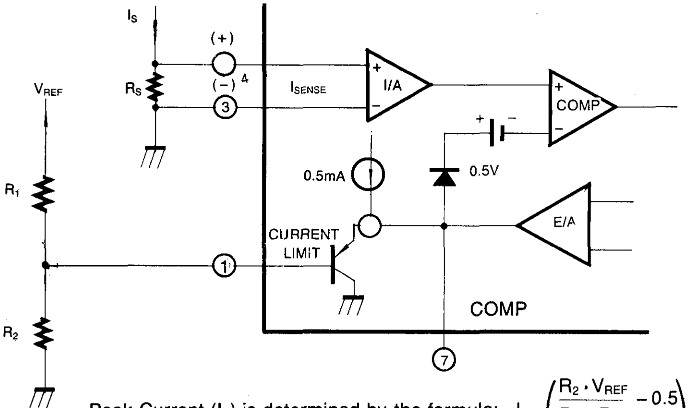
Error amplifier can source up to 0.5mA

**Fig. 3. PARALLEL OPERATION**



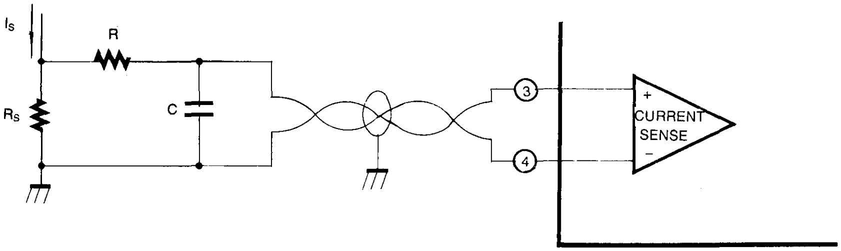
Slaving allows parallel operation of two or more units with equal current sharing

**Fig. 4. PULSE BY PULSE CURRENT LIMITING**



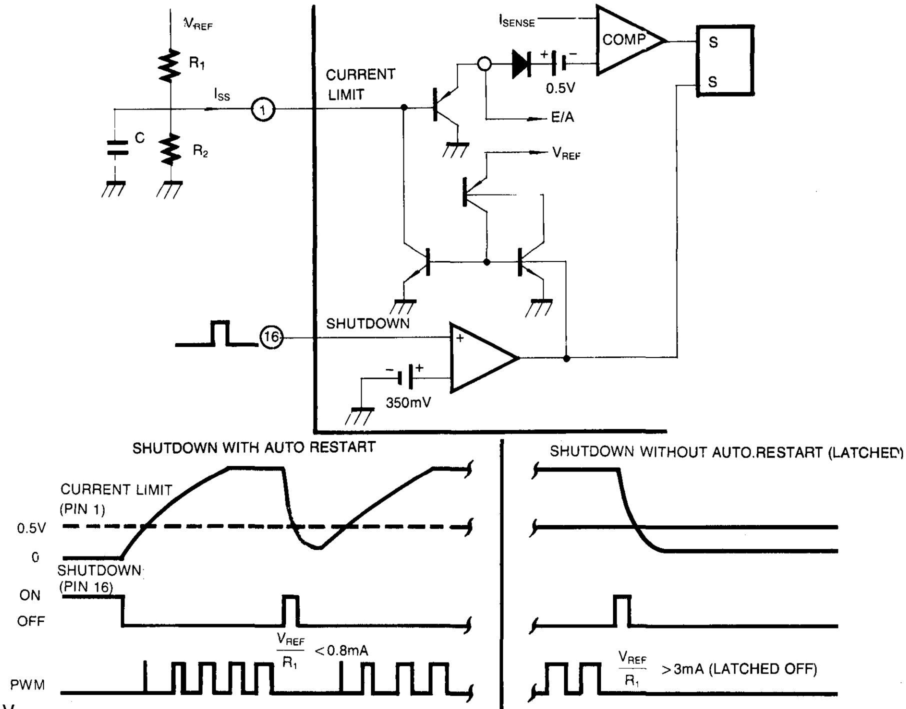
Peak Current ($I_S$) is determined by the formula: $I_S = \left( \frac{\frac{R_2 \cdot V_{REF}}{R_1 + R_2} - 0.5}{3R_S} \right)$

**Fig. 5. CURRENT SENSE AMP CONNECTIONS**



A small RC filter may be required in some applications to reduce switch transients. Differential input allows remote, noise free sensing.

## Fig. 6. SOFT-START AND SHUTDOWN/RESTART FUNCTIONS



If $\frac{V_{REF}}{R_1} < 0.8mA$, the shutdown latch will commutate when $I_{SS} = 0.8mA$ and a restart cycle will be initiated.

If $\frac{V_{REF}}{R_1} > 3mA$, the device will latch off until power is recycled

## Fig. 7. SINGLE ENDED BOOST CONFIGURATION

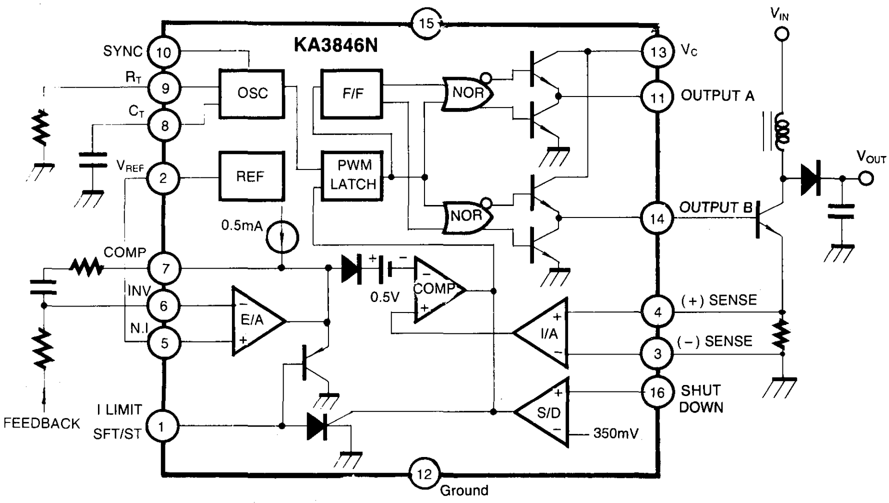


Fig. 8. BUCK CONVERTER WITH CURRENT SENSE WINDING

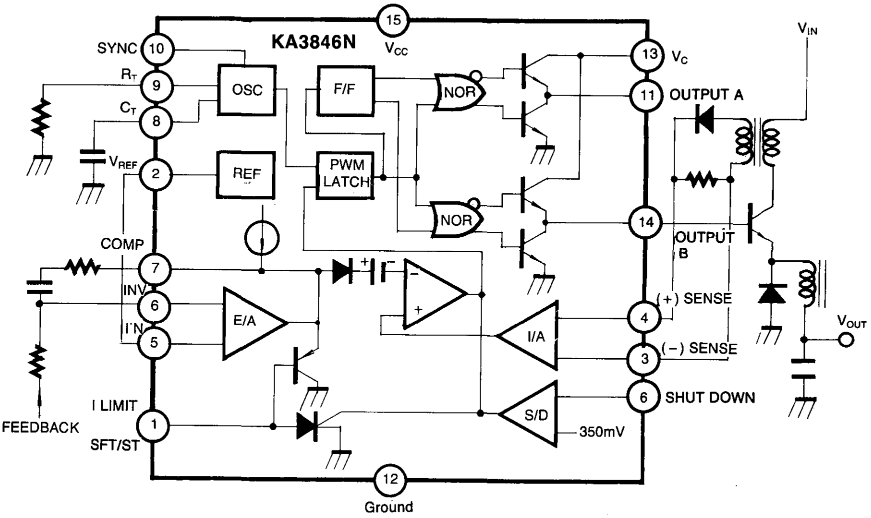
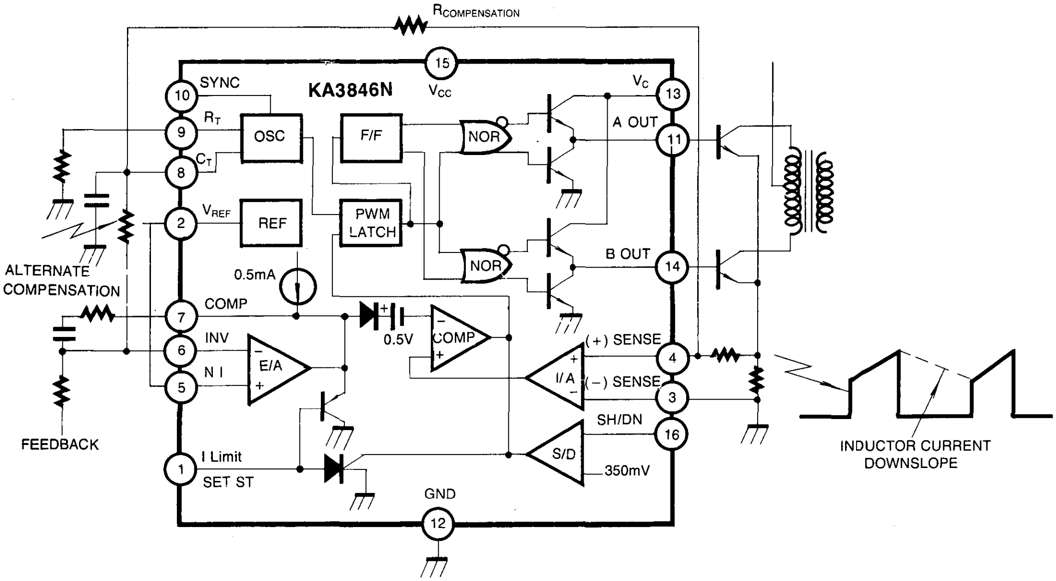


Fig. 9. PUSH-PULL CONVERTER SLOPE COMPENSATION



Current loop instability above 50% duty cycle can be corrected using slope compensation derived from the sawtooth oscillator. Compensation magnitude should be greater than ½ of the downslope of the inductor current waveform as shown. Alternatively, the compensation signal can be summed into the negative input of the error amplifier.

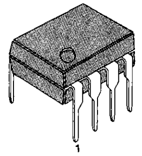
## DC TO DC CONVERTER CONTROLLER

The KA34063 is a monolithic switching regulator subsystem intended for use as DC to DC converter. This device contains an internal temperature compensated reference, comparator, controlled duty cycle oscillator with an active peak current limit circuit, driver and a high current output switch.

It was specifically designed to be incorporated in step-up, step-down and voltage inverting converter applications.

These function are contained in an 8 pin dual in-line package.

**8 DIP**



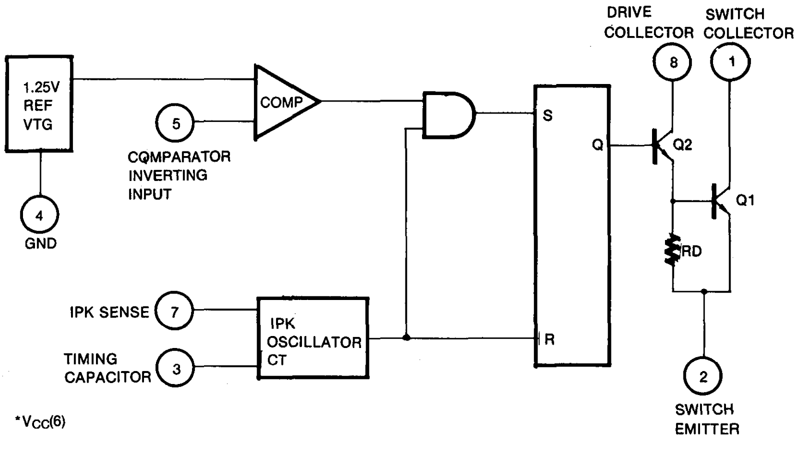
## FEATURES

- **Operation from 2.5 to 40V Input**
- **Short Circuit Current Limiting**
- **Low Standby Current**
- **Output Switch Current of 1.5A**
- **Output Voltage Adjustable from 1.25V to 40V**
- **Frequency of Operation from 100Hz to 100KHz**

## ORDERING INFORMATION

| Device | Package | Operating Frequency |
|---|---|---|
| KA34063N | 8DIP | 0 ~ +70°C |

## BLOCK DIAGRAM



## ABSOLUTE MAXIMUM RATINGS

| Characteristic | Symbol | Value | Unit |
|---|---|---|---|
| Power Supply Voltage | $V_{CC}$ | 40 | V |
| Comparator Input Voltage Range | $V_{IR}$ | −0.3 ~ +40 | V |
| Switch Collector Voltage | $V_{C\,(SW)}$ | 40 | V |
| Switch Emitter Voltage | $V_{E\,(SW)}$ | 40 | V |
| Switch Collector To Emitter Voltage | $V_{CE\,(SW)}$ | 40 | V |
| Driver Collector Voltage | $V_{C\,(driver)}$ | 40 | V |
| Switch Current | $I_{SW}$ | 1.5 | A |

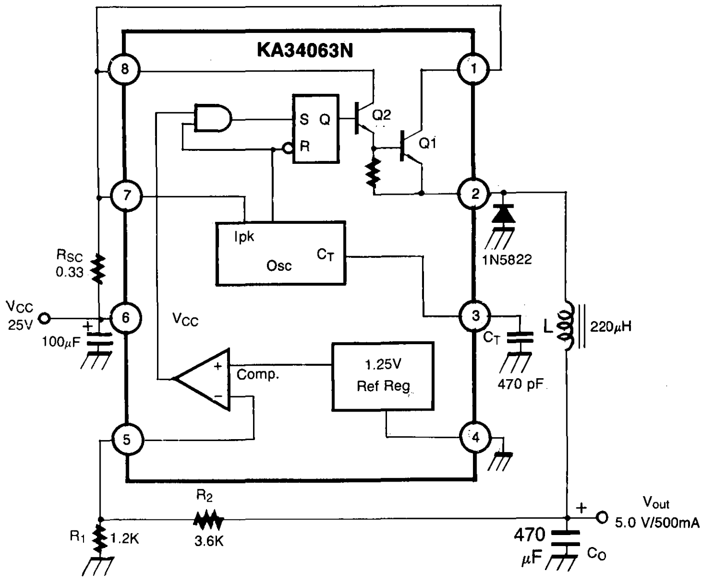
## ELECTRICAL CHARACTERISTICS

($V_{CC}=5.0V$, Ta = 0 ~ +70°C, unless otherwise specified)

| Characteristic | Symbol | Test Condition | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| **OSCILLATOR** | | | | | | |
| Charging Current | $I_{chg}$ | $V_{CC}=5$ to 40V<br>Ta = 25°C | 20 | 35 | 50 | μA |
| Discharge Current | $I_{dischg}$ | $V_{CC}=5$ to 40V<br>Ta = 25°C | 150 | 200 | 250 | μA |
| Voltage Swing | $V_{OSC}$ | Ta = 25°C | | 0.5 | | V |
| Discharge To Charge Current Ratio | $I_{dischg}$<br>$I_{chg}$ | Ipk(sense) = $V_{CC}$,<br>Ta = 25°C | | 6.0 | | |
| Current Limit Sense Voltage | $V_{IPK}$ (sense) | $I_{chg}=I_{dischg}$<br>Ta = 25°C | 250 | 300 | 350 | mV |
| **OUTPUT SWITCH** | | | | | | |
| Saturation Voltage I (Note) | $V_{CE\,(sat)}$ I | $I_{SW}=1.0A$,<br>$V_C$ (driver) = $V_C$ (SW) | | 1.0 | 1.3 | V |
| Saturation Voltage II (Note) | $V_{CE\,(sat)}$ II | $I_{SW}=1.0A$,<br>$V_C$ (driver) = 50mA | | 0.5 | 0.7 | V |
| DC Current Gain (Note) | $h_{FE}$ | $I_{SW}=1.0A$,<br>$V_{CE}=5.0V$, Ta = 25°C | 70 | 150 | | |
| Collector off State Current (Note) | $I_{C\,(off)}$ | $V_{CE}=40V$, Ta = 25°C | | 10 | 200 | nA |
| **COMPARATOR** | | | | | | |
| Threshold Voltage | $V_{TH}$ | | 1.18 | 1.25 | 1.32 | V |
| Threshold Voltage Line Regulation | $\Delta V_{th}$ | $V_{CC}=3$ to 40V | | 0.04 | 0.2 | mV/V |
| Input Bias Current | $I_{IB}$ | $V_{IN}=0V$ | | 35 | 300 | nA |
| **TOTAL DEVICE** | | | | | | |
| Supply Current | $I_{CC}$ | $V_{CC}=5$ to 40V<br>$C_T=0.001\mu F$<br>Ipk (sense) = $V_{CC}$<br>Vpin 5 > Vth<br>pin2 = GND | | 2.4 | 3.5 | mA |

(Note)
Output switch tests are performed under pulsed conditions to minimize power dissipation.

Fig. 1. Step-Down Converter



| Test | Conditions | Results |
|---|---|---|
| Line Regulation | $V_{CC}=15$ to 25V, $I_O=500$mA | 15mV |
| Load Regulation | $V_{CC}=25$V, $I_O=50$ to 500mA | 5.0mV |
| Output Ripple | $V_{CC}=25$ V, $I_O=500$mA | 40mV |
| Short Circuit Current | $V_{CC}=25$V, $R_L=0.1\Omega$ | 2.3A |
| Efficiency | $V_{CC}=25$V, $I_O=500$mA | 84.7% |

## Fig. 2. Step-Up Converter

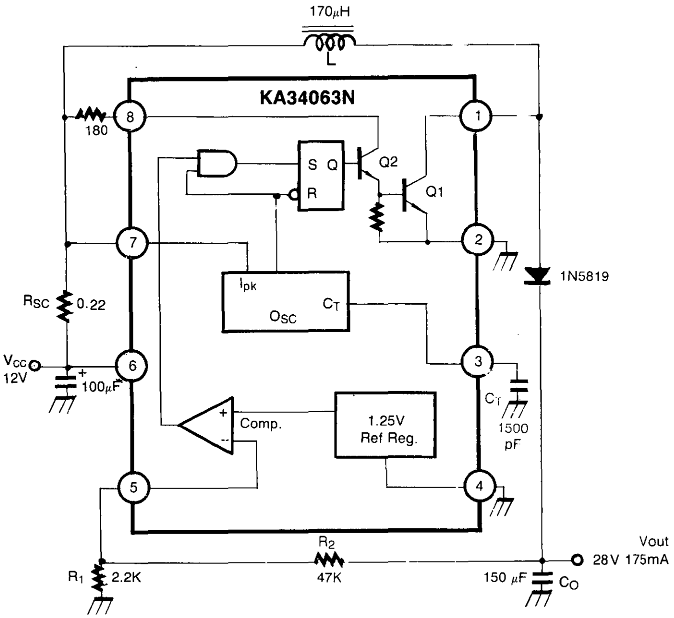


Fig. 6

| Test | Conditions | Results |
|---|---|---|
| Line Regulation | $V_{CC}=8.0$ to 16V, $I_O=175$mA | 12mV |
| Load Regulation | $V_{CC}=12$V, $I_O=75$ to 175mA | 45mV |
| Output Ripple | $V_{CC}=12$ V, $I_O=175$mA | 150mV |
| Short Circuit Current | $V_{CC}=12$V, $R_L=0.1\Omega$ | 2.0A |
| Efficiency | $V_{CC}=12$V, $I_O=175$mA | 93% |

**Table: Design Formula**

| Calculation | Step-Down | Step-Up |
|---|---|---|
| $\frac{\text{ton}}{\text{toff}}$ | $\frac{\text{Vout} + V_F}{V_{CC}\,(\text{min}) - \text{Vsat} - \text{Vout}}$ | $\frac{V_{OUT} + V_F - V_{CC}\,(\text{min})}{V_{CC}\,(\text{min}) - \text{Vsat}}$ |
| (ton + toff) max | $\frac{1}{\text{fmin}}$ | $\frac{1}{\text{fmin}}$ |
| $C_T$ | $4 \times 10^{-5}$ ton | $4 \times 10^{-5}$ ton |
| Ipk (switch) | 2 $I_{OUT}$ (max) | 2 $I_{OUT}$ (max) $\frac{\text{ton} + \text{toff}}{\text{toff}}$ |
| $R_{SC}$ | 0.33/Ipk (switch) | 0.33/Ipk (switch) |
| L (min) | $\frac{V_{CC}\,(\text{min})\text{-Vsat-Vout}}{\text{Ipk (switch)}}$ ton (max) | $\frac{V_{CC}\,(\text{min})\text{-Vsat}}{\text{Ipk (switch)}}$ ton (max) |
| $C_O$ | $\frac{\text{Ipk (switch) (ton + toff)}}{\text{8Vripple (p-p)}}$ | $\frac{I_{OUT}\ \text{ton}}{\text{Vripple (p-p)}}$ |

$V_{sat}$ = Saturation Voltage of the output switch.
$V_F$ = Forward Voltage drop of the rectifier.

**The following power supply characteristics must be chosen:**

**$V_{CC}$:** Normal input voltage, if this voltage is not constant, then use $V_{CC}$ (max) for step-down and $V_{CC}$ (min) for step-up converter.

**Vout:** Desired output voltage, Vout = 1.25 $(1 + \frac{R2}{R1})$

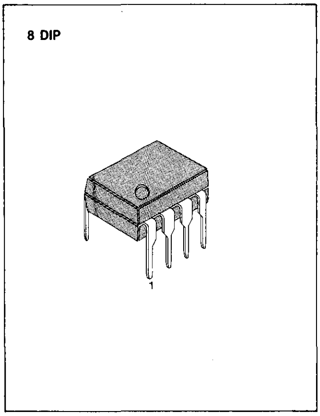
**Iout:** Desired output current.

**fmin:** Minimum desired output switching frequency at the selected values for $V_{CC}$ and Io.

**Vripple** (p-p): Desired peak-to-peak output ripple voltage. in practice, the calculated value will need to be increased due to the capacitor's equivalent series resistance and board layout.
The ripple voltage should be kept to a low value since it will directly effect the line and load regulation.

## DC TO DC CONVERTER CONTROLLER

The KA34063A is a monolithic switching regulator subsystem intended for use as DC to DC converter. This device contains an internal temperature compensated reference, comparator, controlled duty cycle oscillator with an active peak current limit circuit, driver and a high current output switch.
It was specifically designed to be incorporated in step-up, step-down and voltage inverting converter applications.
These function are contained in an 8 pin dual in-line package.



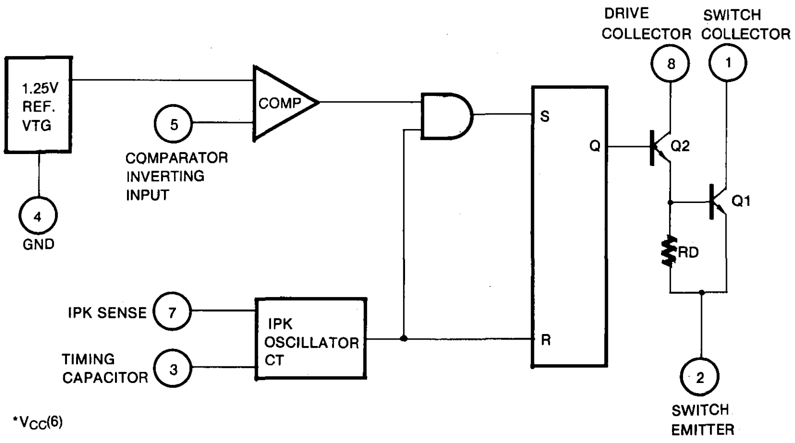
## FEATURES

- **Operation from 3.0 to 40V Input**
- **Short Circuit Current Limiting**
- **Low Standby Current**
- **Output Switch Current of 1.5A**
- **Output Voltage Adjustable**
- **Frequency of Operation from 100Hz to 100KHz**

## ORDERING INFORMATION

| Device | Package | Operating Frequency |
|---|---|---|
| KA34063AN | 8DIP | 0~ +70°C |

## BLOCK DIAGRAM



## ABSOLUTE MAXIMUM RATINGS

| Characteristic | Symbol | Value | Unit |
|---|---|---|---|
| Power Supply Voltage | $V_{CC}$ | 40 | V |
| Comparator Input Voltage Range | $V_{IR}$ | −0.3~+40 | V |
| Switch Collector Voltage | $V_{C\ (SW)}$ | 40 | V |
| Switch Emitter Voltage | $V_{E\ (SW)}$ | 40 | V |
| Switch Collector To Emitter Voltage | $V_{CE\ (SW)}$ | 40 | V |
| Driver Collector Voltage | $V_{C\ (driver)}$ | 40 | V |
| Switch Current | $I_{SW}$ | 1.5 | A |

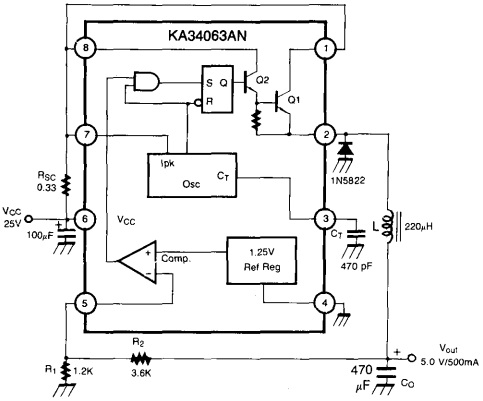
## ELECTRICAL CHARACTERISTICS

($V_{CC}$=5.0V, Ta=0~+70°C, unless otherwise specified)

| Characteristic | Symbol | Test Condition | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| **OSCILLATOR** | | | | | | |
| Charging Current | $I_{chg}$ | $V_{CC}$=5 to 40V<br>Ta=25°C | 22 | 33 | 42 | μA |
| Discharge Current | $I_{dischg}$ | $V_{CC}$=5 to 40V<br>Ta=25°C | 140 | 200 | 260 | μA |
| Voltage Swing | $V_{OSC}$ | Ta=25°C | | 0.5 | | V |
| Discharge To Charge Current Ratio | $I_{dischg}$<br>$I_{chg}$ | Ipk(sense)=$V_{CC}$,<br>Ta=25°C | 5.2 | 6.2 | 7.5 | |
| Current Limit Sense Voltage | $V_{IPK}$<br>(sense) | $I_{chg}=I_{dischg}$<br>Ta=25°C | 250 | 300 | 350 | mV |
| **OUTPUT SWITCH** | | | | | | |
| Saturation Voltage I (Note) | $V_{CE\ (sat)}$ I | $I_{SW}$=1.0A,<br>$V_C$ (driver)=$V_C$ (SW) | | 1.0 | 1.3 | V |
| Saturation Voltage II (Note) | $V_{CE\ (sat)}$ II | $I_{SW}$=1.0A,<br>$V_C$ (driver)=50mA | | 0.45 | 0.7 | V |
| DC Current Gain (Note) | $h_{FE}$ | $I_{SW}$=1.0A,<br>$V_{CE}$=5.0V, Ta=25°C | 50 | 120 | | |
| Collector off State Current (Note) | $I_{C\ (off)}$ | $V_{CE}$=40V, Ta=25°C | | 10 | 100 | nA |
| **COMPARATOR** | | | | | | |
| Threshold Voltage | $V_{TH}$ | | 1.21 | | 1.29 | V |
| Threshold Voltage Line Regulation | $\Delta V_{th}$ | $V_{CC}$=3 to 40V | | 1.4 | 5.0 | mV |
| Input Bias Current | $I_{IB}$ | $V_{IN}$=0V | | 40 | 400 | nA |
| **TOTAL DEVICE** | | | | | | |
| Supply Current | $I_{CC}$ | $V_{CC}$=5 to 40V<br>$C_T$=0.001μF<br>Ipk (sense)=$V_{CC}$<br>Vpin 5>Vth<br>pin2=GND | | 2.5 | 4.0 | mA |

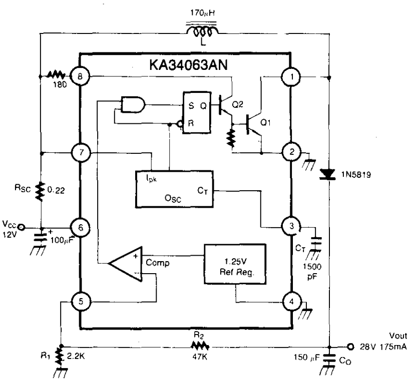
(Note)
Output switch tests are performed under pulsed conditions to minimize power dissipation.

## FIG. 1. STEP-DOWN CONVERTER



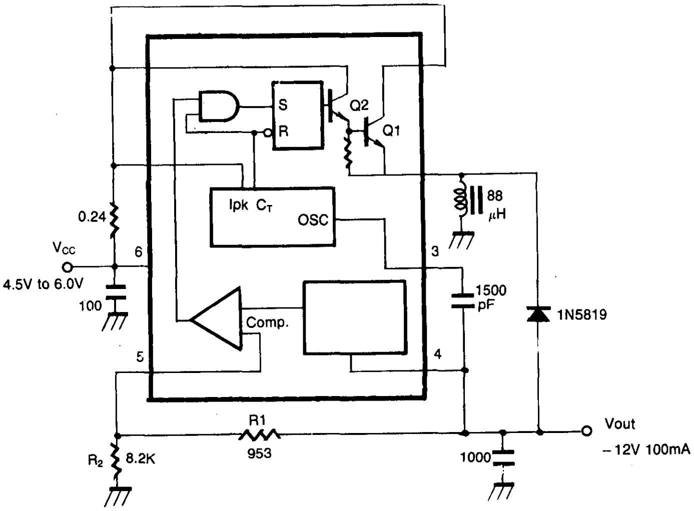
| Test | Conditions | Results |
|---|---|---|
| Line Regulation | $V_{CC}=15$ V to 25 V, $I_O=500$mA | 12mV = ±0.12% |
| Load Regulation | $V_{CC}=25$ V, $I_O=50$ to 500mA | 3.0mV = ±0.03% |
| Output Ripple | $V_{CC}=25$V, $I_O=500$mA | 120mVp-p |
| Short Circuit Current | $V_{CC}=25$V, $R_L=0.1\Omega$ | 1.1A |
| Efficiency | $V_{CC}=25$V, $I_O=500$mA | 82.5% |
| Output Ripple with Optional Filter | $V_{CC}=25$V, $I_O=500$mA | 40mVp-p |

## FIG. 2. STEP-UP CONVERTER



| Test | Conditions | Results |
|---|---|---|
| Line Regulation | $V_{CC}=8.0$ V to 16 V, $I_O=175$mA | 30mV = ±0.05% |
| Load Regulation | $V_{CC}=12$ V, $I_O=75$ to 175mA | 10mV = ±0.017% |
| Output Ripple | $V_{CC}=12$V, $I_O=175$mA | 400mVp-p |
| Efficiency | $V_{CC}=12$V, $I_O=175$mA | 89.2% |
| Output Ripple with Optional Filter | $V_{CC}=12$V, $I_O=175$mA | 40mVp-p |

### Fig. 3. VOLTAGE INVERTING CONVERTER



| Test | Conditions | Results |
|---|---|---|
| Line Regulation | $V_{CC}=4.5$ V to 6.0 V, $I_O=100$mA | 3.0mV = ±0.012% |
| Load Regulation | $V_{CC}=5.0$ V, $I_O=10$ to 100mA | 0.022V = ±0.09% |
| Output Ripple | $V_{CC}=5.0$V, $I_O=100$mA | 50mVp-p |
| Short Circuit Current | $V_{CC}=5.0$V, $R_L=0.1\Omega$ | 910mA |
| Efficiency | $V_{CC}=5.0$V, $I_O=100$mA | 64.5% |
| Output Ripple with Optional Filter | $V_{CC}=5.0$V, $I_O=100$mA | 70mVp-p |

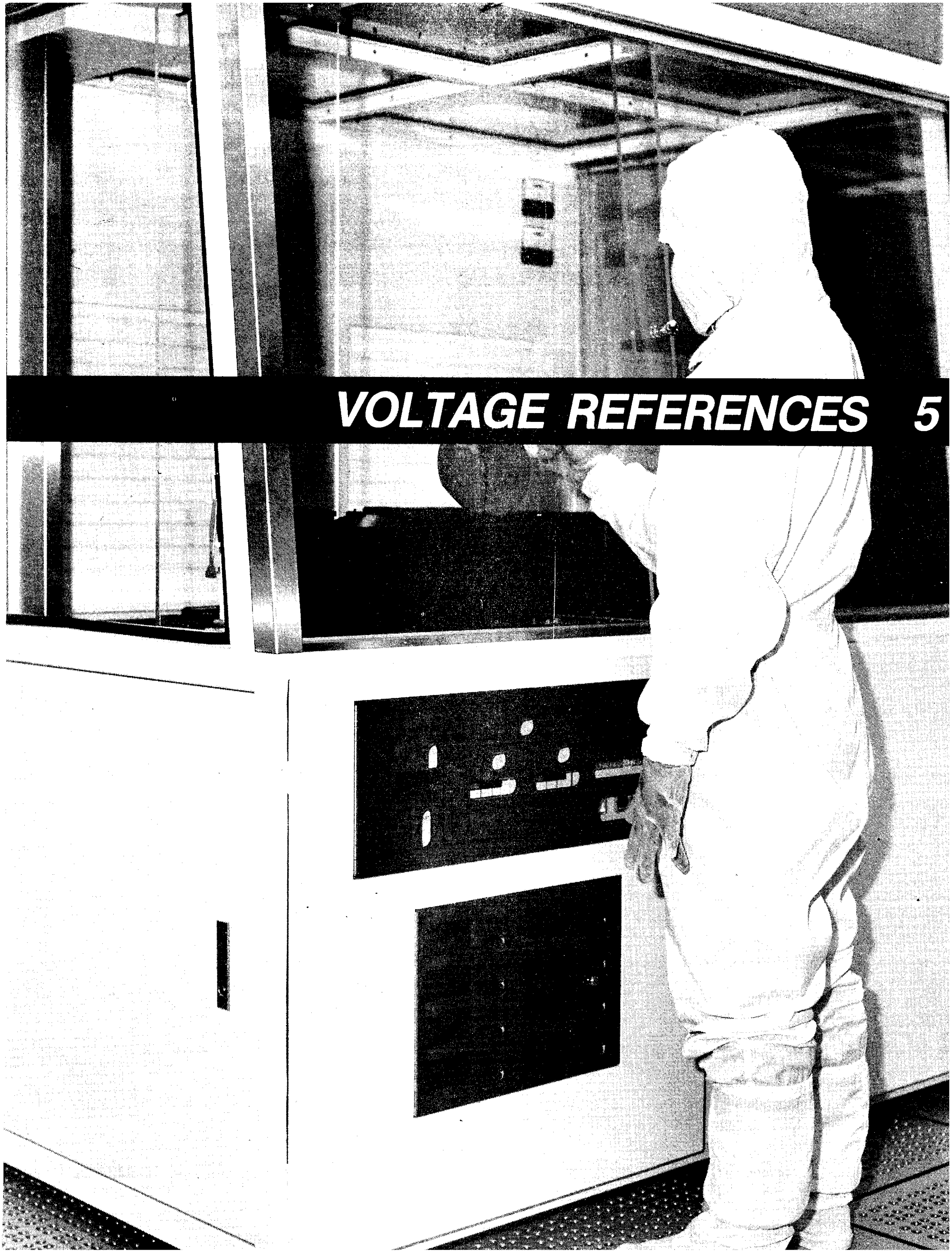
**Table: Design Formula**

| Calculation | Step-Down | Step-Up | Voltage-Inverting |
|---|---|---|---|
| ton<br>toff | $\frac{\text{Vout} + V_F}{V_{CC}\ (\text{min}) - \text{Vsat} - \text{Vout}}$ | $\frac{V_{OUT} + V_F - V_{CC}\ (\text{min})}{V_{CC}\ (\text{min}) - \text{Vsat}}$ | $\frac{\lvert\text{Vout}\rvert + V_F}{\text{Vcc} - \text{Vsat}}$ |
| (ton + toff) max | $\frac{1}{\text{fmin}}$ | $\frac{1}{\text{fmin}}$ | $\frac{1}{\text{fmin}}$ |
| $C_T$ | $4 \times 10^{-5}$ ton | $4 \times 10^{-5}$ ton | $4 \times 10^{-5}$ ton |
| Ipk (switch) | 2 $I_{OUT}$ (max) | 2 $I_{OUT}$ (max) $\left(\frac{\text{ton} + \text{toff}}{\text{toff}}\right)$ | 2Iout(max) (ton/toff + 1) |
| $R_{SC}$ | 0.3/Ipk (switch) | 0.3/Ipk (switch) | 0.3/Ipk (switch) |
| L (min) | $\frac{(V_{CC}\ (\text{min})\text{-Vsat-Vout})}{\text{Ipk (switch)}}$ ton (max) | $\frac{(V_{CC}\ (\text{min})\text{-Vsat})}{\text{Ipk (switch)}}$ ton (max) | $\frac{(\text{Vcc(min)} - \text{Vsat})}{\text{Ipk (switch)}}$ ton (max) |
| $C_O$ | $\frac{\text{Ipk (switch) (ton + toff)}}{\text{8 Vripple (p-p)}}$ | $\frac{I_{OUT}\ \text{ton}}{\text{Vripple (p-p)}}$ | $\frac{I_{OUT}\ \text{ton}}{\text{Vripple (p-p)}}$ |

$V_{sat}$ = Saturation Voltage of the output switch.
$V_F$ = Forward Voltage drop of the rectifier.
**The following power supply characteristics must be chosen:**
**$V_{CC}$:** Normal input voltage, if this voltage is not constant, then use $V_{CC}$ (max) for step-down and $V_{CC}$ (min) for step-up converter.
**Vout:** Desired output voltage, Vout = 1.25 $(1 + \frac{R2}{R1})$
**Iout:** Desired output current.
**fmin:** Minimum desired output switching frequency at the selected values for $V_{CC}$ and Io.
**Vripple** (p-p): Desired peak-to-peak output ripple voltage. in practice, the calculated value will need to be increased due to the capacitor's equivalent series resistance and board layout.
The ripple voltage should be kept to a low value since it will directly effect the line and load regulation.

# NOTES

# VOLTAGE REFERENCES 5

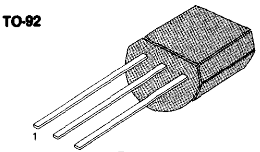


## PROGRAMMABLE PRECISION REFERENCES

The KA431 is a three-terminal adjustable regulator series with a guaranteed thermal stability over applicable temperature ranges. The output voltage may be set to any value between $V_{ref}$ (approximately 2.5 volts) and 36 volts with two external resistors. These devices have a typical dynamic output impedance of 0.2Ω. Active output circuitry provides a very sharp turn-on characteristic, making these devices excellent replacement for zener diodes in many applications.

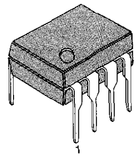
The KA431I is characterized for operation from −40°C to +85°C, and the KA431C/AC from 0°C to 70°C.

TO-92



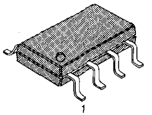
1: Ref. 2: Anode 3: Cathode

8 DIP



1: Cathode 6: Anode 8: Ref.
2, 3, 4, 7: N.C.

8 SOP

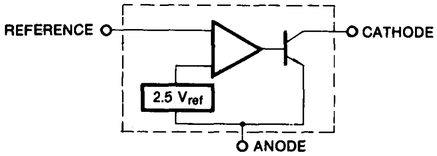


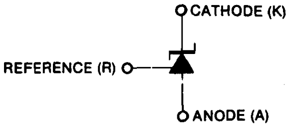
1: Cathode 2, 3, 6, 7: Anode 8: Ref.
4, 5: N.C.

## FEATURES

- **Programmable output voltage to 36 volts**
- **Low dynamic output impedance 0.2Ω typical**
- **Sink current capability of 1.0 to 100mA**
- **Equivalent full-range temperature coefficient of 50ppm/°C typical**
- **Temperature compensated for operation over full rated operating temperature range**
- **Low output noise voltage**
- **Fast turn on response**

## BLOCK DIAGRAM

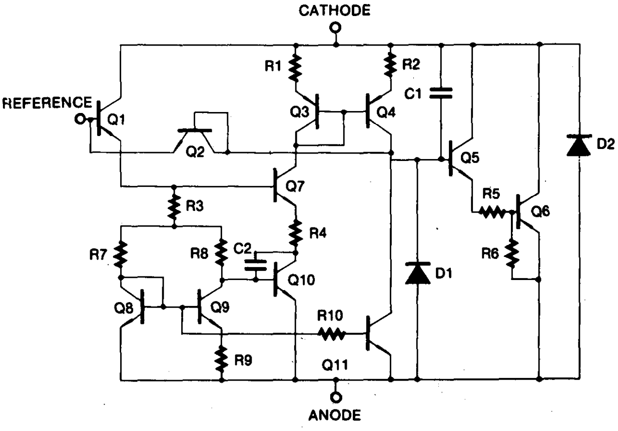




## ORDERING INFORMATION

| Device | Operating Temperature | Package |
|---|---|---|
| KA431CZ | 0 ~ +70°C | TO-92 |
| KA431CN | 0 ~ +70°C | 8 DIP |
| KA431CD | 0 ~ +70°C | 8 SOP |
| KA431IZ | −40 ~ +85°C | TO-92 |
| KA431IN | −40 ~ +85°C | 8 DIP |
| KA431ACZ | 0 ~ +70°C | TO-92 |

## SCHEMATIC DIAGRAM



## ABSOLUTE MAXIMUM RATINGS

(Operating temperature range applies unless otherwise specified.)

| Characteristic | Symbol | Value | Unit |
|---|---|---|---|
| Cathode Voltage | $V_{KA}$ | 37 | V |
| Cathode Current Range (Continuous) | $I_K$ | – 100 ~ + 150 | mA |
| Reference Input Current Range | $I_{REF}$ | 0.05 ~ + 10 | mA |
| Power Dissipation<br>D, Z Suffix Package<br>N Suffix Package | $P_D$ | <br>770<br>1000 | <br>mW<br>mW |
| Operating Temperature Range<br>KA431CZ, KA431CN, KA431CD, KA431ACE<br>KA431IZ, KA431IN | $T_{opr}$ | <br>0 ~ + 70<br>– 40 ~ + 85 | <br>°C<br>°C |
| Storage Temperature Range | $T_{stg}$ | – 65 ~ + 150 | °C |

## RECOMMENDED OPERATING CONDITIONS

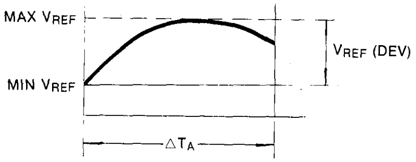
| Characteristic | Symbol | Min | Typ | Max | Unit |
|---|---|---|---|---|---|
| Cathode Voltage | $V_{KA}$ | $V_{REF}$ | | 36 | V |
| Cathode Current | $I_K$ | 1.0 | | 100 | mA |

## ELECTRICAL CHARACTERISTICS (Ta = 25°C, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | | KA431C | | | KA431AC | | | KA431I | | | Unit |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Min | Typ | Max | Min | Typ | Max | Min | Typ | Max | |
| Reference Input Voltage | $V_{REF}$ | $V_{KA}=V_{REF}$, $I_K=10mA$ | | 2.440 | 2.495 | 2.550 | 2.470 | 2.495 | 2.520 | 2.440 | 2.495 | 2.550 | V |
| Deviation of Reference Input Voltage Over-Temperature (Note 1) | $V_{REF\ (dev)}$ | $V_{KA}=V_{REF}$, $I_K=10mA$<br>$T_{min} \leq Ta \leq T_{max}$ | | | 4 | 17 | | 4 | 17 | | 5 | 30 | mV |
| Ratio of Change in Reference Input Voltage to the Change in Cathode Voltage | $\Delta V_{REF}$ | $I_K=10mA$ | $\Delta V_{KA}=10V\text{-}V_{REF}$ | | – 1.4 | – 2.7 | | – 1.4 | – 2.7 | | – 1.4 | – 2.7 | mV/V |
| | $\Delta V_{KA}$ | | $\Delta K_{KA}=36V\text{-}10V$ | | – 1.0 | – 2.0 | | – 1.0 | – 2.0 | | – 1.0 | – 2.0 | |
| Reference Input Current | $I_{REF}$ | $I_K=10mA$, $R_1=10K\Omega$, $R_2=\infty$ | | | 2 | 4 | | 2 | 4 | | 2 | 4 | μA |
| Deviation of Reference Input Current Over Full Temperature Range | $I_{REF(dev)}$ | $I_K=10mA$, $R_1=10K\Omega$, $R_2=\infty$<br>Ta = Full Range | | | 0.4 | 1.2 | | 0.4 | 1.2 | | 0.8 | 2.5 | μA |
| Minimum Cathode Current for Regulation | $I_{K\ (min)}$ | $V_{KA}=V_{REF}$ | | | 0.4 | 1.0 | | 0.4 | 1.0 | | 0.4 | 1.0 | mA |
| Off-State Cathode Current | $I_{K\ (off)}$ | $V_{KA}=36V$, $V_{REF}=0$ | | | 0.1 | 1.0 | | 0.1 | 1.0 | | 0.1 | 1.0 | μA |
| Dynamic Impedance (Note 2) | $Z_{KA}$ | $V_{KA}=V_{REF}$, $I_K=1$ to 100mA<br>$f \leq 1.0KHz$ | | | 0.2 | 0.5 | | 0.2 | 0.5 | | 0.2 | 0.5 | Ω |

*KA431C/AC: $T_{min}=0°C$, $T_{max}=+70°C$
KA431I: $T_{min}=-40°C$, $T_{max}=+85°C$

**Note:** 1. The deviation parameters $V_{REF(dev)}$ and $I_{REF(dev)}$ are defined as the differences between the maximum and minimum values obtained over the rated temperature range. The equivalent full-range temperature coefficient of the reference input voltage, $\alpha V_{REF}$ is defined as:



Max $V_{REF}$ Min $V_{REF}$ $\Delta T_A$ $V_{REF(dev)}$

$$\alpha V_{REF}\ (\frac{ppm}{°C}) = \frac{(\frac{V_{REF(dev)}}{V_{REF}@25°C})\times 10^6}{\Delta T_A}$$

where $\Delta T_A$ is the rated operating free-air temperature range of the device.
$\alpha V_{REF}$ can be positive or negative depending on whether minimum $V_{REF}$ or maximum $V_{REF}$ respectively, occurs at the lower temperature

Example: Max $V_{REF} = 2500mV@30°C$, Min $V_{REF} = 2492mV@0°C$, $V_{REF} = 2495mV@25°C$, $\Delta T_A = 70°C$ for KA431C

$$\left|\alpha V_{REF}\right| = \frac{(\frac{8mV}{2495mV})\times 10^6}{70°C} = 46ppm/°C$$

Because minimum $V_{REF}$ occurs at the lower temperature, the coefficient is positive.

2. The dynamic impedance is defined as:

$$\left|Z_{KA}\right| = \frac{\Delta V_{KA}}{\Delta I_K}$$

When the device is operated with two external resistors (see Figure 2), the total dynamic impedance of the circuit is given by:

$$\left|Z'\right| = \frac{\Delta V}{\Delta I} = \left|Z_{KA}\right|\ (1+\frac{R1}{R2})$$

## TEST CIRCUITS

**Fig. 1 Test Circuit for $V_{KA} = V_{REF}$**

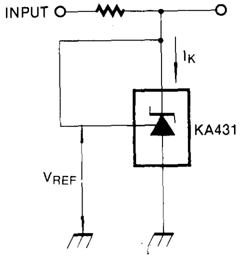


**Fig. 2 Test Circuit for $V_{KA} \geq V_{REF}$**

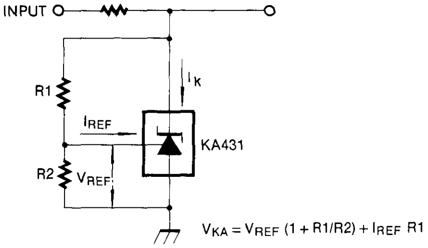
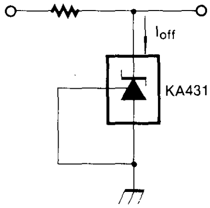


**Fig. 3 Test Circuit for $I_{off}$**



# TYPICAL PERFORMANCE CHARACTERISTICS

Fig. 4 CATHODE CURRENT VS CATHODE VOLTAGE

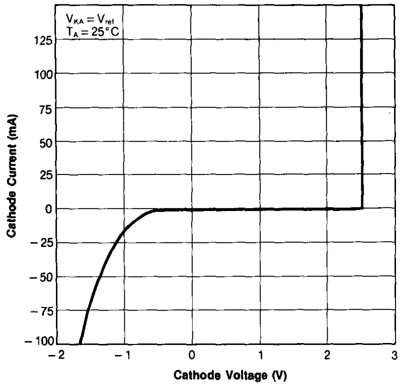


Fig. 5 CATHODE CURRENT VS CATHODE VOLTAGE

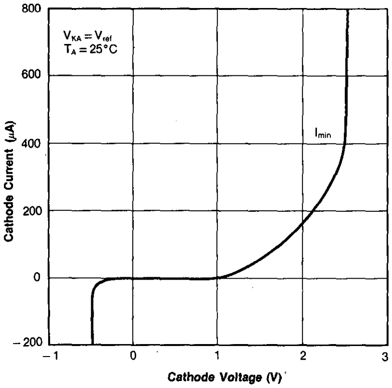


Fig. 6 CHANGE IN REFERENCE INPUT VOLTAGE VS CATHODE VOLTAGE

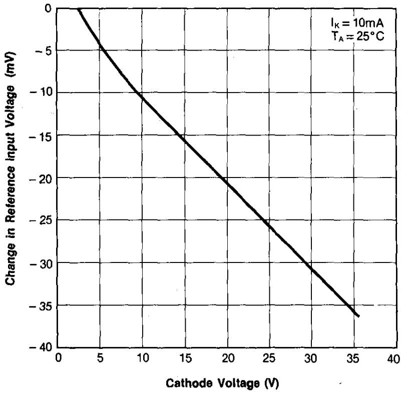


Fig. 7 NOISE VOLTAGE VS FREQUENCY

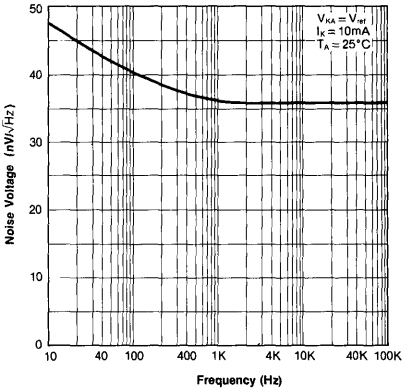


Fig. 8 DYNAMIC IMPEDANCE VS FREQUENCY

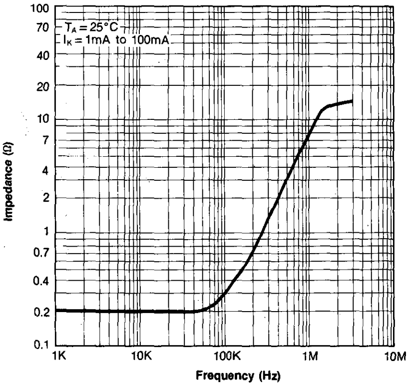
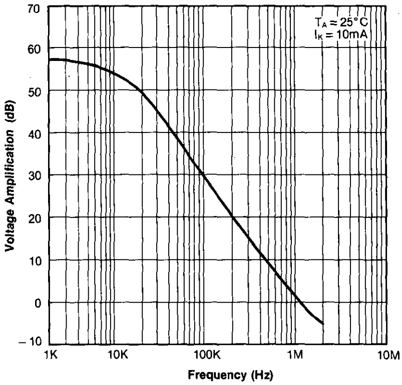
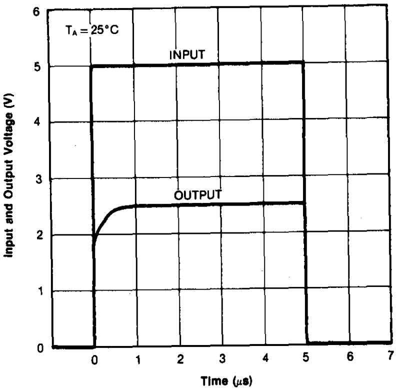


Fig. 9 SMALL SIGNAL VOLTAGE AMPLIFICATION VS FREQUENCY



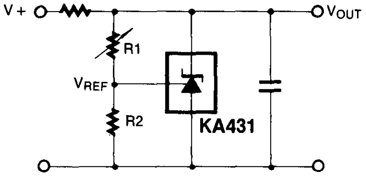
## TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

**Fig. 10 PULSE RESPONSE**



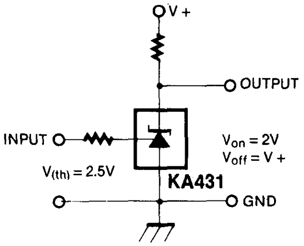
## TYPICAL APPLICATIONS

### FIGURE 11—SHUNT REGULATOR

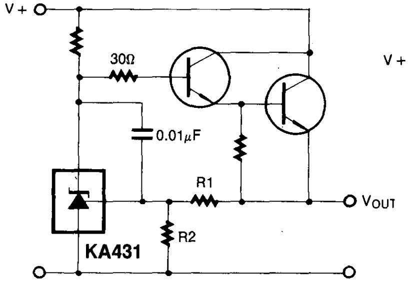


$V_{out} = (1 + \frac{R1}{R2})V_{ref}$

### FIGURE 12—SINGLE-SUPPLY COMPARATOR WITH TEMPERATURE-COMPENSATED THRESHOLD

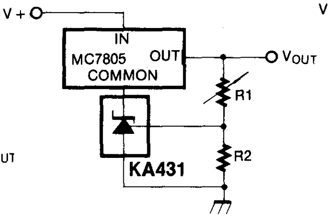


### FIGURE 13—SERIES REGULATOR



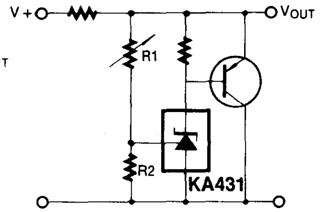
$V_{out} = (1 + \frac{R1}{R2})V_{ref}$

### FIGURE 14—OUTPUT CONTROL OF A THREE-TERMINAL FIXED REGULATOR



$V_{OUT} = V_{REF}(1 + \frac{R1}{R2})$

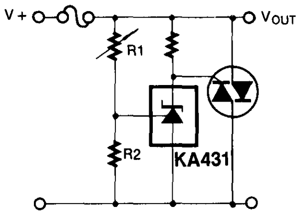
### FIGURE 15—HIGHER-CURRENT SHUNT REGULATOR



$V_{OUT} = (1 + \frac{R1}{R2})V_{ref}$

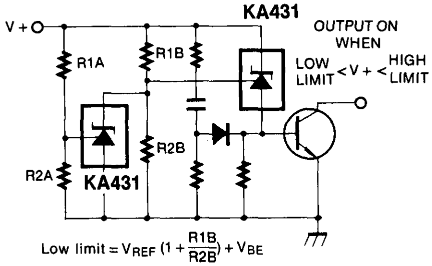
## TYPICAL APPLICATIONS (Continued)

**FIGURE 16—CROWBAR**



$V_{limit} = (1 + \frac{R1}{R2})V_{REF}$

**FIGURE 17—OVER-VOLTAGE/UNDER-VOLTAGE PROTECTION CIRCUIT**

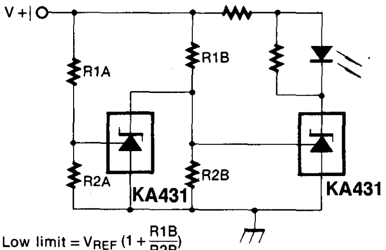


OUTPUT ON WHEN $\text{LOW LIMIT} < V+ < \text{HIGH LIMIT}$

Low limit = $V_{REF}\,(1 + \frac{R1B}{R2B}) + V_{BE}$

High limit = $V_{REF}\,(1 + \frac{R1A}{R2A})$

**FIGURE 18—VOLTAGE MONITOR**

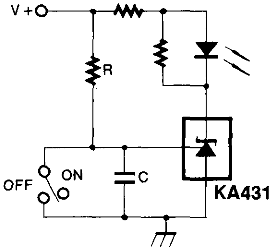


Low limit = $V_{REF}\,(1 + \frac{R1B}{R2B})$

High limit = $V_{REF}\,(1 + \frac{R1A}{R2A})$

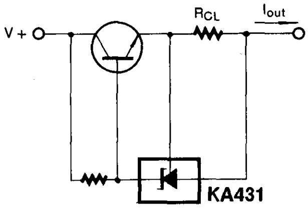
$\text{LOW LIMIT} < V+ < \text{HIGH LIMIT}$

**FIGURE 19—DELAY TIMER**



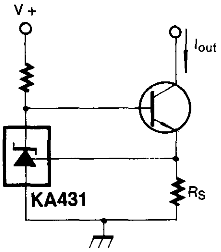
Delay = $R \cdot C \cdot \ln \frac{V+}{(V+) - V_{REF}}$

**FIGURE 20—CURRENT LIMITER OR CURRENT SOURCE**



$I_{out} = \frac{V_{REF}}{R_{CL}}$

**FIGURE 21—CONSTANT-CURRENT SINK**



$I_{out} = \frac{V_{REF}}{R_S}$

## VOLTAGE REFERENCE

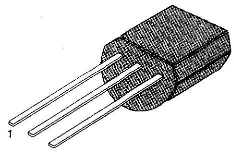
The KA336-2.5 integrated circuit is precision 2.5V shunt regulator. The monolithic IC voltage references operates as a low temperature coefficient 2.5V zener with 0.2Ω dynamic impedance.

A third terminal on the KA336-2.5 allows the reference voltage and temperature coefficient to be trimmed easily.

KA336-2.5 is useful as a precision 2.5V low voltage reference for digital voltmeters, power supplies or op amp circuitry. The 2.5V make it convenient to obtain a stable reference from low voltage supplies.

Further, since the KA336-2.5 operates as a shunt regulator, it can be used as either a positive or negative voltage reference.

TO-92



1: ADJ, 2: +, 3: –

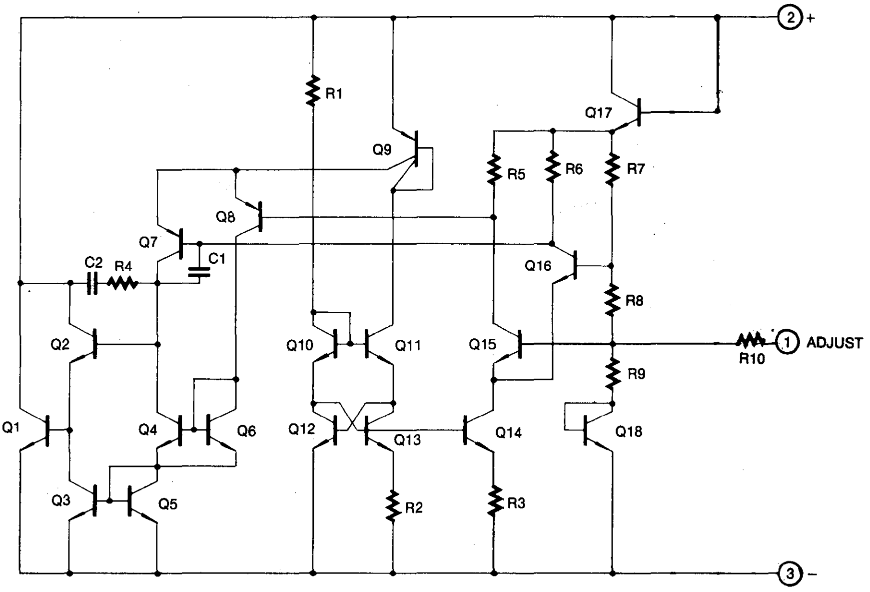
## FEATURE

- **Low temperature coefficient**
- **Guaranteed temperature stability 4mV typical**
- **0.2Ω dynamic impedance**
- **±1.0% initial tolerance available.**
- **Easily trimmed for minimum temperature drift.**

## ORDERING INFORMATION

| Device | Package | Operating Temperature |
|---|---|---|
| KA336-2.5 | TO-92 | 0~70°C |
| KA336-2.5B | | |
| KA236-2.5 | | −25~+85°C |

## SCHEMATIC DIAGRAM



## ABSOLUTE MAXIMUM RATINGS

| Characteristic | Symbol | Value | Unit |
|---|---|---|---|
| Reverse Current | $I_R$ | 15 | mA |
| Forward Current | $I_F$ | 10 | mA |
| Operating Temperature Range KA336-2.5<br>KA236-2.5 | $T_{opr}$ | 0 ~ +70<br>−25 ~ +85 | °C<br>°C |
| Storage Temperature Range | $T_{stg}$ | −60 ~ +150 | °C |

## ELECTRICAL CHARACTERISTICS ($T_{min} < Ta < T_{max}$, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | KA336/236 | | | KA336B | | | Unit |
|---|---|---|---|---|---|---|---|---|---|
| | | | Min | Typ | Max | Min | Typ | Max | |
| Reverse Breakdown Voltage | $V_R$ | $Ta = 25°C$<br>$I_R = 1mA$ | 2.44 | 2.49 | 2.54 | 2.465 | 2.49 | 2.515 | V |
| Reverse Breakdown Change with Current | $\triangle V_R$ | $Ta = 25°C$<br>$400\mu A \leq I_R \leq 10mA$ | | 2.6 | 6 | | 2.6 | 10 | mV |
| Reverse Dynamic Impedance | $Z_D$ | $Ta = 25°C$<br>$I_R = 1mA$ | | 0.2 | 0.6 | | 0.2 | 1 | Ω |
| Temperature Stability | $\triangle V_R T_1$ | $I_R = 1mA$<br>$T_{min} \leq Ta \leq T_{max}$ | | 1.8 | 6 | | 1.8 | 6 | mV |
| Reverse Breakdown Change with Current | $\triangle V_R T_2$ | $T_{min} \leq Ta \leq T_{max}$<br>$400\mu A \leq I_R \leq 10mA$ | | 3 | 10 | | 3 | 12 | mV |
| Reverse Dynamic Impedance | $Z_{DT}$ | $I_R = 1mA$<br>$T_{min} \leq Ta \leq T_{max}$ | | 4 | 1 | | 0.4 | 1.4 | Ω |
| Long Term Stability | S | $I_R = 1mA$<br>$T_{min} \leq Ta \leq T_{max}$ | | 20 | | | 20 | | ppm |

* $T_{min} \leq Ta \leq T_{max}$
KA236: $T_{min} = -25°C$, $T_{max} = 85°C$
KA336: $T_{min} = 0°C$, $T_{max} = 70°C$

## TYPICAL PERFORMANCE CHARACTERISTICS

Fig. 1. REVERSE VOLTAGE CHANGE

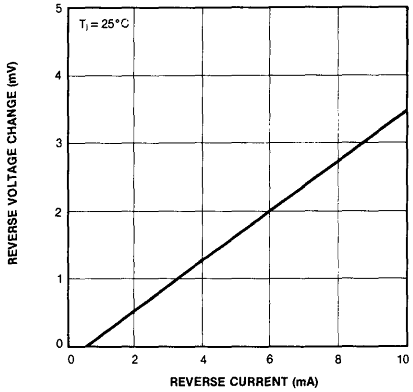


Fig. 2 REVERSE CHARACTERISTICS

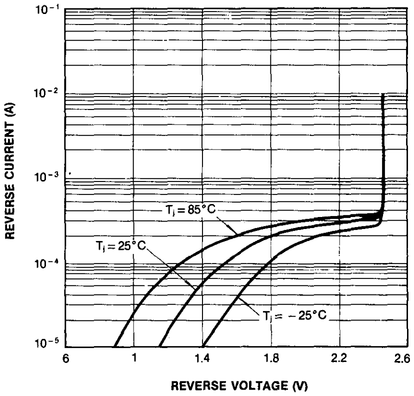


Fig. 3 TEMPERATURE DRIFT

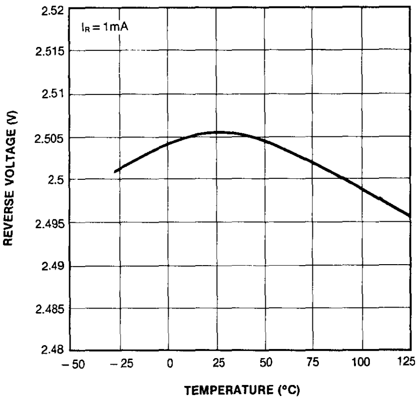
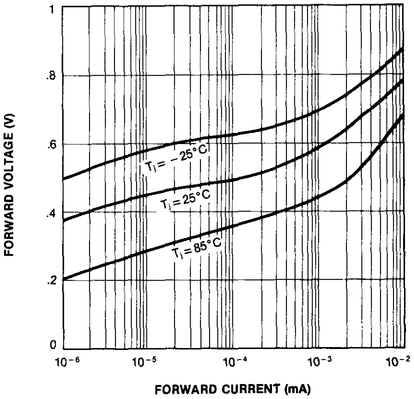


Fig. 4 FORWARD CHARACTERISTICS



## TYPICAL APPLICATIONS

**Fig. 5 2.5V REFERENCE**

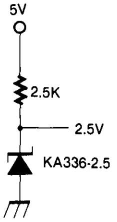
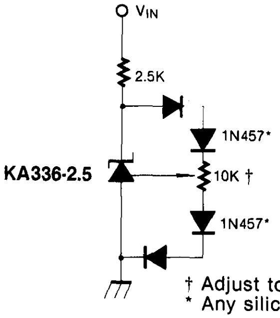
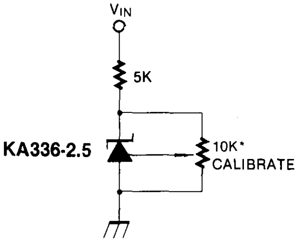


**Fig. 6 2.5V Reference with minimum temperature coefficient**



† Adjust to 2.490V
* Any silicon signal diode

**Fig. 7 Trimmed 4V to 6V reference with temperature coefficient of breakdown voltage independent**



* Does not affect temperature coefficient

**Fig. 8 Precision power regulator with low temperature coefficient**

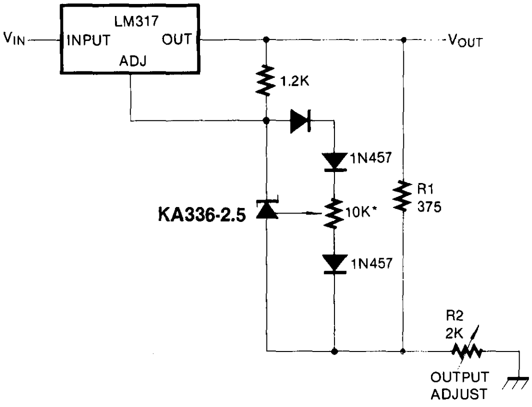
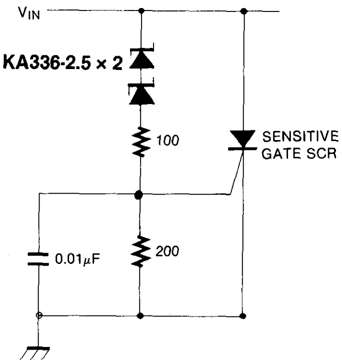


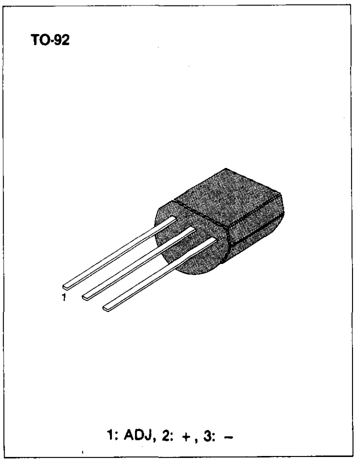
**Fig. 9 5V Crowbar**



## VOLTAGE REFERENCE

The KA236/KA336-5.0 integrated circuit is a precision 5.0 V shunt regulator. The monolithic IC voltage references operate as a low temperature coefficient 5.0 V zener with 0.6 ohm dynamic impedance. A third terminal on the KA236/KA336-5.0 allows the reference voltage and temperature coefficient to be trimmed easily.

The KA236/KA336-5.0 is useful as a precision 5.0 V low voltage references it convenient in obtaining a stable reference from low voltage supplies. Further, since the KA236/KA336-5.0 operates as a shunt regulators, it can be used as either a positive or negative voltage reference. The KA236 is characterized for operation from −25°C to 85°C, and the KA336 from 0°C to 70°C.



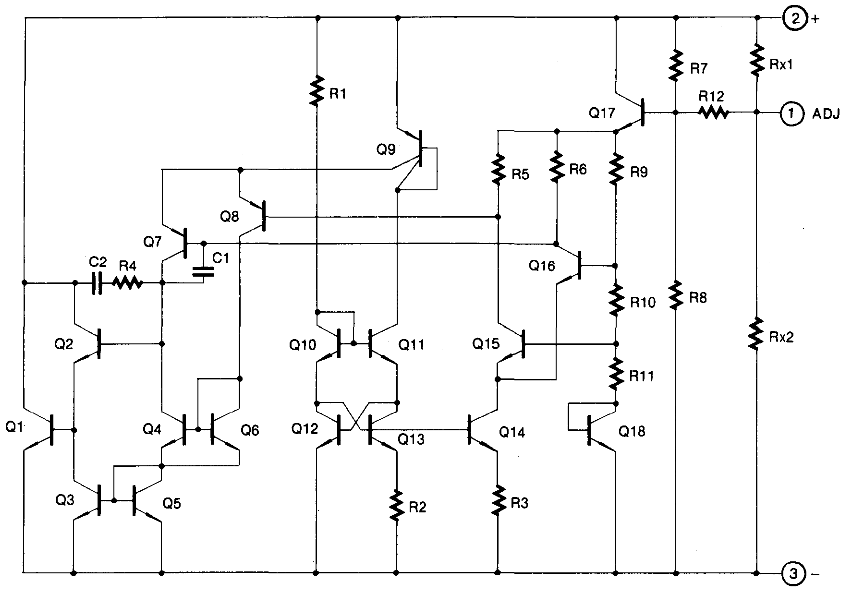
## FEATURES

- Low temperature coefficient
- Adjustable 4V to 6V
- Wide operating range current of 400$\mu$A to 10mA
- Three lead transistor package (To-92)
- 0.6 ohm dynamic impedance
- ±1.0% initial tolerance available
- Guaranteed temperature stability
- Easily trimmed for minimum temperature drift
- Fast turn on

## ORDERING INFORMATION

| Device | Package | Operating Temperature |
|---|---|---|
| KA336-5.0 | TO-92 | 0~70°C |
| KA336-5.0B | | |
| KA236-5.0 | | −25~+80°C |

## SCHEMATIC DIAGRAM



Rx1, Rx2: External
Resistors

## ABSOLUTE MAXIMUM RATINGS

| Characteristic | Symbol | Value | Unit |
|---|---|---|---|
| Reverse Current | $I_R$ | 15 | mA |
| Forward Current | $I_F$ | 10 | mA |
| Operating Temperature Range<br>KA336-5.0<br>KA236-5.0 | $T_{opr}$ | <br>0 ~ +70<br>−25 ~ +85 | °C |
| Storage Temperature Range | $T_{stg}$ | −60 ~ +150 | °C |

## ELECTRICAL CHARACTERISTICS

($T_{min} \leq T_a \leq T_{max}$, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | KA336/236 | | | KA336B | | | Unit |
|---|---|---|---|---|---|---|---|---|---|
| | | | Min | Typ | Max | Min | Typ | Max | |
| Reverse Breakdown Voltage | $V_R$ | $T_a = 25°C$, $I_R = 1mA$ | 4.8 | 5.0 | 5.2 | 4.9 | 5.0 | 5.1 | V |
| Reverse Breakdown Change with Current | $\triangle V_R$ | $T_a = 25°C$<br>$600\mu A \leq I_R \leq 10mA$ | — | 6 | 20 | — | 6 | 20 | mV |
| Reverse Dynamic Impedance | $Z_D$ | $T_a = 25°C$, $I_R = 1mA$ | — | 0.6 | 2 | — | 0.6 | 2 | Ω |
| Temperature Stability | $\triangle V_R T_1$ | $I_R = 1mA$<br>$T_{min} \leq T_a \leq T_{max}$ | — | 4 | 12 | — | 4 | 12 | mV |
| Reverse Breakdown Change with Current | $\triangle V_R T_2$ | $600\mu A \leq I_R \leq 10mA$<br>$T_{min} \leq T_a \leq T_{max}$ | — | 6 | 24 | — | 6 | 24 | mV |
| Reverse Dynamic Impedance | $Z_{DT}$ | $I_R = 1mA$<br>$T_{min} \leq T_a \leq T_{max}$ | — | 0.8 | 2.5 | — | 0.8 | 2.5 | Ω |
| Long Term Stability | S | $I_R = 1mA$<br>$T_{min} \leq T_a \leq T_{max}$ | — | 20 | — | — | 20 | — | ppm |

* $T_{min} \leq T_a \leq T_{max}$
KA236: $T_{min} = -25°C$, $T_{max} = 85°C$
KA336: $T_{min} = 0°C$, $T_{max} = 70°C$

## TYPICAL PERFORMANCE CHARACTERISTICS

**Fig. 1 REVERSE VOLTAGE CHANGE**

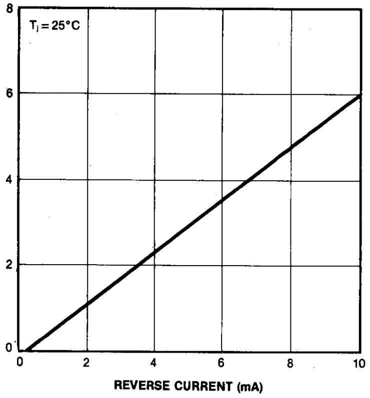
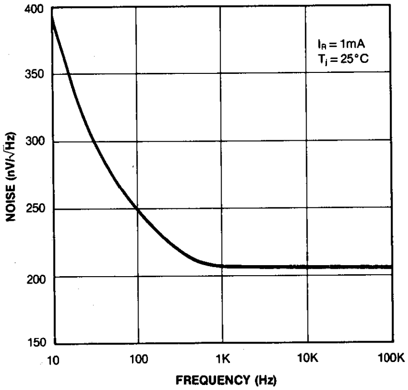


**Fig. 2 ZENER NOISE VOLTAGE**



## TYPICAL PERFORMANCE CHARACTERISTICS

**Fig. 3 DYNAMIC IMPEDANCE**

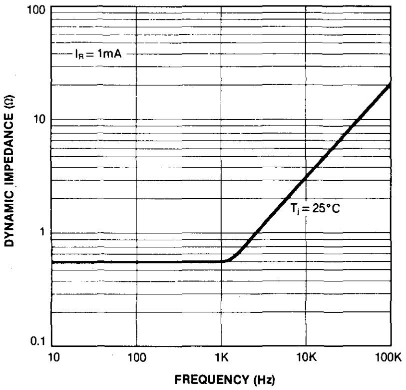


**Fig. 4 RESPONSE TIME**

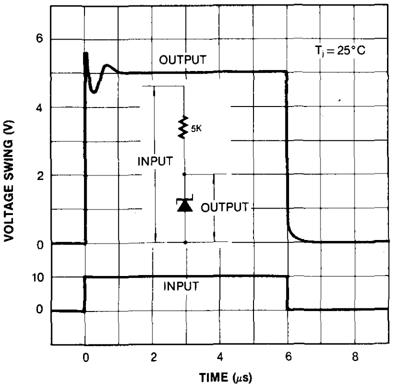


**Fig. 5 REVERSE CHARACTERISTICS**

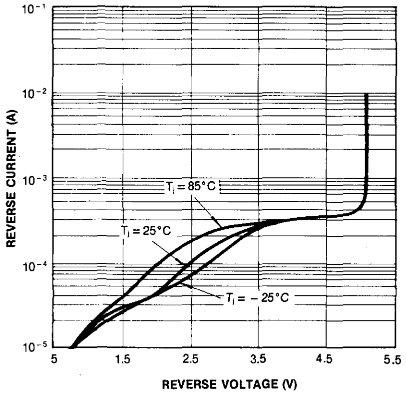


**Fig. 6 TEMPERATURE DRIFT**

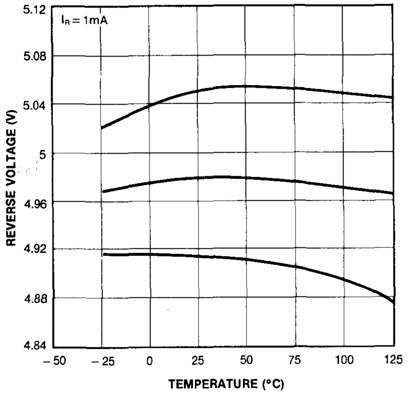
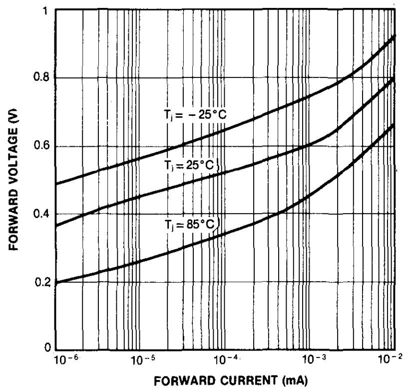


**Fig. 7 FORWARD CHARACTERISTICS**



## TYPICAL APPLICATIONS

**Fig. 8 5.0V REFERENCE**

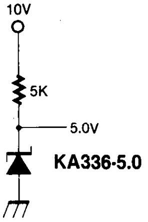
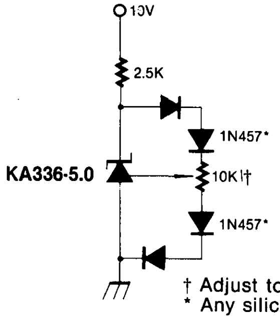
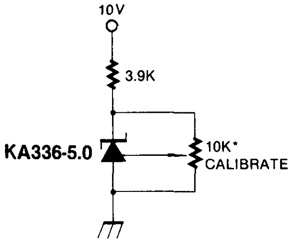


**Fig. 9 5.0V REFERENCE WITH MINIMUM TEMPERATURE COEFFICIENT**



† Adjust to 5V
* Any silicon signal diode

**Fig. 10 TRIMMED 4V TO 6V REFERENCE WITH TEMPERATURE COEFFICIENT INDEPENDENT OF BREAKDOWN VOLTAGE**



* Does not affect temperature coefficient

FIGURE 10

**Fig. 11 PRECISION POWER REGULATOR WITH LOW TEMPERATURE COEFFICIENT**

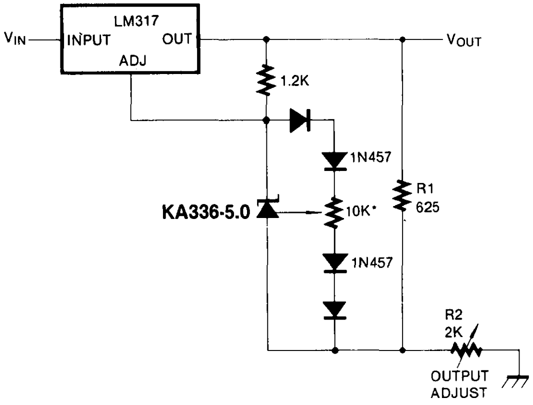
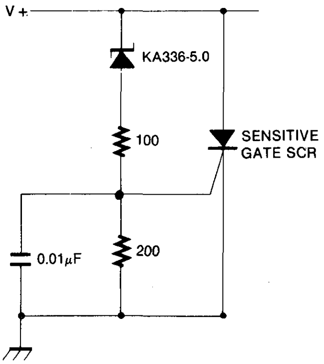
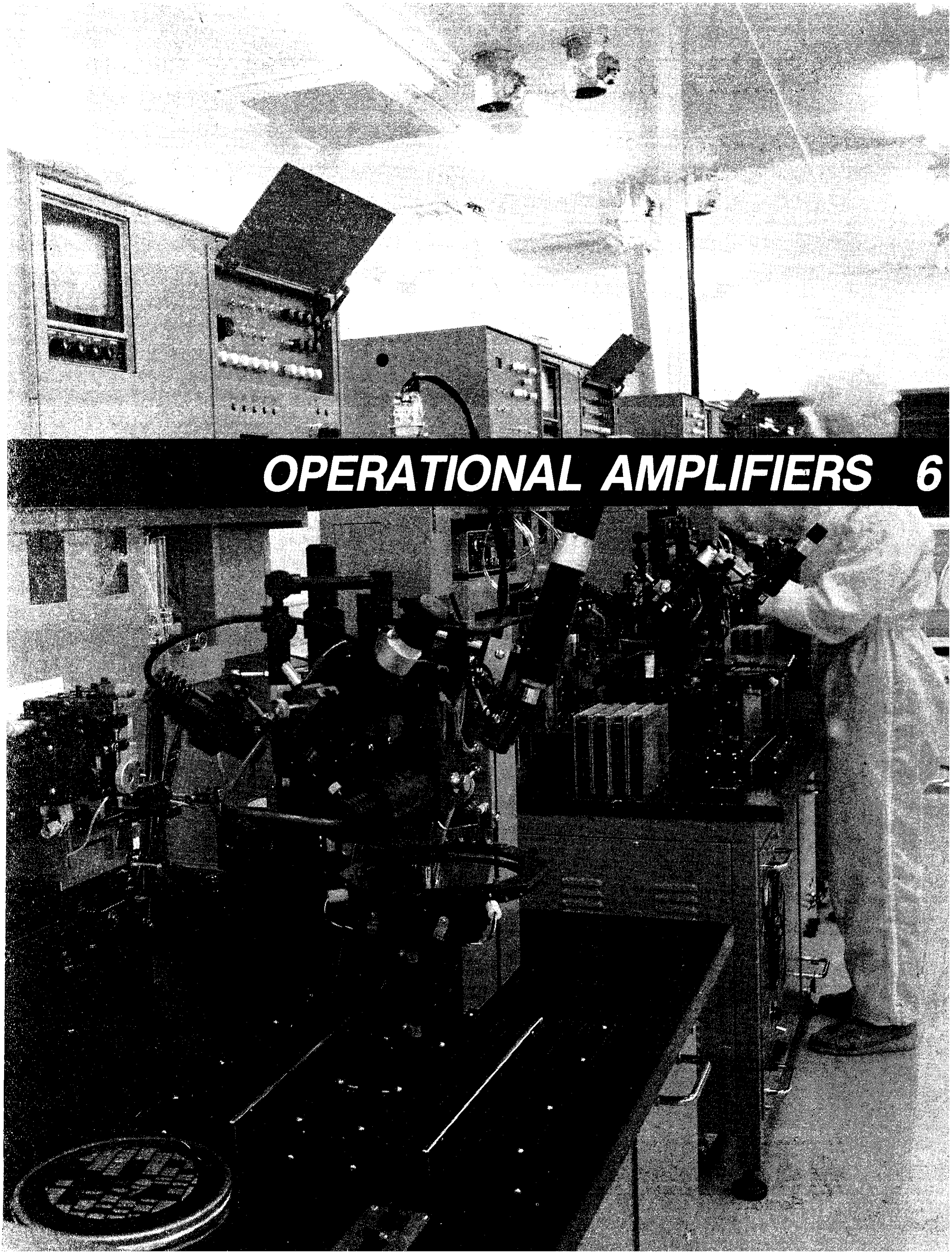


**Fig. 12 5V CROWBAR**



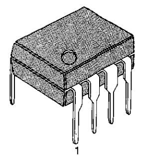


# OPERATIONAL AMPLIFIERS 6

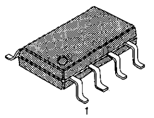
## SINGLE OPERATIONAL AMPLIFIER

The KA201A and KA301A are general-purpose operational amplifiers which are externally phase compensated, permit a choice of operation for optimum high-frequency performance at a selected gain: unity-gain compensation can be obtained with a single capacitor.

**8 DIP**



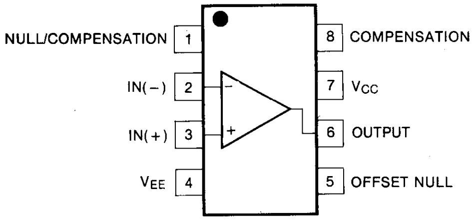
**8 SOP**



## FEATURES

- **Short-circuit protection and latch-free operation**
- **Slew rate of 10V/μs as a summing amplifier**
- **Class AB output provides excellent linearity**
- **Low bias current**

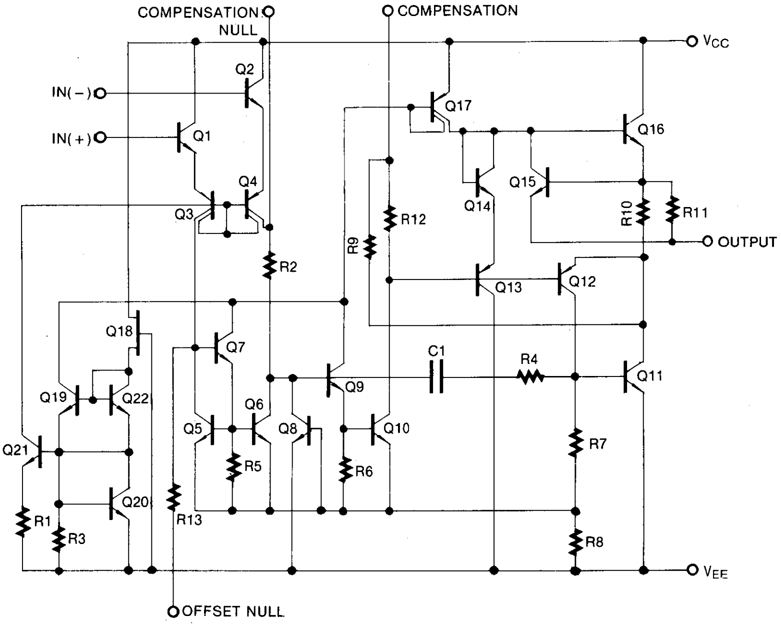
## BLOCK DIAGRAM



## ORDERING INFORMATION

| Device | Package | Operating Temperature |
|---|---|---|
| KA301AN | 8 DIP | 0~+85°C |
| KA201AN | | −25~+70°C |
| KA301AD | 8 SOP | 0~+85°C |
| KA201AD | | −25~+85°C |

## SCHEMATIC DIAGRAM



## ABSOLUTE MAXIMUM RATINGS

| Characteristic | Symbol | KA201A | KA301A | Unit |
|---|---|---|---|---|
| Supply Voltage | $V_S$ | ±22 | ±18 | V |
| Differential Input Voltage | $V_{ID}$ | ±30 | ±30 | V |
| Input Voltage | $V_I$ | ±15 | ±15 | V |
| Output Short Circuit Duration | | Continuous | Continuous | |
| Power Dissipation | $P_D$ | 500 | 500 | mW |
| Operating Temperature Range | $T_{opr}$ | −25 ~ +85 | 0 ~ +70 | °C |
| Storage Temperature Range | $T_{stg}$ | −65 ~ +150 | −65 ~ +150 | °C |

## ELECTRICAL CHARACTERISTICS

($T_a = +25°C$, $V_{CC} = +15V$, $V_{EE} = -15V$, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | | KA201A | | | KA301A | | | Unit |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Min | Typ | Max | Min | Typ | Max | |
| Input Offset Voltage | $V_{IO}$ | $R_S \leq 50K\Omega$ | | | 0.5 | 2.0 | | 2.0 | 7.5 | mV |
| | | | NOTE 1 | | | 3 | | | 10 | mV |
| Input Offset Current | $I_{IO}$ | | | | 1.5 | 10 | | 4.5 | 50 | nA |
| | | | NOTE 1 | | | 20 | | | 70 | nA |
| Input Bias Current | $I_{IB}$ | | | | 40 | 75 | | 60 | 250 | nA |
| | | | NOTE 1 | | | 100 | | | 300 | nA |
| Supply Current | $I_S$ | $V_S = \pm 20V$ | | | 2.0 | 3.0 | | | | mA |
| | | $V_S = \pm 15V$ | | | | | | 2.0 | 3.0 | mA |
| | | $V_S = \pm 20V$, $T_a = T_{amax}$ | | | 1.7 | 2.5 | | | | mA |
| Large Signal Voltage Gain | $A_V$ | $V_{CC} = \pm 15V$, $R_L \geq 2K\Omega$, $V_o = \pm 10V$ | | 50 | 160 | | 25 | 160 | | V/mV |
| | | | NOTE 1 | 25 | | | 15 | | | V/mV |
| Average Temperature Coefficient of Input Offset Voltage | $\Delta V_{IO}/\Delta T$ | NOTE 1 | | | 3.0 | 15 | | 6.0 | 30 | μV/°C |
| Average Temperature Coefficient of Input Offset Current | $\Delta I_{IO}/\Delta T$ | $25°C \leq T_a \leq T_{amax}$ | | | 0.01 | 0.1 | | 0.01 | 0.3 | nA/°C |
| | | $T_{amin} \leq T_a \leq 25°C$ | | | 0.02 | 0.2 | | 0.02 | 0.6 | nA/°C |
| Input Voltage Range | $V_{ICR}$ | $V_S = \pm 20V$ | NOTE 1 | ±15 | | | | | | V |
| | | $V_S = \pm 15V$ | NOTE 1 | | | | ±12 | | | V |
| Common-Mode Rejection Ratio | CMRR | $R_S \leq 50K\Omega$ | NOTE 1 | 80 | 100 | | 70 | 95 | | dB |
| Power Supply Rejection Ratio | PSRR | $R_S \leq 50K\Omega$ | NOTE 1 | 80 | 100 | | 70 | 100 | | dB |
| Output Voltage Swing | $V_{OUT}$ | $V_S = \pm 15V$ | $R_L = 10K\Omega$ | ±12 | ±14 | | ±12 | ±14 | | V |
| | | | $R_L = 2.0K\Omega$ | ±10 | ±13 | | ±10 | ±13 | | V |
| Input Resistance | $R_I$ | | | 1.5 | 4.0 | | 0.5 | 2.0 | | MΩ |

NOTE 1 KA201A: $-25 \leq T_a \leq +85°C$
KA301A: $0 \leq T_a \leq +70°C$

## TYPICAL PERFORMANCE CHARACTERISTICS

Fig. 1 SUPPLY CURRENT

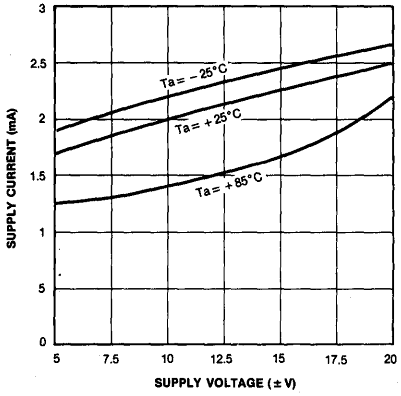


Fig. 2 VOLTAGE GAIN

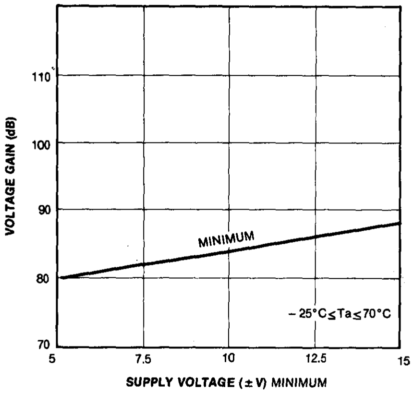


Fig. 3 CURRENT LIMITING

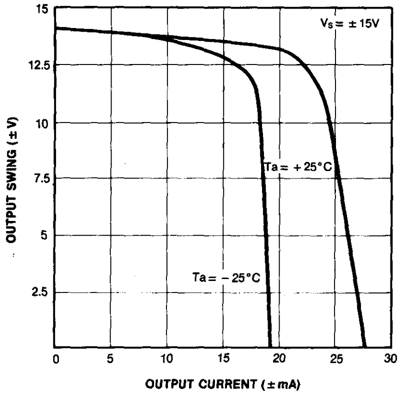


Fig. 4 INPUT CURRENT

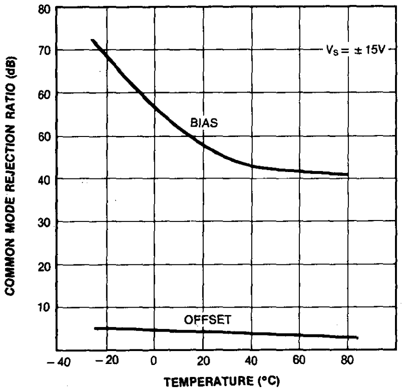


Fig. 5 POWER SUPPLY REJECTION

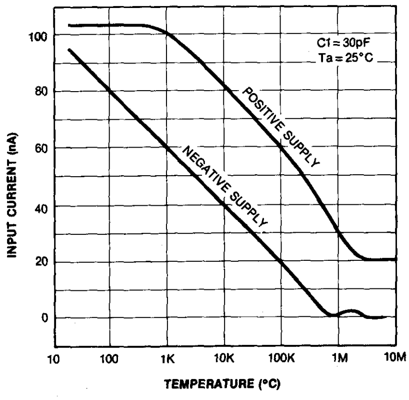


Fig. 6 COMMON MODE REJECTION

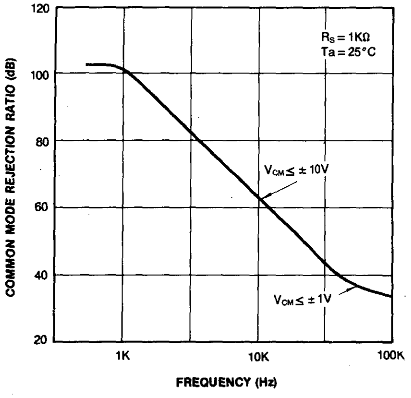
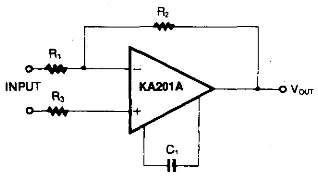


**Fig. 7 SINGLE POLE COMPENSATION**



$$C_1 \geq \frac{R_1C_S}{R_1+R_2}$$

$C_S \geq 30pF$

**Fig. 8 OPEN LOOP FREQUENCY RESPONSE**

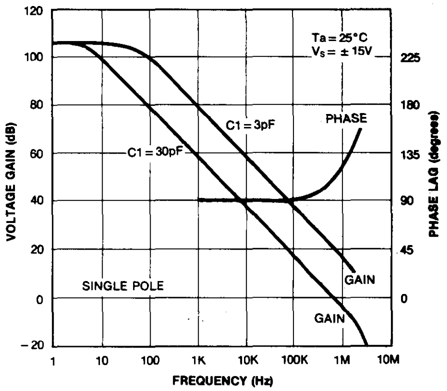


**Fig. 9 LARGE SIGNAL FREQUENCY RESPONSE**

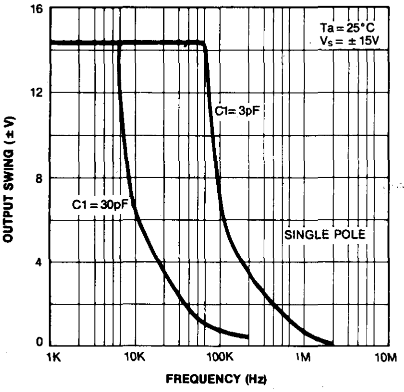


**Fig. 10 VOLTAGE FOLLOWER PULSE RESPONSE**

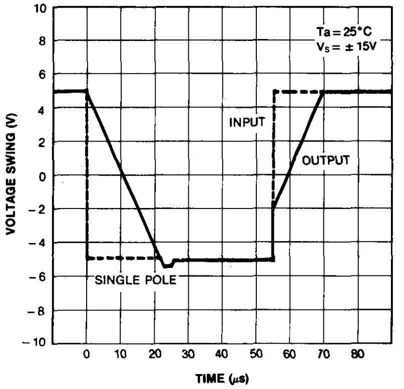
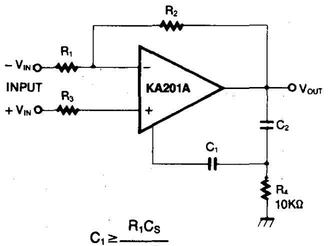


**Fig. 11 TWO POLE COMPENSATION**



$$C_1 \geq \frac{R_1C_S}{R_1+R_2}$$

$C_S = 30pF$

$C_2 = 10C_1$

**Fig. 12 OPEN LOOP FREQUENCY RESPONSE**

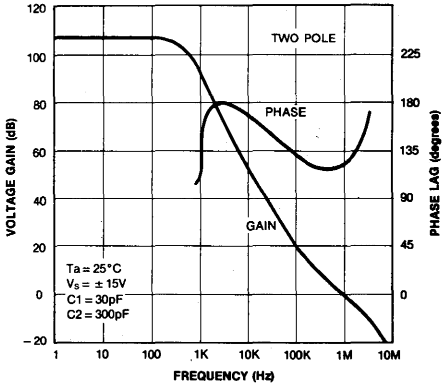


**Fig. 13** LARGE SIGNAL FREQUENCY RESPONSE

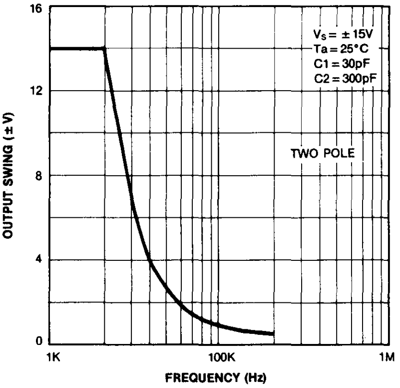


**Fig. 14** VOLTAGE FOLLOWER PULSE RESPONSE

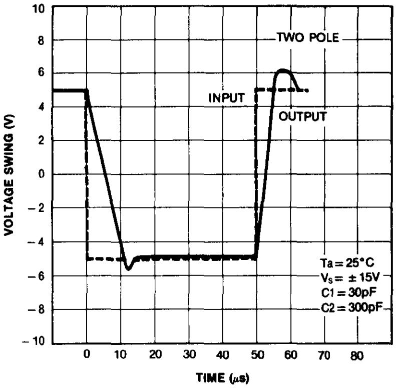


**Fig. 15** FEEDFORWARD COMPENSATION

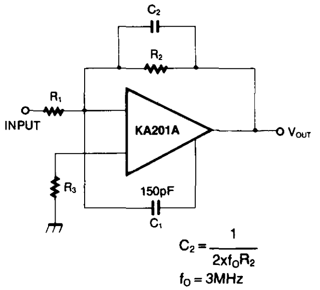


**Fig. 16** OPEN LOOP FREQUENCY RESPONSE

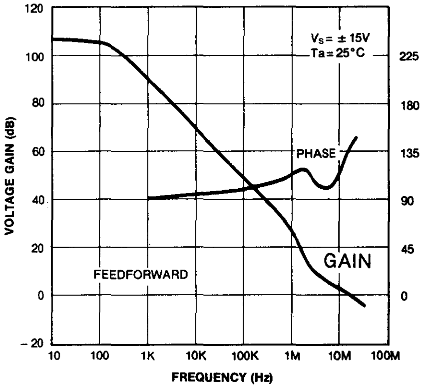


**Fig. 17** LARGE SIGNAL FREQUENCY RESPONSE

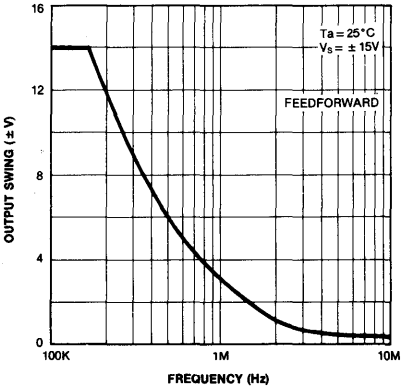
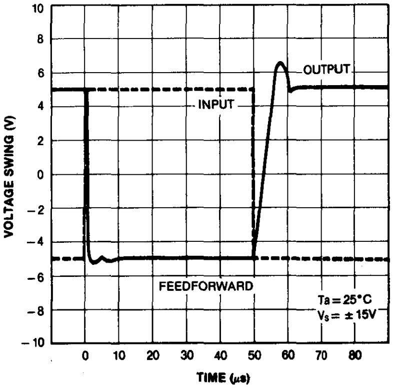


**Fig. 18** INVERTER PULSE RESPOSE

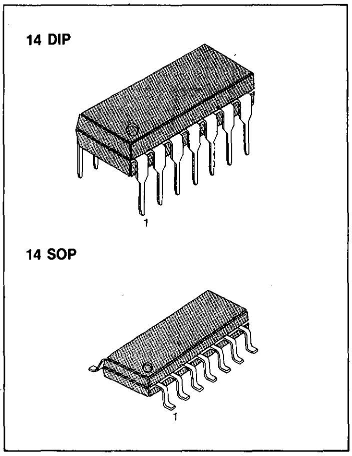


## DIFFERENTIAL VIDEO AMPLIFIER

The KA733C is a monolithic differential input, differential output, wideband video amplifier.

The use of internal series-shunt feedback gives wide bandwidth with low phase distortion and high gain stability. The KA733C offers fixed gains 10,100,400 without external components, and adjustable gains from 10 to 400 by use of an external resistor.

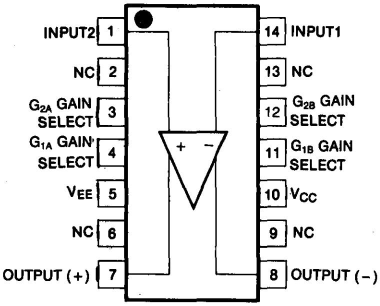
The KA733C is intended for use as a high performance video and pluse amplifier in communications, magnetic memories, displays and video recorder systems.



## FEATURES

- **80MHz bandwidth**
- **170KΩ input resistance**
- **Selectable gains of 10,100,400**
- **No frequency compensation required**

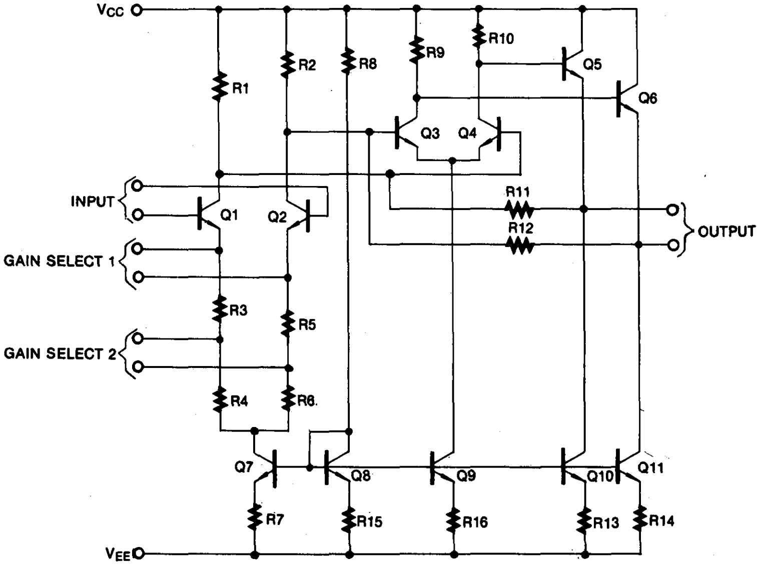
## BLOCK DIAGRAM



## ORDERING INFORMATION

| Device | Package | Operating Temperature |
|---|---|---|
| KA733CN | 14 DIP | 0 ~ +70°C |
| KA733CD | 14 SOP | |

## SCHEMATIC DIAGRAM



## ABSOLUTE MAXIMUM RATINGS

| Characteristic | Symbol | Value | Unit |
|---|---|---|---|
| Differential Input Voltage | $V_{ID}$ | ±5 | V |
| Common mode input Voltage | $V_I$ | ±6 | V |
| Power Supply Voltage | $V_S$ | ±8 | V |
| Output Current | $I_O$ | 10 | mA |
| Power Dissipation | $P_D$ | 500 | mW |
| Operating Temperature Range | $T_{opr}$ | 0 ~ +70 | °C |
| Storage Temperature Range | $T_{stg}$ | −65 ~ +150 | °C |

## ELECTRICAL CHARACTERISTICS

($V_{CC} = +6V$, $V_{EE} = -6V$, $Ta = 25°C$, unless otherwise specified)

| Characteristic | Test Figure | Symbol | Test Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| Differential Voltage Gain<br>Gain 1 (Note 1)<br>Gain 2 ( " 2)<br>Gain 3 ( " 3) | 1 | $A_V$ | $R_L = 2K\Omega$, $V_{out} = 3V_{p\text{-}p}$ | 250<br>80<br>8 | 400<br>100<br>10 | 600<br>120<br>12 | V/V |
| Bandwidth<br>Gain 1 ( " 1)<br>Gain 2 ( " 2)<br>Gain 3 ( " 3) | 2 | BW | $R_S = 50\Omega$ | | 40<br>60<br>80 | | MHz |
| Rise Time<br>Gain 1 ( " 1)<br>Gain 2 ( " 2)<br>Gain 3 ( " 3) | 2 | $t_r$ | $R_S = 50\Omega$<br>$V_{OUT} = 1V_{p\text{-}p}$ | | 10.5<br>4.5<br>2.5 | 12 | ns |
| Propagation Delay<br>Gain 1 ( " 1)<br>Gain 2 ( " 2)<br>Gain 3 ( " 3) | 2 | $t_{pd}$ | $R_S = 50\Omega$<br>$V_{OUT} = 1V_{p\text{-}p}$ | | 6.0<br>6.0<br>3.6 | 10 | ns |
| Input Resistance<br>Gain 1 ( " 1)<br>Gain 2 ( " 2)<br>Gain 3 ( " 3) | 3 | $R_i$ | $V_{OD} \leq 1V$ | 10 | 4.0<br>30<br>170 | | KΩ |
| Input Offset Current | | $I_{IO}$ | | | 0.4 | 5 | μA |
| Input Bias Current | | $I_{IB}$ | | | 9 | 30 | μA |
| Input Voltage Range | 1 | $V_{ICR}$ | | ±1 | | | V |
| Common Mode Rejection Ratio<br>Gain 2<br>Gain 2 | 4 | CMRR | $V_{CM} = \pm 1V$, $f \leq 100KHz$<br>$V_{CM} = \pm 1V$, $f = 5MHz$ | 60 | 86<br>95 | | dB<br>dB |
| Power Supply Rejection Ratio<br>Gain 2 | 1 | PSRR | $\triangle V_S = \pm 0.5V$ | 50 | 86 | | dB |
| Output Offset Voltage<br>Gain 1<br>Gain 2 and 3 | 1 | $V_{OO}$ | $R_L = \infty$ | | 0.6<br>0.35 | 1.5<br>1.5 | V<br>V |
| Input Capacitance | | | Gain 2 | | 2.0 | | pF |

## ELECTRICAL CHARACTERISTIC (Continued)

| Characteristic | Test Figure | Symbol | Test Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| Output Common Mode Voltage | 1 | $V_{OCM}$ | $R_L=\infty$ | 2.4 | 2.9 | 3.4 | V |
| Output Voltage Swing | 1 | $V_{OUT}$ | $R_L=2K\Omega$ | 3.0 | 4.0 | | V |
| Output Sink Current | | $I_{sink}$ | | 2.5 | 3.6 | | mA |
| Power Supply Current | 1 | $I_S$ | $R_L=\infty$ | | 18 | 24 | mA |
| Output Resistance | | $R_o$ | | | 20 | | Ω |

## ELECTRICAL CHARACTERISTICS

The following specifications apply over the range of $0°C \leq Ta \leq 70°C$ $V_{CC}=+6V$, $V_{EE}=-6V$

| Characteristic | Test Figure | Symbol | Test Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| Differential Voltage Gain<br>Gain 1 (Note 1)<br>Gain 2 (Note 2)<br>Gain 3 (Note 3) | 1 | $A_V$ | $R_L=2K\Omega$<br>$V_{out}=3V_{p\text{-}p}$ | <br>250<br>80<br>80 | | <br>600<br>120<br>12 | V/V |
| Input Bias Current | | $I_{IB}$ | | | | 40 | μA |
| Input Offset Current | | $I_{IO}$ | | | | 6.0 | μA |
| Input Voltage Range | 1 | $V_{ICR}$ | | ±1.0 | | | V |
| Input Impedance (Gain 2) | 3 | $R_i$ | | 8.0 | | | KΩ |
| Common Mode Rejection Ratio<br>Gain 2 (Note 2) | 4 | CMRR | $V_{CM}=\pm 1V$, $f \leq 100KHz$ | 50 | | | dB |
| Power Supply Rejection Ratio<br>Gain 2 (Note 2) | 1 | PSRR | $\triangle V_{CC}=\pm 0.5V$<br>$\triangle V_{EE}=\pm 0.5V$ | 50 | | | dB |
| Output Offset Voltage<br>Gain 1 (Note 1)<br>Gain 2 and Gain 3 (Note 2, 3) | 1 | $V_{OO}$ | | | | <br>1.5<br>1.5 | V |
| Output Voltage Swing | 1 | $V_{OP}$ | | 2.8 | | | V |
| Output Sink Current | | $I_{sink}$ | | 2.5 | | | mA |
| Power Supply Current | | $I_S$ | | | | 27 | mA |

Notes 1. Gain select pins $G_{1A}$ and $G_{1B}$ connected together.
2. Gain select pins $G_{2A}$ and $G_{2B}$ connected together.
3. All gain select pins open.

## PARAMETER MEASUREMENT INFORMATION

### TEST CIRCUITS

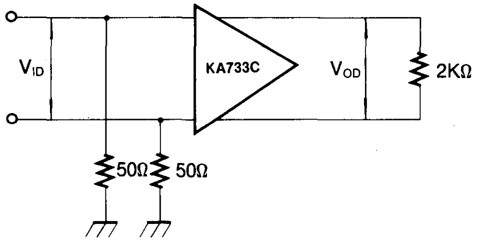


Fig. 1

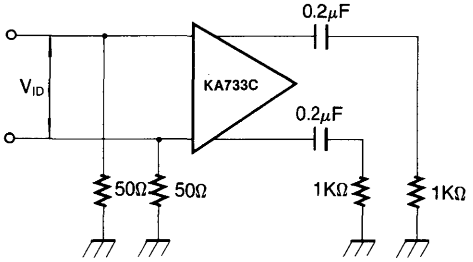


Fig. 2

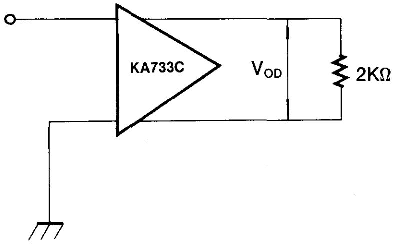


Fig. 3

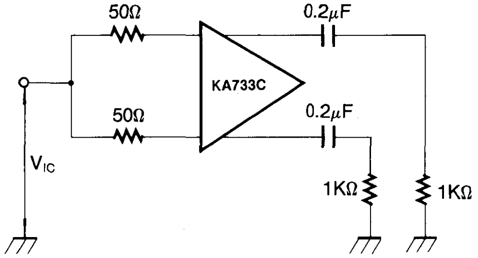


Fig. 4

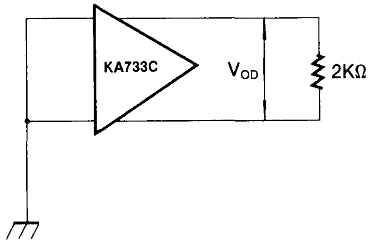
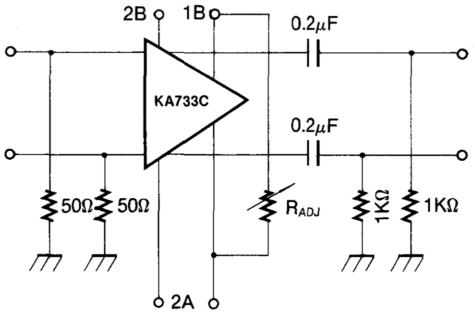


Fig. 5



VOLTAGE AMPLIFICATION ADJUSMENT

Fig. 6

## TYPICAL PERFORMANCE CHARACTERISTICS

**Fig. 7 PHASE SHIFT vs FREQUENCY**

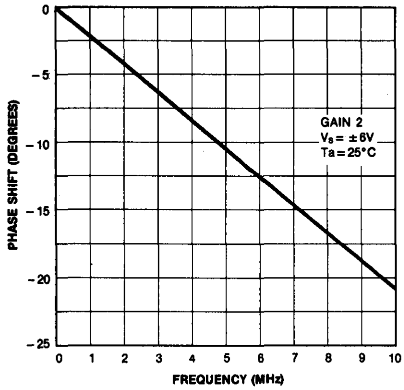


**Fig. 8 PHASE SHIFT vs FREQUENCY**

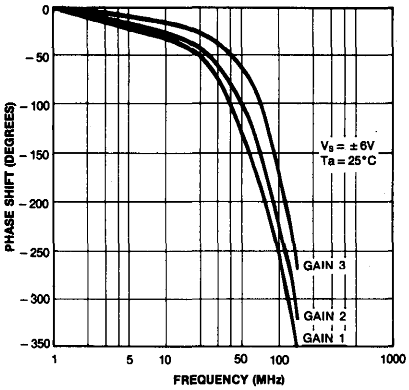


**Fig. 9 VOLTAGE GAIN vs FREQUENCY**

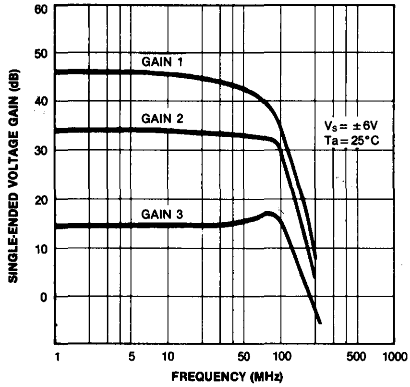


Fig. 9

**Fig. 10 PULSE RESPONSE**

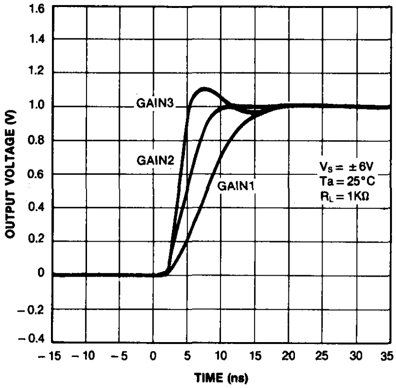


**Fig. 11 PULSE RESPONSE vs SUPPLY VOLTAGE**

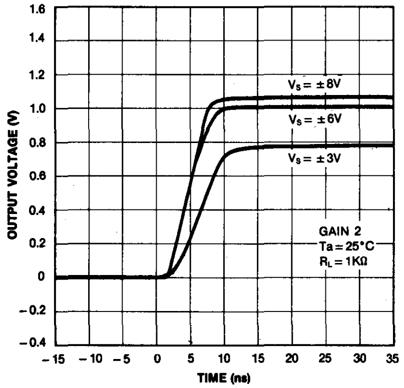


**Fig. 12 PULSE RESPONSE vs TEMPERATURE**

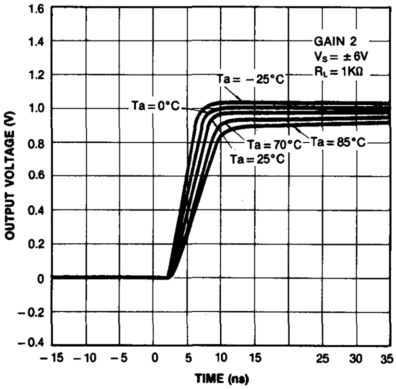


Fig. 13 COMMON MODE REJECTION RATIO vs FREQUENCY

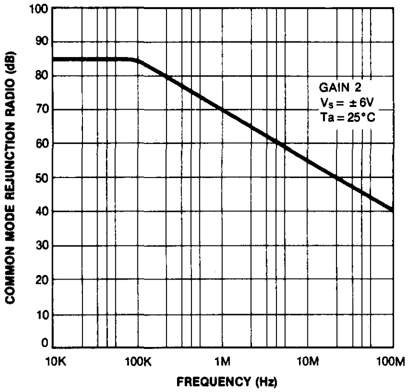


Fig. 14 OUTPUT VOLTAGE SWING vs FREQUENCY

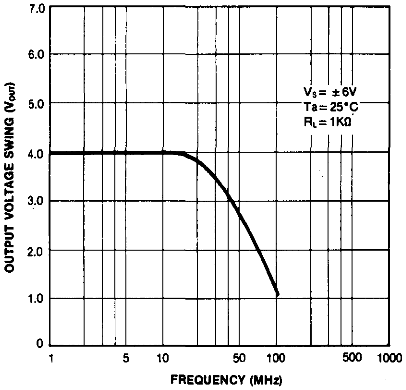


Fig. 15 DIFFERENTIAL OVERDRIVE RECOVERY TIME

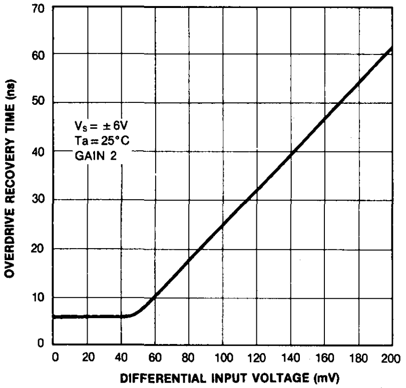


Fig. 16 VOLTAGE GAIN vs SUPPLY VOLTAGE

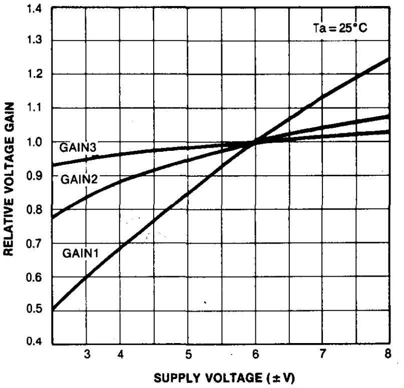


Fig. 17 OUTPUT VOLTAGE SWING vs LOAD RESISTANCE

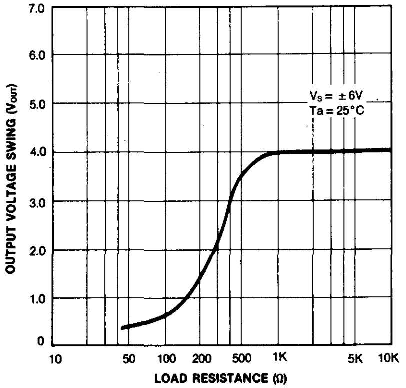


Fig. 18 GAIN vs FREQUENCY vs SUPPLY VOLTAGE

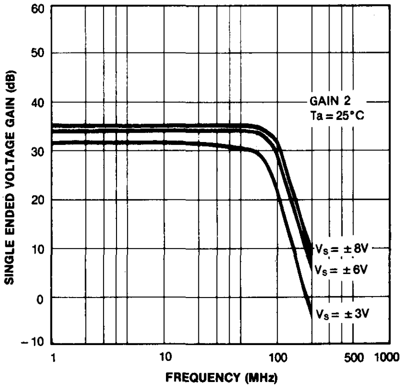


Fig. 19 SUPPLY CURRENT vs TEMPERATURE

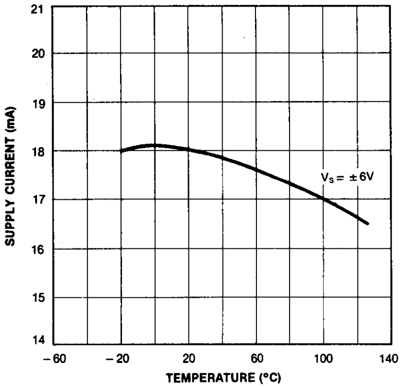


Fig. 20 SUPPLY CURRENT vs SUPPLY VOLTAGE

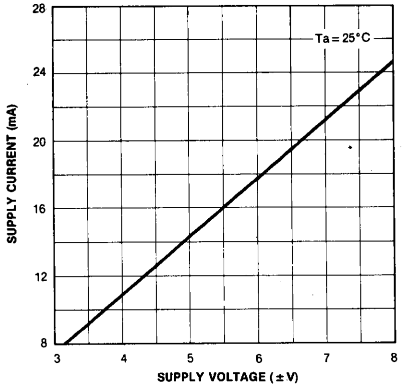


Fig. 21 VOLTAGE GAIN vs $R_{ADJ}$

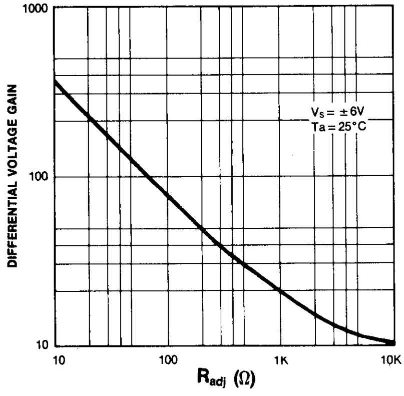
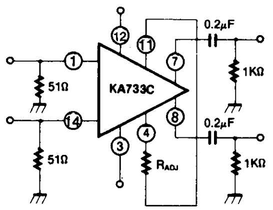


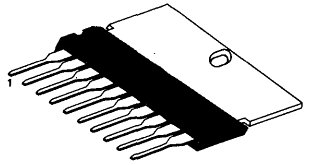
Fig. 22 VOLTAGE GAIN ADJUST CIRCUIT



## DUAL POWER OPERATIONAL AMPLIFIER

The KA9256 is a dual power operational amplifier and it is output maximum current is 1.0A ($V_S = \pm 15V$). It can be used in arm driver for player, driver for brush motors forward and reverse rotation control and CD output driver for hole motor.

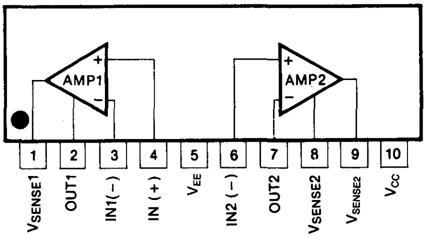
**10 SIP**



## FEATURES

- **Internal current limiting: $I_{OS} = 350mA$ ($R_{SC} = 2.2\Omega$)**
- **High output current: $I_o = 500mA$ max**
- **10 SIP H/S package**
- **Internal phase compensated**

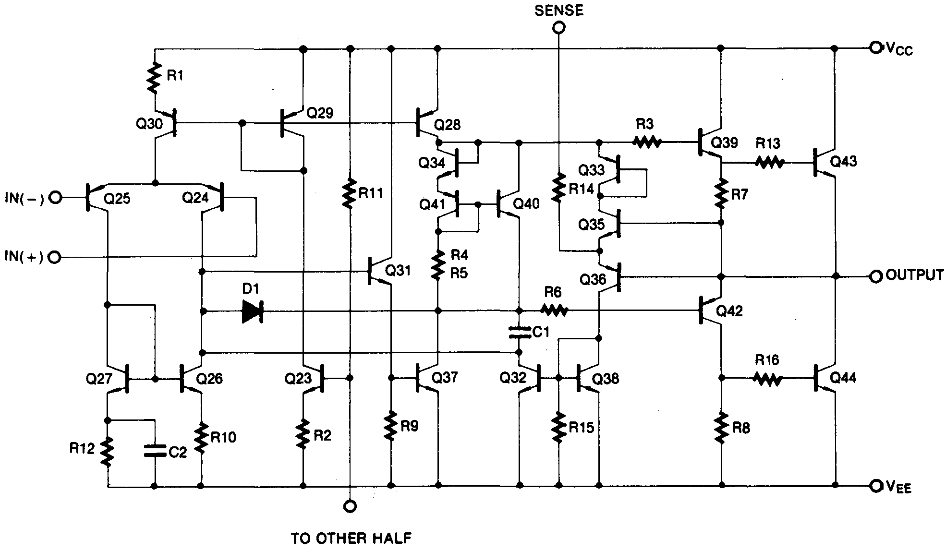
## BLOCK DIAGRAM



## ORDERING INFORMATION

| Device | Package | Operating Temperature |
|---|---|---|
| KA9256 | 10 SIP H/S | −20 ~ +70°C |

## SCHEMATIC DIAGRAM



## ABSOLUTE MAXIMUM RATINGS

| Characteristics | Symbol | Value | Unit |
|---|---|---|---|
| Supply Voltage | $V_S$ | ±18 | V |
| Output Current | $I_o$ | 1.0 | A |
| Power Dissipation | $P_D$ | 12.5 | W |
| Operating Temperature Range | $T_{opr}$ | −20 ~ +70 | °C |
| Storage Temperature Range | $T_{stg}$ | −65 ~ +150 | °C |

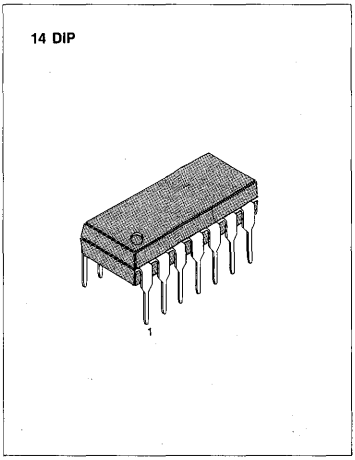
## ELECTRICAL CHARACTERISTICS

($V_{CC}$ = +15V, $V_{EE}$ = −15V, Ta = 25°C, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Input Offset Voltage | $V_{IO}$ | | | 2 | 6 | mV |
| Input Offset Current | $I_{IO}$ | | | 10 | 200 | nA |
| Input Bias Current | $I_{IB}$ | | | 100 | 700 | nA |
| Supply Current | $I_S$ | | | 10 | 20 | mA |
| Output Voltage Swing | $V_{OUT}$ | $R_L = 33\Omega$ | ±12 | ±13 | | V |
| Large Signal Voltage Gain | $A_V$ | | | 100 | | dB |
| Input Voltage Range | $V_{ICR}$ | | ±12 | ±14 | | V |
| Common Mode Rejection Ratio | CMRR | | 70 | 90 | | dB |
| Power Supply Rejection Ratio | PSRR | | | 50 | 150 | μV/V |
| Bandwidth | BW | | | 1.0 | | MHz |
| Slew Rate | SR | $A_V = 1$, $R_L = 33\Omega$, $R = 10\Omega$, $C = 0.1\mu F$ | | 0.15 | | V/μs |
| Limiting Current | $I_{OS}$ | $R_{SC} = 2.2\Omega$ | | 0.35 | | A |
| Cross Talk | CT | $R_L = 33\Omega$, $V_o = 1V_{p\text{-}p}$ | | 60 | | dB |

# QUAD JFET INPUT OPERATIONAL AMPLIFIERS

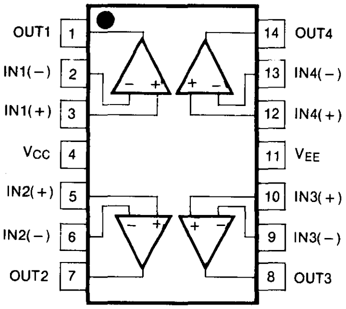
The KF347 is a high speed quad JFET input operational amplifiers. This feature high impedance, wide bandwidth, high slew rate, and low input offset and bias currents. The KF347 may be used in circuits requiring high input impedance, high slew rate and wide bandwidth, low input bias current.



## FEATURES

- **Low input bias**
- **High input impedance**
- **Wide bandwidth: 4 MHz (Typ)**
- **High slew rate: 13 V/μs (Typ)**

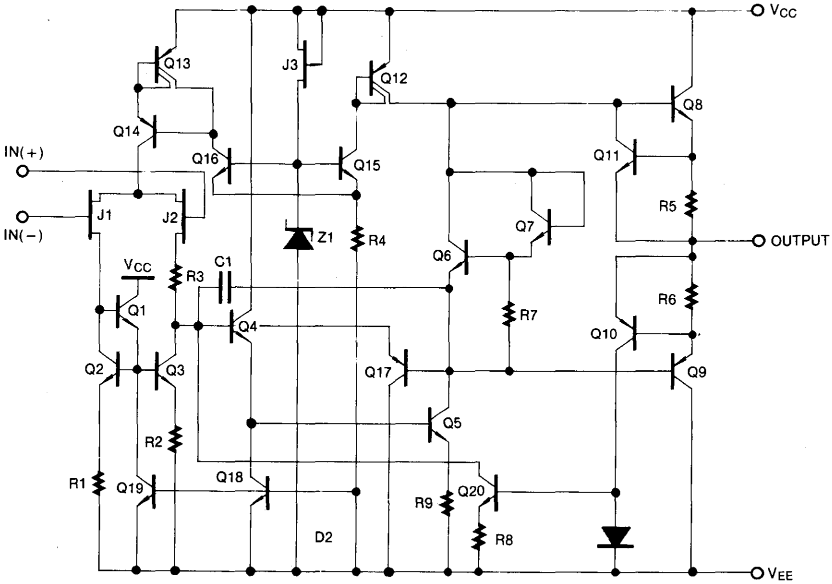
## BLOCK DIAGRAM



## ORDERING INFORMATION

| Device | Package | Operating Temperature |
|---|---|---|
| KF347CN<br>KF347ACN | 14 DIP | 0~ +70°C |

## SCHEMATIC DIAGRAM (One Section Only)



## ABSOLUTE MAXIMUM RATINGS

| Characteristics | Symbol | Value | Unit |
|---|---|---|---|
| Power Supply Voltage | $V_S$ | ±18 | V |
| Differential Input Voltage | $V_{ID}$ | ±30 | V |
| Input Voltage Range | $V_I$ | ±15 | V |
| Output Short Circuit Duration | | Continuous | |
| Power Dissipation | $P_D$ | 570 | mW |
| Operating Temperature Range KF347C/AC | $T_{opr}$ | 0 ~ +70 | °C |
| Storage Temperature Range | $T_{stg}$ | −65 ~ +150 | °C |

## ELECTRICAL CHARACTERISTICS

($V_{CC} = +15V$, $V_{EE} = -15V$, $Ta = 25°C$, unless otherwise specified)

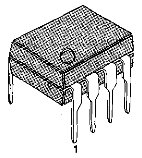
| Characteristic | Symbol | Test Conditions | KF347A | | | KF347C | | | Unit |
|---|---|---|---|---|---|---|---|---|---|
| | | | Min | Typ | Max | Min | Typ | Max | |
| Input Offset Voltage | $V_{IO}$ | $R_S = 10K\Omega$ | | 3 | 5 | | 5 | 10 | mV |
| | | NOTE1 | | | 7 | | | 13 | |
| Input Offset Voltage Drift | $\Delta V_{IO}/\Delta T$ | $R_S = 10K\Omega$ | | 10 | | | 10 | | $\mu$V/°C |
| Input Offset Current | $I_{IO}$ | | | 25 | 100 | | 25 | 100 | pA |
| | | NOTE1 | | | 4 | | | 4 | |
| Input Bias Current | $I_{IB}$ | | | 50 | 200 | | 50 | 200 | pA |
| | | NOTE1 | | | 8 | | | 8 | |
| Large Signal Voltage Gain | $A_V$ | $R_L = 2K\Omega$ | 50 | 100 | | 25 | 100 | | V/mV |
| | | $V_O = \pm 10V$ NOTE1 | 15 | | | 15 | | | |
| Output Voltage Swing | $V_{OUT}$ | $R_L = 10K\Omega$ | ±12 | ±13.5 | | ±12 | ±13.5 | | V |
| Input Voltage Range | $V_{ICR}$ | | ±11 | +15<br>−12 | | ±11 | +15<br>−12 | | V |
| Common-Mode Rejection Ratio | CMRR | $R_S \leq 10K\Omega$ | 80 | 100 | | 80 | 100 | | dB |
| Power Supply Rejection Ratio | PSRR | $R_S \leq 10K\Omega$ | 80 | 100 | | 80 | 100 | | dB |
| Input Resistance | $R_I$ | | | $10^{12}$ | | $10^{12}$ | | | Ω |
| Supply Current | $I_S$ | | | 7.2 | 11 | | 7.2 | 11 | mA |
| Slew Rate | SR | | | 13 | | 13 | | | V/$\mu$S |
| Gain Bandwidth Product | GBW | | | 4 | | 4 | | | MHz |
| Channel Seperation | CS | f = 1Hz ~ 20KHz<br>(input referenced) | | 120 | | | 120 | | dB |
| Equivalent Input Noise Voltage | $e_N$ | $R_S = 100\Omega$<br>f = 1KHz | | 20 | | | 20 | | nV/√Hz |
| Equivalent Input Noise Current | $i_N$ | f = 1KHz | | 0.01 | | | 0.01 | | pA/√Hz |

NOTE 1. KF347C/AC: $0 \leq Ta \leq +70°C$

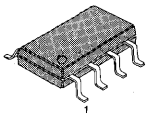
## SINGLE OPERATIONAL AMPLIFIER

The KF351 is JFET input operational amplifier with an internally compensated input offset voltage. The JFET input device provides wide bandwidth, low input bias currents and offset currents.

**8 DIP**



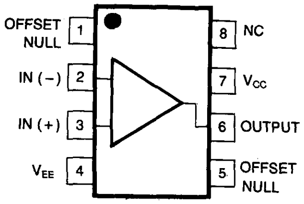
**8 SOP**



## FEATURES

- **Internally trimmed offset voltage: 10mV**
- **Low input bias current: 50pA**
- **Wide gain bandwidth: 4MHz**
- **High slew rate: 13V/μs**
- **High input impedance: $10^{12}\Omega$**

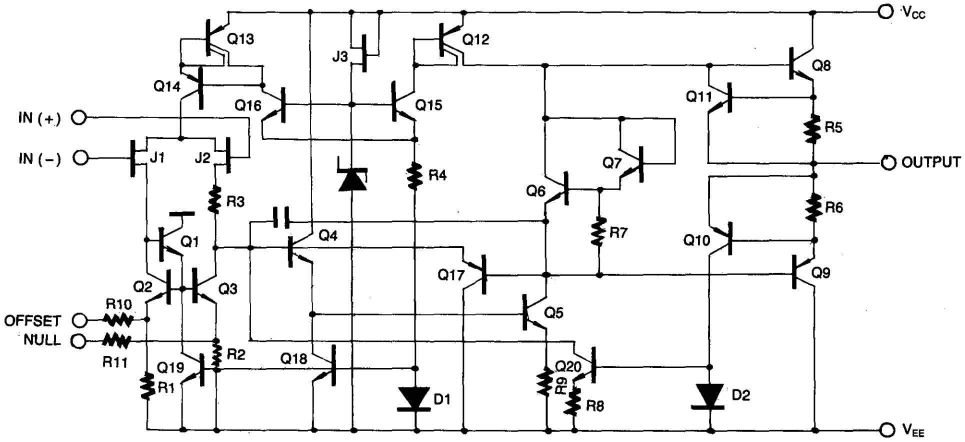
## BLOCK DIAGRAM



## ORDERING INFORMATION

| Device | Package | Operating Temperature |
|---|---|---|
| KF351N | 8 DIP | 0~ +70°C |
| KF351D | 8 SOP | |

## SCHEMATIC DIAGRAM



## ABSOLUTE MAXIMUM RATINGS

| Characteristics | Symbol | Value | Unit |
|---|---|---|---|
| Power Supply Voltage | $V_S$ | ±18 | V |
| Differential Input Voltage | $V_{ID}$ | ±30 | V |
| Input Voltage Range | $V_I$ | ±15 | V |
| Output Short Circuit Duration | | Continuous | |
| Power Dissipation | $P_D$ | 500 | mV |
| Operating Temperature Range | $T_{opr}$ | 0 ~ +70 | °C |
| Storage Temperature Range | $T_{stg}$ | −65 ~ +150 | °C |

## ELECTRICAL CHARACTERISTICS

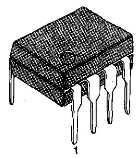
($V_{CC} = +15V$, $V_{EE} = -15V$, $Ta = 25°C$, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| Input Offset Voltage | $V_{IO}$ | $R_S = 10K\Omega$ | | | 5.0 | 10 | mV |
| | | | 0°C ≤ Ta ≤ +70°C | | | 13 | |
| Input Offset Voltage Drift | $\Delta V_{IO}/\Delta T$ | $R_S = 10K\Omega$ | 0°C ≤ Ta ≤ +70°C | | 10 | | μV/°C |
| Input Offset Current | $I_{IO}$ | | | | 25 | 100 | pA |
| | | | 0°C ≤ Ta ≤ +70°C | | | 4 | nA |
| Input Bias Current | $I_{IB}$ | | | | 50 | 200 | pA |
| | | | 0°C ≤ Ta ≤ +70°C | | | 8 | nA |
| Input Resistance | $R_I$ | | | | $10^{12}$ | | Ω |
| Large Signal Voltage Gain | $A_V$ | $V_O = \pm 10V$ | | 25 | 100 | | V/mV |
| | | $R_L = 2K\Omega$ | 0 ≤ Ta ≤ +70°C | 15 | | | |
| Output Voltage Swing | $V_{OUT}$ | $R_L = 10K\Omega$ | | ±12 | ±13.5 | | V |
| Input Voltage Range | $V_{ICR}$ | | | ±11 | $^{+15}_{-12}$ | | V |
| Common Mode Rejection Ratio | CMRR | $R_S \leq 10K\Omega$ | | 70 | 100 | | dB |
| Power Supply Rejection Ratio | PSRR | $R_S \leq 10K\Omega$ | | 70 | 100 | | dB |
| Power Supply Current | $I_S$ | | | | 2.3 | 3.4 | mA |
| Slew Rate | SR | $A_V = 1$ | | | 13 | | V/μs |
| Gain-Bandwidth Product | GBW | | | | 4 | | MHz |

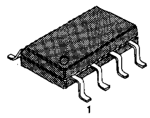
## SINGLE OPERATIONAL AMPLIFIER

The KF353 is a JFET input operational amplifier with an internally compensated input offset voltage. The JFET input device provides with bandwidth, low input bias currents and offset currents.

**8 DIP**



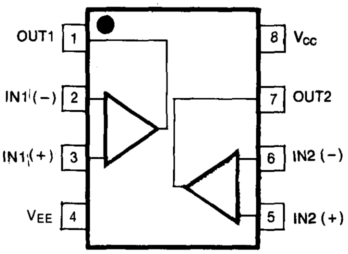
**8 SOP**



## FEATURES

- **Internally trimmed offset voltage: 10mV**
- **Low input bias current: 50pA**
- **Wide gain bandwidth: 4MHz**
- **High slew rate: 13V/μs**
- **High input impedance: $10^{12}\Omega$**

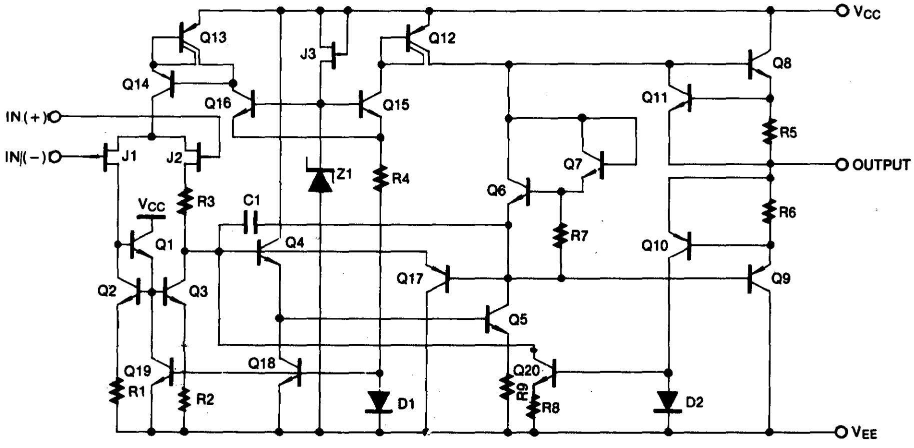
## BLOCK DIAGRAM



## ORDERING INFORMATION

| Device | Package | Operating Temperature |
|---|---|---|
| KF353N | 8 DIP | 0~ +70°C |
| KF353D | 8 SOP | |
| KF353S | 9 SIP | |

## SCHEMATIC DIAGRAM (One Section Only)



## ABSOLUTE MAXIMUM RATINGS

| Characteristics | Symbol | Value | Unit |
|---|---|---|---|
| Power Supply Voltage | $V_S$ | ±18 | V |
| Differential Input Voltage | $V_{ID}$ | ±30 | V |
| Input Voltage Range | $V_I$ | ±15 | V |
| Output Short Circuit Duration | | Continuous | |
| Power Dissipation | $P_D$ | 500 | mW |
| Operating Temperature Range | $T_{opr}$ | 0 ~ +70 | °C |
| Storage Temperature Range | $T_{stg}$ | −65 ~ +150 | °C |

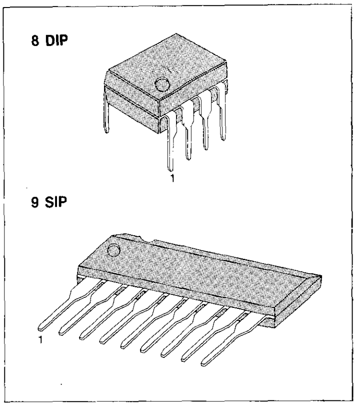
## ELECTRICAL CHARACTERISTICS

($V_{CC}$ = +15V, $V_{EE}$ = −15V, Ta = 25°C, *unless otherwise specified)*

| Characteristic | Symbol | Test Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| Input Offset Voltage | $V_{IO}$ | $R_S = 10K\Omega$ | | | 5.0 | 10 | mV |
| | | | 0°C ≥ Ta ≥ +70°C | | | | |
| Input Offset Voltage Drift | $\Delta V_{IO}/\Delta T$ | $R_S = 10K\Omega$ | 0°C ≥ Ta ≥ +70°C | | 10 | | μV/°C |
| Input Offset Current | $I_{IO}$ | | | | 25 | 100 | pA |
| | | | 0°C ≥ Ta ≥ +70°C | | | 4 | nA |
| Input Bias Current | $I_{IB}$ | | | | 50 | 200 | pA |
| | | | 0°C ≥ Ta ≥ +70°C | | | 8 | nA |
| Input Resistance | $R_I$ | | | | $10^{12}$ | | Ω |
| Large Signal Voltage Gain | $A_V$ | $V_O = \pm 10V$ | | 25 | 100 | | V/mV |
| | | $R_L = 2K\Omega$ | 0 ≥ Ta ≥ +70°C | 15 | | | |
| Output Voltage Swing | $V_{OUT}$ | $R_L = 10K\Omega$ | | ±12 | ±13.5 | | V |
| Input Voltage Range | $V_{ICR}$ | | | ±11 | +15/−12 | | V |
| Common Mode Rejection Ratio | CMRR | $R_S \geq 10K\Omega$ | | 70 | 100 | | dB |
| Power Supply Rejection Ratio | PSRR | $R_S \geq 10K\Omega$ | | 70 | 100 | | dB |
| Power Supply Current | $I_S$ | | | | 3.6 | 6.5 | mA |
| Slew Rate | SR | $A_V = 1$ | | | 13 | | V/μS |
| Gain-Bandwidth Product | GBW | | | | 4 | | MHz |
| Channel Seperation | CS | f = 1Hz ~ 20KHz<br>(Input referenced) | | 120 | 120 | | dB |
| Equivalent Input Noise Voltage | $e_N$ | $R_S = 100\Omega$<br>f = 1KHz | | 16 | 16 | | nV/√Hz |
| Equivalent Input Noise Current | $i_N$ | f = 1KHz | | 0.01 | 0.01 | | pA√Hz |

## DUAL JFET INPUT OPERATIONAL AMPLIFIERS

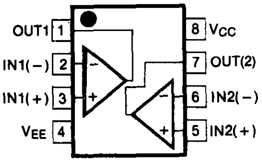
The KF442 is a dual low power operational amplifier. The key feature of this op amp are low power, low input offset voltage, high slew rate, high gain bandwidth.

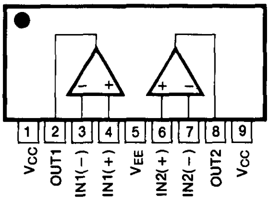


## FEATURES

- **Low supply current: 400$\mu$A MAX**
- **Low input bias current: 50pA MAX**
- **Low input offset voltage: 1mV MAX**
- **High slew rate: 1V/$\mu$s**
- **High gain bandwidth: 1MHz**

## BLOCK DIAGRAM

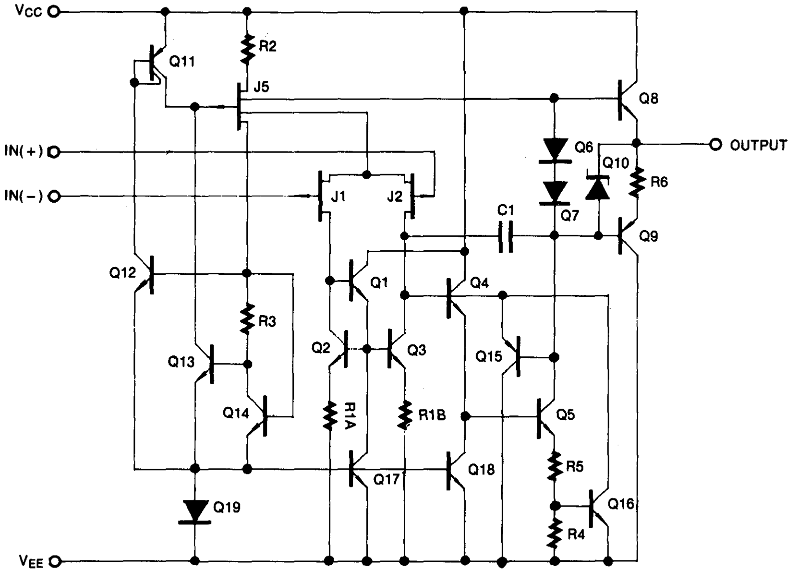




## ORDERING INFORMATION

| Device | Package | Operating Temperature |
|---|---|---|
| KF442CN<br>KF442ACN | 8 DIP | 0 ~ +70°C |
| KF442CS<br>KF442ACS | 9 SIP | |

## SCHEMATIC DIAGRAM (One Section Only)



## ABSOLUTE MAXIMUM RATINGS

| Characteristics | Symbol | Value | Unit |
|---|---|---|---|
| Power Supply Voltage KF442C<br>KF442AC | $V_S$ | ±18<br>±20 | V |
| Differential Input Voltage | $V_{ID}$ | ±30 | V |
| Input Voltage Range | $V_I$ | ±15 | V |
| Output Short Circuit Duration | | Continuous | |
| Power Dissipation | $P_D$ | | mV |
| Operating Temperature Range KF442C/AC | $T_{opr}$ | 0~+70 | °C |
| Storage Temperature Range | $T_{stg}$ | −65~+150 | °C |

## ELECTRICAL CHARACTERISTICS

(Ta=25°C, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | KF442AC | | | KF442C | | | Unit |
|---|---|---|---|---|---|---|---|---|---|
| | | | Min | Typ | Max | Min | Typ | Max | |
| Input Offset Voltage | $V_{IO}$ | $R_S$=10KΩ | | 0.5 | 1.0 | | 1.0 | 5.0 | mV |
| | | NOTE1 | | | | | | 7.5 | |
| Input Offset Voltage Drift | $\Delta V_{IO}/\Delta T$ | $R_S$=10KΩ | | 7 | 10 | | 7 | | μV/°C |
| Input Offset Current | $I_{IO}$ | | | 5 | 25 | | 5 | 50 | pA |
| | | NOTE1 | | | 15 | | | 15 | |
| Input Bias Current | $I_{IB}$ | | | 10 | 50 | | 10 | 100 | pA |
| | | NOTE1 | | | 30 | | | 30 | |
| Large Signal Voltage Gain | $A_V$ | $R_L$=10KΩ | 50 | 200 | | 25 | 200 | | V/mV |
| | | $V_O$=±10V NOTE1 | 25 | 200 | | 15 | 200 | | |
| Output Voltage Swing | $V_{OUT}$ | $R_S$=10KΩ | ±17 | ±18 | | ±12 | ±13 | | V |
| Input Voltage Range | $V_{ICR}$ | | ±16 | +18<br>−17 | | ±11 | +15<br>−12 | | V |
| Common-Mode Rejection Ratio | CMRR | $R_S$≤10KΩ | 80 | 100 | | 70 | 95 | | dB |
| Power Supply Rejection Ratio | PSRR | $R_S$≤10KΩ | 80 | 100 | | 70 | 90 | | dB |
| Input Resistance | $R_I$ | | | $10^{12}$ | | $10^{12}$ | | | Ω |
| Supply Current | $I_S$ | | | 300 | 400 | | 400 | 500 | μA |
| Slew Rate | SR | | 0.8 | 1 | | 0.6 | 1 | | V/μS |
| Gain Bandwidth Product | GBW | | 0.8 | 1 | | 0.6 | 1 | | MHz |
| Channel Seperation | CS | f=1Hz-20KHz<br>(input referenced) | | 120 | | | 120 | | dB |
| Equivalent Input Noise Voltage | $e_N$ | $R_S$=100Ω<br>f=1KHz | | 35 | | | 35 | | nV/√Hz |
| Equivalent Input Noise Current | $i_N$ | f=1KHz | | 0.01 | | | 0.01 | | pA/√Hz |

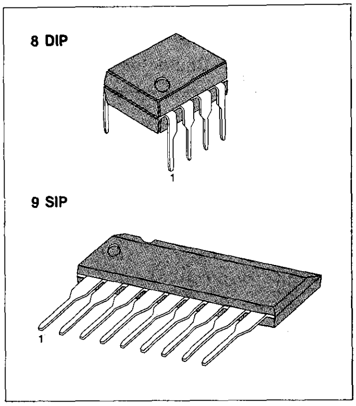
NOTE 1. KF442C/AC: 0≤Ta≤+70°C

# DUAL CMOS OPERATIONAL AMPLIFIER

The KS272 is a CMOS operational amplifier designed to operate with single or dual supplies.

This device has extremely high input impedance, low input bias and offset current.

Application areas include transducer amplifier, amplifier blocks, active filters, signal buffers, and all the conventional OP Amp circuits which can be easily implemented in single power supply systems.

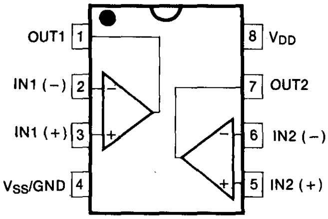


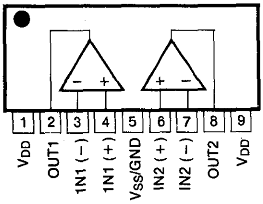
| Device | Package | Operating Temperature |
|---|---|---|
| KS272CN | 8 DIP | 0 ~ 70°C |
| KS272ACN | | |
| KS272CS | 9 SIP | |
| KS272ACS | | |
| KS272IN | 8 DIP | −25 ~ +85°C |
| KS272AIN | | |
| KS272IS | 9 SIP | |
| KS272AIS | | |

## FEATURES

- **Wide operating voltage range; 3V to 18V or or ±1.5V to ±8V**
- **High Input Impedance: $10^{12}\Omega$**
- **Very low input bias current**
- **Common-mode input voltage range includes the negative rail**
- **Single-supply voltage operation.**

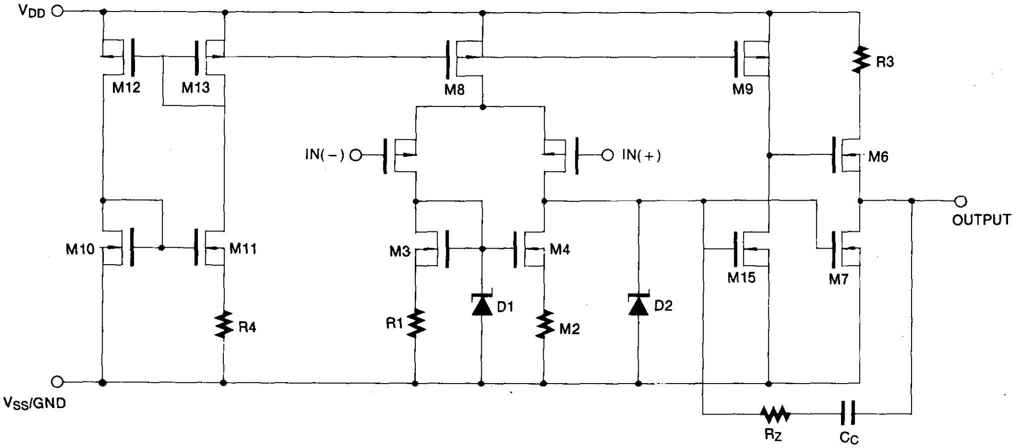
## BLOCK DIAGRAM





## SCHEMATIC DIAGRAM

(one section only)



## ABSOLUTE MAXIMUM RATINGS (Ta = 25°C)

| Characteristic | Symbol | Value | Unit |
|---|---|---|---|
| Supply Voltage | $V_{DD}$ | 18 | V |
| Differential Input Voltage | $V_{ID}$ | 18 | V |
| Input Voltage | $V_I$ | − 0.3 ~ + 18 | V |
| Duration of Short Circuit (Note 1) | | unlimited | |
| Power Dissipation | $P_D$ | 500 | mW |
| Operating Temperature Range KS272C/AC | $T_{opr}$ | 0 ~ + 70 | °C |
| KS272I/AI | | − 25 ~ + 85 | |
| Storage Temperature | $T_{stg}$ | − 65 ~ + 150 | °C |

(Note 1) The output may be shorted to ground or either supply, for $V_{DD} \leq 14V$. Care must be taken to insure that the dissipation rating is not exceeded.

## ELECTRICAL CHARACTERISTICS

($V_{DD} = 10V$, Ta = 25°C, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | KS272C/KS2721 | | | KS272AC/KS272AI | | | Unit |
|---|---|---|---|---|---|---|---|---|---|
| | | | Min | Typ | Max | Min | Typ | Max | |
| Input Offset Voltage | $V_{IO}$ | $V_O = 1.4V$ | | | 10 | | | 5 | mV |
| | | $R_S = 50\Omega$ NOTE2 | | | 12 | | | 12 | |
| Input Offset Current | $I_{IO}$ | $V_{IC} = 5V$ | | 1 | | | 1 | | pA |
| | | $V_O = 5V$ NOTE2 | | | 100 | | | 100 | |
| Input Bias Current | $I_{IB}$ | $V_{IC} = 5V$ | | 1 | | | 1 | | pA |
| | | $V_O = 5V$ NOTE2 | | | 150 | | | 150 | |
| Common-Mode Input Voltage Range | $V_{ICR}$ | | − 0.2 to 9 | | | − 0.2 to 9 | | | V |
| Output Voltage Swing | $V_{OUT}$ | $V_{ID} = 100mV$ | 8 | 8.6 | | 8 | 8.6 | | V |
| | | NOTE2 | 7.8 | | | 7.8 | | | |
| Large Signal Voltage Gain | $A_V$ | $V_O = 1$ to $6V$ | 80 | 92 | | 80 | 92 | | dB |
| | | $R_S = 50\Omega$ NOTE2 | 77.5 | | | 77.5 | | | |
| Common-Mode Rejection Ratio | CMRR | $V_O = 1.4V$<br>$V_{IC} = V_{ICR}$ min | 70 | 88 | | 70 | 88 | | dB |
| Power Supply Rejection Ratio | PSRR | $V_{DD} = 5$ to $10V$<br>$V_O = 1.4V$ | 65 | 82 | | 65 | 82 | | dB |
| Output Current | $I_{source}$ | $V_O = 0V$<br>$V_{ID} = 100mV$ | | − 55 | | | − 55 | | mA |
| | $I_{sink}$ | $V_O = V_{DD}$<br>$V_{ID} = -100mV$ | | 15 | | | 15 | | |
| Supply Current (each amplifier) | $I_{DD}$ | No load, $V_{IC} = 5V$ | | 1 | 2 | | 1 | 2 | mA |
| | | $V_O = 5V$ NOTE2 | | | 2.2 | | | 2.2 | |
| Unity Gain Bandwidth | BW | $A_V = 40dB$, $C_L = 10pF$<br>$R_S = 50\Omega$ | | 4.5 | | | 4.5 | | MHz |
| Slew Rate | SR | Unity Gain<br>$R_L \geq 2K\Omega$, $C_L = 100pF$ | | 2.3 | | | 2.3 | | V/μs |
| Channel Seperation | CS | $A_V = 100$ | | 120 | | | 120 | | dB |

NOTE 1. KS272C/AC: $0 \leq Ta \leq +70°C$
2. KS272I/AI: $-25 \leq Ta \leq +85°C$

## TYPICAL APPLICATION INFORMATION

### Latch Up Avoidance

Junction-isolated CMOS circuits employ configurations which produce a parasitic 4-layer (p-n-p-n) structure that can function as an SCR, and under certain conditions may be triggered into a low impedance state, resulting in excessive supply current. To avoid such conditions, no voltage greater than 0.3V beyond the supply rails may be applied any pin. In general, the OP amp supplies should be established simultaneously with, or before any input signals are applied.

### Output Stage Considerations

The amplifier's output stage consists of a source-follower connected pull up transistor and an open-drain pull-down transistor. The high-level output voltage ($V_{OH}$) is virtually independent of the $I_{DD}$ selection, and increases with higher values of $V_{DD}$ and reduced output loading. The low-level output voltage ($V_{OL}$) decreases with reduced output current and higher input common-mode voltage. With no load, $V_{OL}$ is essentially equal to the GND pin potential.

### Circuit Layout Precaustions

The user is caustioned that, due to extremely high input impedance, care must be exercised in layout, construction board cleanliness, and supply filtering to avoid hum and noise pick up.

## TYPICAL APPLICATIONS

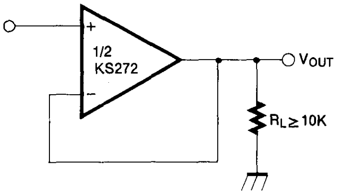


Fig. 1

AC Coupled Non-Inverting Amplifier

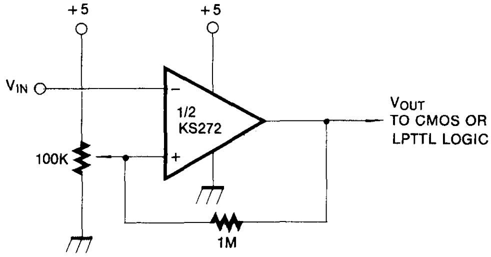


Fig. 2

Pulse Generator

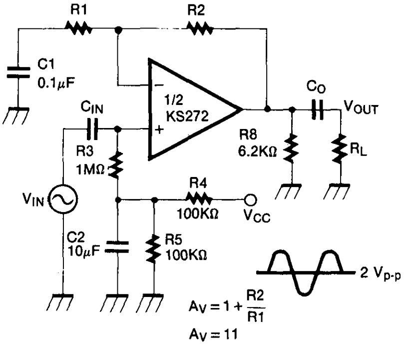


Fig. 3

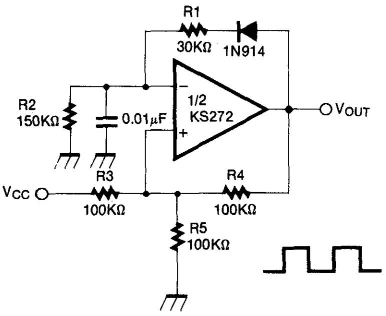
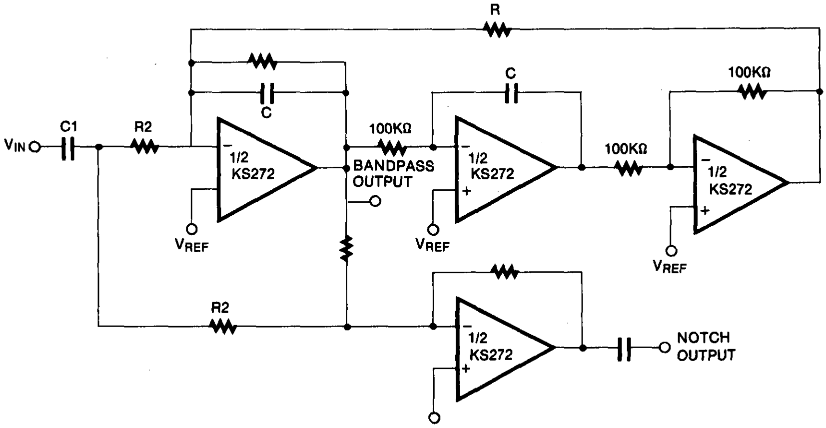


Fig. 4

## TYPICAL APPLICATION

Bi-Quad Filter



$Q = \frac{f_O}{BW}$

where

$A_{VCF}$ = Center frequency gain

$A_{VBN}$ = Bandpass notch gain

$f_O = \frac{1}{2\pi RC}$ $R2 = \frac{R1}{T_{BP}}$

$R1 = QR$ $R3 = T_N R2$

$C1 = 10C$

Example: $f_O = 1000Hz$
$BW = 100Hz$
$A_{VCF} = 1$
$A_{VBN} = 1$
$R = 160K\Omega$
$R1 = 1.6M\Omega$
$R2 = 1.6M\Omega$
$R3 = 1.6M\Omega$
$C = 0.01\mu F$

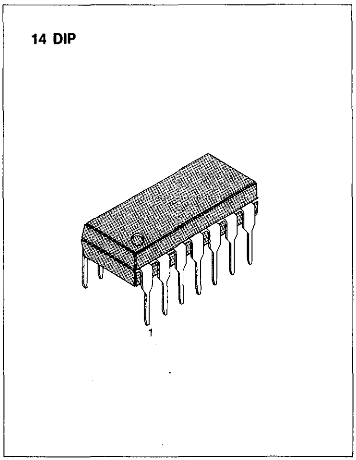
Fig. 5

# QUAD CMOS OPERATIONAL AMPLIFIER

The KS274 is a CMOS operational amplifier designed to operate with single or dual supplies.

This device has extremely high input impedance, low input bias and offset current.

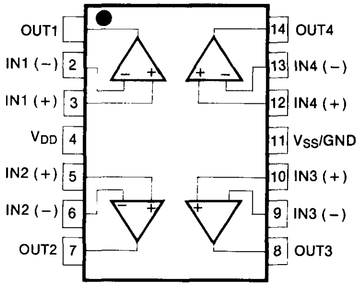
Application areas include translucer amplifier, amplifier blocks, active filters, signal buffers, and all the conventional OP Amp circuits which can be easily implemented in single power supply systems.



## FEATURES

- **Wide operating voltage range; 3V to 16V or or ±1.5V to ±8V**
- **High Input Impedance: $10^{12}\Omega$**
- **Very low input bias current**
- **Common-mode input voltage range includes the negative rail**
- **Single-supply voltage operation.**

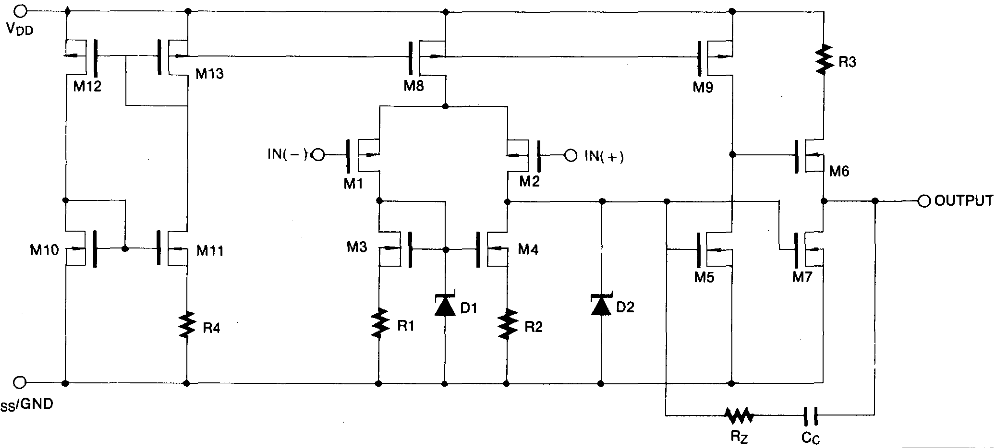
## BLOCK DIAGRAM



## ORDERING INFORMATION

| Device | Package | Operating Temperature |
|---|---|---|
| KS274CN | 14 DIP | 0 ~ +70°C |
| KS274ACN | | |
| KS274IN | 14 DIP | −25 ~ +85°C |
| KS274AIN | | |

## SCHEMATIC DIAGRAM (One Section Only)



## ABSOLUTE MAXIMUM RATINGS (Ta = 25°C)

| Characteristic | Symbol | Value | Unit |
|---|---|---|---|
| Supply Voltage | $V_{DD}$ | 18 | V |
| Differential Input Voltage | $V_{ID}$ | 18 | V |
| Input Voltage | $V_I$ | −0.3 ~ +18 | V |
| Duration of Short Circuit (Note 1) | | unlimited | |
| Power Dissipation | $P_D$ | 570 | mW |
| Operating Temperature Range KS274C/AC | $T_{opr}$ | 0 ~ +70 | °C |
| KS274I/AI | | −25 ~ +85 | |
| Storage Temperature | $T_{stg}$ | −65 ~ +150 | °C |

(Note 1) The output may be shorted to ground or either supply, for $V_{DD} \leq 14V$. Care must be taken to insure that the dissipation rating is not exceeded.

## ELECTRICAL CHARACTERISTICS

($V_{DD}$ = 10V, Ta = 25°C, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | | KS274C/KS2741 | | | KS274AC/KS274AI | | | Unit |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Min | Typ | Max | Min | Typ | Max | |
| Input Offset Voltage | $V_{IO}$ | $V_O$ = 1.4V | | | | 10 | | | 5 | mV |
| | | $R_S$ = 50Ω | NOTE2 | | | 12 | | | 12 | |
| Input Offset Current | $I_{IO}$ | $V_{IC}$ = 5V | | | 1 | | | 1 | | pA |
| | | $V_O$ = 5V | NOTE2 | | | 100 | | | 100 | |
| Input Bias Current | $I_{IB}$ | $V_{IC}$ = 5V | | | 1 | | | 1 | | pA |
| | | $V_O$ = 5V | NOTE2 | | | 150 | | | 150 | |
| Common-Mode Input Voltage Range | $V_{ICR}$ | | | −0.2 to 9 | | | −0.2 to 9 | | | V |
| Output Voltage Swing | $V_{OUT}$ | $V_{ID}$ = 100mV | | 8 | 8.6 | | 8 | 8.6 | | V |
| | | | NOTE2 | 7.8 | | | 7.8 | | | |
| Large Signal Voltage Gain | $A_V$ | $V_O$ = 1 to 6V | | 80 | 92 | | 80 | 92 | | dB |
| | | $R_S$ = 50Ω | NOTE2 | 77.5 | | | 77.5 | | | |
| Common-Mode Rejection Ratio | CMRR | $V_O$ = 1.4V<br>$V_{IC}$ = $V_{ICR}$ min | | 70 | 88 | | 70 | 88 | | dB |
| Power Supply Rejection Ratio | PSRR | $V_{DD}$ = 5 to 10V<br>$V_O$ = 1.4V | | 65 | 82 | | 65 | 82 | | dB |
| Output Current | $I_{source}$ | $V_O$ = 0V<br>$V_{ID}$ = 100mV | | | −55 | | | −55 | | mA |
| | $I_{sink}$ | $V_O$ = $V_{DD}$<br>$V_{ID}$ = −100mV | | | 15 | | | 15 | | |
| Supply Current (each amplifier) | $I_{DD}$ | No load, $V_{IC}$ = 5V | | | 1 | 2 | | 1 | 2 | mA |
| | | $V_O$ = 5V | NOTE2 | | | 2.2 | | | 2.2 | |
| Unity Gain Bandwidth | BW | $A_V$ = 40dB, $C_L$ = 10pF<br>$R_S$ = 50Ω | | | 2.3 | | | 2.3 | | MHz |
| Slew Rate | SR | Unity Gain<br>$R_L \geq 2K\Omega$, $C_L$ = 100pF | | | 4.5 | | | 4.5 | | V/μs |
| Channel Seperation | CS | $A_V$ = 100 | | | 120 | | | 120 | | dB |

NOTE 1. KS274C/AC: $0 \leq Ta \leq +70°C$
2. KS274I/AI: $-25 \leq Ta \leq +85°C$

# TYPICAL APPLICATION INFORMATION

## Latch Up Avoidance

Junction-isolated CMOS circuits employ configurations which produce a parasitic 4-layer (p-n-p-n) structure that can function as an SCR, and under certain conditions may be triggered into a low impedance state, resulting in excessive supply current. To avoid such conditions, no voltage greater than 0.3V beyond the supply rails may be applied any pin. In general, the OP amp supplies should be established simultaneously with, or before any input signals are applied.

## Output Stage Considerations

The amplifier's output stage consists of a source-follower connected pull up transistor and an open-drain pull-down transistor. The high-level output voltage ($V_{OH}$) is virtually independent of the $I_{DD}$ selection, and increases with higher values of $V_{DD}$ and reduced output loading. The low-level output voltage ($V_{OL}$) decreases with reduced output current and higher input common-mode voltage. With no load, $V_{OL}$ is essentially equal to the GND pin potential.

## Circuit Layout Precautions

The user is cautioned that, due to extremely high input impedance, care must be exercised in layout, construction board cleanliness, and supply filtering to avoid hum and noise pick up.

# TYPICAL APPLICATIONS

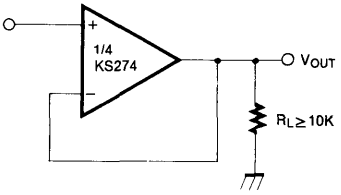


Fig. 1

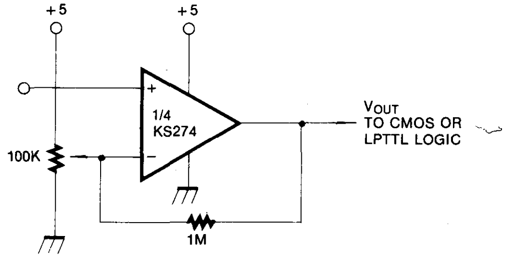


Fig. 2

AC Coupled Non-Inverting Amplifier

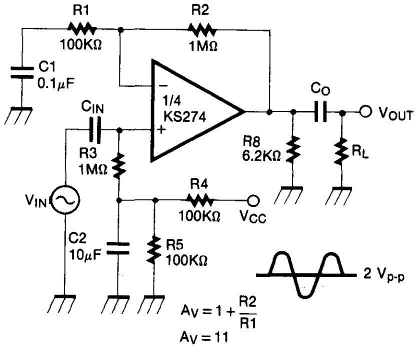


Fig. 3

Pulse Generator

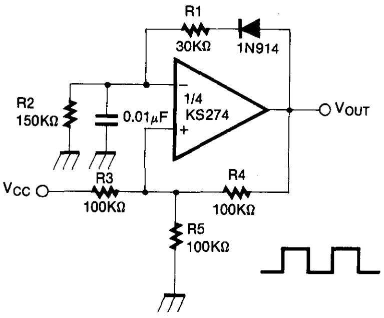
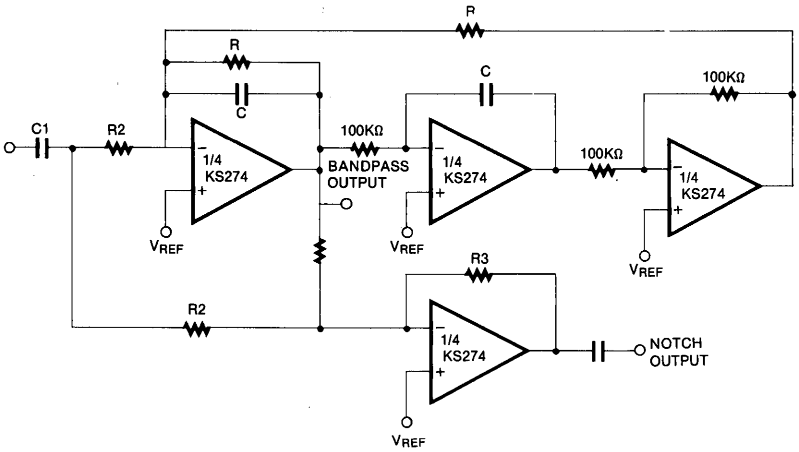


Fig. 4

## TYPICAL APPLICATION INFORMATION

Bi-Quad Filter



$Q = \frac{f_O}{BW}$
where
$A_{VCF}$ = Center frequency gain
$A_{VBN}$ = Bandpass notch gain
$f_O = \frac{1}{2\pi RC}$   $R2 = \frac{R1}{T_{BP}}$
$R1 = QR$   $R3 = T_N R2$
$C1 = 10C$
Example: $f_O = 1000Hz$
$BW = 100Hz$
$A_{VCF} = 1$
$A_{VBN} = 1$
$R = 160K\Omega$
$R1 = 1.6M\Omega$
$R2 = 1.6M\Omega$
$R3 = 1.6M\Omega$
$C = 0.01\mu F$

**Fig. 5**

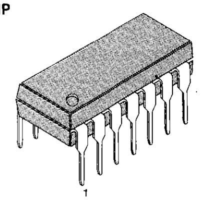
## QUAD OPERATIONAL AMPLIFIERS

The LM224 series consists of four independent, high gain, internally frequency compensated operational amplifiers which were designed specifically to operate from a single power supply over a wide voltage range.

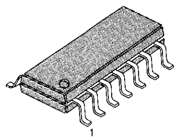
Operation from split power supplies is also possible so long as the difference between the two supplies is 3 volts to 32 volts.
voltage.

Application areas include transducer amplifier, DC gain blocks and all the conventional OP amp circuits which now can be easily implemented in single power supply systems.

**14 DIP**



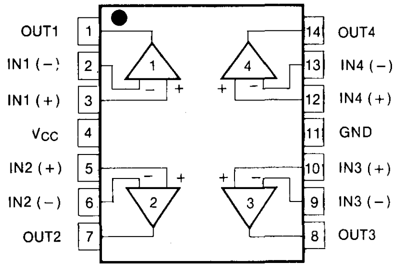
**14 SOP**



## FEATURES

- **Internally frequency compensated for unity gain**
- **Large DC voltage gain: 100dB**
- **Wide power supply range: LM224/A, LM324/A: 3V ~ 32V (or ±1.5V ~ 16V)**
  **LM2902: 3V ~ 26V (or ±1.5V ~ 13V)**
- **Input common-mode voltage range includes ground**
- **Large output voltage swing: 0V DC to $V_{CC}$-1.5V DC**
- **Power drain suitable for battery operation.**

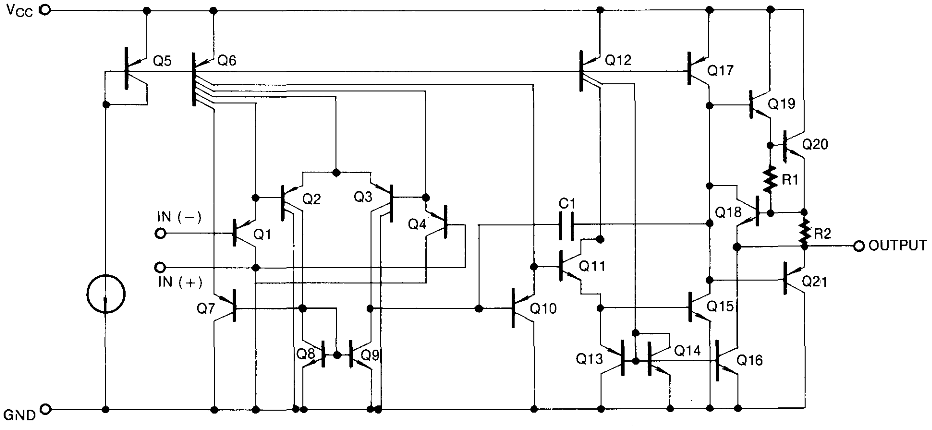
## BLOCK DIAGRAM



## ORDERING INFORMATION

| Device | Package | Operating Temperature |
|---|---|---|
| LM324N<br>LM324AN | 14 DIP | 0 ~ +70°C |
| LM324D<br>LM324AD | 14 SOP | |
| LM224N<br>LM224AN | 14 DIP | −25 ~ +85°C |
| LM224D<br>LM224AD | 14 SOP | |
| LM2902N | 14 DIP | −40 ~ +85°C |
| LM2902D | 14 SOP | |

## SCHEMATIC DIAGRAM (One Section Only)



## ABSOLUTE MAXIMUM RATINGS

| Characteristic | Symbol | LM224/LM224A | LM324/LM324A | LM2902 | Unit |
|---|---|---|---|---|---|
| Power Supply Voltage | $V_S$ | ± 18 or 32 | ± 18 or 32 | ± 13 or 26 | V |
| Differential Input Voltage | $V_{ID}$ | 32 | 32 | 26 | V |
| Input Voltage | $V_I$ | −0.3 to +32 | −0.3 to +32 | −0.3 to +26 | V |
| Output Short Circuit to GND $V_{CC} \leq 15V$ Ta=25°C (One Amp) | | Continuous | Continuous | Continuous | |
| Power Dissipation | $P_D$ | 570 | 570 | 570 | mW |
| Operating Temperature Range | $T_{opr}$ | −25 ~ +85 | 0 ~ +70 | −40 ~ +85 | °C |
| Storage Temperature Range | $T_{stg}$ | −65 ~ +150 | −65 ~ +150 | −65 ~ +150 | °C |

## ELECTRICAL CHARACTERISTICS

($V_{CC}$=5.0V, $V_{EE}$=GND, Ta=25°C, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | | LM224 | | | LM324 | | | LM2902 | | | Unit |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Min | Typ | Max | Min | Typ | Max | Min | Typ | Max | |
| Input Offset Voltage | $V_{IO}$ | $V_{ICM}$=0V to $V_{CC}$−1.5V<br>$V_o$=1.4V, $R_S$=0Ω | | | 1.5 | 5.0 | | 1.5 | 7.0 | | 1.5 | 7.0 | mV |
| Input Offset Current | $I_{IO}$ | | | | 2.0 | 30 | | 3.0 | 50 | | 3.0 | 50 | nA |
| Input Bias Current | $I_{IB}$ | | | | 40 | 150 | | 40 | 250 | | 40 | 250 | nA |
| Input Common-Mode Voltage Range | $V_{ICR}$ | $V_{CC}$=30V<br>($V_{CC}$=26V for LM2902) | | 0 | | $V_{CC}$ -1.5 | 0 | $V_{CC}$ -1.5 | | 0 | | $V_{CC}$ -1.5 | V |
| Supply Current | $I_{CC}$ | $R_L=\infty$, $V_{CC}$=30V (all Amps)<br>($V_{CC}$=26V for LM2902) | | | 1.0 | 3 | | 1.0 | 3 | | 1.0 | 3 | mA |
| | | $R_L=\infty$, $V_{CC}$=5V (all Amps) | | | 0.7 | 1.2 | | 0.7 | 1.2 | | 0.7 | 1.2 | mA |
| Large Signal Voltage Gain | $A_V$ | $V_{CC}$=15V, $R_L \geq 2K\Omega$<br>$V_O$=1V to 11V | | 50 | 100 | | 25 | 100 | | | 100 | | V/mV |
| Output Voltage Swing | $V_{OH}$<br>$V_{OL}$ | $V_{CC}$=30V<br>$V_{CC}$=26V for 2902 | $R_L$=2KΩ | 26 | | | 26 | | | 22 | | | V |
| | | | $R_L$=10KΩ | 27 | 28 | | 27 | 28 | | 23 | 24 | | V |
| | | $V_{CC}$=5V, $R_L \geq 10K\Omega$ | | | 5 | 20 | | 5 | 20 | | 5 | 100 | mV |
| Common-Mode Rejection Ratio | CMRR | | | 70 | 85 | | 65 | 75 | | 50 | 75 | | dB |
| Power Supply Rejection Ratio | PSRR | | | 65 | 100 | | 65 | 100 | | 50 | 100 | | dB |
| Channel Separation | CS | f=1KHz to 20KHz | | | 120 | | | 120 | | | 120 | | dB |
| Short Circuit to GND | $I_{OS}$ | | | | 40 | 60 | | 40 | 60 | | 40 | 60 | mA |
| Output Current | $I_{source}$ | $V_{in+}$=1V, $V_{in-}$=0V<br>$V_{CC}$=15V, $V_o$=2V | | 20 | 40 | | 20 | 40 | | 20 | 40 | | mA |
| | $I_{sink}$ | $V_{in+}$=0V, $V_{in-}$=1V<br>$V_{CC}$=15V, $V_o$=2V | | 10 | 13 | | 10 | 13 | | 10 | 13 | | mA |
| | | $V_{in+}$=0V, $V_{in-}$=1V<br>$V_{CC}$=15V, $V_o$=200mV | | 12 | 45 | | 12 | 45 | | | | | μA |
| Differential Input Voltage | $V_{ID}$ | | | | | $V_{CC}$ | | | $V_{CC}$ | | | $V_{CC}$ | V |

## ELECTRICAL CHARACTERISTICS

($V_{CC}=5.0V$, $V_{EE}=GND$, unless otherwise specified)
The following specification apply over the range of $-25°C \leq Ta \leq +85°C$ for the LM224; and the $0°C \leq Ta \leq +70°C$ for the LM324; and the $-40°C \leq Ta \leq +85°C$ for the LM2902

| Characteristic | Symbol | Test Conditions | LM224 | | | LM324 | | | LM2902 | | | Unit |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Min | Typ | Max | Min | Typ | Max | Min | Typ | Max | |
| Input Offset Voltage | $V_{IO}$ | $V_{ICM}=0V$ to $V_{CC}-1.5V$<br>$V_O=1.4V$, $R_S=0\Omega$ | | | 7.0 | | | 9.0 | | | 10.0 | mV |
| Input Offset Voltage Drift | $\triangle V_{IO}/\triangle T$ | | | 7.0 | | | 7.0 | | | 7.0 | | μV/°C |
| Input Offset Current | $I_{IO}$ | | | | 100 | | | 150 | | | 200 | nA |
| Input Offset Current Drift | $\triangle I_{IO}/\triangle T$ | | | 10 | | | 10 | | | 10 | | pA/°C |
| Input Bias Current | $I_{IB}$ | | | | 300 | | | 500 | | | 500 | nA |
| Input Common-Mode Voltage Range | $V_{ICR}$ | $V_{CC}=30V$<br>($V_{CC}=26V$ for LM2902) | 0 | | $V_{CC}$ -2.0 | 0 | | $V_{CC}$ -2.0 | 0 | | $V_{CC}$ -2.0 | V |
| Large Signal Voltage Gain | $A_V$ | $V_{CC}=15V$, $R_L \geq 2.0K\Omega$<br>$V_O=1V$ to $11V$ | 25 | | | 15 | | | 15 | | | V/mV |
| Output Voltage Swing | $V_{OH}$ | $V_{CC}=30V$<br>$V_{CC}=26V$ for 2902<br>$R_L=2K\Omega$ | 26 | | | 26 | | | 22 | | | V |
| | | $R_L=10K\Omega$ | 27 | 28 | | 27 | 28 | | 23 | 24 | | V |
| | $V_{OL}$ | $V_{CC}=5V$, $R_L \geq 10K\Omega$ | | 5 | 20 | | 5 | 20 | | 5 | 100 | mV |
| Output Current | $I_{source}$ | $V_{in+}=1V$, $V_{in-}=0V$<br>$V_{CC}=15V$, $V_O=2V$ | 10 | 20 | | 10 | 20 | | 10 | 20 | | mA |
| | $I_{sink}$ | $V_{in+}=0V$, $V_{in-}=1V$<br>$V_{CC}=15V$, $V_O=2V$ | 10 | 13 | | 5 | 8 | | 5 | 8 | | mA |
| Differential Input Voltage | $V_{ID}$ | | | | $V_{CC}$ | | | $V_{CC}$ | | | $V_{CC}$ | V |

## ELECTRICAL CHARACTERISTICS

($V_{CC} = 5.0V$, $V_{EE} = GND$, $Ta = 25°C$, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | LM224A | | | LM324A | | | Unit |
|---|---|---|---|---|---|---|---|---|---|
| | | | Min | Typ | Max | Min | Typ | Max | |
| Input Offset Voltage | $V_{IO}$ | $V_{ICM} = 0V$ to $V_{CC} - 1.5V$<br>$V_O = 1.4V$, $R_S = 0$ | | 1.0 | 3.0 | | 1.5 | 3.0 | mV |
| Input Offset Current | $I_{IO}$ | | | 2 | 15 | | 3.0 | 30 | nA |
| Input Bias Current | $I_{IB}$ | | | 40 | 80 | | 40 | 100 | nA |
| Input Common-Mode Voltage Range | $V_{ICR}$ | $V_{CC} = 30V$ | 0 | | $V_{CC}$ -1.5 | 0 | | $V_{CC}$ -1.5 | V |
| Supply Current (All Amps) | $I_{CC}$ | $R_L =$ , $V_{CC} = 30V$ | | 1.5 | 3 | | 1.5 | 3 | mA |
| | | $R_L =$ , $V_{CC} = 5V$ | | 0.7 | 1.2 | | 0.7 | 1.2 | mA |
| Large Signal Voltage Gain | $A_V$ | $V_{CC} = 15V$, $R_L \geq 2K\Omega$<br>$V_O = 1V$ to $11V$ | 50 | 100 | | 25 | 100 | | V/mV |
| Output Voltage Swing | $V_{OH}$ | $V_{CC} = 30V$<br>$V_{CC} = 26V$ for 2902 — $R_L = 2K\Omega$ | 26 | | | 26 | | | V |
| | | $R_L = 10K\Omega$ | 27 | 28 | | 27 | 28 | | V |
| | $V_{OL}$ | $V_{CC} = 5V$, $R_L \geq 10K\Omega$ | | 5 | 20 | | 5 | 20 | mV |
| Common-Mode Rejection Ratio | CMRR | | 70 | 85 | | 65 | 85 | | dB |
| Power Supply Rejection Ratio | PSRR | | 65 | 100 | | 65 | 100 | | dB |
| Channel Separation | CS | f = 1KHz to 20KHz | | 120 | | | 120 | | dB |
| Short Circuit to GND | $I_{OS}$ | | | 40 | 60 | | 40 | 60 | mA |
| Output Current | $I_{source}$ | $V_{in+} = 1V$, $V_{in-} = 0V$<br>$V_{CC} = 15V$ | 20 | 40 | | 20 | 40 | | mA |
| | $I_{sink}$ | $V_{in+} = 0V$, $V_{in-} = 1V$<br>$V_{CC} = 15V$, $V_O = 2V$ | 10 | 20 | | 10 | 20 | | mA |
| | | $V_{in+} = 0V$, $V_{in-} = 1V$<br>$V_{CC} = 15V$, $V_O = 200mV$ | 12 | 50 | | 12 | 50 | | μA |
| Differential Input Voltage | $V_{ID}$ | | | | $V_{CC}$ | | | $V_{CC}$ | V |

## ELECTRICAL CHARACTERISTICS

($V_{CC} = 5.0V$, $V_{EE} = GND$, unless otherwise specified)
The following specification apply over the range of $-25°C \leq Ta \leq +85°C$ for the LM224A; and the $0°C \leq Ta \leq +70°C$ for the LM324A

| Characteristic | Symbol | Test Conditions | LM224A | | | LM324A | | | Unit |
|---|---|---|---|---|---|---|---|---|---|
| | | | Min | Typ | Max | Min | Typ | Max | |
| Input Offset Voltage | $V_{IO}$ | $V_{ICM} = 0V$ to $V_{CC} - 1.5V$<br>$V_O = 1.4V$ $R_S = 0\Omega$ | | | 4.0 | | | 5.0 | mV |
| Input Offset Voltage Drift | $\Delta V_{IO}/\Delta T$ | | | 7.0 | 20 | | 7.0 | 30 | μV/°C |
| Input Offset Current | $I_{IO}$ | | | | 30 | | | 75 | nA |
| Input Offset Current Drift | $\Delta I_{IO}/\Delta T$ | | | 10 | 200 | | 10 | 300 | pA/°C |
| Input Bias Current | $I_{IB}$ | | | 40 | 100 | | 40 | 200 | nA |
| Input Common-Mode Voltage Range | $V_{ICR}$ | $V_{CC} = 30V$ | 0 | | $V_{CC}$ -2.0 | 0 | | $V_{CC}$ -2.0 | V |
| Large Signal Voltage Gain | $A_V$ | $V_{CC} = 15V$ $R_L \geq 2.0K\Omega$ | 25 | | | 15 | | | V/mV |
| Output Voltage Swing | $V_{OH}$<br>$V_{OL}$ | $V_{CC} = 30V$ $R_L = 2K\Omega$ | 26 | | | 26 | | | V |
| | | $R_L = 10K\Omega$ | 27 | 28 | | 27 | 28 | | |
| | | $V_{CC} = 5V$ $R_L \leq 10K\Omega$ | | 5 | 20 | | 5 | 20 | mV |
| Output Current | $I_{source}$ | $V_{in+} = 1V$ $V_{in-} = 0V$<br>$V_{CC} = 15V$ | 10 | 20 | | 10 | 20 | | mA |
| | $I_{sink}$ | $V_{in+} = 0V$ $V_{in-} = 1V$<br>$V_{CC} = 15V$ | 5 | 8 | | 5 | 8 | | mA |
| Differential Input Voltage | $V_{ID}$ | | | | $V_{CC}$ | | | $V_{CC}$ | V |

## APPLICATION NOTE

The LM224 series are op amps which operate with only a single power supply voltage, have true-differential inputs, and remain in the linear mode with an input common-mode voltage of 0 $V_{DC}$. These amplifiers operate over a wide range of power supply voltage with little change in performance characteristics. At 25°C amplifier operation is possible down to a minimum supply voltage of 2.3 $V_{DC}$.

The pinouts of the package have been designed to simplify PC board layouts. Inverting inputs are adjacent to outputs for all of the amplifiers and the outputs have also been placed at the corners of the package (pins 1, 7, 8, and 14).

Precautions should be taken to insure that the power supply for the integrated circuit never becomes reversed in polarity or that the unit is inadvertently installed backwards in a test socket as an unlimited current surge through the resulting forward diode within the IC could cause fusing of the internal conductors and result in a destroyed unit.

Large differential input voltages can be easily accommodated and, as input differential voltage protection diodes are not needed, no large input currents result from large differential input voltages. The differential input voltage may be larger than the $V_{CC}$ without damaging the device. Protection should be provided to prevent the input voltages from going negative more than $-0.3$ $V_{DC}$ (at 25°C). An input clamp diode with a resistor to the IC input terminal can be used.

To reduce the power supply current drain, the amplifiers have a class A output stage for small signal levels which converts to class B in a large signal mode. This allows the amplifiers to both source and sink large output currents. Therefore both NPN and PNP external current boost transistors can be used to extend the power capability of the basic amplifiers. The output voltage needs to raise approximately 1 diode drop above ground to bias the on-chip vertical PNP transistor for output current sinking applications.

For ac applications, where the load is capacitively coupled to the output of the amplifier, a resistor should be used, from the output of the amplifier to ground to increase the class A bias current and prevent crossover distortion. Where the load is directly coupled, as in dc applications, there is no crossover distortion.

Capacitive loads which are applied directly to the output of the amplifier reduce the loop stability margin. Values of 50 pF can be accommodated using the worst-case noninverting unity gain connection. Large closed loop gains or resistive isolation should be used if larger load capacitance must be driven by the amplifier.

The bias network of the LM224 establishes a drain current which is independent of the magnitude of the power supply voltage over the range of 3 $V_{DC}$ to 30 $V_{DC}$.

Output short circuits either to ground or to the positive power supply should be of short time duration. Units can be destroyed, not as a result of the short circuit current causing metal fusing, but rather due-to the large increase in IC chip dissipation which will cause eventual failure due to excessive junction temperatures. Putting direct short-circuits on more than one amplifier at a time will increase the total IC power dissipation to destructive levels, if not properly protected with external dissipation limiting resistors in series with the output source current which is available at 25°C provides a larger output current capability at elevated temperatures (see typical performance characteristics) than a standard IC op amp.

The circuits presented in the section on typical applications emphasize operation on only a single power supply voltage. If complementary power supplies are available, all of the standard op amp circuits can be used. in general, introducing a pseudo-ground (a bias voltage reference of $V_{CC}/2$) will allow operation above and below this value in single power supply systems. Many application circuits are shown which take advantage of the wide input common-mode voltage range which includes ground. In most cases, input biasing is not required and input voltages which range to ground can easily be accommodated.

Fig. 1 INPUT VOLTAGE RANGE

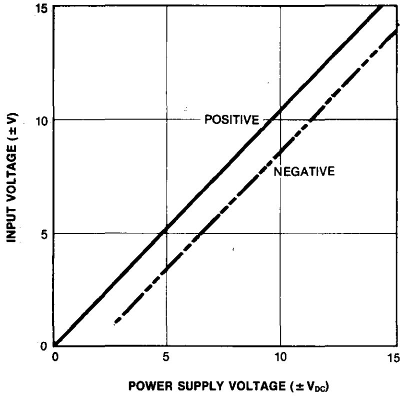


Fig. 2 INPUT CURRENT

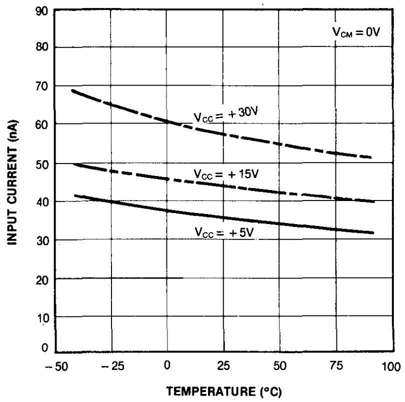


Fig. 3 SUPPLY CURRENT

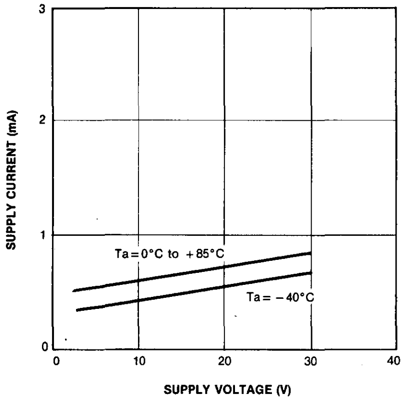


Fig. 4 VOLTAGE GAIN

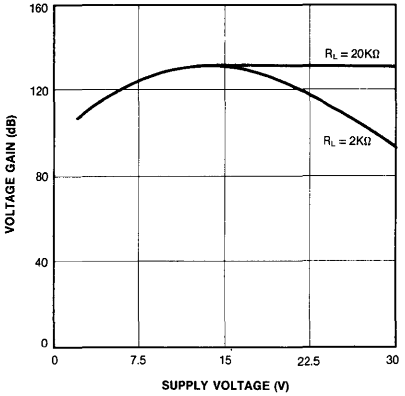


Fig. 5 OPEN LOOP FREQUENCY RESPONSE

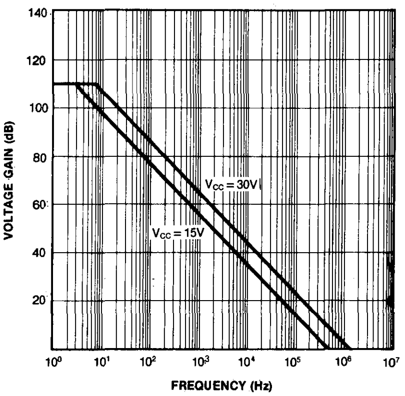
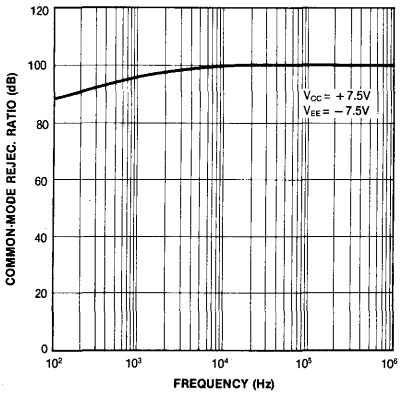


Fig. 6 COMMON-MODE REJECTION RATIO



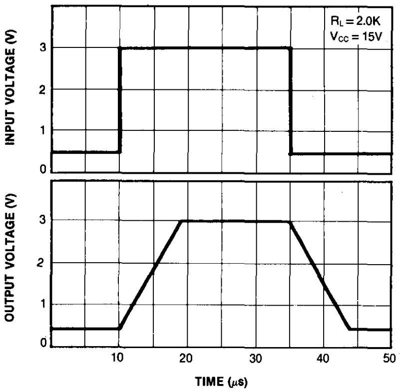


Fig. 8 VOLTAGE FOLLOWER PULSE RESPONSE (SMALL SIGNAL)

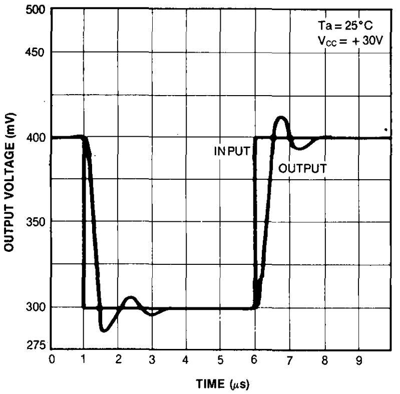


Fig. 9 LARGE SIGNAL FREQUENCY RESPONSE

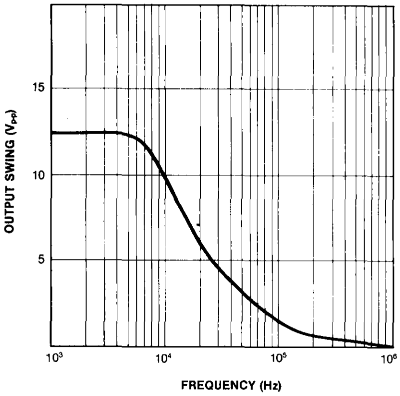


Fig. 10 OUTPUT CHARACTERISTICS CURRENT SOURCING

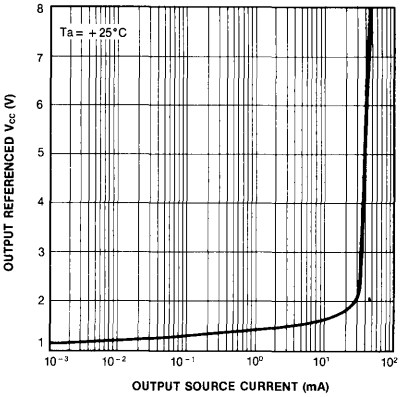
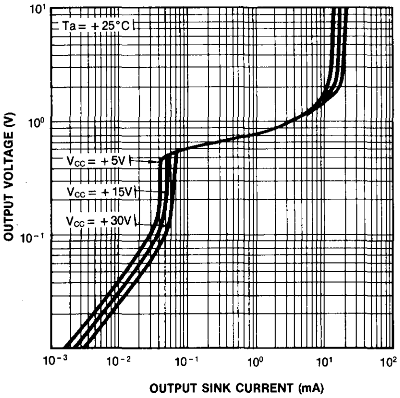
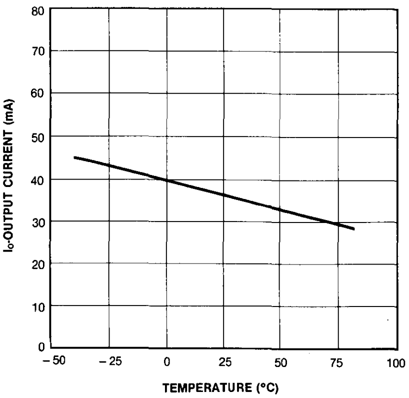


Fig. 11 OUTPUT CHARACTERISTICS CURRENT SINKING

Fig. 12 CURRENT LIMITING





## TYPICAL APPLICATIONS ($V_{CC} = 5.0V$)

**Fig. 13 Voltage Reference**

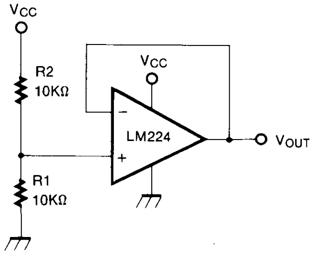


**Fig. 14 Non-Inverting DC Gain**

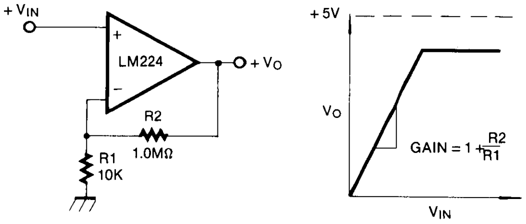


**Fig. 15 AC Coupled Non-Inverting Amplifier**

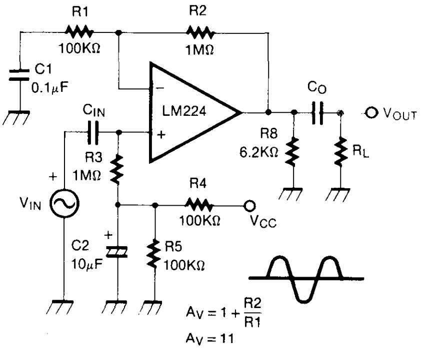


**Fig. 16 Pulse Generator**

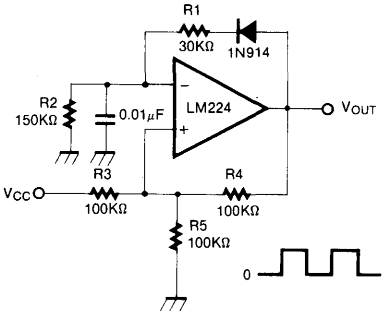
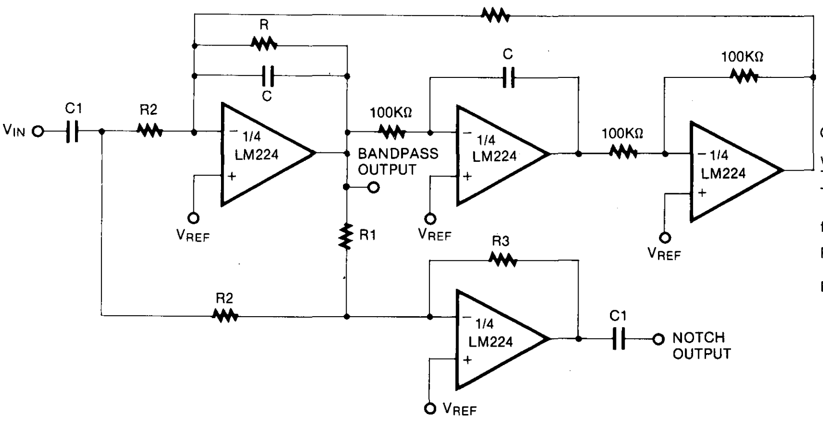


**Fig. 17 Bi-Quad Filter**



$Q = \frac{BW}{f_O}$

where

$T_{BP}$ = Center frequency gain

$T_N$ = Bandpass notch gain

$f_O = \frac{1}{2\pi RC}$ $R2 = \frac{R1}{T_{BP}}$

$R1 = QR$ $R3 = T_N R2$

$C1 = 10C$

Example: $f_O = 1000Hz$

$BW = 100Hz$

$T_{BP} = 1$

$T_N = 1$

$R = 160K\Omega$

$R1 = 1.6M\Omega$

$R2 = 1.6M\Omega$

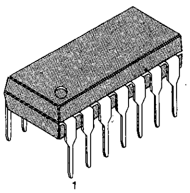
$R3 = 1.6M\Omega$

$C = 0.01\mu F$

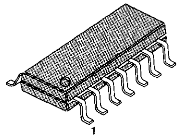
## QUAD OPERATIONAL AMPLIFIERS

The LM248/LM348 is a true quad LM741. It consists of four independent, high-gain, internally compensated, low-power operational amplifiers which have been designed to provide functional characteristics identical to those of the familiar LM741 operational amplifier. In addition the total supply current for all four amplifiers is comparable to the supply current of a single LM741 type OP Amp. Other features include input offset currents and input bias current which are much less than those of a standard LM741. Also, excellent isolation between amplifiers has been achieved by independently biasing each amplifier and using layout techniques which minimize thermal coupling.

**14 DIP**



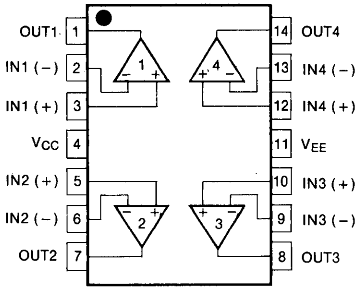
**14 SOP**



## FEATURES

- **LM741 OP Amp operating characteristics**
- **Low supply current drain**
- **Class AB output stage-no crossover distortion**
- **Pin compatible with the LM324 & MC3403**
- **Low input offset voltage-1mV Typ.**
- **Low input offset current-4nA Typ.**
- **Low input bias current-30nA Typ.**
- **Gain bandwidth product for LM348 (unity gain)-1.0MHz Typ.**
- **High degree of isolation between amplifiers-120dB**
- **Overload protection for inputs and outputs**

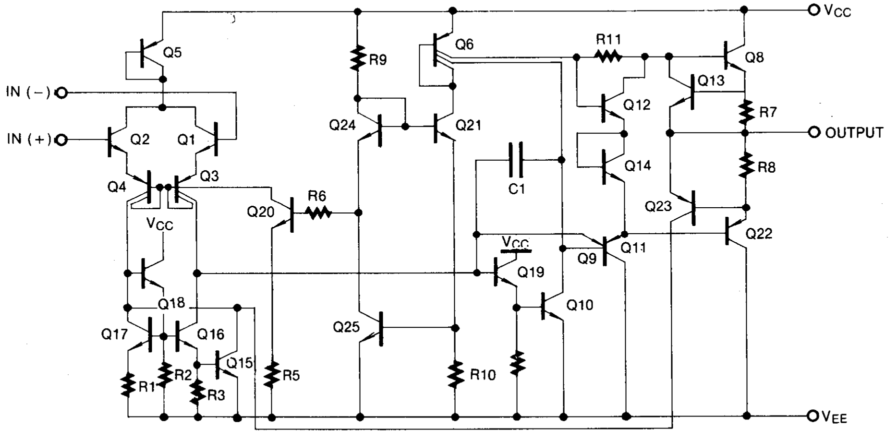
## BLOCK DIAGRAM



## ORDERING INFORMATION

| Device | Package | Operating Temperature |
|---|---|---|
| LM348N | 14 DIP | 0 ~ +70°C |
| LM348D | 14 SOP | |
| LM248N | 14 DIP | −25 ~ +85°C |
| LM248D | 14 SOP | |

## SCHEMATIC DIAGRAM (One Section Only)



## ABSOLUTE MAXIMUM RATINGS (Ta = 25°C)

| Characteristic | Symbol | Value | Unit |
|---|---|---|---|
| Supply Voltage | $V_S$ | ± 18 | V |
| Differential Input Voltage | $V_{ID}$ | ± 36 | V |
| Input Voltage | $V_I$ | ± 18 | V |
| Output Short Circuit Duration | | Continuous | |
| Operating Temperature LM248 | $T_{opr}$ | − 25 ~ + 85 | °C |
| LM348 | | 0 ~ + 70 | °C |
| Storage Temperature | $T_{stg}$ | − 65 ~ + 150 | °C |

## ELECTRICAL CHARACTERISTICS

($V_{CC}$ = 15V, $V_{EE}$ = − 15V, Ta = 25°C, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | | LM248 | | | LM348 | | | Unit |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Min | Typ | Max | Min | Typ | Max | |
| Input Offset Voltage | $V_{IO}$ | $R_S \leq 10K\Omega$ | | | 1 | 6.0 | | 1 | 6.0 | mV |
| | | | NOTE 1 | | | 7.5 | | | 7.5 | |
| Input Offset Current | $I_{IO}$ | | | | 4 | 50 | | 4 | 50 | nA |
| | | | NOTE 1 | | | 125 | | | 100 | |
| Input Bias Current | $I_{IB}$ | | | | 30 | 200 | | 30 | 200 | nA |
| | | | NOTE 1 | | | 500 | | | 400 | |
| Input Resistance | $R_i$ | | | 0.8 | 2.5 | | 0.8 | 2.5 | | MΩ |
| Supply Current (all Amplifiers) | $I_S$ | | | | 2.4 | 4.5 | | 2.4 | 4.5 | mA |
| Large Signal Voltage Gain | $A_V$ | $R_L \geq 2K\Omega$ | | 25 | 160 | | 25 | 160 | | V/mV |
| | | | NOTE 1 | 15 | | | 15 | | | |
| Channel Separation | CS | f = 1KHz to 20KHz | | | 120 | | | 120 | | dB |
| Common Mode Input Voltage Range | $V_{ICR}$ | | NOTE 1 | ± 12 | | | ± 12 | | | V |
| Small Signal Bandwidth | BW | $A_V = 1$ | | | 1.0 | | | 1.0 | | MHz |
| Phase Margin | $\phi m$ | $A_V = 1$ | | | 60 | | | 60 | | Degrees |
| Slew Rate | SR | $A_V = 1$ | | | 0.5 | | | 0.5 | | V/µs |
| Output Short Circuit Current | $I_{OS}$ | | | | 25 | | | 25 | | mA |
| Output Voltage Swing | $V_{OUT}$ | $R_L \geq 10K\Omega$ | NOTE 1 | ± 12 | ± 13 | | ± 12 | ± 13 | | V |
| | | $R_L \geq 2K\Omega$ | | ± 10 | ± 12 | | ± 10 | ± 12 | | |
| Common Mode Rejection Ratio | CMRR | $R_S \geq 10K\Omega$ | NOTE 1 | 70 | 90 | | 70 | 90 | | dB |
| Power Supply Rejection Ratio | PSRR | $R_S \geq 10K\Omega$ | NOTE 1 | 77 | 96 | | 77 | 96 | | dB |

* NOTE 1

LM348: 0 ≥ Ta ≥ + 70°C

LM248: − 25 ≥ Ta ≥ + 85°C

## TYPICAL PERFORMANCE CHARACTERISTICS

Fig. 1 SUPPLY CURRENT

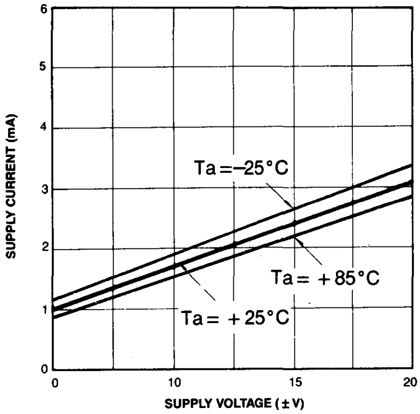


Fig. 2 VOLTAGE SWING

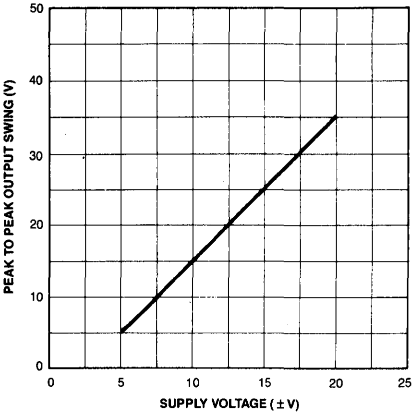


Fig. 3 SOURCE CURRENT LIMIT

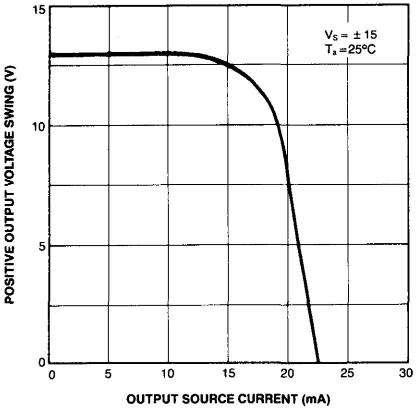


Fig. 4 SINK CURRENT LIMIT

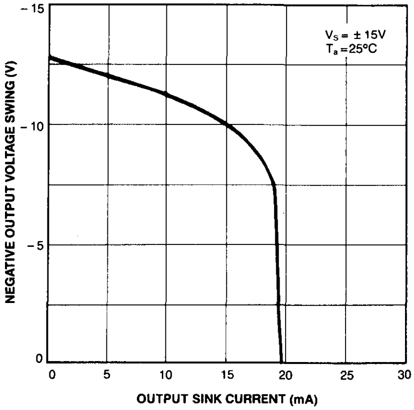


Fig. 5 OUTPUT IMPEDANCE

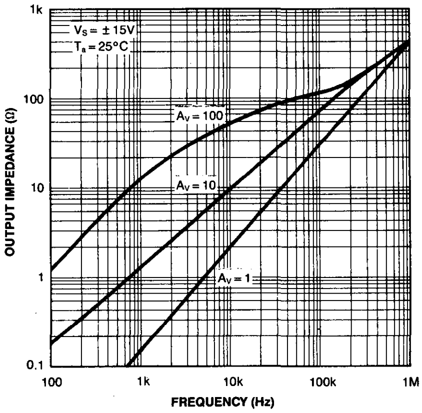


Fig. 6 COMMON-MODE REJECTION RATIO

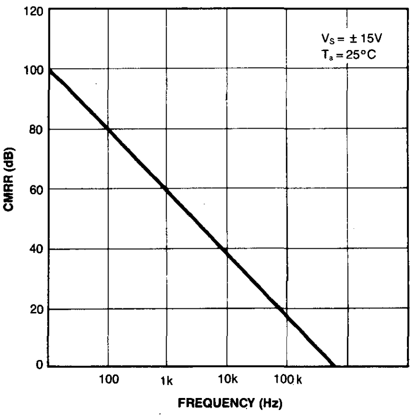


**Fig. 7 OPEN LOOP FREQUENCY RESPONSE**

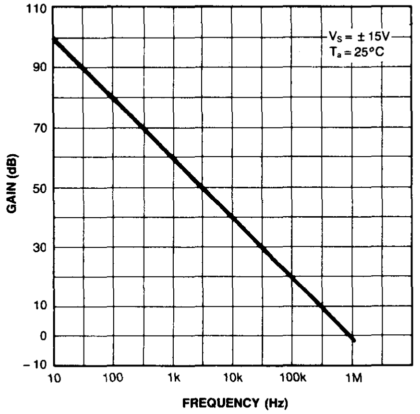


**Fig. 8 BODE PLOT**

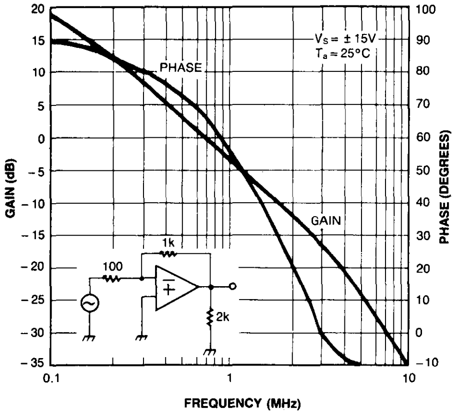


**Fig. 9 LARGE SIGNAL PULSE RESPONSE**

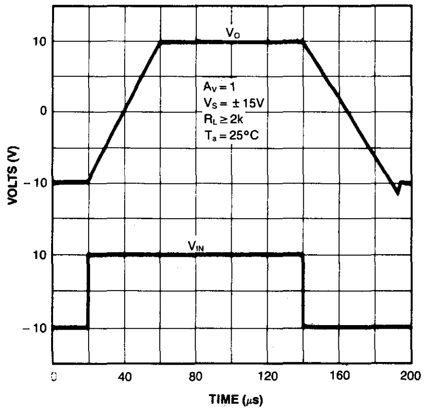


**Fig. 10 SMALL SIGNAL PULSE RESPONSE**

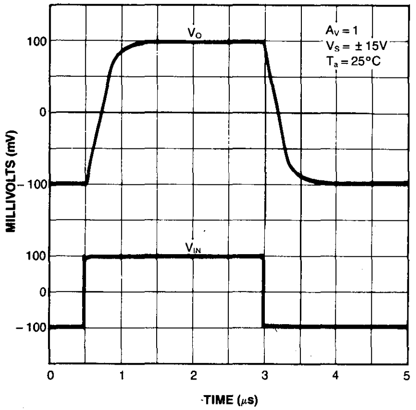


**Fig. 11 UNDISTORTED OUTPUT VOLTAGE SWING**

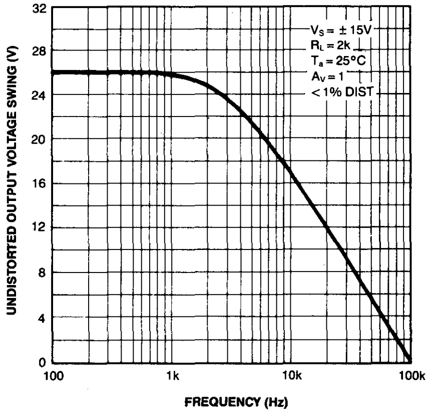


**Fig. 12 INVERTING LARGE SIGNAL PULSE RESPONSE**

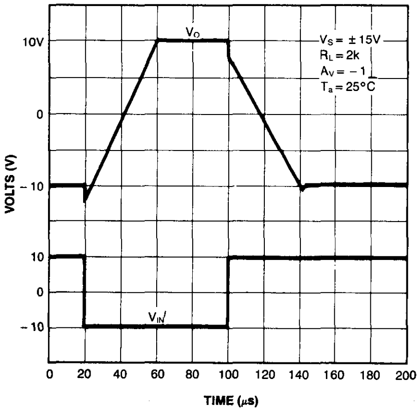


Fig. 13 INPUT NOISE VOLTAGE AND NOISE CURRENT

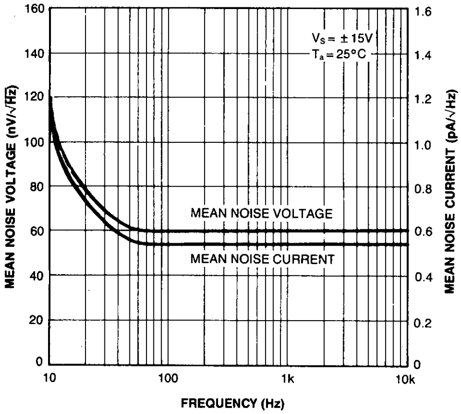


Fig. 14 POSITIVE COMMON-MODE INPUT VOLTAGE LIMIT

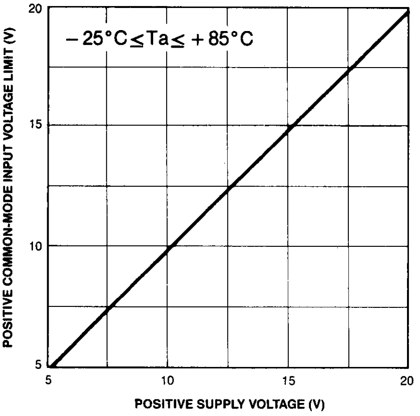
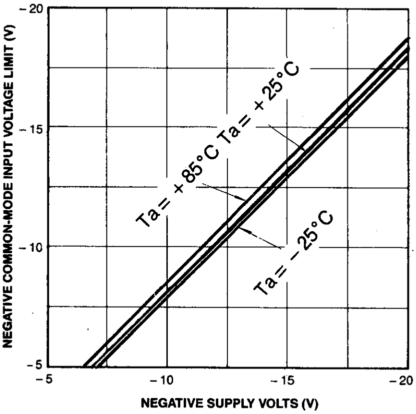
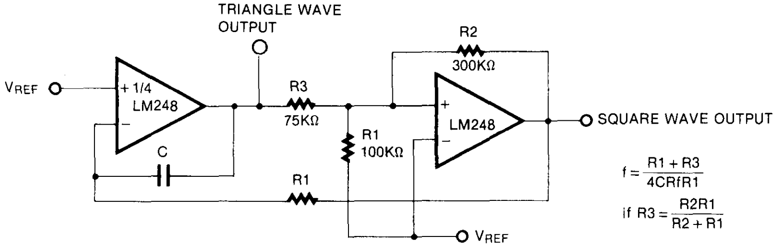


Fig. 15 NEGATIVE COMMON-MODE INPUT VOLTAGE LIMIT



## TYPICAL APPLICATIONS

### Fig. 16 Function Generator

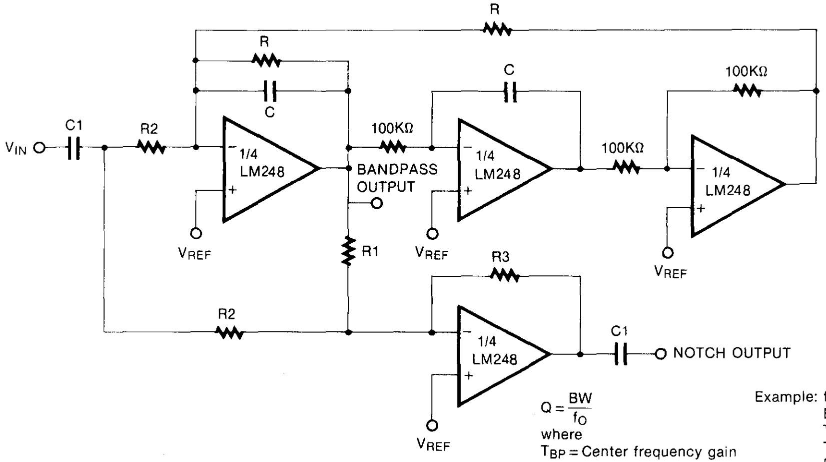


$f = \frac{R1 + R3}{4CRfR1}$

if $R3 = \frac{R2R1}{R2 + R1}$

Fig. 16

### Fig. 17 Bi-Quad Filter



$Q = \frac{BW}{f_O}$

where

$T_{BP}$ = Center frequency gain

$T_N$ = Bandpass notch gain

$f_O = \frac{1}{2\pi RC}$ $R2 = \frac{R1}{T_{BP}}$

$R1 = QR$ $R3 = T_N R2$

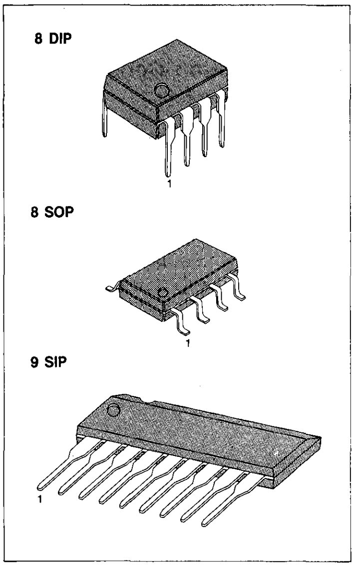
$C1 = 10C$

Example: $f_O = 1000Hz$
$BW = 100Hz$
$T_{BP} = 1$
$T_N = 1$
$R = 160K\Omega$
$R1 = 1.6M\Omega$
$R2 = 1.6M\Omega$
$R3 = 1.6M\Omega$
$C = 0.01\mu F$

Fig. 17

## DUAL OPERATIONAL AMPLIFIERS

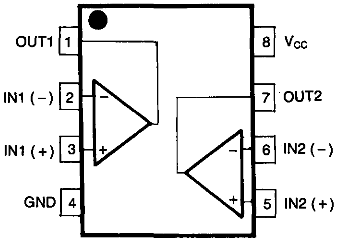
The LM258 series consists of four independent, high gain, internally frequency compensated operational amplifiers which were designed specifically to operate from a single power supply over a wide range of voltage. Operation from split power supplies is also possible and the low power supply current drain is independent of the magnitude of the power supply voltage. Application areas include transducer amplifier, DC gain blocks and all the conventional OP amp circuits which now can be easily implemented in single power supply systems.

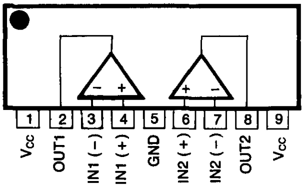


## FEATURES

- **Internally frequency compensated for unity gain**
- **Large DC voltage gain: 100dB**
- **Wide power supply range: LM258/A, LM358/A: 3V ~ 32V (or ± 1.5V ~ ± 16V)**
  **LM2904: 3V ~ 26V (or ± 1.5V ~ ± 13V)**
- **Input common-mode voltage range includes ground**
- **Large output voltage swing: 0V DC to $V_{CC}$ - 1.5V DC**
- **Power drain suitable for battery operation.**

## BLOCK DIAGRAM

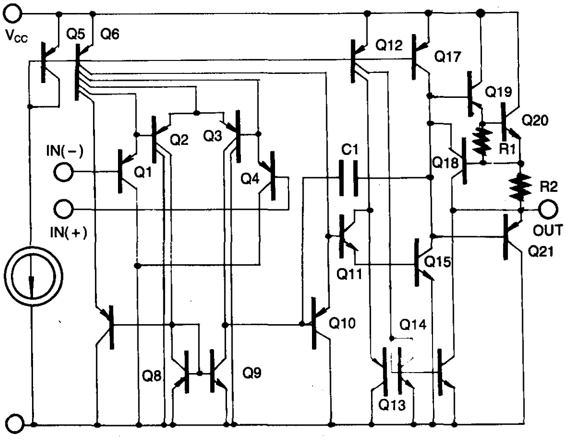




## ORDERING INFORMATION

| Device | Package | Operating Temperature |
|---|---|---|
| LM358N<br>LM358AN | 8 DIP | 0 ~ +70°C |
| LM358S<br>LM358AS | 9 SIP | |
| LM358D<br>LM358AD | 8 SOP | |
| LM258N<br>LM258AN | 8 DIP | -25 ~ +85°C |
| LM258S<br>LM258AS | 9 SIP | |
| LM258D<br>LM258AD | 8 SOP | |
| LM2904N | 8 SIP | -40 ~ +85°C |
| LM2904S | 9 SIP | |
| LM2904D | 8 SIP | |

## SCHEMATIC DIAGRAM (One section only)



## ABSOLUTE MAXIMUM RATINGS

| Characteristic | Symbol | LM258/LM258A | LM358/LM358A | LM2904 | Unit |
|---|---|---|---|---|---|
| Power Supply Voltage | $V_S$ | ± 16 or 32 | ± 16 or 32 | ± 13 or 26 | V |
| Differential Input Voltage | $V_{ID}$ | ± 32 | ± 32 | ± 26 | V |
| Input Voltage | $V_I$ | − 0.3 to + 32 | − 0.3 to + 32 | − 0.3 to + 26 | V |
| Output Short Circuit to GND<br>$V_{CC} \leq 15V$ Ta = 25°C (One Amp) | | Continuous | Continuous | Continuous | |
| Operating Temperature Range | $T_{opr}$ | − 25 ~ + 85 | 0 ~ + 70 | − 40 ~ + 85 | °C |
| Storage Temperature Range | $T_{stg}$ | − 65 ~ + 150 | − 65 ~ + 150 | − 65 ~ + 150 | °C |

## ELECTRICAL CHARACTERISTICS

($V_{CC} = 5.0V$, $V_{EE}$ = GND, Ta = 25°C, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | | LM258 | | | LM358 | | | LM2904 | | | Unit |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Min | Typ | Max | Min | Typ | Max | Min | Typ | Max | |
| Input Offset Voltage | $V_{IO}$ | $V_{ICM} = 0V$ to $V_{CC} - 1.5V$<br>$V_o = 1.4V$, $R_S = 0\Omega$ | | | 2.9 | 5.0 | | 2.9 | 7.0 | | 2.9 | 7.0 | mV |
| Input Offset Current | $I_{IO}$ | | | | 3 | 30 | | 5 | 50 | | 5 | 50 | nA |
| Input Bias Current | $I_{IB}$ | | | | 45 | 150 | | 45 | 250 | | 45 | 250 | nA |
| Input Common-Mode Voltage Range | $V_{ICR}$ | $V_{CC} = 30V$<br>(LM2904, $V_{CC} = 26V$) | | 0 | | $V_{CC}$<br>-1.5 | 0 | | $V_{CC}$<br>-1.5 | 0 | | $V_{CC}$<br>-1.5 | V |
| Supply Current | $I_{CC}$ | $R_L = \infty$, $V_{CC} = 30V$<br>(LM2902, $V_{CC} = 26V$) | | | 0.8 | 2.0 | | 0.8 | 2.0 | | 0.8 | 2.0 | mA |
| | | $R_L = \infty$ ,over full temperature range | | | 0.5 | 1.2 | | 0.5 | 1.2 | | 0.5 | 1.2 | mA |
| Large Signal Voltage Gain | $A_V$ | $V_{CC} = 15V$, $R_L \geq 2K\Omega$<br>$V_O = 1V$ to $11V$ | | 50 | 100 | | 25 | 100 | | 25 | 100 | | V/mV |
| Output Voltage Swing | $V_{OH}$<br>$V_{OL}$ | $V_{CC} = 30V$<br>$V_{CC} = 26V$ for 2904 | $R_L = 2K\Omega$ | 26 | | | 26 | | | 22 | | | V |
| | | | $R_L = 10K\Omega$ | 27 | 28 | | 27 | 28 | | 23 | 24 | | V |
| | | $V_{CC} = 5V$ $R_L \geq 10K\Omega$ | | | 5 | 20 | | 5 | 20 | | 5 | 100 | mV |
| Common-Mode Rejection Ratio | CMRR | | | 70 | 85 | | 65 | 80 | | 50 | 80 | | dB |
| Power Supply Rejection Ratio | PSRR | | | 65 | 100 | | 65 | 100 | | 50 | 100 | | dB |
| Channel Separation | CS | f = 1KHz to 20KHz | | | 120 | | | 120 | | | 120 | | dB |
| Short Circuit to GND | $I_{OS}$ | | | | 40 | 60 | | 40 | 60 | | 40 | 60 | mA |
| Output Current | $I_{source}$ | $V_{in+} = 1V$, $V_{in-} = 0V$<br>$V_{CC} = 15V$, $V_o = 2V$ | | 10 | 30 | | 10 | 30 | | 10 | 30 | | mA |
| | $I_{sink}$ | $V_{in+} = 0V$, $V_{in-} = 1V$<br>$V_{CC} = 15V$, $V_o = 2V$ | | 10 | 15 | | 10 | 15 | | 10 | 15 | | mA |
| | | $V_{in+} = 0V$, $V_{in-} = 1V$<br>$V_{CC} = 15V$, $V_o = 200mV$ | | 12 | 100 | | 12 | 100 | | | | | μA |
| Differential Input Voltage | $V_{ID}$ | | | | | $V_{CC}$ | | | $V_{CC}$ | | | $V_{CC}$ | V |

## ELECTRICAL CHARACTERISTICS

($V_{CC}=5.0V$, $V_{EE}=GND$, unless otherwise specified)
The following specification apply over the range of $-25°C \leq Ta \leq +85°C$ for the LM258; and the $0°C \leq Ta \leq +70°C$ for the LM358; and the $-40°C \leq Ta \leq +85°C$ for the LM2904

| Characteristic | Symbol | Test Conditions | LM258 | | | LM358 | | | LM2904 | | | Unit |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Min | Typ | Max | Min | Typ | Max | Min | Typ | Max | |
| Input Offset Voltage | $V_{IO}$ | $V_{ICM}=0V$ to $V_{CC}-1.5V$<br>$V_O=1.4V$, $R_S=0\Omega$ | | | 7.0 | | | 9.0 | | | 10.0 | mV |
| Input Offset Voltage Drift | $\Delta V_{IO}/\Delta T$ | $R_S=0\Omega$ | | 7.0 | | | 7.0 | | | 7.0 | | μV/°C |
| Input Offset Current | $I_{IO}$ | | | | 100 | | | 150 | | 45 | 200 | nA |
| Input Offset Current Drift | $\Delta I_{IO}/\Delta T$ | | | 10 | | | 10 | | | 10 | | pA/°C |
| Input Bias Current | $I_{IB}$ | | | 40 | 300 | | 40 | 500 | | 40 | 500 | nA |
| Input Common-Mode Voltage Range | $V_{ICR}$ | $V_{CC}=30V$<br>(LM2904, $V_{CC}=26V$) | 0 | | $V_{CC}$ -2.0 | 0 | | $V_{CC}$ -2.0 | 0 | | $V_{CC}$ -2.0 | V |
| Large Signal Voltage Gain | $A_V$ | $V_{CC}=15V$, $R_L \geq 2.0K\Omega$<br>$V_O=1V$ to $11V$ | 25 | | | 15 | | | 15 | | | V/mV |
| Output Voltage Swing | $V_{OH}$ | $V_{CC}=30V$<br>$V_{CC}=26V$ for 2904<br>$R_L=2K\Omega$ | 26 | | | 26 | | | 26 | | | V |
| | | $R_L=10K\Omega$ | 27 | 28 | | 27 | 28 | | 27 | 28 | | V |
| | $V_{OL}$ | $V_{CC}=5V$, $R_L \geq 10K\Omega$ | | 5 | 20 | | 5 | 20 | | 5 | 100 | mV |
| Output Current | $I_{source}$ | $V_{in+}=1V$, $V_{in-}=0V$<br>$V_{CC}=15V$, $V_O=2V$ | 10 | 30 | | 10 | 30 | | 10 | 30 | | mA |
| | $I_{sink}$ | $V_{in+}=0V$, $V_{in-}=1V$<br>$V_{CC}=15V$, $V_O=2V$ | 5 | 8 | | 5 | 9 | | 5 | 9 | | mA |
| Differential Input Voltage | $V_{ID}$ | | | | $V_{CC}$ | | | $V_{CC}$ | | | $V_{CC}$ | V |

## ELECTRICAL CHARACTERISTICS

($V_{CC}$ = 5.0V, $V_{EE}$ = GND, Ta = 25°C, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | | LM258A | | | LM358A | | | Unit |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Min | Typ | Max | Min | Typ | Max | |
| Input Offset Voltage | $V_{IO}$ | $V_{ICM}$ = 0V to $V_{CC}$ − 1.5V<br>$V_O$ = 1.4V, $R_S$ = 0 | | | 1.0 | 3.0 | | 2.0 | 3.0 | mV |
| Input Offset Current | $I_{IO}$ | | | | 2 | 15 | | 5 | 30 | nA |
| Input Bias Current | $I_{IB}$ | | | | 40 | 80 | | 45 | 100 | nA |
| Input Common-Mode Voltage Range | $V_{ICR}$ | $V_{CC}$ = 30V | | 0 | | $V_{CC}$ -1.5 | 0 | | $V_{CC}$ -1.5 | V |
| Supply Current | $I_{CC}$ | $R_L$ = ∞ , $V_{CC}$ = 30V | | | 0.8 | 2.0 | | 0.8 | 2.0 | mA |
| | | $R_L$ = ∞, over full temperature range | | | 0.5 | 1.2 | | 0.5 | 1.2 | mA |
| Large Signal Voltage Gain | $A_V$ | $V_{CC}$ = 15V, $R_L \geq$ 2KΩ<br>$V_O$ = 1V to 11V | | 50 | 100 | | 25 | 100 | | V/mV |
| Output Voltage Swing | $V_{OH}$ | $V_{CC}$ = 30V<br>$V_{CC}$ = 26V for 2904 | $R_L$ = 2KΩ | 26 | | | 26 | | | V |
| | | | $R_L$ = 10KΩ | 27 | 28 | | 27 | 28 | | V |
| | $V_{OL}$ | $V_{CC}$ = 5V, $R_L \geq$ 10KΩ | | | 5 | 20 | | 5 | 20 | mV |
| Common-Mode Rejection Ratio | CMRR | | | 70 | 85 | | 65 | 85 | | dB |
| Power Supply Rejection Ratio | PSRR | | | 65 | 100 | | 65 | 100 | | dB |
| Channel Separation | CS | f = 1KHz to 20KHz | | | 120 | | | 120 | | dB |
| Short Circuit to GND | $I_{OS}$ | | | | 40 | 60 | | 40 | 60 | mA |
| Output Current | $I_{source}$ | $V_{in+}$ = 1V, $V_{in-}$ = 0V<br>$V_{CC}$ = 15V, $V_O$ = 2V | | 20 | 30 | | 20 | 30 | | mA |
| | $I_{sink}$ | $V_{in+}$ = 0V, $V_{in-}$ = 1V<br>$V_{CC}$ = 15V, $V_O$ = 2V | | 10 | 15 | | 10 | 15 | | mA |
| | | $V_{in+}$ = 0V, $V_{in-}$ = 1V<br>$V_O$ = 200mV | | 12 | 100 | | 12 | 100 | | μA |
| Differential Input Voltage | $V_{ID}$ | | | | | $V_{CC}$ | | | $V_{CC}$ | V |

## ELECTRICAL CHARACTERISTICS ($V_{CC}=5.0V$, $V_{EE}=GND$, unless otherwise specified)

The following specification apply over the range of $-25°C \leq Ta \leq +85°C$ for the LM258A; and the $0°C \leq Ta \leq +70°C$ for the LM358A

| Characteristic | Symbol | Test Conditions | | LM258A | | | LM358A | | | Unit |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Min | Typ | Max | Min | Typ | Max | |
| Input Offset Voltage | $V_{IO}$ | $V_{ICM}=0V$ to $V_{CC}-1.5V$<br>$V_O=1.4V$, $R_S=0\Omega$ | | | | 4.0 | | | 5.0 | mV |
| Input Offset Voltage Drift | $\Delta V_{IO}/\Delta T$ | | | | 7.0 | 15 | | 7.0 | 20 | μV/°C |
| Input Offset Current | $I_{IO}$ | | | | | 30 | | | 75 | nA |
| Input Offset Current Drift | $\Delta I_{IO}/\Delta T$ | | | | 10 | 200 | | 10 | 300 | pA/°C |
| Input Bias Current | $I_{IB}$ | | | | 40 | 100 | | 40 | 200 | nA |
| Input Common-Mode Voltage Range | $V_{ICR}$ | $V_{CC}=30V$ | | 0 | | $V_{CC}$<br>-2.0 | 0 | | $V_{CC}$<br>-2.0 | V |
| Output Voltage Swing | $V_{OH}$ | $V_{CC}=30V$ | $R_L=2K\Omega$ | 26 | | | 26 | | | V |
| | | $V_{CC}=30V$ | $R_L=10K\Omega$ | 27 | 28 | | 27 | 28 | | V |
| | $V_{OL}$ | $V_{CC}=5V$, $R_L\geq10K\Omega$ | | | 5 | 20 | | 5 | 20 | mV |
| Large Signal Voltage Gain | $A_V$ | $V_{CC}=15V$, $R_L\geq2.0K\Omega$<br>$V_O=1V$ to $11V$ | | 25 | | | 15 | | | V/mV |
| Output Current | $I_{source}$ | $V_{in+}=1V$, $V_{in-}=0V$<br>$V_{CC}=15V$, $V_O=2V$ | | 10 | 30 | | 10 | 30 | | mA |
| | $I_{sink}$ | $V_{in+}=0V$, $V_{in-}=1V$<br>$V_{CC}=15V$, $V_O=2V$ | | 5 | 9 | | 5 | 9 | | mA |
| Differential Input Voltage | $V_{ID}$ | | | | | $V_{CC}$ | | | $V_{CC}$ | V |

## TYPICAL PERFORMANCE CHARACTERISTICS

**Fig. 1 SUPPLY CURRENT**

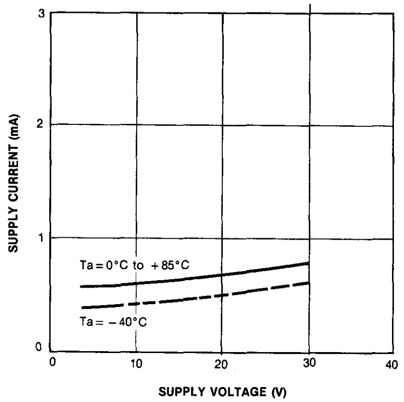


**Fig. 2 VOLTAGE GAIN**

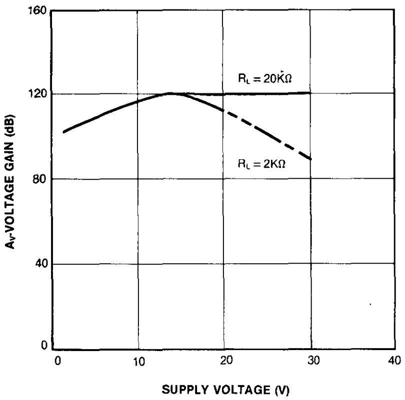


**Fig. 3 OPEN LOOP FREQUENCY RESPONSE**

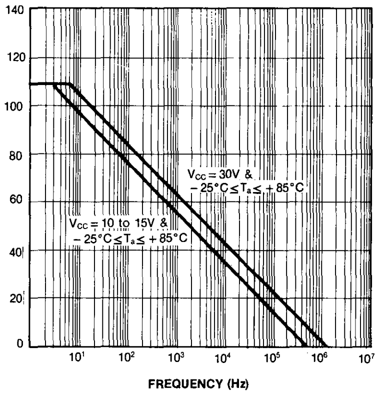


**Fig. 4 LARGE SIGNAL FREQUENCY**

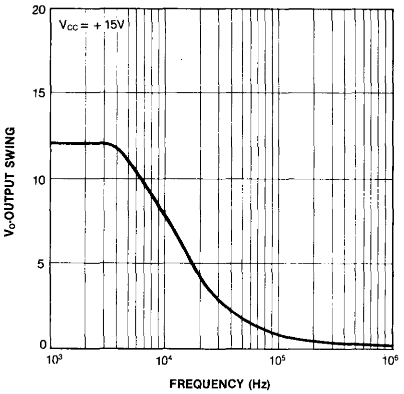


**Fig. 5 OUTPUT CHARACTERISTICS CURRENT SOURCING**

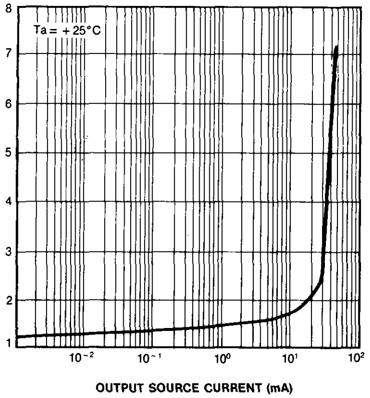


**Fig. 6 OUTPUT CHARACTERISTICS CURRENT SINKING**

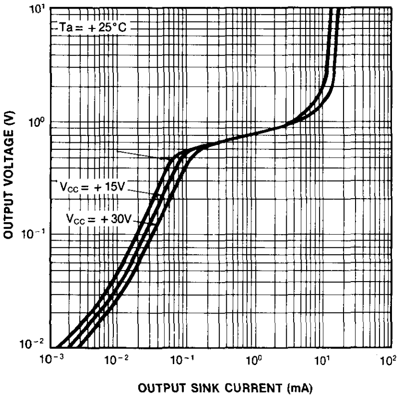


Fig. 7 INPUT VOLTAGE RANGE

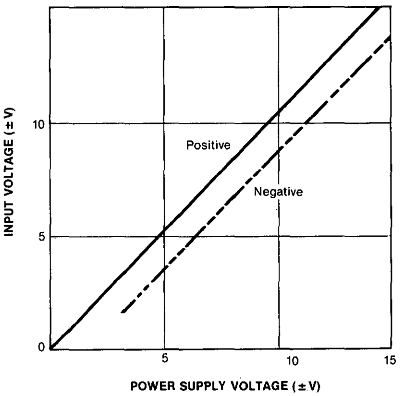


Fig. 8 COMMON-MODE REJECTION RATIO

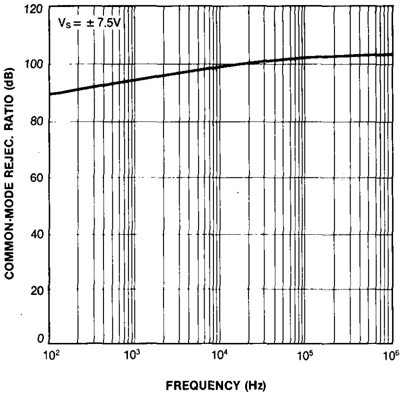


Fig. 9 CURRENT LIMITING

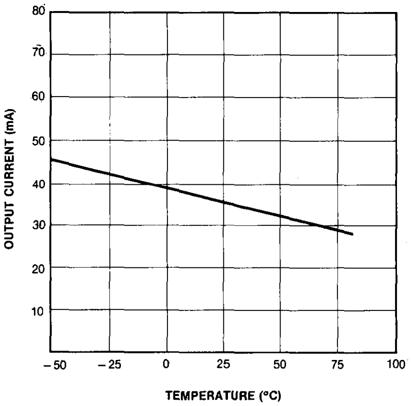


Fig. 10 INPUT CURRENT

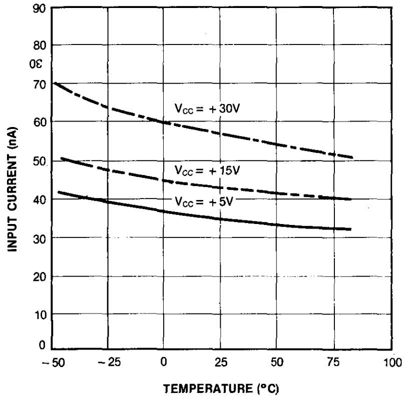


Fig. 11 VOLTAGE FOLLOWER PULSE RESPONSE

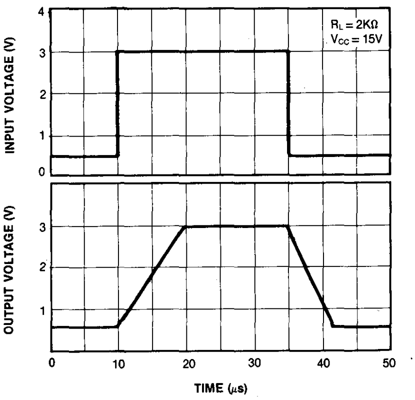
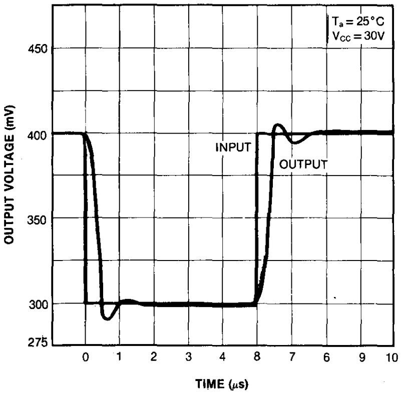


Fig. 12 VOLTAGE FOLLOWER PULSE RESPONSE (SMALL SIGNAL)



## TYPICAL APPLICATIONS ($V_{CC}=5.0V$)

**Fig. 13 Voltage Reference**

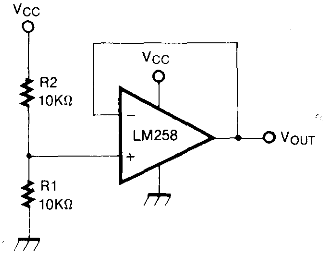


**Fig. 14 Non-Inverting DC Gain**

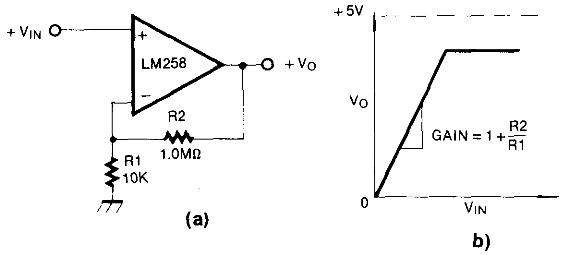


**Fig. 15 AC Coupled Non-Inverting Amplifier**

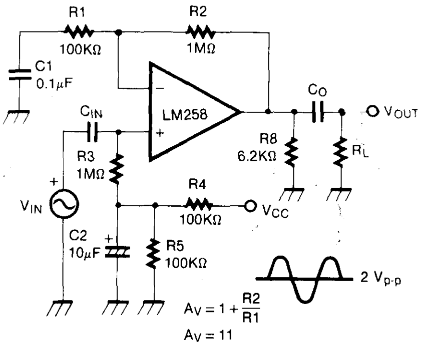


**Fig. 16 Pulse Generator**

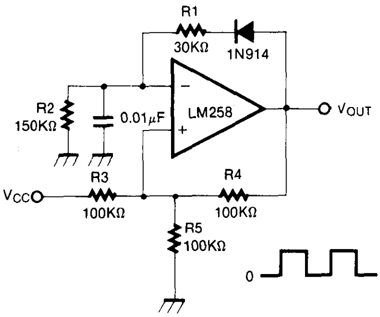
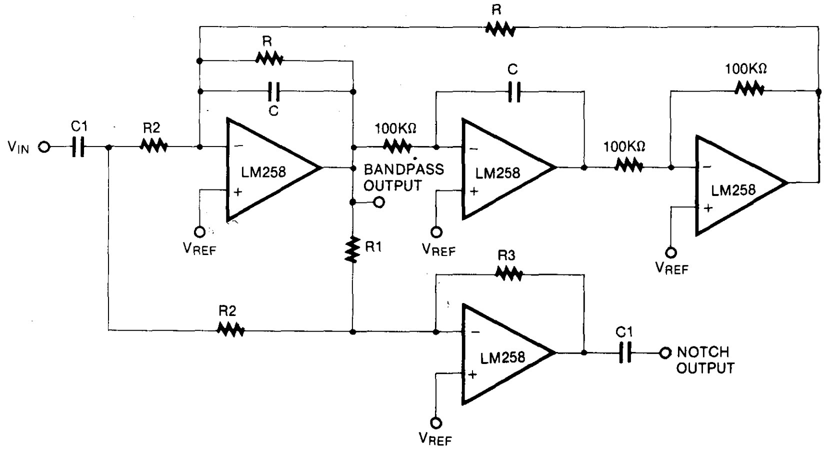


**Fig. 17 Bi-Quad Filter**



$Q=\frac{BW}{f_O}$

where

$T_{BP}$ = Center frequency gain

$T_N$ = Bandpass notch gain

$f_O=\frac{1}{2\pi RC}$  $R2=\frac{R1}{T_{BP}}$

$R1=QR$  $R3=T_NR2$

$C1=10C$

Example: $f_O=1000Hz$

$BW=100Hz$

$T_{BP}=1$

$T_N=1$

$R=160K\Omega$

$R1=1.6M\Omega$

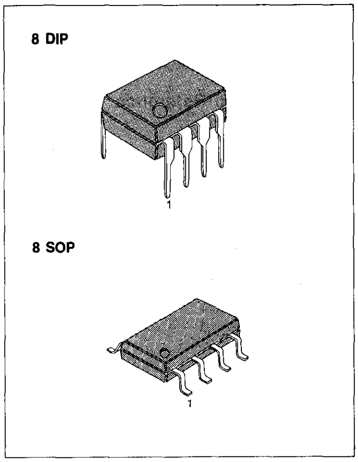
$R2=1.6M\Omega$

$R3=1.6M\Omega$

$C=0.01\mu F$

## SINGLE OPERATIONAL AMPLIFIERS

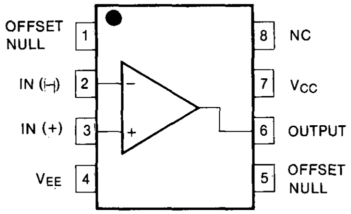
The LM741 series are general purpose operational amplifiers which feature improved performance over industry standards like the LM709. It is intended for a wide range of analog applications.
The high gain and wide range of operating voltage provide superior performance in intergrator, summing amplifier, and general feedback applications.



## FEATURES

- **Short circuit protection**
- **Excellent temperature stability**
- **Internal frequency compensation**
- **High input voltage range**
- **Null of offset**

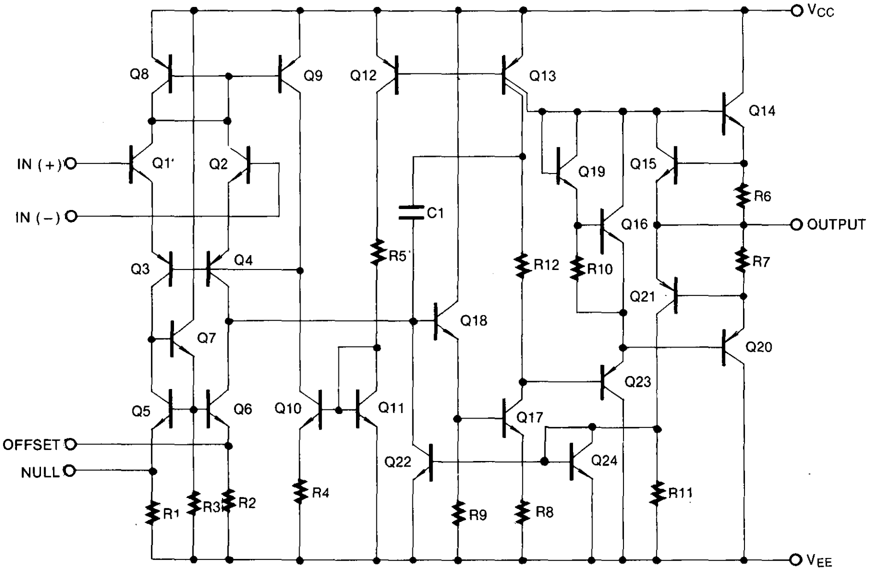
## BLOCK DIAGRAM



## ORDERING INFORMATION

| Device | Package | Operating Temperature |
|---|---|---|
| LM741ECN<br>LM741CN | 8 DIP | 0 ~ +70°C |
| LM741ECD<br>LM741CD | 8 SOP | |
| LM741IN<br>LM741EIN | 8 DIP | −40~ +85°C |
| LM741ID<br>LM741EID | 8 SOP | |

## SCHEMATIC DIAGRAM



## ABSOLUTE MAXIMUM RATINGS ($T_a = 25°C$)

| Characteristic | Symbol | LM741C | LM741E | LM741I | Unit |
|---|---|---|---|---|---|
| Power Supply Voltage | $V_S$ | ±18 | ±22 | ±18 | V |
| Differential Input Voltage | $V_{ID}$ | ±30 | ±30 | ±30 | V |
| Input Voltage | $V_I$ | ±15 | ±15 | ±15 | V |
| Output Short Circuit Duration | | Indefinite | Indefinite | Indefinite | |
| Power Dissipation | $P_D$ | 500 | 500 | 500 | mW |
| Operating Temperature Range | $T_{opr}$ | 0 ~ +70 | 0 ~ +70 | −40 ~ +85 | °C |
| Storage Temperature Range | $T_{stg}$ | −65 ~ +150 | −65 ~ +150 | −65 ~ +150 | °C |

## ELECTRICAL CHARACTERISTICS

($V_{CC} = 15V$, $V_{EE} = -15V$, $T_a = 25°C$, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | | LM741E | | | LM741C/LM741I | | | Unit |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Min | Typ | Max | Min | Typ | Max | |
| Input Offset Voltage | $V_{IO}$ | $R_S \leq 10K\Omega$ | | | | | | 2.0 | 6.0 | mV |
| | | $R_S \leq 50\Omega$ | | | 0.8 | 3.0 | | | | |
| Input Offset Voltage Adjustment Range | $V_{IOR}$ | $V_S = \pm 20V$ | | ±10 | | | | ±15 | | mV |
| Input Offset Current | $I_{IO}$ | | | | 3.0 | 30 | | 20 | 200 | nA |
| Input Bias Current | $I_{IB}$ | | | | 30 | 80 | | 80 | 500 | nA |
| Input Resistance | $R_i$ | $V_S = \pm 20V$ | | 1.0 | 6.0 | | 0.3 | 2.0 | | MΩ |
| Input Voltage Range | $V_{ICR}$ | | | ±12 | ±13 | | ±12 | ±13 | | V |
| Large Signal Voltage Gain | $A_V$ | $R_L \geq 2K\Omega$ | $V_S = \pm 20V$, $V_O = \pm 15V$ | 50 | | | | | | V/mV |
| | | | $V_S = \pm 15V$, $V_O = \pm 10V$ | | | | 20 | 200 | | |
| Output Short Circuit Current | $I_{OS}$ | | | 10 | 25 | 35 | | 25 | | mA |
| Output Voltage Swing | $V_{OUT}$ | $V_S = \pm 20V$ | $R_L \geq 10K\Omega$ | ±16 | | | | | | V |
| | | | $R_L \geq 2K\Omega$ | ±15 | | | | | | |
| | | $V_S = \pm 15V$ | $R_L \geq 10K\Omega$ | | | | ±12 | ±14 | | |
| | | | $R_L \geq 2K\Omega$ | | | | ±10 | ±13 | | |
| Common Mode Rejection Ratio | CMRR | $R_S \leq 10K\Omega$, $V_{CM} = \pm 12V$ | | | | | 70 | 90 | | dB |
| | | $R_S \leq 50K\Omega$, $V_{CM} = \pm 12V$ | | 80 | 95 | | | | | |
| Power Supply Rejection Ratio | PSRR | $V_S = \pm 20V$ to $V_S = \pm 5V$<br>$R_S \leq 50\Omega$ | | 86 | 96 | | | | | dB |
| | | $V_S = \pm 15V$ to $V_S = \pm 5V$<br>$R_S \leq 10K\Omega$ | | | | | 77 | 96 | | |

## ELECTRICAL CHARACTERISTICS (Continued)

| Characteristic | | Symbol | Test Conditions | LM741E | | | LM741C/LM741I | | | Unit |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Min | Typ | Max | Min | Typ | Max | |
| Transient Response | Rise Time | $t_r$ | Unity Gain | | 0.25 | 0.8 | | 0.3 | | $\mu$s |
| | Overshoot | OS | | | 6.0 | 20 | | 10 | | % |
| Bandwidth | | BW | | 0.43 | 1.5 | | | | | MHz |
| Slew Rate | | SR | Unity Gain | 0.3 | 0.7 | | | 0.5 | | V/$\mu$s |
| Supply Current | | $I_S$ | $R_L = \infty \Omega$ | | | | | 1.5 | 2.8 | mA |
| Power Consumption | | $P_C$ | $V_S = \pm 20V$ | | 80 | 150 | | | | mW |
| | | | $V_S = \pm 15V$ | | | | | 50 | 85 | |

## ELECTRICAL CHARACTERISTICS

($-40°C \leq Ta \leq 85°C$ for the LM741I, $0°C \leq Ta \leq 70°C$ for the LM741C and LM741E, $V_{CC} = \pm 15V$, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | | LM741E | | | LM741C/LM741I | | | Unit |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Min | Typ | Max | Min | Typ | Max | |
| Input Offset Voltage | $V_{IO}$ | $R_S \leq 50\Omega$ | | | | 4.0 | | | | mV |
| | | $R_S \leq 10K\Omega$ | | | | | | | 7.5 | |
| Input Offset Voltage Drift | $\Delta V_{IO}/\Delta T$ | | | | 15 | | | | | $\mu$V/°C |
| Input Offset Current | $I_{IO}$ | | | | | 70 | | | 300 | nA |
| Input Offset Current Drift | $\Delta I_{IO}/\Delta T$ | | | | | 0.5 | | | | nA/°C |
| Input Bias Current | $I_{IB}$ | | | | | 0.21 | | | 0.8 | $\mu$A |
| Input Resistance | $R_i$ | $V_S = \pm 20V$ | | 0.5 | | | | | | M$\Omega$ |
| Input Voltage Range | $V_{ICR}$ | | | ±12 | ±13 | | ±12 | ±13 | | V |
| Output Voltage Swing | $V_{OUT}$ | $V_S = \pm 20V$ | $R_L \geq 10K\Omega$ | ±16 | | | | | | V |
| | | | $R_L \geq 2K\Omega$ | ±15 | | | | | | |
| | | $V_S = \pm 15V$ | $R_L \geq 10K\Omega$ | | | | ±12 | ±14 | | |
| | | | $R_L \geq 2K\Omega$ | | | | ±10 | ±13 | | |
| Output Short Circuit Current | $I_{OS}$ | | | 10 | | 40 | 10 | | 40 | mA |
| Common Mode Rejection Ratio | CMRR | $R_S \leq 10K\Omega$, $V_{CM} = \pm 12V$ | | | | | 70 | 90 | | dB |
| | | $R_S \leq 50K\Omega$, $V_{CM} = \pm 12V$ | | 80 | 95 | | | | | |
| Power Supply Rejection Ratio | PSRR | $V_S = \pm 20V$ to $\pm 5V$ | $R_S \leq 50\Omega$ | 86 | 96 | | | | | dB |
| | | | $R_S \leq 10K\Omega$ | | | | 77 | 96 | | |
| Large Signal Voltage Gain | $A_V$ | $R_L \geq 2K\Omega$ | $V_S = \pm 20V$,<br>$V_o = \pm 15V$ | 32 | | | | | | V/mV |
| | | | $V_S = \pm 15V$,<br>$V_O = \pm 10V$ | | | | 15 | | | |
| | | | $V_S = \pm 15$,<br>$V_O = 2V$ | 10 | | | | | | |

## TYPICAL PERFORMANCE CHARACTERISTICS

Fig. 7 OUTPUT RESISTANCE vs FREQUENCY

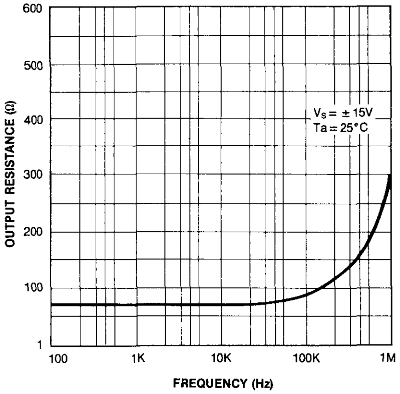


Fig. 8 INPUT RESISTANCE AND INPUT CAPACITANCE vs FREQUENCY

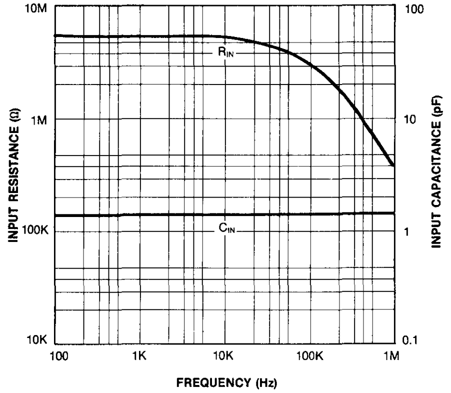


Fig. 9 INPUT BIAS CURRENT vs AMBIENT TEMPERATURE

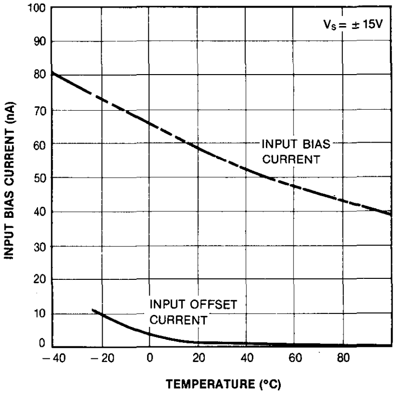


Fig. 10 POWER CONSUMPTION vs AMBIENT TEMPERATURE

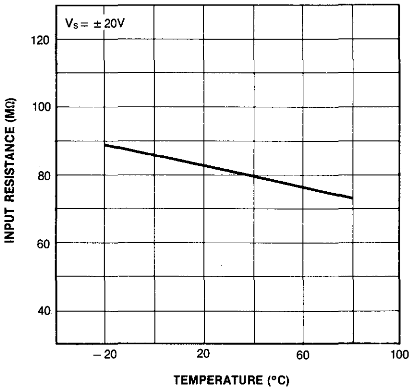


Fig. 11 INPUT OFFSET CURRENT vs AMBIENT TEMPERATURE

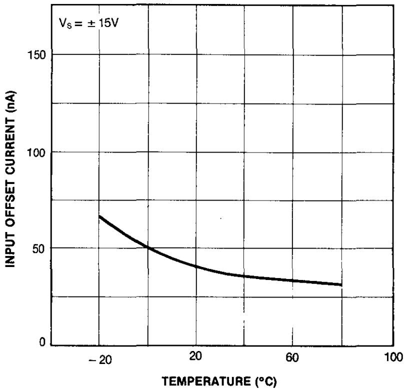


Fig. 12 INPUT RESISTANCE vs AMBIENT TEMPERATURE

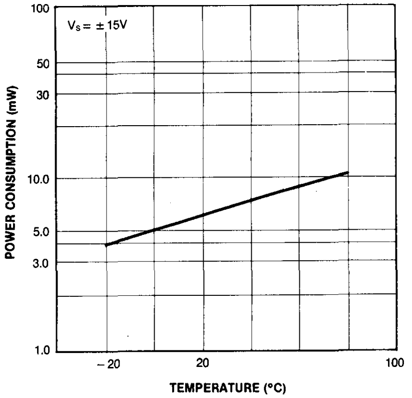


**Fig. 13 NORMALIZED DC PARAMETERS vs AMBIENT TEMPERATURE**

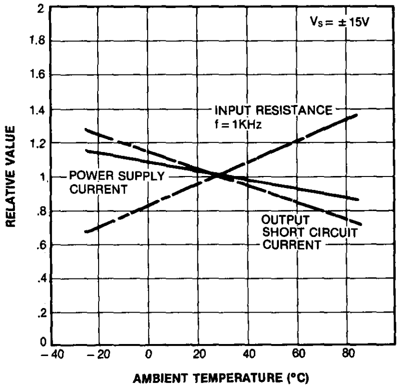


**Fig. 14 FREQUENCY CHARACTERISTICS vs AMBIENT TEMPERATURE**

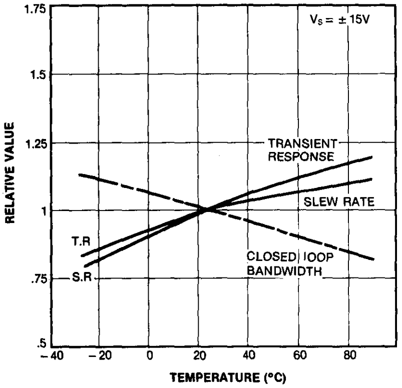


**Fig. 15 FREQUENCY CHARACTERISTICS vs SUPPLY VOLTAGE**

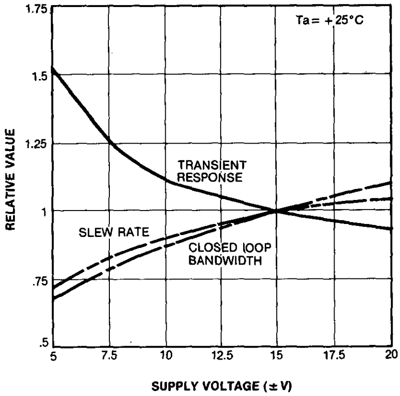


**Fig. 16 OUTPUT SHORT CIRCUIT CURRENT vs AMBIENT TEMPERATURE**

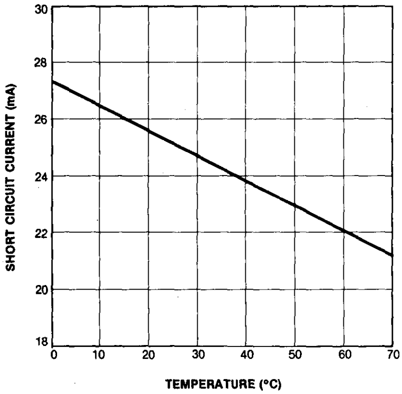


**Fig. 17 TRANSIENT RESPONSE**

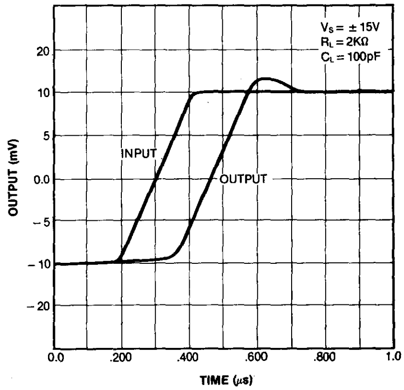


**Fig. 18 COMMON-MODE REJECTION RATIO vs FREQUENCY**

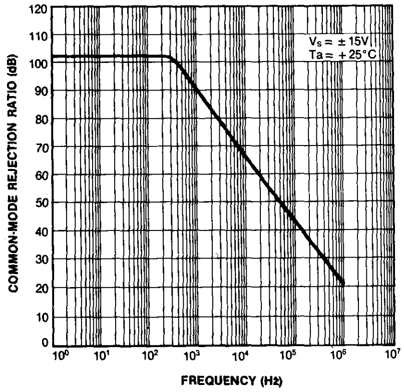


**Fig. 18 VOLTAGE FOLLOWER LARGE SIGNAL PULSE RESPONSE**

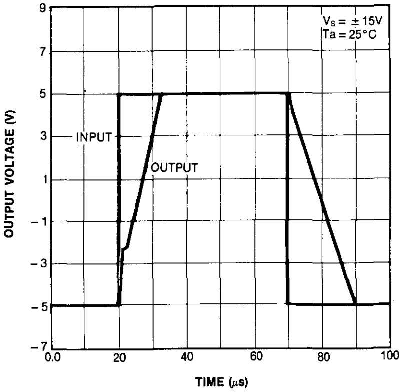
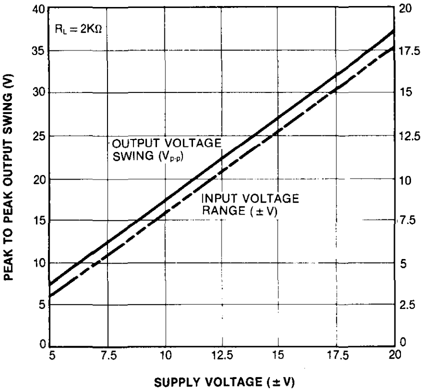
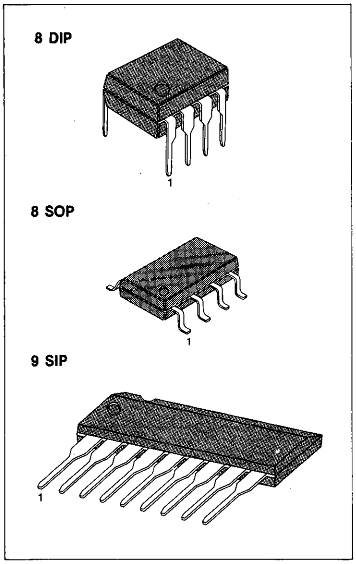


**Fig. 19 OUTPUT SWING AND INPUT RANGE vs SUPPLY VOLTAGE**



## DUAL OPERATIONAL AMPLIFIERS

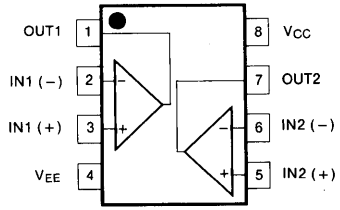
The MC1458 series is a dual general purpose operational amplifier. The MC1458 series is a short circuit protected and require no external components for frequency compensation.
High common mode voltage range and absence of "latch up" make the MC1458 ideal for use as voltage followers.
The high gain and wide range of operating voltage provides superior performance in intergrator, summing amplifier and general feedback applications.

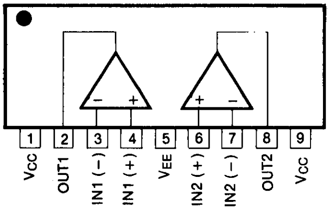


## FEATURES

- **Interal frequency compensation**
- **Short circuit protection**
- **Large common mode and differential voltage range**
- **No latch up**
- **Low power consumption**

## BLOCK DIAGRAM

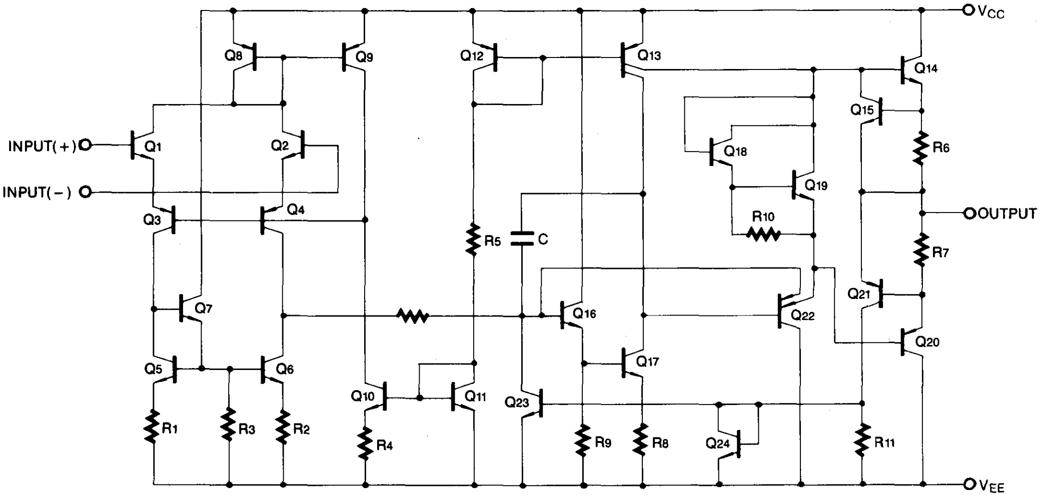




## ORDERING INFORMATION

| Device | Package | Operation Temperature |
|---|---|---|
| MC1458CN<br>MC1458ACN | 8 DIP | 0 ~ +70°C |
| MC1458CS<br>MC1458ACS | 9 SIP | |
| MC1458CD<br>MC1458ACD | 8 SOP | |
| MC1458IN<br>MC1458AIN | 8 DIP | −25 ~ +85°C |
| MC1458IS<br>MC1458AIS | 9 SIP | |
| MC1458ID<br>MC1458AID | 8 SOP | |

## SCHEMATIC DIAGRAM



## ABSOLUTE MAXIMUM RATINGS

| Characteristic | Symbol | Value | Unit |
|---|---|---|---|
| Power Supply Voltage | $V_S$ | ±18 | V |
| Input Differential Voltage | $V_{ID}$ | ±30 | V |
| Input Voltage | $V_I$ | ±15 | V |
| Operating Temperature Range MC1458I/AI | $T_{opr}$ | −25 ~ +85 | °C |
| MC1458C/AC |  | 0 ~ +70 | °C |
| Storage Temperature Range | $T_{stg}$ | −65 ~ +150 | °C |

## ELECTRICAL CHARACTERISTICS

($V_{CC} = +15V$, $V_{EE} = -15V$, $Ta = 25°C$, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | MC1458AC/AI | | | MC4558C/I | | | Unit |
|---|---|---|---|---|---|---|---|---|---|
| | | | Min | Typ | Max | Min | Typ | Max | |
| Input Offset Voltage | $V_{IO}$ | $R_S \leq 10K\Omega$ | | 2.0 | 6.0 | | 2.0 | 10 | mV |
| Input Offset Current | $I_{IO}$ | | | 20 | 200 | | 20 | 300 | nA |
| Input Bias Current | $I_{IB}$ | | | 80 | 500 | | 80 | 700 | nA |
| Large Signal Voltage Gain | $A_V$ | $V_o = \pm 10V$, $R_L \geq 2.0K\Omega$ | 20 | 200 | | 20 | 200 | | V/mV |
| Input Voltage Range | $V_{ICR}$ | | ±12 | ±13 | | ±11 | ±13 | | V |
| Input Resistance | $R_I$ | | 0.3 | 1.0 | | 0.3 | 1.0 | | MΩ |
| Common Mode Rejection Ratio | CMRR | $R_S \leq 10K\Omega$ | 70 | 90 | | 60 | 90 | | dB |
| Power Supply Rejection Ratio | PSRR | $R_S \leq 10K\Omega$ | 77 | 90 | | 77 | 90 | | dB |
| Supply Current (Both Amplifier) | $I_S$ | | | 2.3 | 5.6 | | 2.3 | 8.0 | mA |
| Output Voltage Swing | $V_{OUT}$ | $R_L = 10K\Omega$ | ±12 | ±14 | | ±11 | ±14 | | V |
| | | $R_L = 2K\Omega$ | ±10 | ±13 | | ±9 | ±13 | | |
| Output Short Circuit Current | $I_{OS}$ | | | 20 | | | 20 | | mA |
| Power Consumption | $P_C$ | $V_o = 0V$ | | 70 | 170 | | 70 | 240 | mW |
| Transient Response (Unity Gain) | | | | | | | | | |
| Rise Time | $t_r$ | $V_i = 20mV$, $R_L \geq 2K\Omega$, $C_L \leq 100pF$ | | 0.3 | | | 0.3 | | μs |
| Overshoot | OS | $V_i = 20mV$, $R_L \geq 2K\Omega$, $C_L \leq 100pF$ | | 15 | | | 15 | | % |
| Slew Rate | SR | $V_i = 10V$, $R_L \geq 2K\Omega$, $C_L \leq 100pF$ | | 0.5 | | | 0.5 | | V/μs |

## ELECTRICAL CHARACTERISTICS

($V_{CC} = +15V$, $V_{EE} = -15V$, NOTE 1, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | MC1458AC/AI | | | MC1458C/I | | | Unit |
|---|---|---|---|---|---|---|---|---|---|
| | | | Min | Typ | Max | Min | Typ | Max | |
| Input Offset Voltage | $V_{IO}$ | $R_S \leq 10K\Omega$ | | | 7.5 | | | 12 | mV |
| Input Offset Current | $I_{IO}$ | | | | 300 | | | 400 | nA |
| Input Bias Current | $I_{IB}$ | | | | 800 | | | 1000 | nA |
| Large Signal Voltage Gain | $A_V$ | $V_O = \pm 10V$, $R_L \leq 2.0K\Omega$ | 15 | | | 15 | | | V/mV |
| Common Mode Rejection Ratio | CMRR | $R_S \geq 10K\Omega$ | 70 | 90 | | 70 | 90 | | dB |
| Power Supply Rejection Ratio | PSRR | $R_S \geq 10K\Omega$ | 77 | 90 | | 77 | 90 | | dB |
| Output Voltage Swing | $V_{OUT}$ | $R_L = 10K\Omega$ | ±12 | ±14 | | ±11 | ±14 | | V |
| | | $R_L = 2K\Omega$ | ±10 | ±13 | | ±9 | ±13 | | |
| Input Voltage Range | $V_{ICR}$ | | ±12 | | | ±12 | | | V |

NOTE 1

MC1458C/AC: $0 \geq Ta \geq 70°C$

MC1458I/AI: $-25 \geq Ta \geq +85°C$

## TYPICAL PERFORMANCE CHARACTERISTICS

Fig. 1 OPEN-LOOP VOLTAGE GAIN vs POWER SUPPLY VOLTAGES

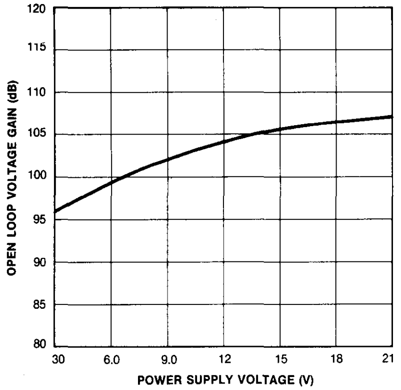


Fig. 2 OPEN-LOOP FREQUENCY RESPONSE

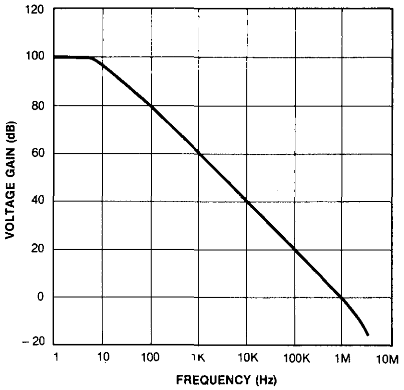


Fig. 3 POWER BANDWIDTH (LARGE SIGNAL SWING vs FREQUENCY)

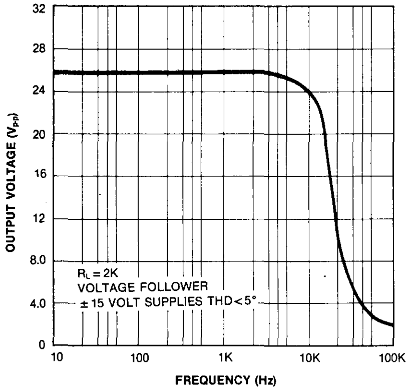
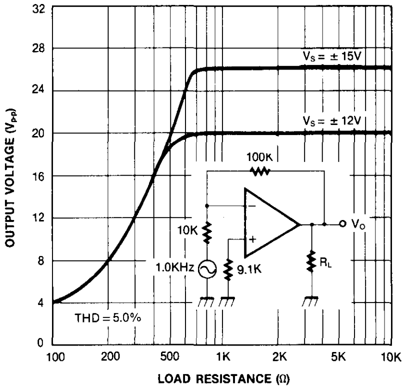
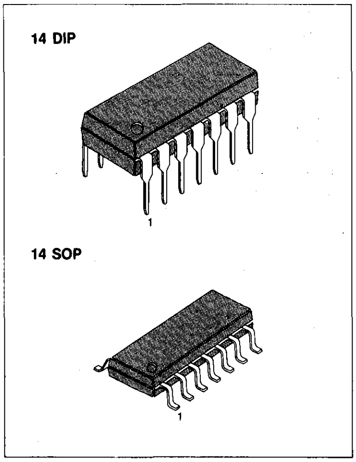


Fig. 4 OUTPUT VOLTAGE SWING vs LOAD RESISTANCE



## QUAD OPERATIONAL AMPLIFIER

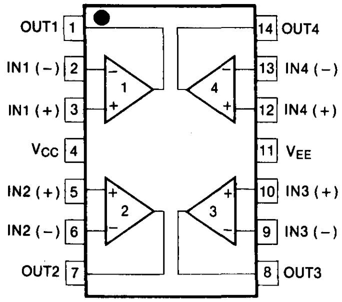
The MC3303 series is a monolithic Quad operational amplifier consisting of four independent amplifiers. The device has high gain, internally frequency, compensated operational amplifiers designed to operate from a single power supply or dual power supplies over a wide range of voltages. The common made input range includes the negative supply, thereby eliminating the necessity for external biasing components in many applications.



## FEATURES

- **Output voltage can swing to GND or negative supply**
- **Wide power supply range;**
  **Single supply of 3.0V to 36V**
  **Dual supply of ±1.5V to ±18V**
- **Electrical characteristics similar to the popular LM741**
- **CLASS AB output stage for minimal crossover distortion**
- **Short circuit protected output.**

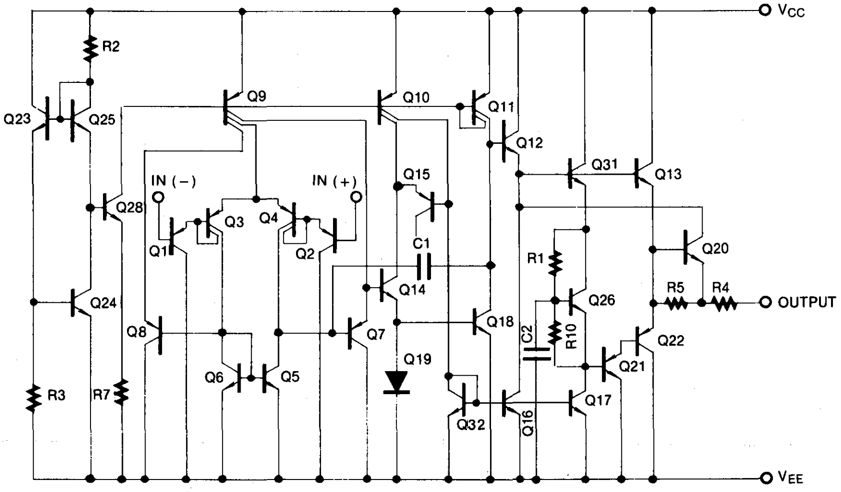
## BLOCK DIAGRAM



## ORDERING INFORMATION

| Device | Package | Operating Temperature |
|---|---|---|
| MC3403N | 14 DIP | 0 ~ +70°C |
| MC3403D | 14 SOP | |
| MC3303N | 14 DIP | −40 ~ +85°C |
| MC3303D | 14 SOP | |

## SCHEMATIC DIAGRAM



## ABSOLUTE MAXIMUM RATINGS

| Characteristic | Symbol | Value | Unit |
|---|---|---|---|
| Supply Voltage | $V_S$ | ±18 or +36 | V |
| Differential Input Voltage | $V_{ID}$ | ±36 | V |
| Input Voltage | $V_I$ | ±18 | V |
| Output Short Circuit Duration | | Continuous | |
| Power Dissipation | $P_D$ | 670 | mW |
| Operating Temperature MC3303 | $T_{opr}$ | −40 ~ +85 | °C |
| MC3403 | | 0 ~ +70 | °C |
| Storage Temperature | $T_{stg}$ | −65 ~ +150 | °C |

## ELECTRICAL CHARACTERISTICS

($V_{CC}$ = +15V, $V_{EE}$ = −15V for MC3403, $V_{CC}$ = +14V, $V_{EE}$ = GND for MC3303, Ta = 25°C, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | MC3303 | | | MC3403 | | | Unit |
|---|---|---|---|---|---|---|---|---|---|
| | | | Min | Typ | Max | Min | Typ | Max | |
| Input Offset Voltage | $V_{IO}$ | | | 1.5 | 8.0 | | 1.5 | 10 | mV |
| | | NOTE1 | | | 10 | | | 12 | |
| Input Offset Current | $I_{IO}$ | | | 5 | 75 | | 5 | 50 | nA |
| | | NOTE1 | | | 150 | | | 100 | |
| Input Bias Current | $I_{IB}$ | | | 30 | 200 | | 30 | 200 | nA |
| | | NOTE1 | | | 500 | | | 400 | |
| Large Signal Voltage Gain | $A_V$ | $V_O$ = ±10V | 20 | 200 | | 20 | 200 | | V/mV |
| | | $R_L$ = 2KΩ NOTE1 | 15 | | | 15 | | | |
| Input Impedance | $R_i$ | | 0.3 | 1.0 | | 0.3 | 1.0 | | MΩ |
| Output Voltage Swing | $V_{OUT}$ | $R_L$ = 10KΩ | +12 | +12.5 | | ±12 | ±13.5 | | V |
| | | $R_L$ = 2KΩ | +10 | +12 | | ±10 | ±13 | | |
| | | $R_L$ = 2KΩ NOTE1 | +10 | | | ±10 | | | |
| Input Common Mode Voltage Range | $V_{ICR}$ | | 12V-$V_{EE}$ | 12.5V-$V_{EE}$ | | 13V-$V_{EE}$ | 13.5V-$V_{EE}$ | | V |
| Common Mode Rejection Ratio | CMRR | $R_S$ ≥ 10KΩ | 70 | 90 | | 70 | 90 | | dB |
| Power Supply Current | $I_S$ | $V_O$ = 0, $R_L$ = ∞ | | 2.8 | 7.0 | | 2.3 | 7.0 | mA |
| Output Short Circuit Current | $I_{OS}$ | Each amplifier | ±10 | ±30 | ±45 | ±10 | ±20 | ±45 | mA |
| Positive Supply Rejection Ratio | $PSRR^+$ | | | 30 | 150 | | 30 | 150 | μV/V |
| Negative Supply Rejection Ratio | $PSRR^-$ | | | | | | 30 | 150 | μV/V |
| Average Temperature Coefficient of Input Offset Current | $\Delta I_{IO}/\Delta T$ | | | 50 | | | 50 | | pA/°C |

## ELECTRICAL CHARACTERISTICS (Continued)

($V_{CC} = +15V$, $V_{EE} = -15V$ for MC3403, $V_{CC} = +14V$, $V_{EE} = GND$ for MC3303, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | MC3303 | | | MC3403 | | | Unit |
|---|---|---|---|---|---|---|---|---|---|
| | | | Min | Typ | Max | Min | Typ | Max | |
| Input Offset Voltage Drift | $\Delta V_{IO}/\Delta T$ | | | 10 | | | 10 | | μV/°C |
| Power Bandwidth | GBW | $A_V = 1$, $R_L = 2K\Omega$, $V_o = 20V_{p\text{-}p}$, THD = 5% | | 9.0 | | | 9.0 | | KHz |
| Small Signal Bandwidth | BW | $A_V = 1$, $R_L = 10K\Omega$, $V_o = 50mV$ | | 1.0 | | | 1.0 | | MHz |
| Slew Rate | SR | $A_V = 1$, $V_{IN} = -10V$ to $+10V$ | | 0.4 | | | 0.4 | | V/μs |
| Rise Time | $t_r$ | $A_V = 1$, $R_L = 10K\Omega$, $V_o = 50mV$ | | 0.35 | | | 0.35 | | μs |
| Fall Time | $t_f$ | $A_V = 1$, $R_L = 10K\Omega$, $V_o = 50mV$ | | 0.35 | | | 0.35 | | μs |
| Over Shoot | OS | $A_V = 1$, $R_L = 10K\Omega$, $V_O = 50mV$ | | 20 | | | 20 | | % |
| Phase Margin | $\emptyset m$ | $A_V = 1$, $R_L = 2K\Omega$, $C_L = 200pF$ | | 60 | | | 60 | | Degrees |
| Crossover Distortion | CD | $V_{IN} = 30mV_{p\text{-}p}$, $V_o = 2.0V_{p\text{-}p}$, f = 10KHz | | 1.0 | | | 1.0 | | % |

NOTE 1
MC3403: $0 \leq Ta \leq +70$°C
MC3303: $-40 \geq Ta \geq +85$°C

## ELECTRICAL CHARACTERISTICS

($V_{CC} = 5.0V$, $V_{EE} = GND$, Ta = 25°C unless otherwise specified)

| Characteristic | Symbol | Test Conditions | MC3303 | | | MC3403 | | | Unit |
|---|---|---|---|---|---|---|---|---|---|
| | | | Min | Typ | Max | Min | Typ | Max | |
| Input Offset Voltage | $V_{IO}$ | | | | 10 | | 2.0 | 10 | mV |
| Input Offset Current | $I_{IO}$ | | | | 75 | | 30 | 50 | nA |
| Input Bias Current | $I_{IB}$ | | | | 500 | | 200 | 500 | nA |
| Large Signal Open Loop Voltage Gain | $A_V$ | $R_L = 2.0K\Omega$ | 10 | 200 | | 10 | 200 | | V/mV |
| Power Supply Rejection Ratio | PSRR | | | | 150 | | | 150 | μV/V |
| Output Voltage Range | $V_{OUT}$ | $R_L = 10K\Omega$, $V_{CC} = 5.0V$ | 3.3 | 3.5 | | 3.3 | 3.5 | | V |
| | | $R_L = 10K\Omega$, $5.0V \geq V_{CC} \geq 30V$ | $V_{CC}$-2.0 | $V_{CC}$-1.7 | | $V_{CC}$-2.0 | $V_{CC}$-1.7 | | |
| Supply Current | $I_{CC}$ | | | 2.5 | 7.0 | | 2.5 | 7.0 | mA |
| Channel Separation | CS | f = 1KHz to 20KHz | | 120 | | | 120 | | dB |

## TYPICAL PERFORMANCE CHARACTERISTICS

Fig. 1 OPEN LOOP FREQUENCY RESPONSE

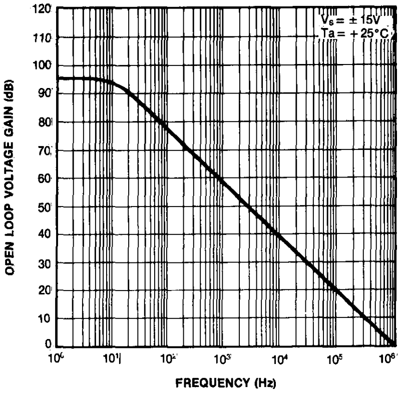


Fig. 2. Wave Response

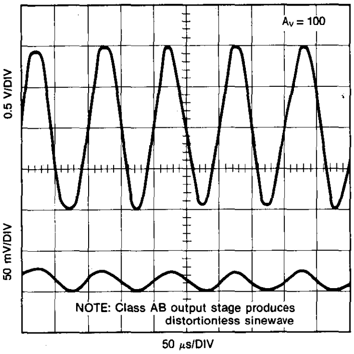


Fig. 3 OUTPUT SWING

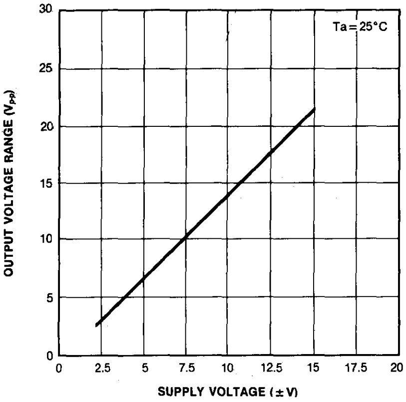


Fig. 4 OUTPUT VOLTAGE vs FREQUENCY

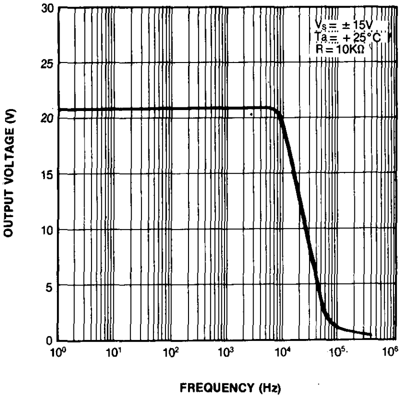


Fig. 5 INPUT BIAS CURRENT vs TEMPERATURE

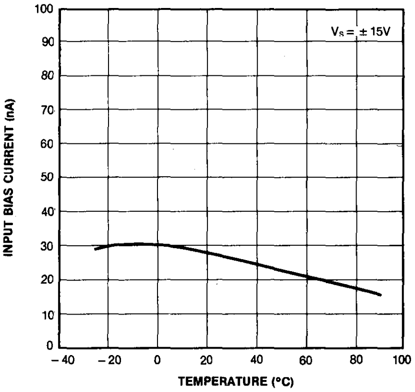
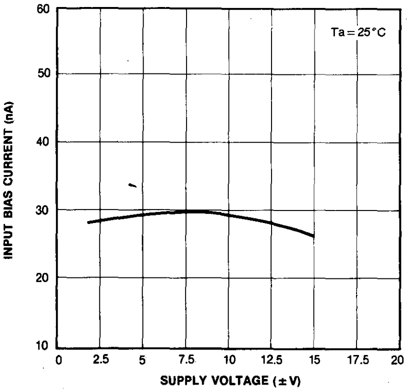
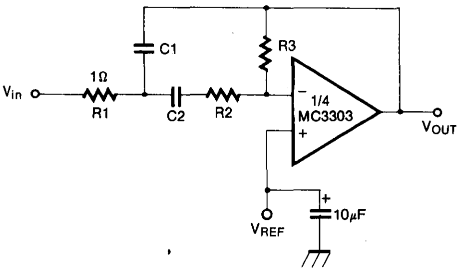


Fig. 6 INPUT BIAS CURRENT vs SUPPLY VOLTAGE



## TYPICAL APPLICATIONS

### Fig. 7. Multiple feedback bandpass filter



$f_o$ = center frequency

BW = Bandwidth

R in kΩ

C in μF

$$Q = \frac{f_o}{BW} < 10$$

$$C1 = C2 = \frac{Q}{3}$$

$$\left.\begin{array}{l} R1 = R2 = 1 \\ R_3 = 9Q^2 - 1 \end{array}\right\}$$ Use scaling factors in these expressions.

If source impedance is high or varies, filter may be preceded with voltage follower buffer to stabilize filter parameters.

Design example:

given: $Q = 5$, $f_o = 1$ kHz

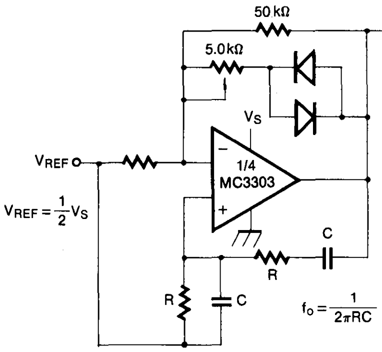
Let R1 = R2 = 10 kΩ

then $R3 = 9(5)^2 - 10$

R3 = 215 kΩ

$$C = \frac{5}{3} = 1.6 \text{ nF}$$

### Fig. 8. Wein bridge oscillator

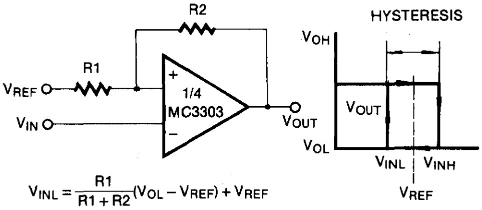


$$f_o = \frac{1}{2\pi RC}$$ for $f_o = 1$ kHz

R = 16 kΩ

C = 0.01 μF

### Fig. 9. Comparator with hysteresis

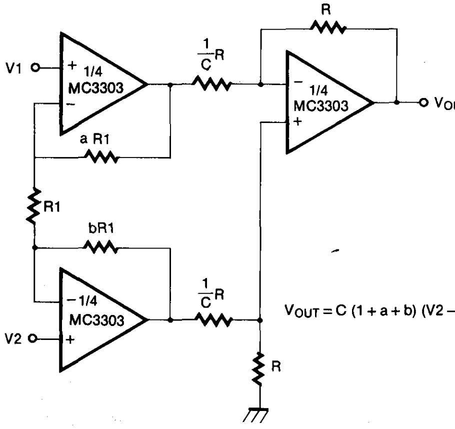


$$V_{INL} = \frac{R1}{R1 + R2}(V_{OL} - V_{REF}) + V_{REF}$$

$$V_{INH} = \frac{R1}{R1 + R2}(V_{OH} - V_{REF}) + V_{REF}$$

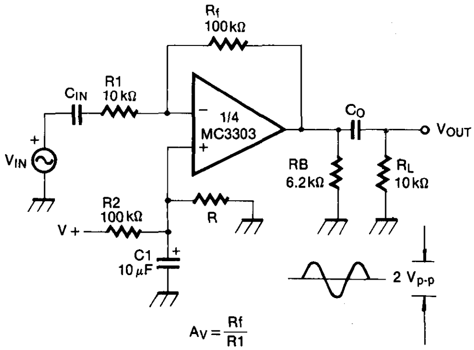
$$H = \frac{R1}{R1 + R2}(V_{OH} - V_{OL})$$

### Fig. 10. High impedance differential amplifier



$V_{OUT} = C\,(1 + a + b)\,(V2 - V1)$

### Fig. 11. AC Coupled inverting amplifier



$$A_V = \frac{R_f}{R1}$$

$A_V = 10$ (as shown)

**Fig. 12. Ground referencing a differential input signal**

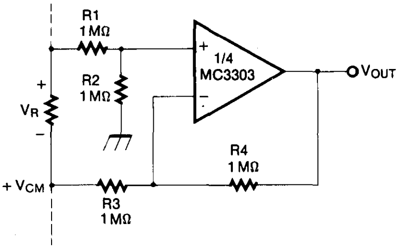
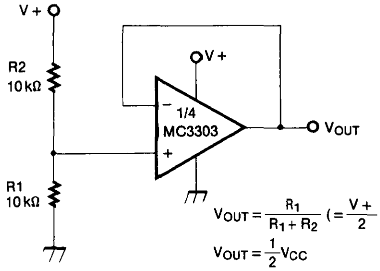


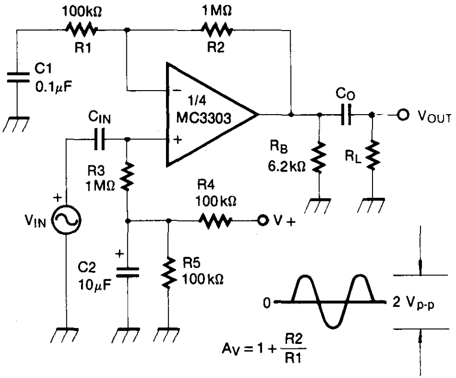
**Fig. 13. Voltage reference**



$V_{OUT} = \frac{R_1}{R_1 + R_2}$ $(= \frac{V+}{2}$ as shown)

$V_{OUT} = \frac{1}{2} V_{CC}$

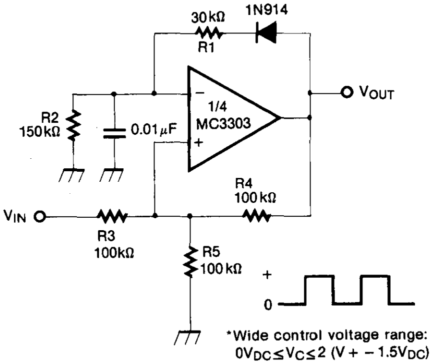
**Fig. 14. AC Coupled non-inverting amplifier**



$A_V = 1 + \frac{R2}{R1}$

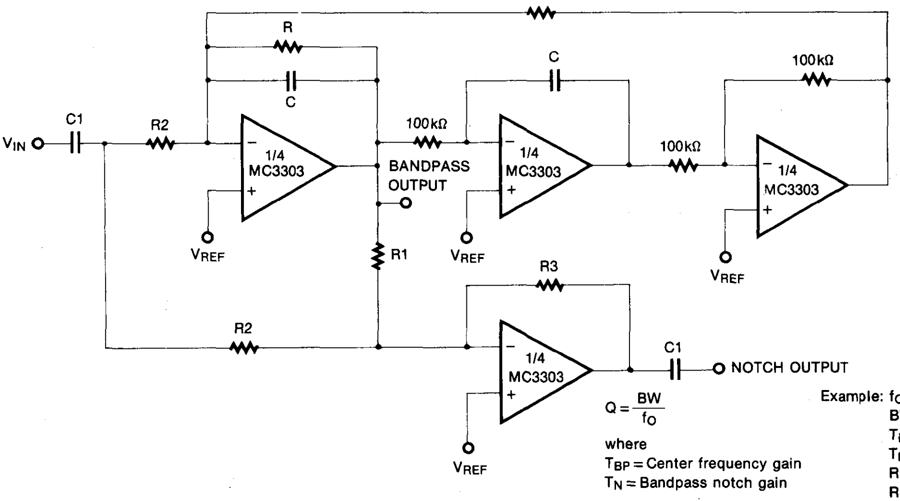
$A_V = 11$ (as shown)

**Fig. 15. Pulse generator**



*Wide control voltage range: $0V_{DC} \leq V_C \leq 2\ (V+ - 1.5V_{DC})$

**Fig. 16. Bi-Quad filter**



$Q = \frac{BW}{f_O}$

where

$T_{BP}$ = Center frequency gain

$T_N$ = Bandpass notch gain

$f_O = \frac{1}{2\pi RC}$ $R2 = \frac{R1}{T_{BP}}$

$R1 = QR$ $R3 = T_N R2$

$C1 = 10C$

Example: $f_O = 1000$ Hz
$BW = 100$ Hz
$T_{BP} = 1$
$T_N = 1$
$R = 160$ kΩ
$R1 = 1.6$ MΩ
$R2 = 1.6$ MΩ
$R3 = 1.6$ MΩ
$C = 0.001$ μF

Fig. 17. Voltage controlled oscillator

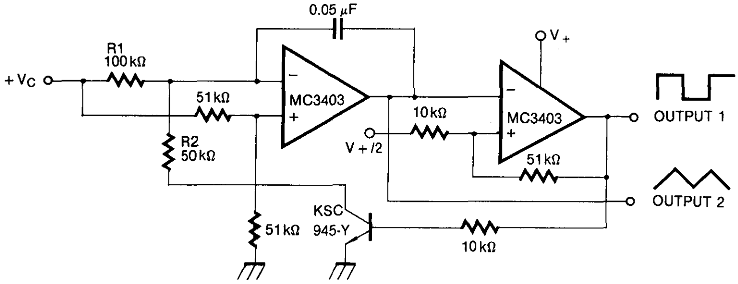
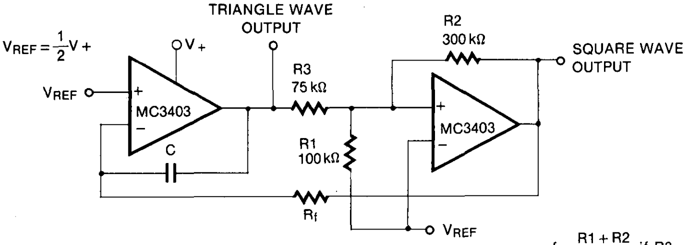


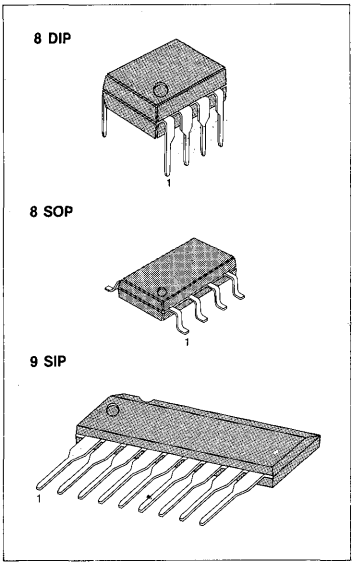
Fig. 18. Function generator



$$f = \frac{R1 + R2}{4CR_fR1} \text{ if } R3 = \frac{R2R1}{R2 + R1}$$

## DUAL OPERATIONAL AMPLIFIER

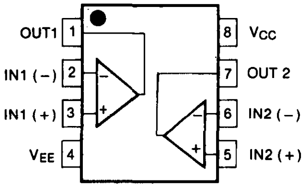
The MC4558 series is a monolithic integrated circuit designed for dual operational amplifier.

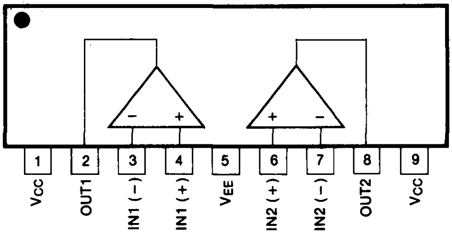


## FEATURES

- **No frequency compensation required.**
- **No latch-up.**
- **Large common mode and differential voltage range.**
- **Parameter tracking over temperature range.**
- **Gain and phase match between amplifiers.**
- **Internally frequency compensated.**
- **Low noise input transistors.**

## BLOCK DIAGRAM

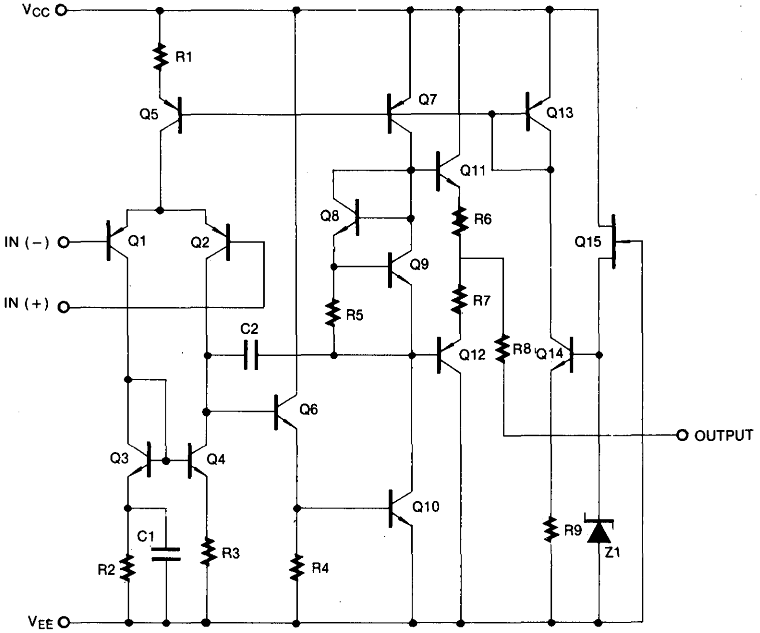




## ORDERING INFORMATION

| Device | Package | Operation Temperature |
|---|---|---|
| MC4558CN<br>MC4558ACN | 8 DIP | 0 ~ +70°C |
| MC4558CS<br>MC4558ACS | 9 SIP | |
| MC4558CD<br>MC4558ACD | 8 SOP | |
| MC4558IN<br>MC4558AIN | 8 DIP | −40 ~ +85°C |
| MC4558IS<br>MC4558AIS | 9 SIP | |
| MC4558ID<br>MC4558AID | 8 SOP | |

## SCHEMATIC DIAGRAM (One Section Only)



## ABSOLUTE MAXIMUM RATINGS

| Characteristic | Symbol | Value | Unit |
|---|---|---|---|
| Power Supply Voltage MC4558AC/AI | $V_S$ | ±22 | V |
| MC4558C/I | | ±18 | V |
| Differential Input Voltage | $V_{ID}$ | ±30 | V |
| Input Voltage | $V_i$ | ±15 | V |
| Power Dissipation | $P_D$ | 400 | mW |
| Operating Temperature Range MC4558I/AI | $T_{opr}$ | −40 ~ +85 | °C |
| MC4558C/MC4558AC | | 0 ~ +70 | °C |
| Storage Temperature Range | $T_{stg}$ | −65 ~ +150 | °C |

## ELECTRICAL CHARACTERISTICS

($V_{CC} = 15V$, $V_{EE} = -15V$, $Ta = 25°C$, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | | MC4558AC/AI | | | MC4558C/I | | | Unit |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Min | Typ | Max | Min | Typ | Max | |
| Input Offset Voltage | $V_{IO}$ | $R_S \leq 10K\Omega$ | | | 1 | 5 | | 2 | 6 | mV |
| | | | NOTE 1 | | 1 | 6 | | | 7.5 | |
| Input Offset Current | $I_{IO}$ | | | | 5 | 200 | | 5 | 200 | nA |
| | | | $T_a = T_{max}$ | | 3 | 200 | | | 300 | |
| | | | $T_a = T_{min}$ | | 20 | 500 | | | 300 | |
| Input Bias Current | $I_{IB}$ | | | | 30 | 500 | | 30 | 500 | nA |
| | | | $T_a = T_{max}$ | | 20 | 500 | | | 800 | |
| | | | $T_a = T_{min}$ | | 100 | 1500 | | | 800 | |
| Large Signal Voltage Gain | $A_V$ | $V_O = \pm 10V$, $R_L \leq 2K\Omega$ | | 50 | 200 | | 20 | 200 | | V/mV |
| | | | NOTE 1 | 25 | | | 15 | | | |
| Common Mode Input Voltage Range | $V_{ICR}$ | | | ± 12 | ± 13 | | ± 12 | ± 13 | | V |
| | | | NOTE 1 | ± 12 | ± 13 | | | | | |
| Common Mode Rejection Ratio | CMRR | $R_S \leq 10K\Omega$ | | 70 | 90 | | 70 | 90 | | dB |
| | | | NOTE 1 | 70 | 90 | | | | | |
| Supply Voltage Rejection Ratio | PSRR | $R_S \leq 10K\Omega$ | | 76 | 90 | | 76 | 90 | | dB |
| | | | NOTE 1 | 76 | 90 | | 76 | 90 | | |
| Output Voltage Swing | $V_{OUT}$ | $R_L \geq 10K\Omega$ | NOTE 1 | ± 12 | ± 14 | | ± 12 | ± 14 | | V |
| | | $R_L \geq 2K\Omega$ | | ± 10 | ± 13 | | ± 10 | ± 13 | | |
| Supply Current (Both Amplifiers) | $I_S$ | | | | 3.5 | 5.0 | | 3.5 | 5.6 | mA |
| | | | $T_a = T_{max}$ | | | 4.5 | | | 5.0 | |
| | | | $T_a = T_{min}$ | | | 6.0 | | | 6.7 | |
| Power Consumption (Both Amplifiers) | $P_C$ | | | | 70 | 150 | | 70 | 170 | mV |
| | | | $T_a = T_{max}$ | | | 135 | | | 150 | |
| | | | $T_a = T_{min}$ | | | 180 | | | 200 | |
| Slew Rate | SR | $V_i = 10V$, $R_L \geq 2K\Omega$<br>$C_L \leq 100pF$ | | 1.2 | | | 1.2 | | | V/μs |
| Rise Time | $t_r$ | $V_i = 20mV$, $R_L \geq 2K\Omega$,<br>$C_L \leq 100pF$ | | | 0.3 | | | 0.3 | | μs |
| Overshoot | OS | $V_i = 20mV$, $R_L \geq 2K\Omega$,<br>$C_L \leq 100pF$ | | | 15 | | | 15 | | % |

**NOTE 1**

MC4558C/AC: $T_{min} \leq Ta \leq T_{max} = 0 \leq Ta \leq +70°C$

MC4558AI/I: $T_{min} \leq Ta \leq T_{max} = -40 \leq Ta \leq +85°C$

## TYPICAL PERFORMANCE CHARACTERISTICS

**Fig. 1 BURST NOISE vs SOURCE RESISTANCE**

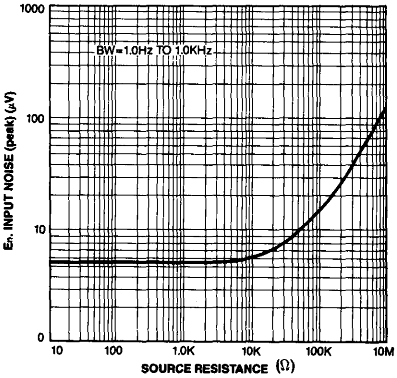


**Fig. 2 RMS NOISE vs SOURCE RESISTANCE**

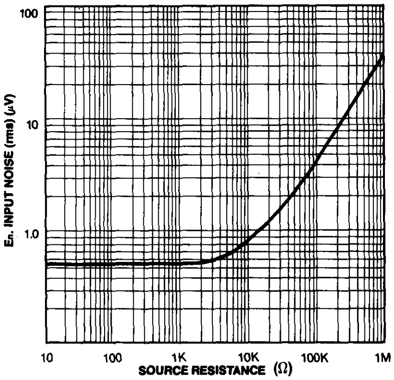


**Fig. 3 OUTPUT NOISE vs SOURCE RESISTANCE**

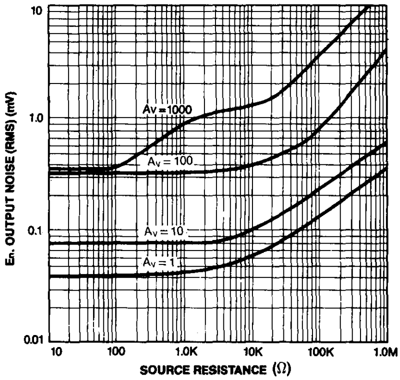


**Fig. 4 SPECTRAL NOISE DENSITY**

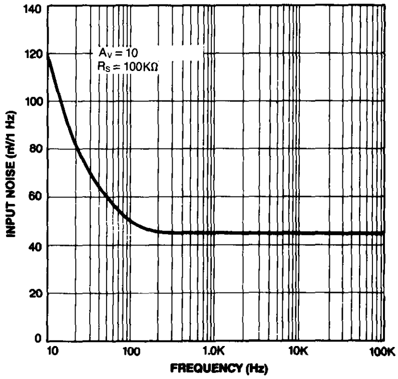


**Fig. 5 OPEN LOOP FREQUENCY RESPONSE**

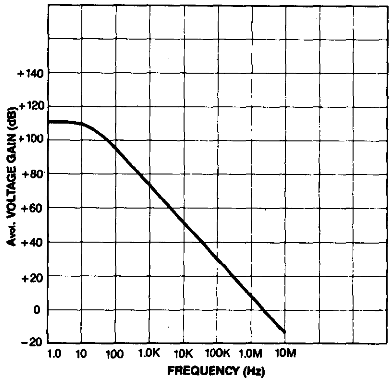


**Fig. 6 PHASE MARGIN vs FREQUENCY**

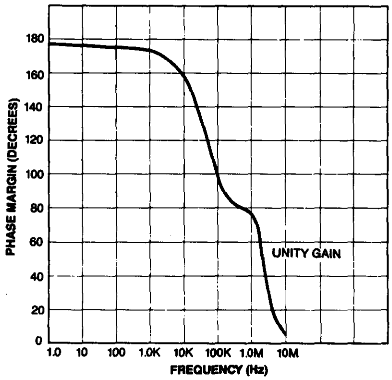


**Fig. 7 POSITIVE OUTPUT VOLTAGE SWING vs LOAD RESISTANCE**

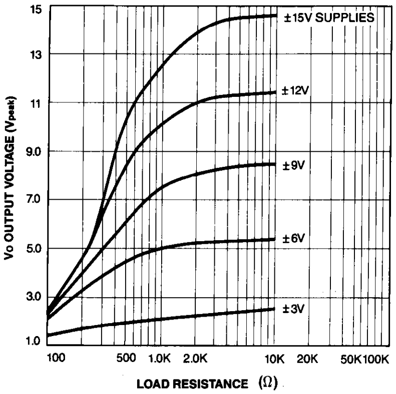


**Fig. 8 NEGATIVE OUTPUT VOLTAGE SWING vs LOAD RESISTANCE**

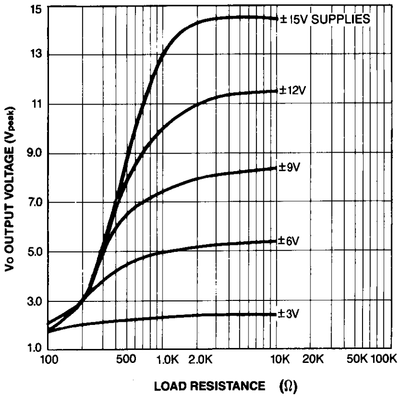


**Fig. 9 POWER BANDWIDTH (LARGE SIGNAL SWING VERSUS FREQUENCY)**

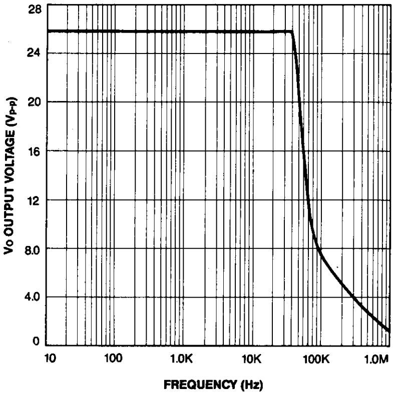
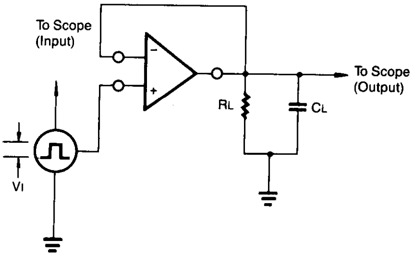


**Fig. 10 TRANSIENT RESPONSE TEST CIRCUIT**



# NOTES

# COMPARATORS 7

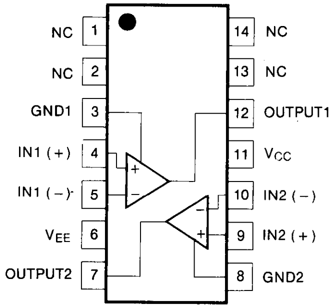
## DUAL HIGH SPEED VOLTAGE COMPARATOR

The KA219 is a dual high speed voltage comparator designed to operate from a single +5V supply up to ±15V dual supplies.
Open collector of the output stage makes the KA219 compatible with RTL, DTL and TTL as well as capable of driving lamps and relays at currents up to 25mA. Typical response time of 80ns with ±15V power supplies makes the KA219 ideal for application in fast A/D converts, level shifters, oscillaters, and multivibrators.

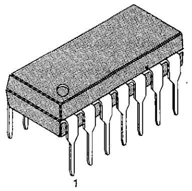
## FEATURES

- **Operates form a single 5V supply**
- **Typically 80ns response time at ±15V**
- **Open collector outputs: up to +35V**
- **High output drive current: 25mA**
- **Inputs and outputs can be isolated from system ground**
- **Minimum fan-out of 2 (each side)**
- **Two independent compators**

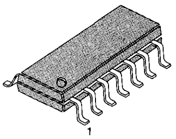
## BLOCK DIAGRAM



14 DIP



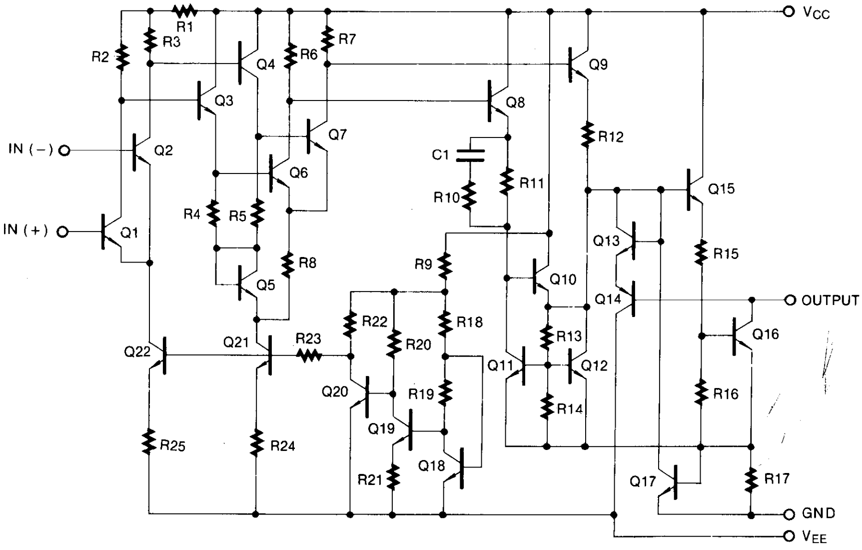
14 SOP



## ORDERING INFORMATION

| Device | Package | Operating Temperature |
|---|---|---|
| KA319N | 14 DIP | 0 ~ +70°C |
| KA319D | 14 SOP | |
| KA219N | 14 DIP | −25 ~ +85°C |
| KA219D | 14 SOP | |

## SCHEMATIC DIAGRAM



## ABSOLUTE MAXIMUM RATINGS

| Characteristic | Symbol | Value | Unit |
|---|---|---|---|
| Supply Voltage | $V_S$ | 36 | V |
| Output to Negative Supply Voltage | $V_O - V_{EE}$ | 36 | V |
| Ground to Negative Supply Voltage | $GND - V_{EE}$ | 25 | V |
| Ground to Positive Supply Voltage | $GND - V_{CC}$ | 18 | V |
| Differential Input Voltage | $V_{ID}$ | ±5 | V |
| Input Voltage | $V_I$ | ±15 | V |
| Output Short Circuit Duration | | 10 | sec |
| Power Dissipation | $P_D$ | 500 | mW |
| Operating Temperature Range KA219 | $T_{opr}$ | −25 ~ +85 | °C |
| KA319 | | 0 ~ +70 | |
| Storage Temperature Range | $T_{stg}$ | −65 ~ +150 | °C |

## ELECTRICAL CHARACTERISTICS

($V_{CC} = +15V$, $V_{EE} = -15V$, $Ta = 25°C$, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | KA219 | | | KA319 | | | Unit |
|---|---|---|---|---|---|---|---|---|---|
| | | | Min | Typ | Max | Min | Typ | Max | |
| Input Offset Voltage (Note 1) | $V_{IO}$ | $R_S \leq 5K\Omega$ | | 0.7 | 4.0 | | 2.0 | 8.0 | mV |
| | | Note 3 | | | 7.0 | | | 10 | |
| Input Offset Current (Note 1) | $I_{IO}$ | | | 10 | 75 | | 10 | 200 | nA |
| | | Note 3 | | | 100 | | | 300 | |
| Input Bias Current | $I_{IB}$ | | | 150 | 500 | | 250 | 1000 | nA |
| | | Note 3 | | | 1000 | | | 1200 | |
| Voltage Gain | $A_V$ | | 10 | 40 | | 8 | 40 | | V/mV |
| Response Time (Note 2) | $t_r$ | $V_S = \pm 15V$ | | 80 | | | 80 | | ns |
| Saturation Voltage | $V_{OL}$ | $V_{in} \leq -5mV$, $I_o = 25mA$ | | 0.6 | 1.5 | | | | V |
| | | $V_{in} \leq -10mV$, $I_o = 25mA$ | | | | | 0.6 | 1.5 | V |
| | | $V_{CC} \geq 4.5V$, $V_{EE} = 0V$<br>$V_{in} \leq -6mV$, $I_{sink} \leq 3.2mA$ | | 0.23 | 0.4 | | | | V |
| | | $V_{CC} \geq 4.5V$, $V_{EE} = 0V$<br>$V_{in} \leq -10mV$, $I_{sink} \leq 3.2mA$ | | | | | 0.3 | 0.4 | V |
| Output Leakage Current | $I_{OL}$ | $V_{in} \geq 5mV$, $V_O = 35V$ | | 0.2 | 2 | | | | μA |
| | | Note 3 | | 1 | 10 | | | | |
| | | $V_{in} \geq 10mV$, $V_O = 35V$ | | | | | 0.2 | 10 | μA |
| Input Voltage Range | $V_{ICR}$ | Note 3 $V_S = \pm 15V$ | | ±13 | | | ±13 | | V |
| | | $V_{CC} = 5V$, $V_{EE} = 0V$ | 1 | | 3 | 1 | | 3 | |

## ELECTRICAL CHARACTERISTICS

($V_{CC}=+15V$, $V_{EE}=-15V$, Ta=25°C, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | KA219 | | | KA319 | | | Unit |
|---|---|---|---|---|---|---|---|---|---|
| | | | Min | Typ | Max | Min | Typ | Max | |
| Differential Input Voltage | $V_{ID}$ | | ±5 | | | ±5 | | | V |
| Positive Supply Current | $I_{CC1}$ | $V_{CC}=5V$, $V_{EE}=0V$ | | 3.6 | | | 3.6 | | mA |
| Positive Supply Current | $I_{CC2}$ | $V_S=\pm15V$ | | 7.5 | 11.5 | | 7.5 | 12.5 | mA |
| Negative Supply Current | $I_{EE}$ | $V_S=\pm15V$ | | 3 | 4.5 | | 3 | 5 | mA |

Note 1. The offset voltage and offset currents given are the maximum values required to drive the output within a volt of either supply with a 1mA load. Thus, these parameters define an error band and take into account the worst case effects of voltage gain and input impedance.

2. The response time specified is for a 100mV input step with 5mV overdrive.

3. KA319: $0\leq Ta\leq+70°C$
KA219: $-25\leq Ta\leq+85°C$

## TYPICAL PERFORMANCE CHARACTERISTICS

**Fig. 1 INPUT CURRENT**

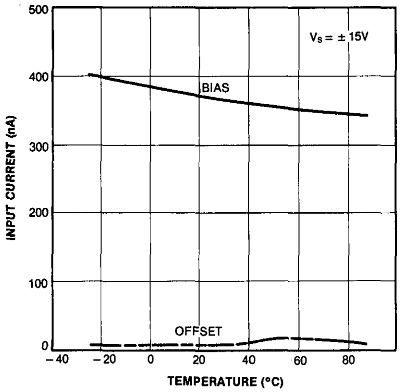


**Fig. 2 OUTPUT SATURATION VOLTAGE**

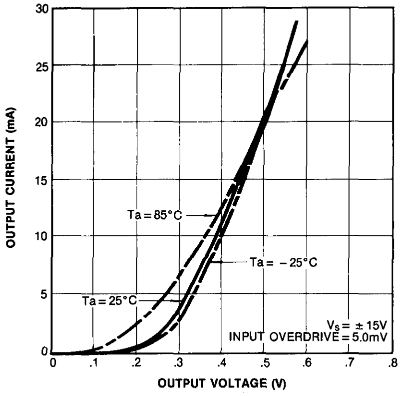


**Fig. 3 TRANSFER FUNCTION**

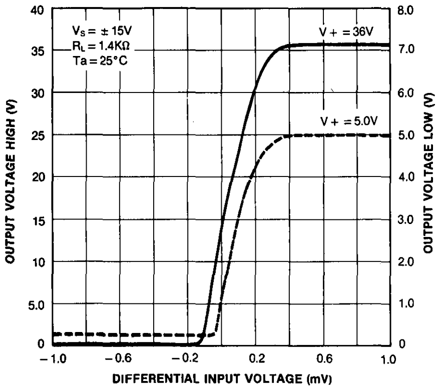


**Fig. 4 RESPONSE TIME FOR VARIOUS INPUT OVERDRIVER**

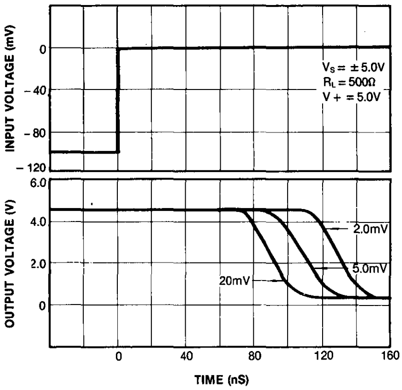


**Fig. 5 RESPONSE TIME FOR VARIOUS INPUT OVERDRIVER**

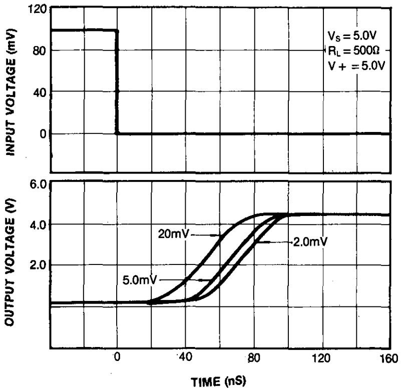


**Fig. 6 INPUT CHARACTERISTICS**

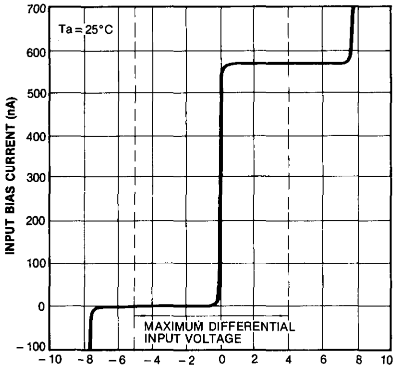


Fig. 7 RESPONSE TIME FOR VARIOUS INPUT OVERDRIVER

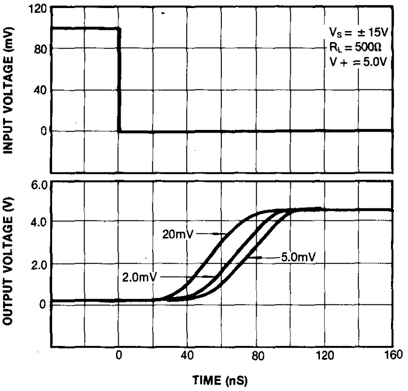


Fig. 8 RESPONSE TIME FOR VARIOUS INPUT OVERDRIVER

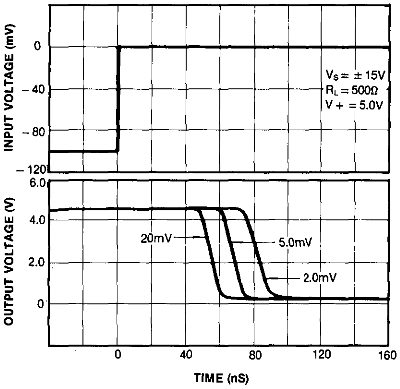


Fig. 9 SUPPLY CURRENT

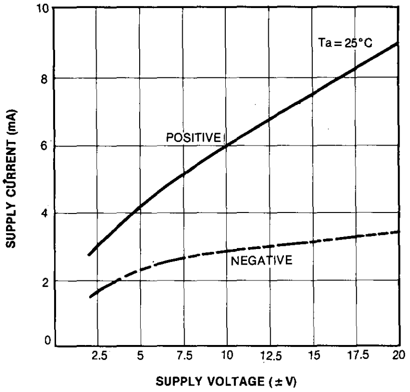


Fig. 10 SUPPLY CURRENT

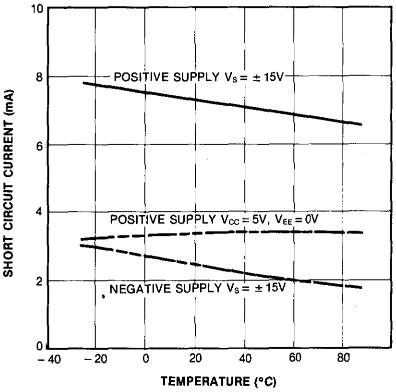


Fig. 11 COMMON MODE LIMITS

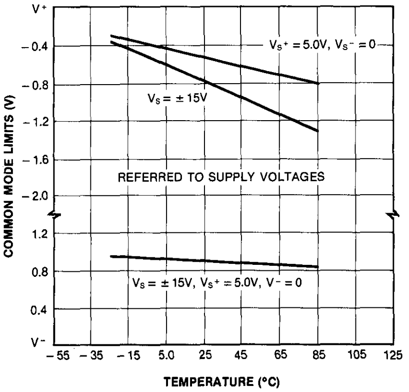
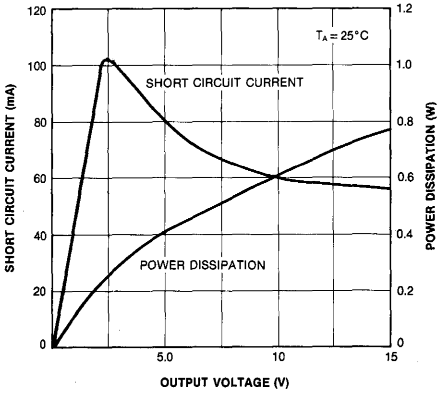


Fig. 12 OUTPUT LIMITING CHARACTERISTICS

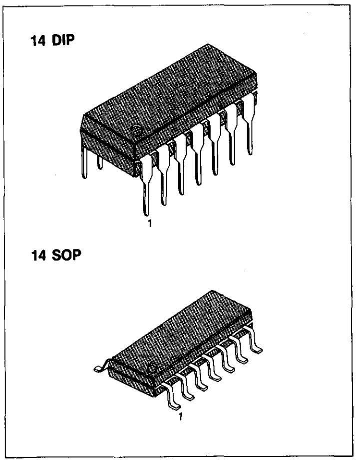


## HIGH SPEED VOLTAGE COMPARATOR

The KA710C/I is a high speed voltage comparator intended for use as an accurate, low-level digital level sensor or as a replacement for operational amplifiers in comparator applications where speed is of prime importance.

The output of the comparator is compatible with all intergrated logic forms.

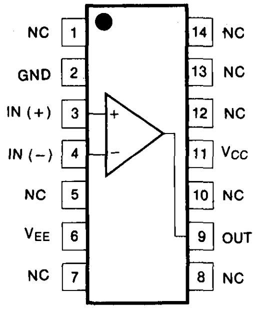
The KA710C/I is useful as pulse height disciminators, a variable threshold schmitt trigger, voltage comparators in high-speed A/D converters, a memory sense amplifier or a high noise immunity line receiver.



## FEATURES

- **Low offset voltage: 5mV**
- **High gain: 1000 V/V**
- **High speed: 40ns Typ**

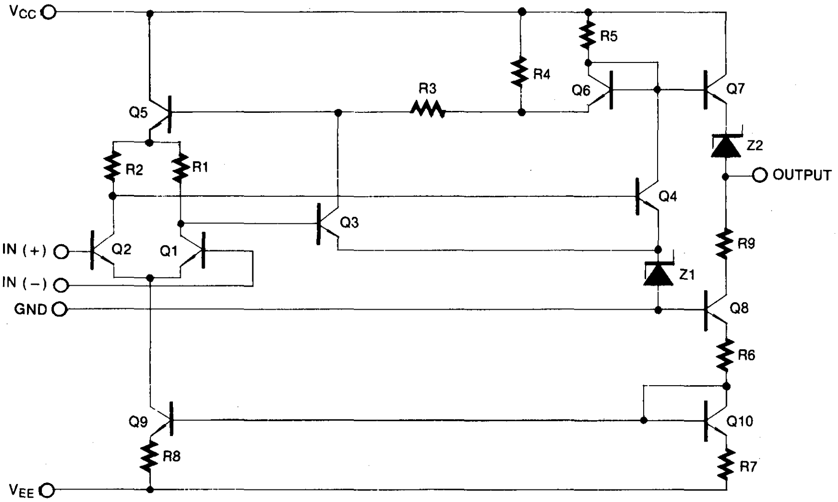
## BLOCK DIAGRAM



## ORDERING INFORMATION

| Device | Package | Operating Temperature |
|---|---|---|
| KA710CN | 14 DIP | 0 ~+70°C |
| KA710CD | 14 SOP | |
| KA710IN | 14 DIP | −25 ~+85°C |
| KA710ID | 14 SOP | |

## SCHEMATIC DIAGRAM



## ABSOLUTE MAXIMUM RATINGS

| Characteristic | Symbol | Value | Unit |
|---|---|---|---|
| Positive Supply Voltage | $V_{CC}$ | +14 | V |
| Negative Supply Voltage | $V_{EE}$ | −7 | V |
| Peak Output Current | $I_{peak}$ | 10 | mA |
| Output Short Circuit Duration | | 10 | Sec |
| Differential Input Voltage | $V_{ID}$ | ±5 | V |
| Input Voltage | $V_I$ | ±7 | V |
| Power Dissipation | $P_D$ | 300 | mW |
| Operating Temperature Range KA710C | $T_{opr}$ | 0 ~ +70 | °C |
| KA710I | | −25 ~ +85 | |
| Storage Temperature Range | $T_{stg}$ | −65 ~ +150 | °C |

## ELECTRICAL CHARACTERISTICS ($V_{CC}$ = +12V, $V_{EE}$ = −6V, Ta = 25°C, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | KA710I | | | KA710C | | | Unit |
|---|---|---|---|---|---|---|---|---|---|
| | | | Min | Typ | Max | Min | Typ | Max | |
| Input Offset Voltage | $V_{IO}$ | $R_S \leq 200\Omega$, NOTE 1 | | 0.6 | 2.0 | | 1.6 | 5.0 | mV |
| | | Note 2 | | | 3.0 | | | 6.5 | |
| Input Offset Current (Note 1) | $I_{IO}$ | NOTE 1 | | 0.75 | 3.0 | | 1.8 | 5.0 | μA |
| | | Note 2 | | 1.8 | 7.0 | | | 7.5 | |
| Input Bias Current | $I_{IB}$ | | | 5.0 | 20 | | 7.0 | 25 | μA |
| | | Note 2 | | 27 | 45 | | 25 | 40 | |
| Large Signal Voltage Gain | $A_V$ | | 1250 | 1800 | | 1000 | 1700 | | V/V |
| | | Note 2 | | | | | | | |
| Input Voltage Range | $V_{ICR}$ | $V_{CC}$ = −7V | ±5.0 | | | ±5.0 | | | V |
| Common Mode Rejection Ratio | CMRR | $R_S \leq 200\Omega$, NOTE 2 | 80 | 95 | | 70 | 94 | | dB |
| Differential Input Voltage Range | $V_{IDR}$ | | ±5.0 | | | ±5.0 | | | V |
| Positive Output Level | $V_{OH}$ | $0 \leq I_O < 5mA$, $V_{in} \geq 5mV$ | 2.5 | 2.9 | 4.0 | 2.5 | 2.9 | 4.0 | V |
| Negative Output Level | $V_{OL}$ | $V_{in} \geq 5mV$ | −1.0 | −0.5 | 0 | −1.0 | −0.5 | 0 | V |
| Output Sink Current | $I_{sink}$ | $V_O$ = 0V $V_{in} \geq 5mV$ | 2.0 | 2.2 | | 1.6 | 2.2 | | mA |
| Positive Supply Current | $I_{CC}$ | $V_O \leq 0V$ | | 4.7 | 9.0 | | 4.7 | 9.0 | mA |
| Negative Supply Current | $I_{EE}$ | $V_O$ = 0V, $V_{in}$ = +5mV | | 4.0 | 7.0 | | 4.0 | 7.0 | mA |
| Power Consumption | $P_D$ | $V_O$ = 0V, $V_{in}$ = 10mV | | 80 | 150 | | | 150 | mV |
| Response Time | $t_r$ | (Note 3) | | 40 | | | 40 | | nS |

Note 1. The input offset voltage and input offset current are specified for a logic threshold voltage as follows: For 710I, 1.65V at −25°C, 1.4V at +25°C, 1.15V at +85°C. For 710C, 1.5V at 0°C, 1.4V at +25°C, 1.2V at +70°C.

Note 2. KA710C: 0≤Ta≤ +70°C
KA710I: −25≤Ta≤ +85°C

Note 3. The response time specified is a 100mV input step with 5mV overdrive (KA710).

## TYPICAL PERFORMANCE CHARACTERISTICS

Fig. 1 SUPPLY CURRENT

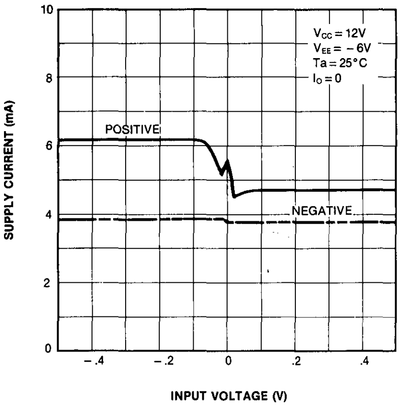


Fig. 2 VOLTAGE GAIN

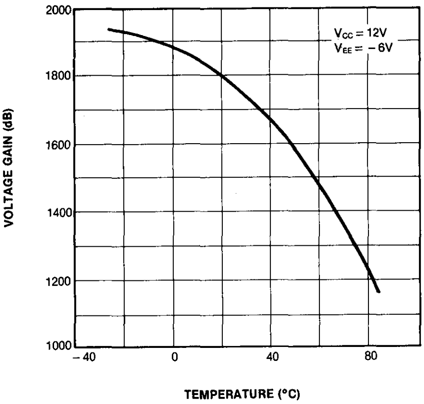


Fig. 3 INPUT OFFSET CURRENT

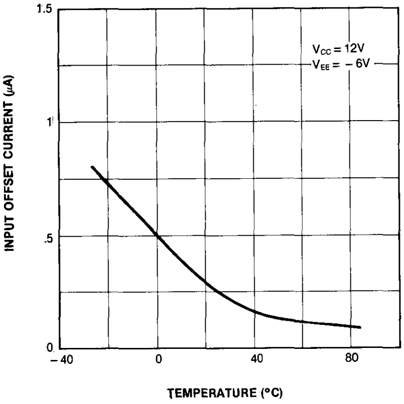


Fig. 4 INPUT BIAS CURRENT

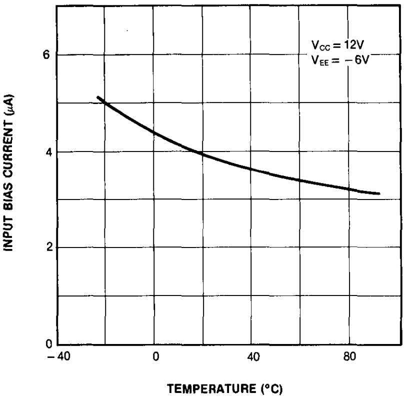


Fig. 5 OUTPUT VOLTAGE LEVEL

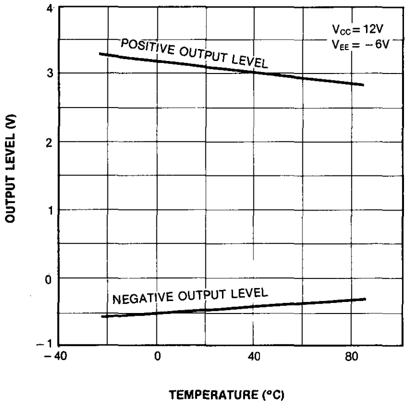


Fig. 6 OUTPUT SINK CURRENT

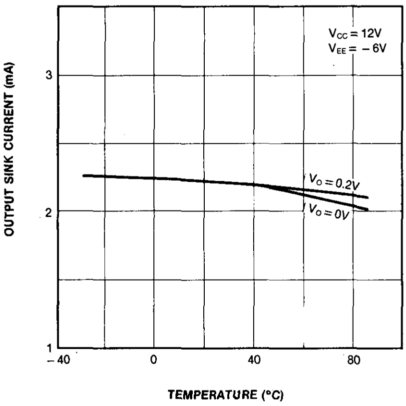


Fig. 7 RESPONSE TIME

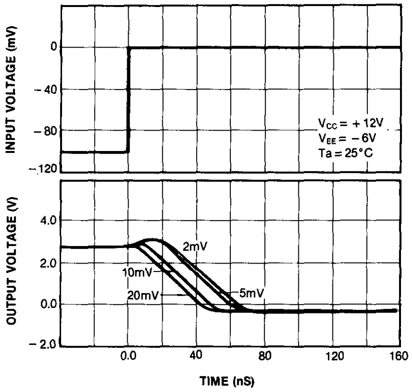
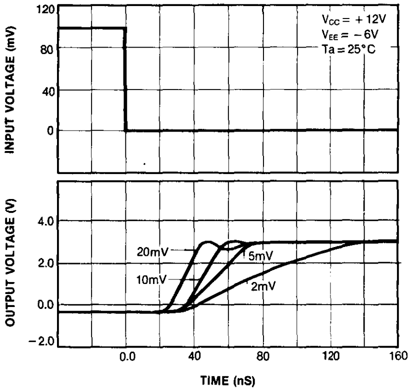


Fig. 8 RESPONSE TIME

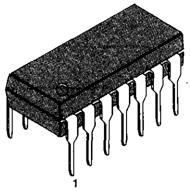


## DUAL HIGH-SPEED DIFFERENTIAL COMPARATOR

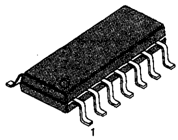
The KA711C/I contain two voltage comparators th with separate differential inputs, a common output and provision for strobing each side independently. The device features high accuracy, fast response, low offset voltage, a large input voltage range, low power consumption and compatibility with practically all integrated logic forms.

The KA711C/I can be used as a sense amplifier for memories, and a dual comparator with OR'ed outputs is required, such as a double-ended limit detector.

**14 DIP**



**14 SOP**



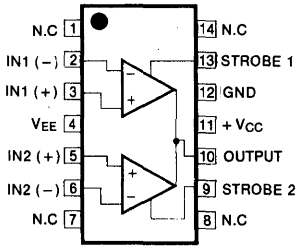
## FEATURES

- **Fast response time: 40ns (Typ)**
- **Output compatible with most TTL circuits**
- **Independent strobing of each comparator**
- **Low offset voltage**

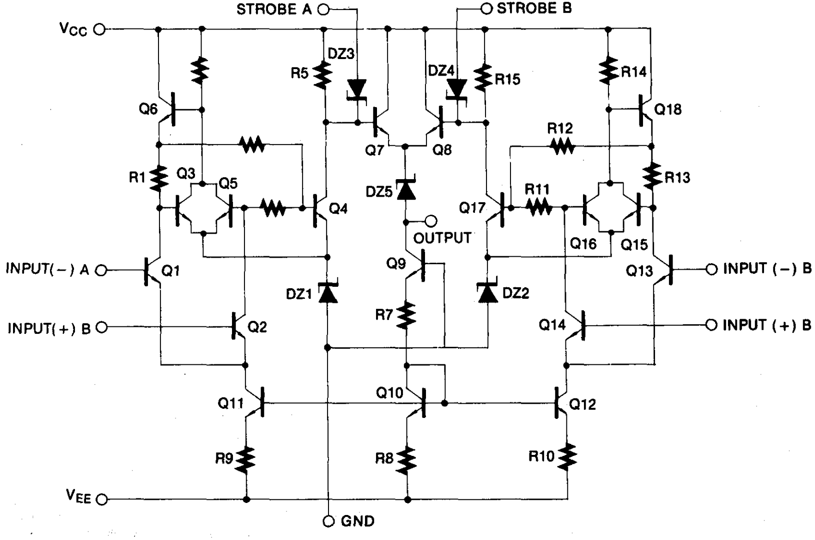
## ORDERING INFORMATION

| Device | Package | Operating Temperature |
|---|---|---|
| KA711CN | 14 DIP | 0 ~ + 70°C |
| KA711CD | 14 SOP | |
| KA711IN | 14 DIP | − 25 ~ + 85°C |
| KA711ID | 14 SOP | |

## BLOCK DIAGRAM



## SCHEMATIC DIAGRAM



## ABSOLUTE MAXIMUM RATINGS (Ta = 25°C)

| Characteristic | Symbol | Value | Unit |
|---|---|---|---|
| Positive Supply Voltage | $V_{CC}$ | +14 | V |
| Negative Supply Voltage | $V_{EE}$ | −7 | V |
| Differential Input Voltage | $V_{ID}$ | ±5 | V |
| Input Voltage | $V_I$ | ±7 | V |
| Strobe Voltage | $V_{st}$ | 0 ~ 6 | V |
| Peak Output Current | $I_{peak}$ | 50 | mA |
| Continuous Total Power Dissipation | $P_D$ | 500 | mW |
| Operating Temperature Range KA711C | $T_{opr}$ | 0 ~ +70 | °C |
| KA711I | | −65 ~ +150 | |
| Storage Temperature Range | $T_{stg}$ | −25 ~ +85 | °C |

## ELECTRICAL CHARACTERISTICS

($V_{CC}$ = +12V, $V_{EE}$ = −6V, Ta = 25°C, unless otherwise specified)

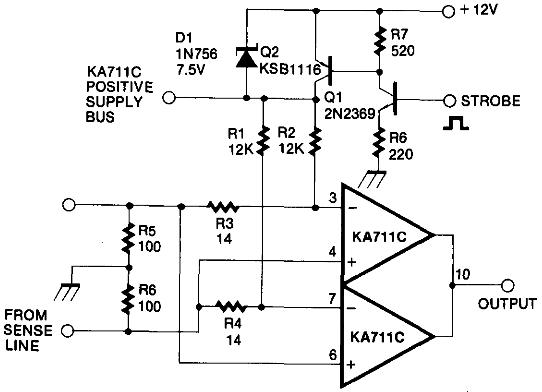
| Characteristic | Symbol | Test Conditions | KA711I | | | KA711C | | | Unit |
|---|---|---|---|---|---|---|---|---|---|
| | | | Min | Typ | Max | Min | Typ | Max | |
| Input Offset Voltage | $V_{IO}$ | $R_S \geq 200\Omega$, $V_{ICM} = 0V$ | | 1.0 | 3.5 | | 1.0 | 5.0 | mV |
| | | $V_{OUT} = 1.4V$ NOTE 2 | | | 4.5 | | | 6.0 | |
| Input Offset Current | $I_{IO}$ | $V_{OUT} = 1.4V$ | | 0.5 | 10.0 | | 0.5 | 15 | μA |
| | | NOTE 2 | | | 20 | | | 25 | |
| Input Bias Current | $I_{IB}$ | | | 25 | 75 | | 25 | 100 | μA |
| | | Ta = 0°C | | | 150 | | | 150 | |
| Large Signal Voltage Gain | $A_V$ | | 750 | 1500 | | 700 | 1500 | | V/V |
| | | NOTE 2 | 500 | | | 500 | | | |
| Input Voltage Range | $V_{ICR}$ | $V_{EE} = -7.0V$ | ±5.0 | | | ±5.0 | | | V |
| Differential Input Voltage Range | $V_{IDR}$ | | ±5.0 | | | ±5.0 | | | V |
| Output Resistance | $R_O$ | | | 200 | | | 200 | | Ω |
| Output Voltage (High) | $V_{OH}$ | $V_{IN} \geq 10mV$ | | 4.5 | 5.0 | | 4.5 | 5.0 | V |
| Output Voltage (Low) | $V_{OL}$ | $V_{IN} \leq 10mV$ | −1.0 | | 0 | −1.0 | −0.5 | 0 | V |
| Loaded Output High Level | $V_{LOM}$ | $V_{IN} \geq 10mV$, $I_O = 5mA$ | 2.5 | 3.5 | | 2.5 | 3.5 | | V |
| Strobed Output Level | $V_{SO}$ | $V_{strobe} \leq 0.3V$ | −1.0 | | 0 | −1.0 | | 0 | V |
| Output Sink Current | $I_{sink}$ | $V_{IN} \geq 10mV$, $V_O \geq 0V$ | 0.5 | 0.8 | | 0.5 | 0.8 | | mA |
| Positive Supply Current | $I_{CC}$ | $V_O = 0V$, $V_{IN} = 10mV$ | | 8.6 | | | 8.6 | | mA |
| Negative Supply Current | $I_{EE}$ | $V_O = 0V$, $V_{IN} = 10mV$ | | 3.9 | | | 3.9 | | mA |
| Strobe Current | $I_{st}$ | $V_{strobe} = 100mV$ | | 1.2 | 2.5 | | 1.2 | 2.5 | mA |
| Power Consumption | $P_D$ | $V_O = 0V$, $V_{IN} \geq 10mV$ | | 130 | 200 | | 130 | 230 | mW |
| Response Time | $t_r$ | (NOTE 1) | | 40 | | | 40 | | ns |
| Strobe Release Time | $t_{rs}$ | | | 12 | | | 12 | | ns |

Note: 1. The response time specified is for a 100mV input step with 10mV overdrive

2. KA711C: $0 \leq Ta \leq +70°C$
   KA711I: $-25 \leq Ta \leq +85°C$
3. The input offset voltage and input offset current are specified for a logic threshold voltage of 711I, 1.65V at −25°C, 1.4V at +25°C, 1.15V at +85°C, for 711C, 1.5V at 0°C, 1.4V at +25°C, 1.2V at +70°C.

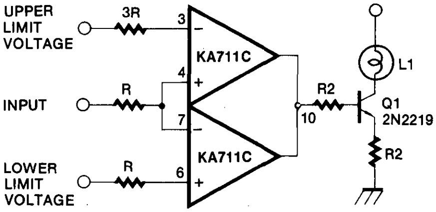
## TYPICAL APPLICATIONS

**Fig. 1** Sense Amplifier With Supply Strobing for Reduced Power Consumption*



* Standby dissipation is about 40mW

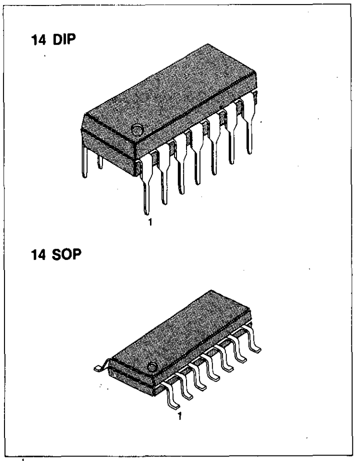
**Fig. 2** Double-Ended Limit Detactor With Lamp Driver



# LM239/A, LM339/A, LM2901, LM3302 LINEAR INTEGRATED CIRCUIT

## QUAD DIFFERENTIAL COMPARATOR

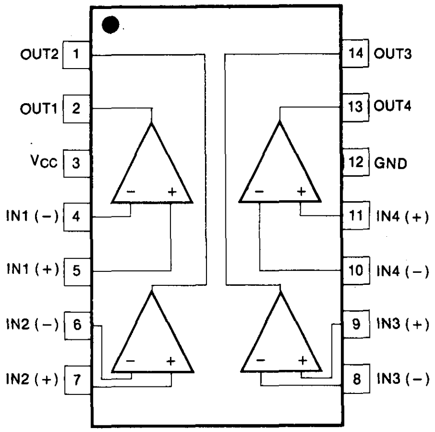
The LM239 series consists of four independent voltage comparators designed to operate from single power supply over a wide voltage range.



## FEATURES

- **Single or dual supply operation**
- **Wide range of supply voltages LM239/A, LM339/A: 2 ~ 36V**
  **LM2901 ,(or ±1 ~ ±18V)**
  **LM3302: 2 ~ 28V**
  **(or ±1 ~ ±14V)**
- **Low supply current drain 800μA Typ.**
- **Open collector outputs for wired and connectors**
- **Low input bias current 25nA Typ.**
- **Low input offset current ±2.3nA Typ.**
- **Low input offset voltage ±1.4mV Typ.**
- **Common mode input voltage range includes ground.**
- **Low output saturation voltage**
- **Output compatible with TTL, DTL and MOS logic system**

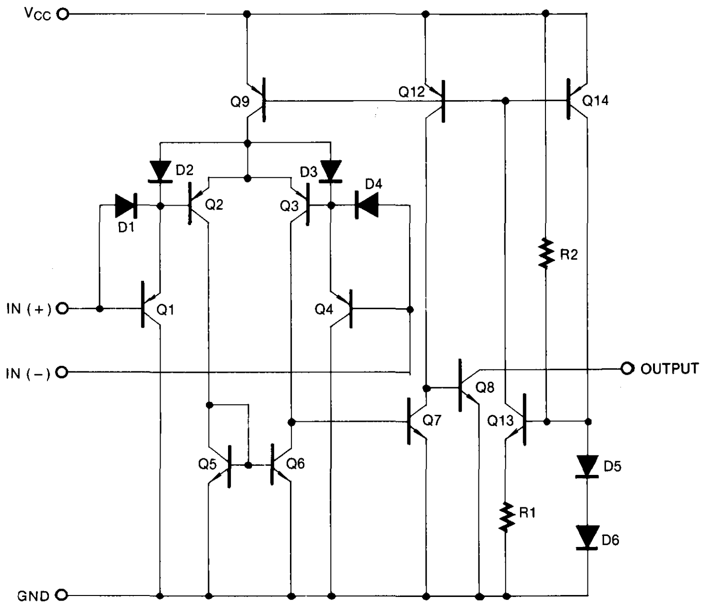
## BLOCK DIAGRAM



## ORDERING INFORMATION

| Device | Package | Operating Temperature |
|---|---|---|
| LM339N<br>LM339AN | 14 DIP | 0 ~ 70°C |
| LM339D<br>LM339AD | 14 SOP | |
| LM239N<br>LM239AN | 14 DIP | −25 ~ +85°C |
| LM239D<br>LM239AD | 14 SOP | |
| LM2901N | 14 DIP | 0 ~ +85°C |
| LM2901D | 14 SOP | |
| LM3302N | 14 DIP | |
| LM3302D | 14 SOP | |

## SCHEMATIC DIAGRAM



## ABSOLUTE MAXIMUM RATINGS

| Characteristic | Symbol | Value | Unit |
|---|---|---|---|
| Power Supply Voltage | $V_S$ | ± 18 or 36 | V |
| Power Supply Voltage Only LM3302 | $V_S$ | ± 14 or 28 | V |
| Differential Input Voltage | $V_{ID}$ | 36 | V |
| Differential Input Voltage Only LM3302 | $V_{ID}$ | 28 | V |
| Input Voltage | $V_I$ | − 0.3 to + 36 | V |
| Input Voltage Only LM3302 | $V_I$ | − 0.3 to + 28 | V |
| Output Short Circuit to GND | | Continuous | |
| Power Dissipation | $P_D$ | 570 | mW |
| Operating Temperature LM239/LM239A | $T_{opr}$ | 0 ~ + 70 | °C |
| LM339/LM339A | | − 25 ~ + 85 | °C |
| LM2901/LM3302 | | − 40 ~ + 85 | °C |
| Storage Temperature | $T_{stg}$ | − 65 ~ + 150 | °C |

## ELECTRICAL CHARACTERISTICS

($V_{CC}=5V$, $Ta=25°C$, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | | LM239A/LM339A | | | LM239/LM339 | | | Unit |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Min | Typ | Max | Min | Typ | Max | |
| Input Offset Voltage | $V_{IO}$ | $V_{ICM}=0V$ to $V_{CC}-1.5V$ | | | ±1 | ±2 | | ±1.4 | ±5 | mV |
| | | $V_O=1.4V$, $R_S=0$ | NOTE 1 | | | ±4.0 | | | ±9.0 | |
| Input Offset Current | $I_{IO}$ | | | | ±2.3 | ±50 | | ±2.3 | ±50 | nA |
| | | | NOTE 1 | | | ±150 | | | ±150 | |
| Input Bias Current | $I_B$ | | | | 57 | 250 | | 57 | 250 | nA |
| | | | NOTE 1 | | | 400 | | | 400 | |
| Input Common Mode Voltage Range | $V_{ICR}$ | | | 0 | | $V_{CC}$-1.5 | 0 | | $V_{CC}$-1.5 | V |
| | | | NOTE 1 | 0 | | $V_{CC}$-2 | 0 | | $V_{CC}$-2 | |
| Supply Current | $I_{CC}$ | | $R_L=\infty$ | | 1.1 | 2.0 | | 1.1 | 2.0 | mA |
| Voltage Gain | $A_{VOL}$ | $V_{CC}=15V$, $R_L \geq 15K\Omega$ (for large swing) | | 50 | 200 | | 50 | 200 | | V/mV |
| Large Signal Response Time | $t_{RES}$ | $V_{IN}=$ TTL Logic Swing<br>$V_{ref}=1.4V$, $V_{RL}=5V$, $R_L=5.1K\Omega$ | | | 350 | | | 350 | | ns |
| Response Time | $t_{RES}$ | $V_{RL}=5V$, $R_L=5.1K\Omega$ | | | 1.4 | | | 1.4 | | $\mu$s |
| Output Sink Current | $I_{sink}$ | $V_{IN^-} \geq 1V$, $V_{IN^+}=0V$, $V_O \leq 1.5V$ | | 6 | 18 | | 6 | 18 | | mA |
| Output Saturation Voltage | $V_{sat}$ | $V_{IN^-} \geq 1V$, $V_{IN^+}=0V$ | | | 140 | 400 | | 140 | 400 | mV |
| | | $I_{sink}=4mA$ | NOTE 1 | | | 700 | | | 700 | |
| Output Leakage Current | $I_{leak}$ | $V_{IN^-}=0$ | $V_O=5V$ | | 0.1 | | | 0.1 | | nA |
| | | $V_{IN^+}=1V$ | $V_O=30V$ | | | 1.0 | | | 1.0 | $\mu$A |
| Differential Voltage | $V_{ID}$ | | NOTE 1 | | | 36 | | | 36 | V |

* NOTE 1

LM339/A: $0 \leq Ta \leq +70°C$

LM239/A: $-25 \leq Ta \leq +85°C$

LM2901/3302: $-40 \leq Ta < +85°C$

## ELECTRICAL CHARACTERISTICS

($V_{CC}=5V$, $Ta=25°C$, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | | LM2901 | | | LM3302 | | | Unit |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Min | Typ | Max | Min | Typ | Max | |
| Input Offset Voltage | $V_{IO}$ | $V_{ICM}=0V$ to $V_{CC}=1.5V$ | | | 2 | 7 | | 2 | 20 | mV |
| | | $V_O=1.4V$, $R_S=0$ | NOTE 1 | | 9 | 15 | | | 40 | |
| Input Offset Current | $I_{IO}$ | | | | 2.3 | 50 | | 3 | 100 | nA |
| | | | NOTE 1 | | 50 | 200 | | | 300 | |
| Input Bias Current | $I_B$ | | | | 57 | 250 | | 57 | 250 | nA |
| | | | NOTE 1 | | 200 | 500 | | | 1000 | |
| Input Common Mode Voltage Range | $V_{ICR}$ | | | 0 | | $V_{CC}$-1.5 | 0 | | $V_{CC}$-1.5 | V |
| | | | NOTE 1 | 0 | | $V_{CC}$-2 | 0 | | $V_{CC}$-2 | |
| Supply Current | $I_{CC}$ | | $R_L=\infty$, | | 1.1 | 2.0 | | 1.1 | 2.0 | mA |
| | | | $R_L=\infty$, $V_{CC}=30V$ | | 1.6 | 2.5 | | | | |
| Voltage Gain | $A_{VOL}$ | $V_{CC}=15V$, $R_L\geq 15K\Omega$ (for large swing) | | 25 | 100 | | 2 | 30 | | V/mV |
| Large Signal Response Time | $t_{REST}$ | $V_{IN}$ = TTL Logic Swing<br>$V_{ref}=1.4V$, $R_{RL}=5V$, $R_L=5.1K\Omega$ | | | 350 | | | 350 | | ns |
| Response Time | $t_{RES2}$ | $V_{RL}=5V$, $R_L=5.1K\Omega$ | | | 1.4 | | | 1.4 | | µs |
| Output Sink Current | $I_{sink}$ | $V_{IN-}\geq 1V$, $V_{IN+}=0V$, $V_O\leq 1.5V$ | | 6 | 18 | | 6 | 18 | | mA |
| Output Saturation Voltage | $V_{sat}$ | $V_{IN-}\geq 1V$, $V_{IN+}=0V$ | | | 140 | 400 | | 140 | 400 | mV |
| | | $I_{sink}=4mA$ | NOTE 1 | | | 700 | | | 700 | |
| Output Leakage Current | $I_{leak}$ | $V_{IN+}=0$ | $V_O=5V$ | | 0.1 | | | 0.1 | | nA |
| | | $V_{IN+}=1V$ | $V_O=30V$ | | | 1.0 | | | 1.0 | µA |
| Differential Voltage | $V_{ID}$ | | NOTE 1 | 0 | | 36 | | | 28 | V |

NOTE 1 LM339/A: $0\leq Ta\leq +70°C$
LM239/A: $-25\leq Ta\leq +85°C$
LM2901/3302: $-40\leq Ta< +85°C$

## TYPICAL PERFORMANCE CHARACTERISTICS

**Fig. 1 SUPPLY CURRENT**

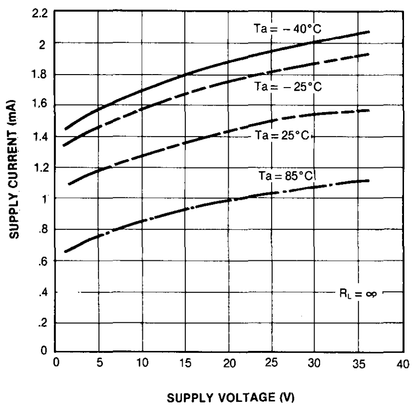


**Fig. 2 INPUT CURRENT**

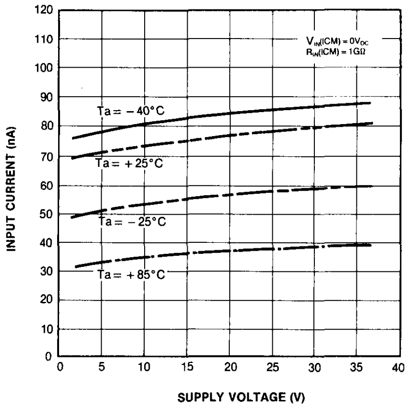


**Fig. 3 OUTPUT SATURATION VOLTAGE**

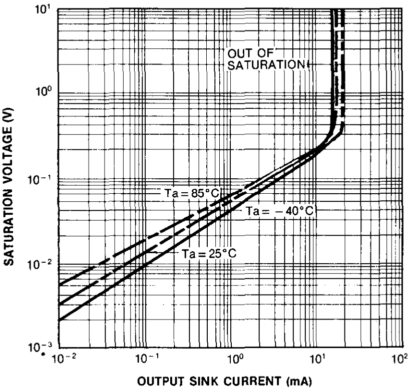


**Fig. 4 RESPONSE TIME FOR VARIOUS INPUT OVERDRIVE-NEGATIVE TRANSITION**

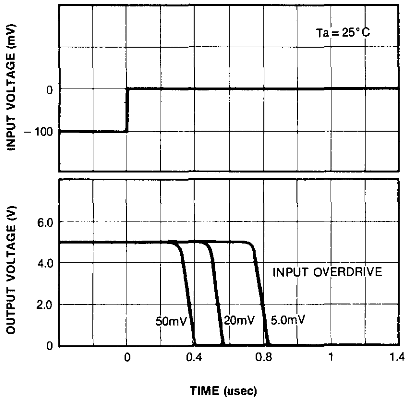
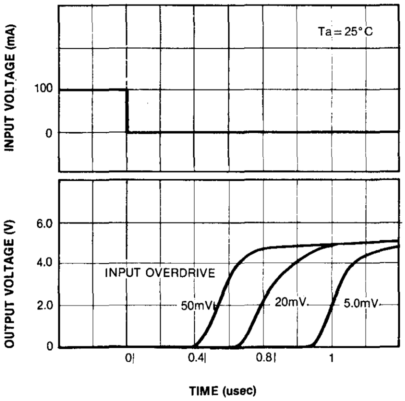


**Fig. 5 RESPONSE TIME FOR VARIOUS INPUT OVERDRIVE-POSITIVE TRANSITION**



## APPLICATION INFORMATION

The LM239 series includes four high gain, wide bandwidth devices which, like most comparators, can easily oscillate if the output lead is inadvertently allowed to capacitively couple to the inputs via stray capacitance. That occurs during the output voltage transitions, when the comparator changes state.

To minimize this problem, the PC board layout should be designed to reduce stray input-output coupling; reducing the input resistors to less than 10 KΩ reduces the feedback signal levels and finally, adding even a small amount (1 to 10mV) of positive feedback (hysteresis) causes such a rapid transition that oscillations due to stray feedback are not possible.

It is a good design practice to ground all unused pins.

The differential input voltage may be larger than positive supply without damaging the device. Note that voltages more negative than −0.3V should not be used: an input clamping diode can be used as protection.

The output LM339 is the uncommitted collector of a NPN transistor with grounded emitter. This allows the device to be used like any open-collector gate providing the OR-wide facility.

The output sink current capability is approximately 16 mA; if this limit is exceeded, the output transistor will come out of saturation and the output voltage will rise very rapidly.

Under this limit, the output saturation voltage is limited by the approximately 60Ω $r_{sat}$ of the outpput transistor.

## TYPICAL APPLICATIONS ($V_{CC} = +15V$)

Fig. 6 Basic comparator

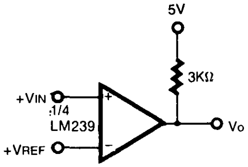


Fig. 7 Non-inverting comparator with Hysteresis

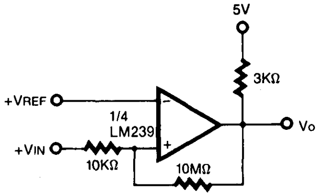


Fig. 8 Inverting comparator with Hysteresis

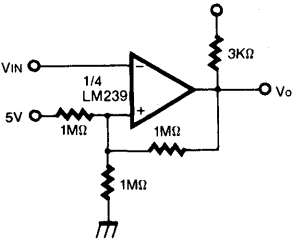


Fig. 9 Driving C/MOS

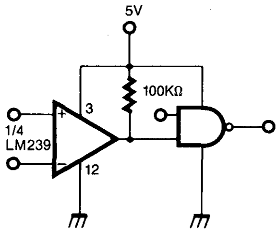


Fig. 10 Driving TTL

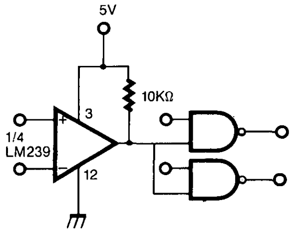


Fig. 11 AND gate

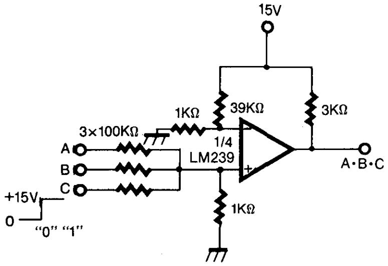


Fig. 12 OR gate

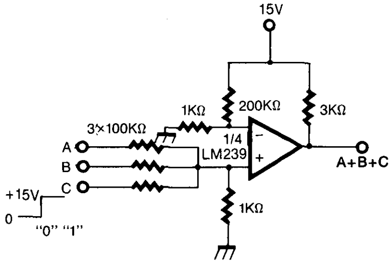


Fig. 13 Large fan-in AND gate

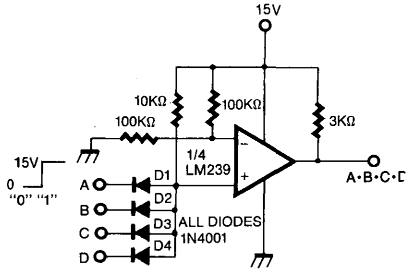


Fig. 14 Squarewave oscillator

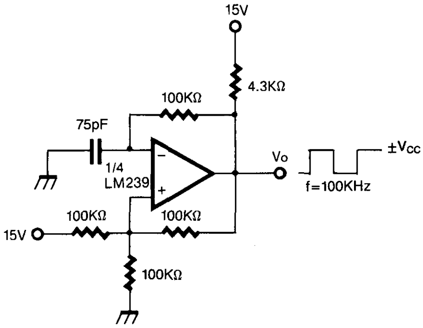


Fig. 15 ORing the outputs

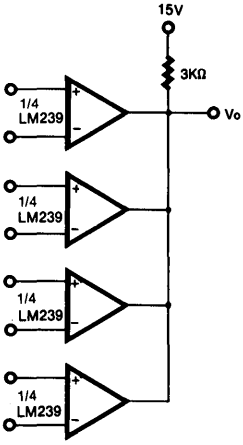


Fig. 16 Peak audio level display

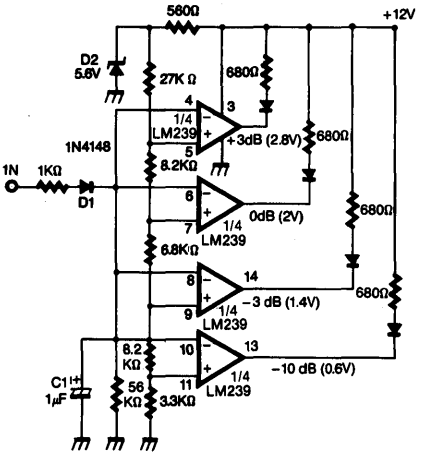


Fig. 17 Zero crossing detector (single supply)

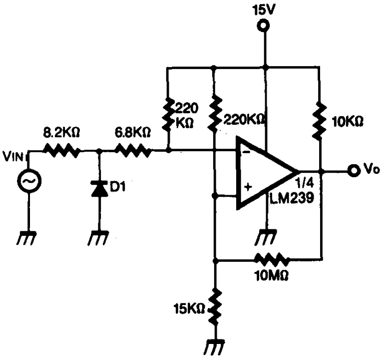
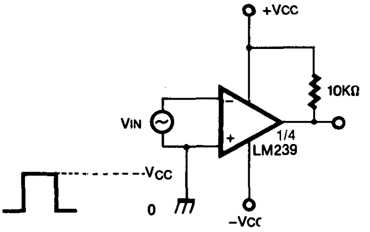


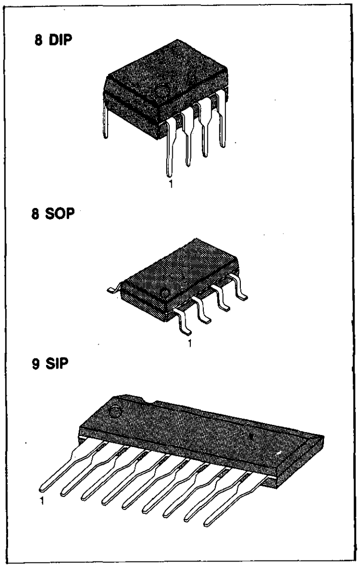
Fig. 18 Zero crossing detector (split supplies)

$V_{INmin} \approx 0.4V$ peak for 1% phase distortion ($\Delta\theta$)



## DUAL DIFFERENTIAL COMPARATOR

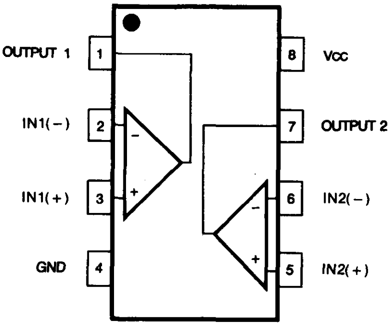
The LM293 series consists of two independent voltage comparators designed to operate from a single power supply over a wide voltage range.

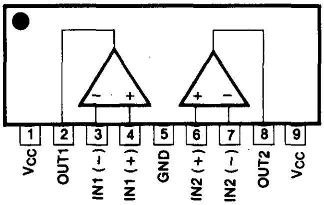


## FEATURES

- **Single Supply Operation: 2V to 36V**
- **Dual Supply Operation: ±1V to ±18V**
- **Allow Comparison of Voltages Near Ground Potential**
- **Low Current Drain 800μA Typ**
- **Compatible with all Forms of Logic**
- **Low Input Bias Current 25nA Typ**
- **Low Input Offset Current ±5nA Typ**
- **Low Offset Voltage ±1mV Typ**

## BLOCK DIAGRAM

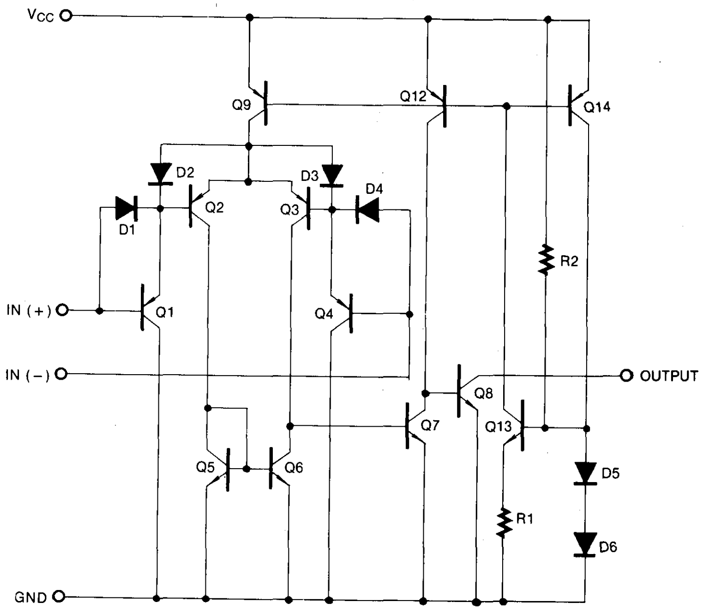




## ORDERING INFORMATION

| Device | Package | Operating Temperature |
|---|---|---|
| LM393N<br>LM393AN | 8 DIP | 0 ~ +75°C |
| LM393S<br>LM393AS | 9 SIP | |
| LM393D<br>LM393AD | 8 SOP | |
| LM293N<br>LM293AN | 8 DIP | −25 ~ +85°C |
| LM293S<br>LM293AS | 9 SIP | |
| LM293D<br>LM293AD | 8 SOP | |
| LM2903N | 8 DIP | −40 ~ +85°C |
| LM2903D | 8 SOP | |
| LM2903S | 9 SIP | |

## SCHEMATIC DIAGRAM



## ABSOLUTE MAXIMUM RATINGS

| Characteristic | Symbol | Value | Unit |
|---|---|---|---|
| Power Supply Voltage | $V_S$ | ±18 or 36 | V |
| Differential Input Voltage | $V_{ID}$ | 36 | V |
| Input Voltage | $V_I$ | −0.3 to +36 | V |
| Output Short Circuit to GND | | Continuous | |
| Power Dissipation | $P_D$ | 570 | mW |
| Operating Temperature<br>LM393/LM393A<br>LM293/LM293A<br>LM2903 | $T_{opr}$ | <br>0 ~ +70<br>−25 ~ +85<br>−40 ~ +85 | °C |
| Storage Temperature | $T_{stg}$ | −65 ~ +150 | °C |

## ELECTRICAL CHARACTERISTICS ($V_{CC}=5V$, Ta = 25°C, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | | LM293A/LM393A | | | LM293/LM393 | | | Unit |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Min | Typ | Max | Min | Typ | Max | |
| Input Offset Voltage | $V_{IO}$ | $V_{ICM}=0V$ to $V_{CC}-1.5V$ | | | ±1 | ±2 | | ±1 | ±5 | mV |
| | | $V_o=1.4V$, $R_s=0$ | NOTE 1 | | | ±4.0 | | | ±9.0 | |
| Input Offset Current | $I_{IO}$ | | | | ±5 | ±50 | | ±5 | ±50 | nA |
| | | | NOTE 1 | | | ±150 | | | ±150 | |
| Input Bias Current | $I_B$ | | | | 65 | 250 | | 65 | 250 | nA |
| | | | NOTE 1 | | | 400 | | | 400 | |
| Input Common Mode Voltage Range | $V_{ICR}$ | | | 0 | | $V_{CC}$-1.5 | 0 | | $V_{CC}$-1.5 | V |
| | | | NOTE 1 | 0 | | $V_{CC}$-2 | 0 | | $V_{CC}$-2 | |
| Supply Current | $I_{CC}$ | $R_L=\infty$ | | | 0.6 | 1 | | 0.6 | 1 | mA |
| | | $R_L=\infty$ $V_{CC}=30V$ | | | 0.8 | 2.5 | | 0.8 | 2.5 | |
| Voltage Gain | $A_V$ | $V_{CC}=15V$, $R_L \geq 15K\Omega$(for large $V_o$ swing) | | 50 | 200 | | 50 | 200 | | V/mV |
| Large Signal Response Time | $t_{RES1}$ | $V_{IN}$ = TTL Logic Swing<br>$V_{ref}=1.4V$, $V_{RL}=5V$, $R_L=5.1K\Omega$ | | | 350 | | | 350 | | nS |
| Response Time | $t_{RES2}$ | $V_{RL}=5V$, $R_L=5.1K\Omega$ | | | 1.4 | | | 1.4 | | µS |
| Output Sink Current | $I_{sink}$ | $V_{IN}^- \geq 1V$, $V_{IN}^+ = 0V$, $V_o \leq 1.5V$ | | 6 | 18 | | 6 | 18 | | mA |
| Output Saturation Voltage | $V_{sat}$ | $V_{IN}^- \geq 1V$, $V_{IN}^+ = 0V$ | | | 160 | 400 | | 160 | 400 | mV |
| | | $I_{sink}=4mA$ | NOTE 1 | | | 700 | | | 700 | |
| Output Leakage Current | $I_{leak}$ | $V_{IN}^- = 0$,<br>$V_{in}^+ = 1V$ | $V_o=5V$ | | 0.1 | | | 0.1 | | nA |
| | | | $V_o=30V$ | | | 1.0 | | | 1.0 | µA |

NOTE 1

LM393/A: 0 ≤ Ta ≤ +70°C

LM293/A: −25 ≤ Ta ≤ +85°C

LM2903: −40 ≤ Ta ≤ +85°C

## ELECTRICAL CHARACTERISTICS ($V_{CC}=5V$, $Ta=25°C$, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | | LM2903 | | | Unit |
|---|---|---|---|---|---|---|---|
| | | | | Min | Typ | Max | |
| Input Offset Voltage | $V_{IO}$ | $V_{ICM}=0V$ to $V_{CC}-1.5V$ | | | ± 1 | ± 7 | mV |
| | | $V_o=1.4V$, $R_s=0$ | NOTE 1 | | ± 9 | ± 15 | |
| Input Offset Current | $I_{IO}$ | | | | ± 5 | ± 50 | nA |
| | | | NOTE 1 | | ± 50 | ± 200 | |
| Input Bias Current | $I_B$ | | | | 65 | 250 | nA |
| | | | NOTE 1 | | | 500 | |
| Input Common Mode Voltage Range | $V_{ICR}$ | | | 0 | | $V_{CC}$-1.5 | V |
| | | | NOTE 1 | 0 | | $V_{CC}$-2 | |
| Supply Current | $I_{CC}$ | $R_L=\infty$ | | | 0.6 | 1 | mA |
| | | $R_L=\infty$ $V_{CC}=30V$ | | | 1 | 2.5 | |
| Voltage Gain | $A_V$ | $V_{CC}=15V$, $R_L \geq 15K\Omega$ (for large $V_o$ swing) | | 25 | 100 | | V/mV |
| Large Signal Response Time | $t_{RES1}$ | $V_{IN}$ = TTL Logic Swing<br>$V_{ref}=1.4V$, $V_{RL}=5V$, $R_L=5.1K\Omega$ | | | 350 | | nS |
| Response Time | $t_{RES2}$ | $V_{RL}=5V$, $R_L=5.1K\Omega$ | | | 1.5 | | $\mu$S |
| Output Sink Current | $I_{sink}$ | $V_{IN^-} \geq 1V$, $V_{IN^+}=0V$, $V_o \leq 1.5V$ | | 6 | 16 | | mA |
| Output Saturation Voltage | $V_{sat}$ | $V_{IN^-} \geq 1V$, $V_{IN^+}=0V$ | | | 160 | 400 | mV |
| | | $I_{sink}=4mA$ | NOTE 1 | | | 700 | |
| Output Leakage Current | $I_{leak}$ | $V_{IN^-}=0$, | $V_o=5V$ | | 0.1 | | nA |
| | | $V_{in^+}=1V$ | $V_o=30V$ | | | 1.0 | $\mu$A |

NOTE 1
LM393/A: $0 \leq Ta \leq +70°C$
LM293/A: $-25 \leq Ta \leq +85°C$
LM2903: $-40 \leq Ta \leq +85°C$

## TYPICAL PERFORMANCE CHARACTERISTICS

**Fig. 1 SUPPLY CURRENT**

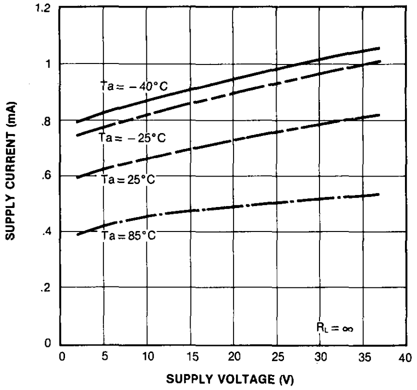


**Fig. 2 INPUT CURRENT**

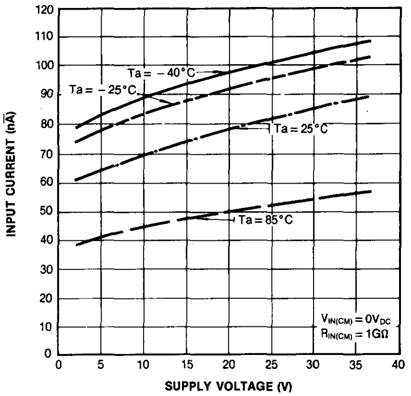


**Fig. 3 OUTPUT SATURATION VOLTAGE**

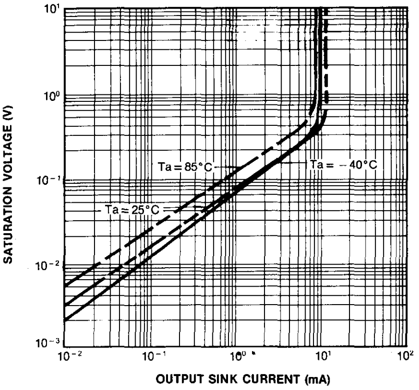


**Fig. 4 RESPONSE TIME FOR VARIOUS INPUT OVERDRIVE-NEGATIVE TRANSITION**

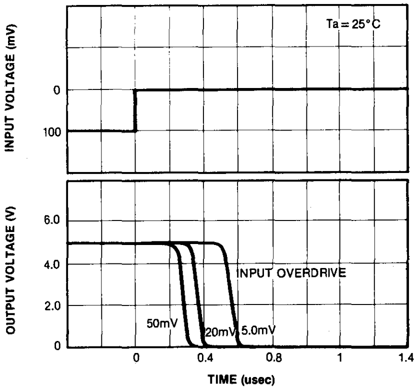
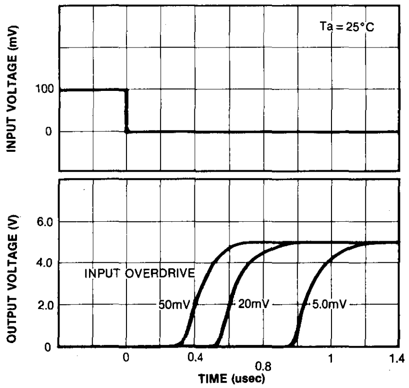


**Fig. 5 RESPONSE TIME FOR VARIOUS INPUT OVERDRIVE-POSITIVE TRANSITION**



## APPLICATION INFORMATION

The LM293 series are high gain, wide bandwidth devices which, like most comparators, can easily oscillate if the output is inadvertently allowed to capacitively couple to the inputs via stray capacitance. That occurs during the output voltage transitions, when the comparator changes state.

To minimize this problem, the PC board layout should be designed to reduce stray input-output coupling; reducing the input resistors to less than 10 KΩ reduces the feedback signal levels and finally, adding even a small amount (1 to 10mV) of positive feedback (hysteresis) causes such a rapid transition that oscillations due to stray feedback are not possible.

It is a good design practice to ground all unused pins.

The differential input voltage may be larger than positive supply without damaging the device. Note that voltages more negative than −0.3V should not used: an input clamping diode can be used as protection.

The output of the LM239 series is the uncommitted collector of a NPN transistor with grounded emitter. The allows the device to be used like any open-collector gate providing the OR-wide facility.

The output sink current capability is approximately 16mA; if this limit is exceeded, the output transistor will come out of saturation and the output voltate will rise very rapidly.

Under this limit, the output saturation voltage is limited by the approximatively 60Ω $r_{sat}$ of the output transistor.

## TYPICAL APPLICATIONS ($V_{CC} = +15V$)

**Fig. 6 Basic comparator**

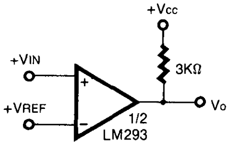


**Fig. 7 Non-inverting comparator with Hysteresis**

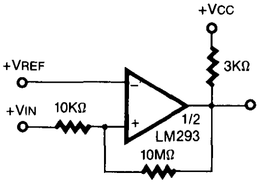


**Fig. 8 Inverting comparator with Hysteresis**

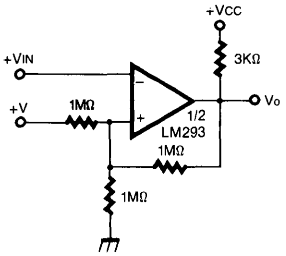


**Fig. 9 Driving C-MOS**

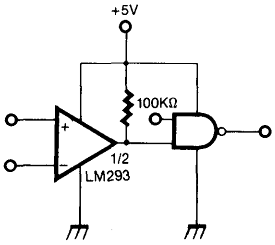
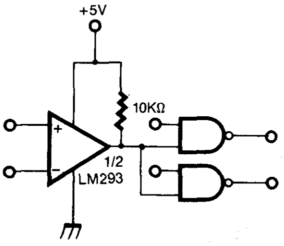


**Fig. 10 Driving TTL**



## APPLICATION INFORMATION (continued)

**Fig. 11 AND gate**

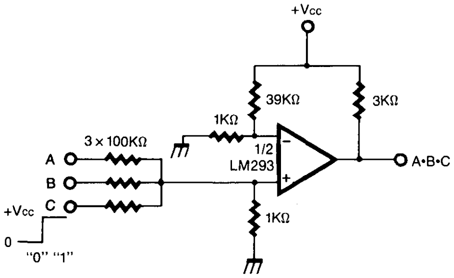


**Fig. 12 OR gate**

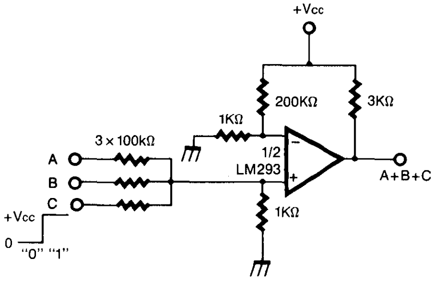


**Fig. 13 Large fan-in AND gate**

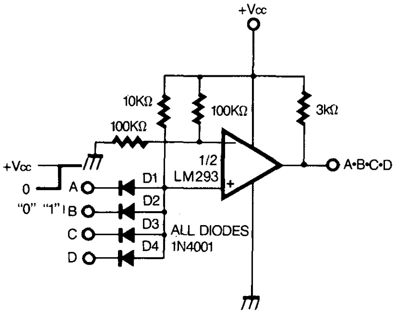


**Fig. 14 Squarewave oscillator**

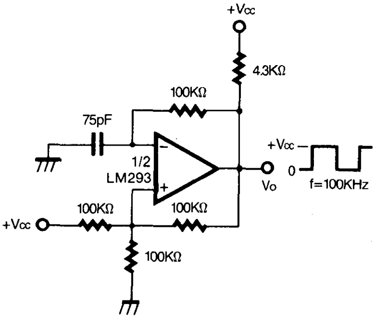


**Fig. 15 Pulse generator**

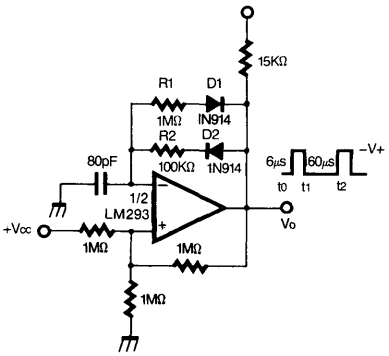
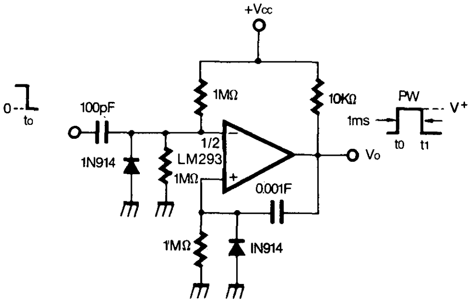


**Fig. 16 One-shot multivibrator**



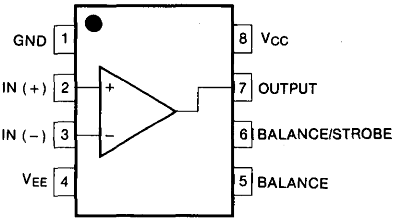
## VOLTAGE COMPARATOR

The LM311 series is a monolithic, low input current voltage comparator.
The device is also designed to operate from dual or single supplies voltage.

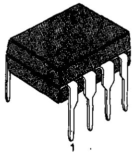
## FEATURE

- **Low input bias current: 250nA (Max)**
- **Low input offset current: 50nA (Max)**
- **Differential Input Voltage: ±30V.**
- **Power supply voltage: single 5.0V supply to ±15V.**
- **Offset voltage null capability.**
- **Strobe capability.**

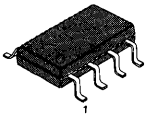
## BLOCK DIAGRAM



**8 DIP**



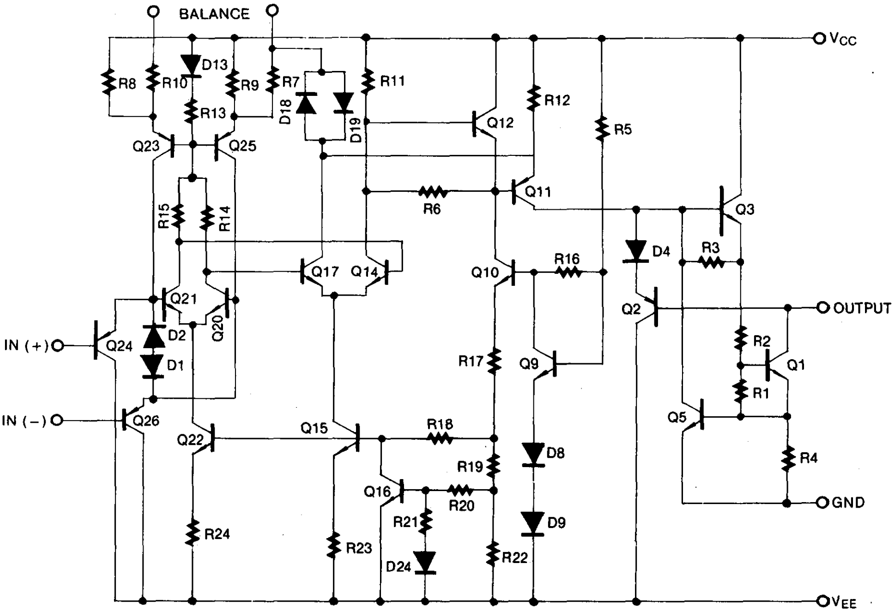
**8 SOP**



## ORDERING INFORMATION

| Device | Package | Operating Temperature |
|---|---|---|
| LM311N | 8 DIP | 0 ~ +70°C |
| LM311D | 8 SOP | |

## SCHEMATIC DIAGRAM



## ABSOLUTE MAXIMUM RATINGS

| Characteristic | Symbol | Value | Unit |
|---|---|---|---|
| Total Supply Voltage | $V_S$ | 36 | V |
| Output to Negative Supply Voltage LM311 | $V_O - V_{EE}$ | 40 | V |
| Ground to Negative Supply Voltage | $V_{EE}$ | 30 | V |
| Differential Input Voltage | $V_{ID}$ | ±30 | V |
| Input Voltage | $V_{IN}$ | ±15 | V |
| Output Short Circuit Duration | | 10 | sec |
| Power Dissipation | $P_D$ | 500 | mW |
| Operating Temperature Range | $T_{opr}$ | 0 ~ +70 | °C |
| Storage Temperature Range | $T_{stg}$ | −65 ~ +150 | °C |

## ELECTRICAL CHARACTERISTICS ($V_{CC} = 15V$, $V_{EE} = -15V$, $Ta = 25°C$, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Input Offset Voltage | $V_{IO}$ | $R_S \le 50K\Omega$ | | 1.0 | 7.5 | mV |
| | | NOTE 1 | | | 10 | |
| Input Offset Current | $I_{IO}$ | | | 6 | 50 | nA |
| | | NOTE 1 | | | 70 | |
| Input Bias Current | $I_{IB}$ | | | 100 | 250 | nA |
| | | NOTE 1 | | | 300 | |
| Voltage Gain | $A_V$ | | 40 | 200 | | V/mV |
| Response Time | $t_r$ | NOTE 2 | | 200 | | nS |
| Saturation Voltage | $V_{sat}$ | $I_O = 50mA$, $V_{IN} \le -10mV$ | | 0.75 | 1.5 | |
| | | $V_{CC} \ge 4.5V$, $V_{EE} = 0V$<br>$I_{sink} \le 8mA$, $V_{IN} \le -10mV$, NOTE 1 | | 0.23 | 0.4 | |
| Strove "ON" Current | $I_S$ | | | 3 | | mA |
| Output Leakage Current | $I_{leak}$ | $I_{strobe} = 3mA$, $V_{IN} \ge 10mV$<br>$V_O = 35V$, $V_{EE} = V_{GND} = -5V$ | | 0.2 | 50 | nA |
| Input Voltage Range | $V_{ICR}$ | NOTE 1 | −14.5 to 13.0 | −14.7 to 13.8 | | V |
| Positive Supply Current | $I_{CC}$ | | | 3.0 | 7.5 | mA |
| Negative Supply Current | $I_{EE}$ | | | −2.2 | −5.0 | mA |
| Strobe Current | $I_{strobe}$ | | | 3 | | mA |

NOTE 1. $0 \ge Ta \ge +70°C$

2. The response time specified is for a 100mV input step with 5mV over drive.

## TYPICAL PERFORMANCE CHARACTERISTICS

Fig. 1 INPUT BIAS CURRENT

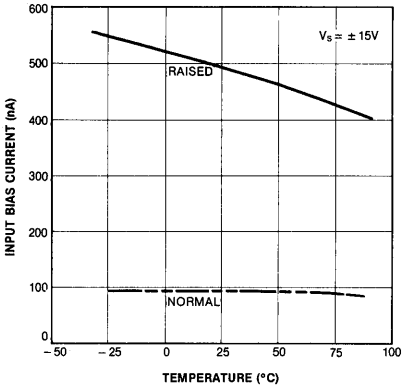


Fig. 2 INPUT OFFSET CURRENT

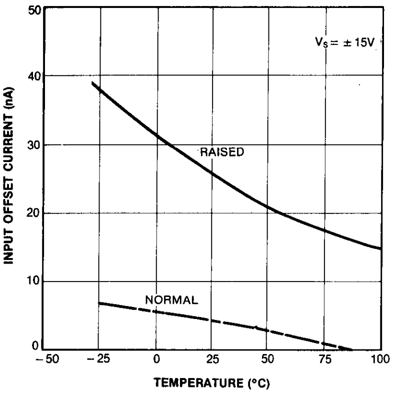


Fig. 3 OFFSET VOLTAGE VS INPUT RESISTANCE

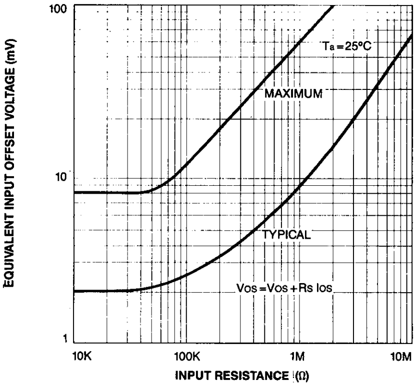


Fig. 4 INPUT BIAS CURRENT VS DIFFERENTIAL

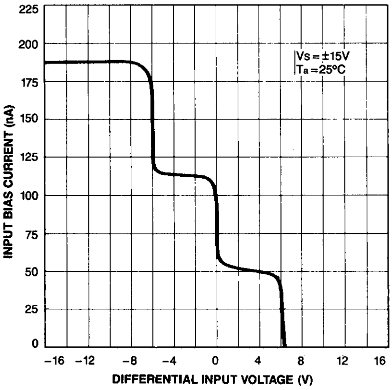


Fig. 5 COMMON MODE LIMITS VS TEMPERATURE

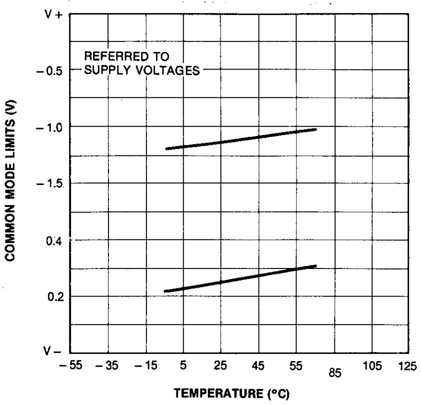


Fig. 6 OUTPUT VOLTAGE VS DIFFERENTIAL

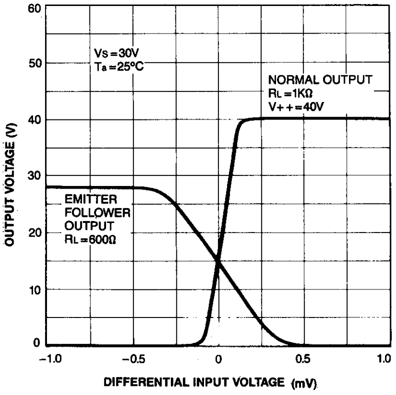


Fig. 7 SATURATION VOLTAGE VS CURRENT

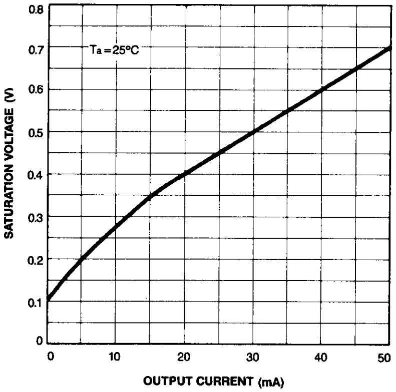


Fig. 8 SUPPLY CURRENT VS TEMPERATURE

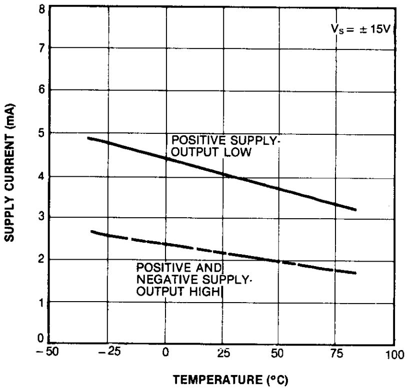


Fig. 9 LEAKAGE CURRENTS VS TEMPERATURE

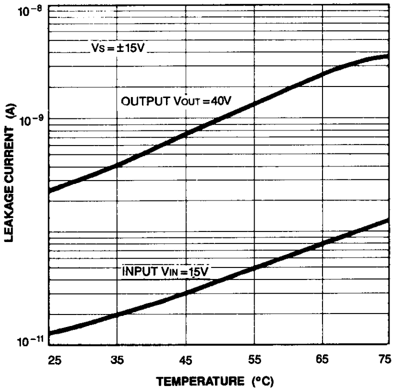


Fig. 10 SUPPLY CURRENT VS SUPPLY VOLTAGE

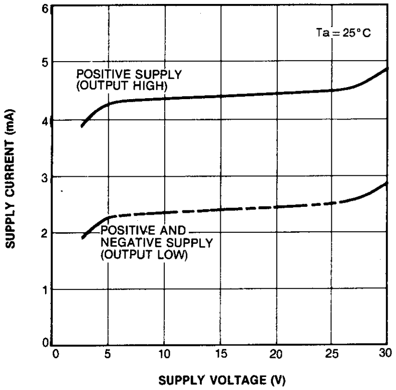


Fig. 11 OUTPUT SATURATION VOLTAGE

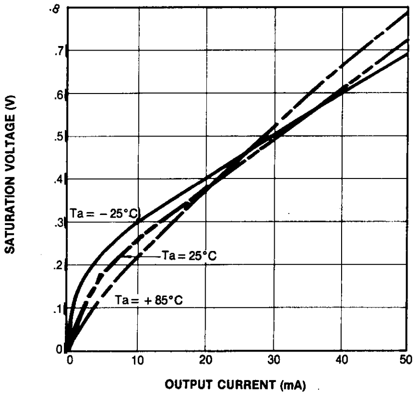
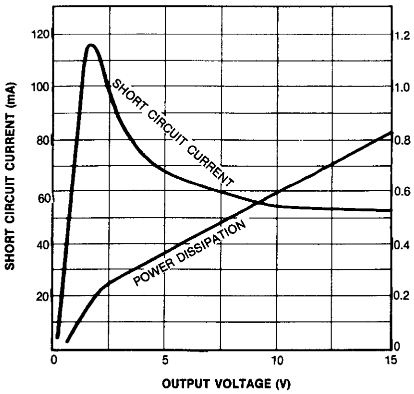
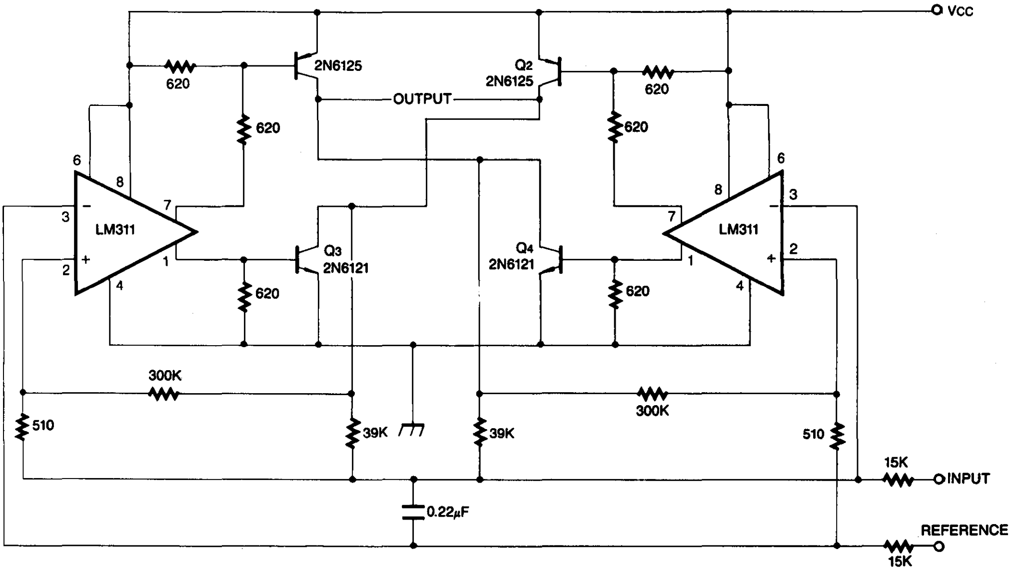


Fig. 12 OUTPUT LIMITING CHARACTERISTICS

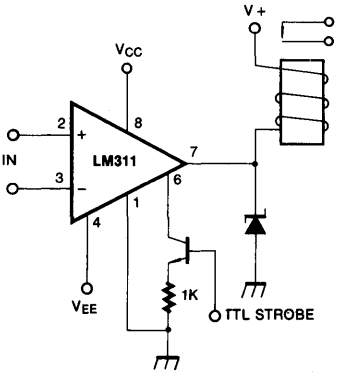


## TYPICAL APPLICATIONS

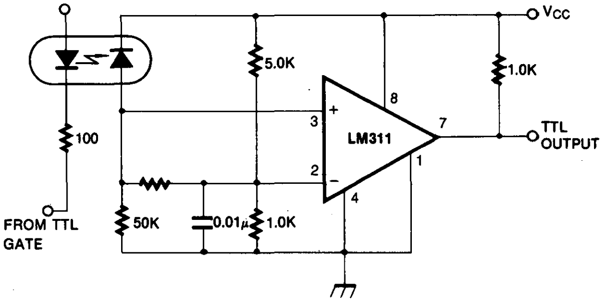
### Fig. 1 Switching Power Amplifier



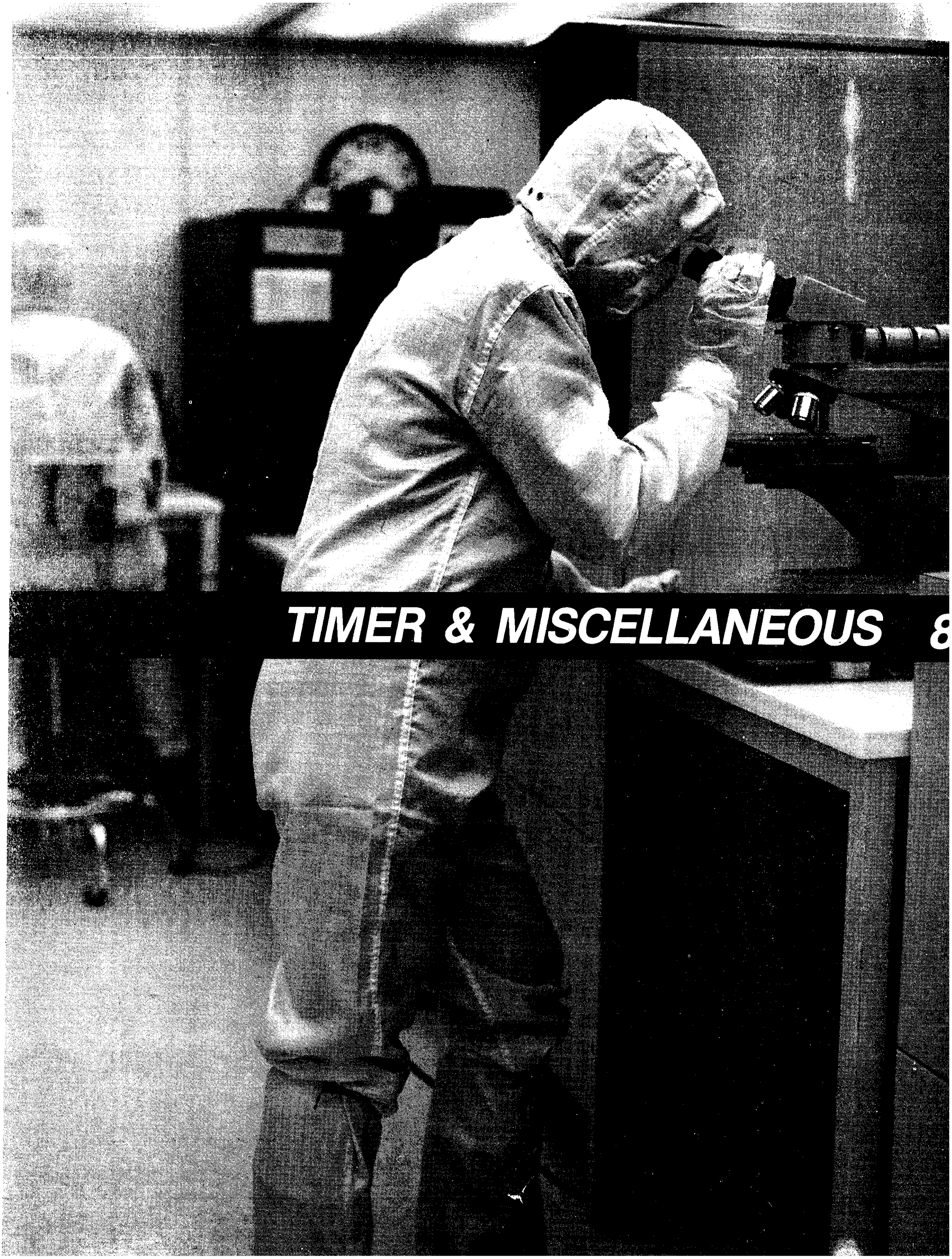
### Fig. 2 Relay Driver with Strobe

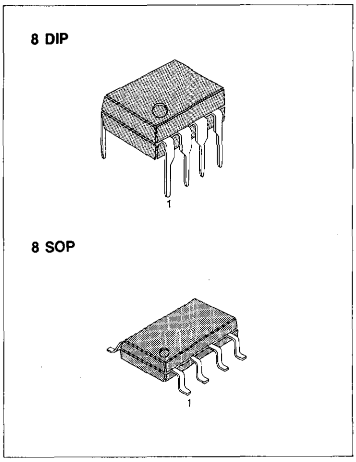


### Fig. 3 Digital Transmission Isolator



# TIMER & MISCELLANEOUS 8





## SINGLE TIMER

The NE555 series are a monolithic integrated circuit and high stable device for generating accurate time delay or oscillation. The NE555I is characterized for operation from −40°C to +85°C, and the NE555C from 0°C to 70°C.

## FEATURES

- **Turn off time less than 2μs**
- **Maximum operating frequency greater than 500KHz**
- **Timing from microseconds to hours**
- **Operates in both astable and monostable modes**
- **High output current**
- **Adjustable duty cycle**
- **Temperature stability of 0.005% per °C**

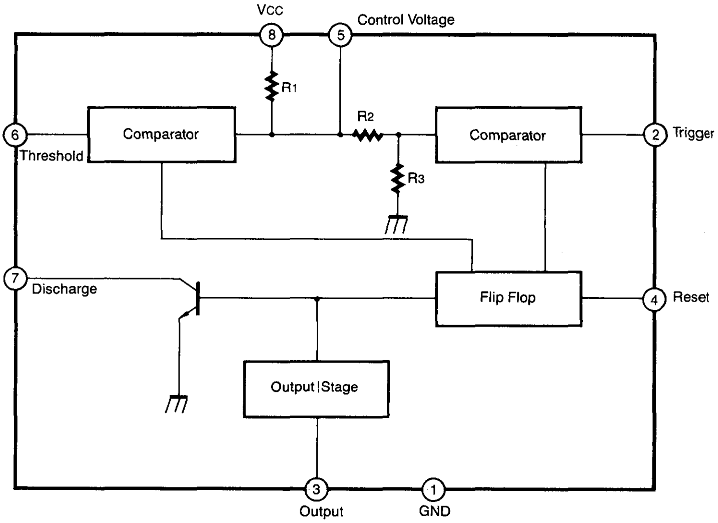
## APPLICATIONS

- Precision timing
- Time delay generation
- Pulse generation
- Pulse position modulation
- Sequential timing
- Missing pulse detector

## ORDERING INFORMATION

| Device | Package | Operating Temperature |
|---|---|---|
| NE555CN | 8 DIP | 0~ +70°C |
| NE555CD | 8 SOP | |
| NE555IN | 8 DIP | -40~ +85°C |
| NE555ID | 8 SOP | |

## BLOCK DIAGRAM



## ABSOLUTE MAXIMUM RATINGS (Ta = 25°C)

| Characteristic | Symbol | Value | Unit |
|---|---|---|---|
| Supply Voltage | $V_{CC}$ | 16 | V |
| Lead Temperature (soldering 10 sec) | $T_{lead}$ | 300 | °C |
| Power Dissipation | $P_D$ | 600 | mW |
| Operating Temperature Range NE555C | $T_{opr}$ | 0 ~ +70 | °C |
| NE555I | | −40 ~ +85 | °C |
| Storage Temperature Range | $T_{stg}$ | −65 ~ +150 | °C |

## ELECTRICAL CHARACTERISTICS

($T_a$ = 25°C, $V_{CC}$ = 5 ~ 15V, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Supply Voltage | $V_{CC}$ | | 4.5 | | 16 | V |
| Supply Current<br>*[1](low stable) | $I_{CC}$ | $V_{CC}$ = 5V, $R_L$ = ∞ | | 3 | 6 | mA |
| | | $V_{CC}$ = 15V, $R_L$ = ∞ | | 10 | 15 | mA |
| *Timing Error<br>(Monsotable) | | | | | | |
| [2]Initial Accurary | $MT_1$ | $R_A$ = 1KΩ to | | 1.0 | 3.0 | % |
| Drift with Temperature | | 100KΩ | | 50 | | ppm/°C |
| Drift with Supply Voltage | | C = 0.1μF | | 0.1 | 0.5 | %/V |
| *Timing Error | | | | | | |
| (astable) | | $R_A$ = 1K to | | | | |
| [2]Initial Accurary | $MT_2$ | 100KΩ | | 2.25 | | % |
| Drift with Temperature | | C = 0.1μF | | 150 | | ppm/°C |
| Drift with Supply Voltage | | | | 0.3 | | %/V |
| Control Voltage | $V_C$ | $V_{CC}$ = 15V | 9.0 | 10.0 | 11.0 | V |
| | | $V_{CC}$ = 5V | 2.6 | 3.33 | 4.0 | V |
| Threshold Voltage | $V_{TH}$ | $V_{CC}$ = 15V | | 10.0 | | V |
| | | $V_{CC}$ = 5V | | 3.33 | | V |
| *[3]Threshold Current | $I_{TH}$ | | | 0.1 | 0.25 | μA |
| Trigger Voltage | $V_{TR}$ | $V_{CC}$ = 5 | 1.1 | 1.67 | 2.2 | V |
| Trigger Voltage | $V_{TR}$ | $V_{CC}$ = 15V | 4.5 | 5 | 5.6 | V |
| Trigger Current | $I_{TR}$ | $V_T$ = 0V | | 0.5 | 2.0 | μA |
| Reset Voltage | $V_{RE}$ | | 0.4 | 0.7 | 1.0 | V |
| Reset Current | $I_{RE}$ | | | 0.1 | 0.4 | mA |

## ELECTRICAL CHARACTERISTICS

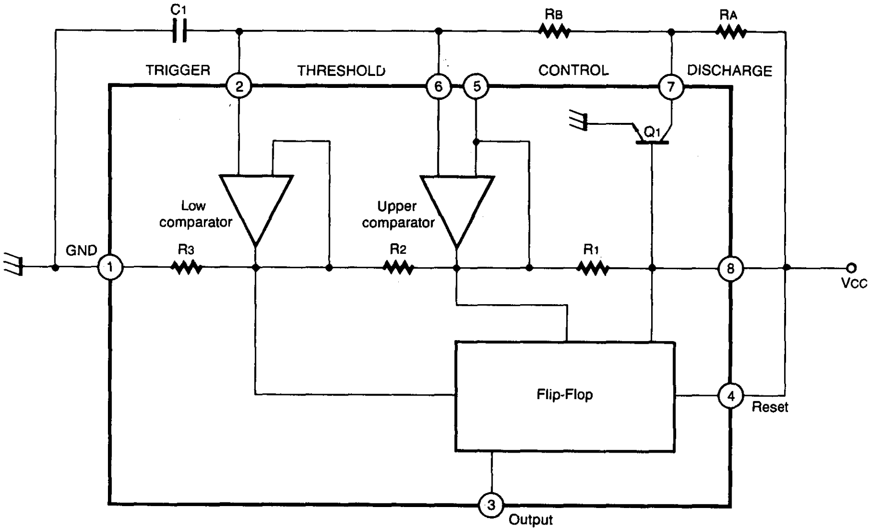
($T_a$=25°C, $V_{CC}$=5~15V, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Output Voltage (low) | $V_{OL}$ | $V_{CC}$=15V<br>$I_{sink}$=10mA | | 0.1 | 0.25 | V |
| | | $I_{sink}$=50mA | | 0.4 | 0.75 | V |
| | | $V_{CC}$= 5V<br>$I_{sink}$=5mA | | 0.25 | 0.35 | V |
| Output Voltage (high) | $V_{OH}$ | $V_{CC}$=15V<br>$I_{source}$=200mA | | 12.5 | | V |
| | | $I_{source}$=100mA | 12.75 | 13.3 | | V |
| | | $V_{CC}$=5V<br>$I_{source}$=100mA | 2.75 | 3.3 | | V |
| Rise Time of Output | $T_r$ | | | 100 | | nsec |
| Fall Time of Output | $T_f$ | | | 100 | | nsec |
| Discharge Leakage Current | $I_D$ | | | 20 | 100 | nA |

Notes:

1. Supply current when output is high is typically 1mA less at $V_{CC}$=5V.
2. Tested at $V_{CC}$=5.0V and $V_{CC}$=15V
3. This will determine the maximum value of $R_A+R_B$ for 15V operation, the max total R=20MΩ, and for 5V operation the max total R=6.7MΩ.

## APPLICATION CIRCUIT



## APPLICATION NOTE

The application circuit shows astable mode.
Pin 6 (threshold) is tied to Pin 2 (trigger) and Pin 4 (reset) is tied to $V_{CC}$ (Pin 8).
The external capacitor $C_1$ of Pin 6 and Pin 2 charges through $R_A$, $R_B$ and discharges through $R_B$ only.
In the internal circuit of the NE555 one input of the upper comparator is the 2/3 $V_{CC}$ ($*R_1 = R_2 = R_3$), another input if it is connected Pin 6..
As soon as charging $C_1$ is higher than 2/3 $V_{CC}$, discharge transistor $Q_1$ turns on and $C_1$ discharges to collector of transistor $Q_1$.
Therefore, the flip-flop circuit is reset and output is low.
One input of lower comparator is the 1/3 $V_{CC}$, discharge transistor $Q_1$ turn off and $C_1$ charges through $R_A$ and $R_B$.
Therefore, the flip-flop circuit is set and output is high.
**So to say, when $C_1$ charges through $R_A$ and $R_B$ output is high and when $C_1$ discharges through $R_b$ output is low**
**The charge time (output is high) $T_1$ is 0.693 $(R_A+R_B)$ $C_1$ and the discharge time (output is low) $T_2$ is 0.693 $(R_B C_1)$.**

$$(l_n \frac{V_{CC}-1/3V_{CC}}{V_{CC}-2/3V_{CC}} = 0.693)$$

**Thus the total period time T is given by**
**$T=T_1+T_2=0.693\,(R_A+2R_B).C_1$.**
**Then the frequency of astable mode is given by**

$$f=\frac{1}{T}=\frac{1.44}{(R_A+2R_B)C_1}$$

**The duty cycle is given by**

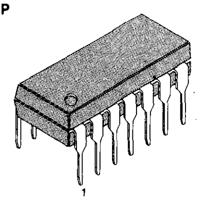
$$D.C=\frac{T_2}{T}=\frac{R_B}{R_A+2R_B}$$

If you make use of the NE556 you can make two astable modes.
***If you want another application note, request information on our timer IC application circuit designer.***

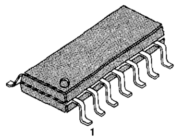
## DUAL TIMER

The NE556 series dual monolithic timing circuits are highly stable controllers capable of producing accurate time delays or oscillation.
The NE556 is a dual NE555. Timing is provided by an external resistor and capacitor for each timing function.
The two timers operate independently of each other, sharing only $V_{CC}$ and ground.
The circuits may be triggered and reset on falling waveforms. The output structures may sink or source 200 mA.
The NE556I is characterized for operation from −40°C to +85°C, and the NE556C from 0°C to 70°C.

14 DIP



14 SOP



## FEATURES

- **Direct replacement for NE556**
- **Replaces two NE555 timers**
- **Operates in both astable and monostable modes**
- **High output current**
- **TTL compatible**
- **Timing from microsecond to hours**
- **Adjustable duty cycle**
- **Temperature stability of 0.005% per °C**

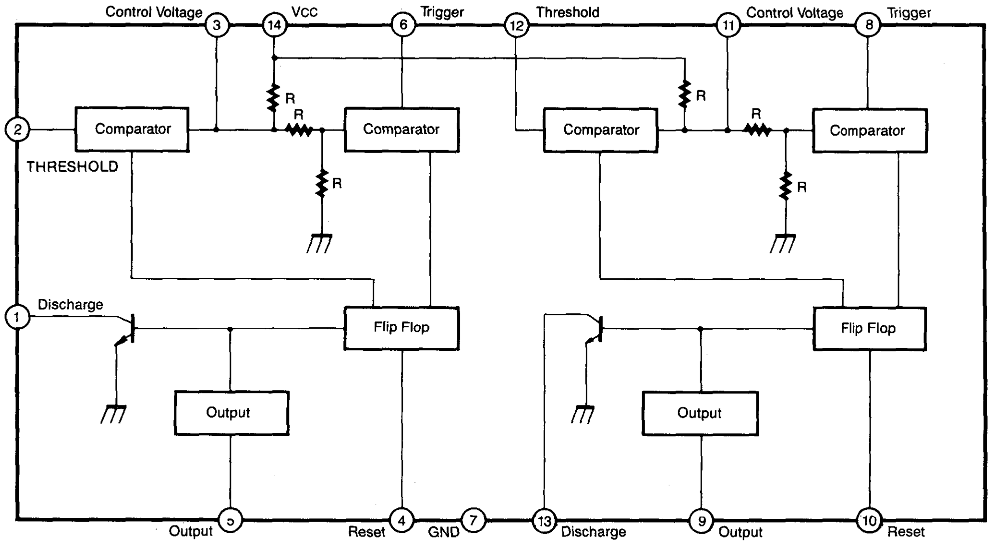
## APPLICATIONS

- Precision timing
- Pulse shaping
- Pulse width modulation
- Frequency division
- Traffic light control
- Sequential timing
- Pulse generator
- Time delay generator
- Touch tone encoder
- Tone burst generator

## ORDERING INFORMATION

| Device | Package | Operating Temperature |
|---|---|---|
| NE556CN | 14 DIP | 0 ~ +70°C |
| NE556CD | 14 SOP | |
| NE556IN | 14 DIP | -40 ~ +85°C |
| NE556ID | 14 SOP | |

## BLOCK DIAGRAM



## ABSOLUTE MAXIMUM RATINGS (Ta = 25°C)

| Characteristic | Symbol | Value | Unit |
|---|---|---|---|
| Supply Voltage | $V_{CC}$ | 16 | V |
| Lead Temperature (soldering 10 sec) | $T_{lead}$ | 300 | °C |
| Power Dissipation | $P_D$ | 600 | mW |
| Operating Temperature Range NE556C | $T_{opr}$ | 0 ~ +70 | °C |
| NE556I | | −40 ~ +85 | °C |
| Storage Temperature Range | $T_{stg}$ | −65 ~ +150 | °C |

## ELECTRICAL CHARACTERISTICS

($V_{CC}$ = +5V to +15V, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Supply Voltage | $V_{CC}$ | | 4.5 | | 16 | V |
| *1 Supply Current (Two timers)<br>(low state) | $I_{CC}$ | $V_{CC}$ = 5V, $R_L = \infty$<br>$V_{CC}$ = 15V, $R_L = \infty$ | | 5<br>16 | 12<br>30 | mA<br>mA |
| *2 Timing Error (monostable)<br>Initial Accuracy<br>Drift with Temperature<br>Drift with Supply Voltage | $MT_1$ | $R_A$ = 2KΩ to 100KΩ<br>C = 0.1μF<br>T = 1.1$R_C$ | | <br>0.75<br>50<br>0.1 | | <br>%<br>ppm/°C<br>%/V |
| Control Voltage | $V_C$ | $V_{CC}$ = 15V | 9.0 | 10.0 | 11.0 | V |
| | | $V_{CC}$ = 5V | 2.6 | 3.33 | 4.0 | V |
| Threshold Voltage | $V_{TH}$ | $V_{CC}$ = 15V | | 10.0 | | V |
| | | $V_{CC}$ = 5V | | 3.33 | | V |
| *3 Threshold Current | $I_{TH}$ | | | 30 | 250 | nA |
| Trigger Voltage | $V_{TR}$ | $V_{CC}$ = 15V | 4.5 | 5.0 | 5.6 | V |
| | | $V_{CC}$ = 5V | 1.1 | 1.67 | 2.2 | V |
| Trigger Current | $I_{TR}$ | $V_T$ = 0V | | 0.5 | 2.0 | μA |
| *5 Reset Voltage | $V_{RE}$ | | 0.4 | 0.7 | 1.0 | V |
| Reset Current | $I_{RE}$ | | | 0.1 | 0.6 | mA |
| Output Voltage Low | $V_{OL}$ | $V_{CC}$ = 15V | | | | |
| | | $I_{sink}$ = 10mA | | 0.1 | 0.25 | V |
| | | $I_{sink}$ = 50mA | | 0.4 | 0.75 | V |
| | | $I_{sink}$ = 100mA | | 2.0 | 3.2 | V |
| | | $I_{sink}$ = 200mA | | 2.5 | | V |
| | | $V_{CC}$ = 5V | | | | |
| | | $I_{sink}$ = 8mA | | 0.25 | 0.3 | V |
| | | $I_{sink}$ = 5mA | | 0.15 | 0.25 | V |

## ELECTRICAL CHARACTERISTICS

($V_{CC}$=+5V to +15V, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Output Voltage (high) | $V_{OH}$ | $V_{CC}$=15V | | | | |
| | | $I_{source}$=200mA | | 12.5 | | V |
| | | $I_{source}$=100mA | 12.75 | 13.3 | | V |
| | | $V_{CC}$=5V | | | | |
| | | $I_{source}$=100mA | 2.75 | 3.3 | | V |
| Rise Time of Output | $T_r$ | | | 100 | 300 | nsec |
| Fall Time of Output | $T_f$ | | | 100 | 300 | nsec |
| Discharge Leakage Current | $I_D$ | | | 20 | 100 | nA |
| *4 Matching Characteristics | | | | | | |
| Initial Accuracy | $M_{CH}$ | | | 1.0 | 2.0 | % |
| Drift with Temperature | | | | 10 | | ppm/°C |
| Drift with Supply Voltage | | | | 0.2 | 0.5 | %/V |
| *2 Timing Error (astable) | | $R_A$, $R_B$=1kΩ to 100kΩ | | | | |
| Initial Accuracy | $MT_2$ | C=0.1µF | | 2.25 | | % |
| Drift with Temperature | | $V_{CC}$=15V | | 150 | | ppm/°C |
| Drift with Supply Voltage | | | | 0.3 | | %/V |

Notes:

*1. Supply current when output is high is typically 1.0mA less at $V_{CC}$=5V.

*2. Tested at $V_{CC}$=5V and $V_{CC}$=15V

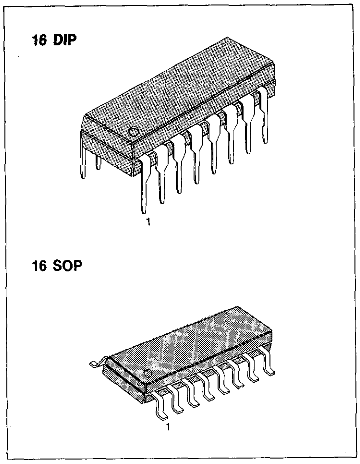
*3. This will determine the maximum value of $R_A+R_B$ for 15V operation.
The maximum total R=20MΩ, and for 5V operation the maximum total R=6.6MΩ.

*4. Matching characteristics refer to the difference between performance characteristics of each timer section in the monostable mode.

*5. As reset voltage lowers, timing is inhibited and then the output goes low.

## QUAD TIMER

The NE558 series are monolithic Quad Timers which can be used to produce four entirely independent timing functions. These highly stable, general purpose controllers can be used in a monostable mode to produce accurate time delays, from microseconds to hours. The time is precisely controlled by one external resistor and one capacitor in the time delay mode. A stable mode can be operated by using two of four time sections. The NE558I is characterized for operation from −40°C to +85°C, and the NE558C from 0°C to 70°C.



## FEATURES

- **Wide supply voltage range: 4.5V to 16V**
- **100mA output current per section**
- **Edge triggered without coupling capacitor**
- **Time period equals RC**
- **Output independent of trigger conditions.**

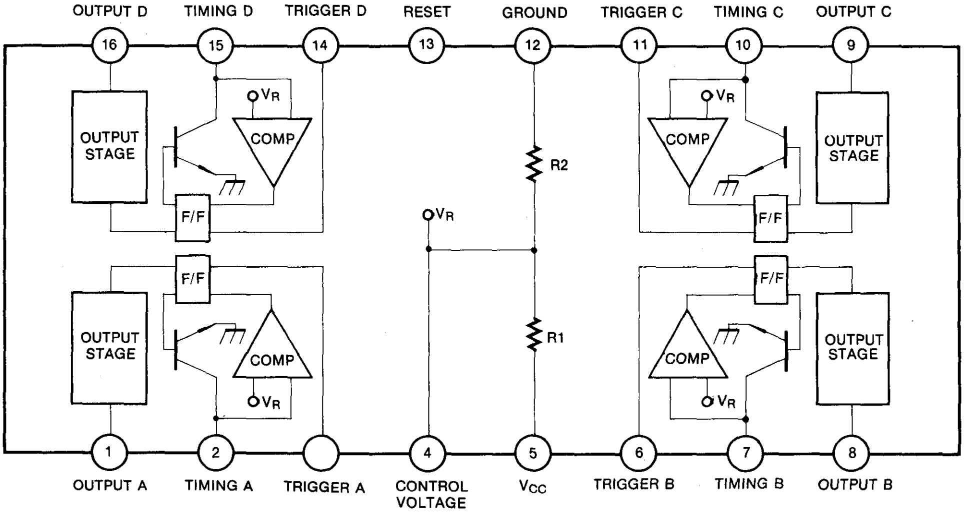
## APPLICATIONS

- Quad one-shot
- Sequential timing
- Precision timing
- **Time delay generation**

## ORDERING INFORMATION

| Device | Package | Operating Temperature |
|---|---|---|
| NE558CN | 16 DIP | 0~ +70°C |
| NE558CD | 16 SOP | |
| NE558IN | 16 DIP | −40~ +85°C |

## BLOCK DIAGRAM



## ABSOLUTE MAXIMUM RATINGS (Ta = 25°C)

| Characteristic | Symbol | Value | Unit |
|---|---|---|---|
| Supply Voltage | $V_{CC}$ | 16 | V |
| Lead Temperature (soldering 10 sec) | $T_{lead}$ | 300 | °C |
| Power Dissipation | $P_D$ | 600 | mW |
| Operating Temperature Range NE556C | $T_{opr}$ | 0 ~ +70 | °C |
| NE556I | | −40 ~ +85 | °C |
| Storage Temperature Range | $T_{stg}$ | −65 ~ +150 | °C |

## ELECTRICAL CHARACTERISTICS

($V_{CC}$ = 5V ~ 15V, Ta = 25°C unless otherwise specified)

| Characteristic | Symbol | Test Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Timing Error (T = RC)<br>Initial Accuracy | $M_T$ | R = 2KΩ to 100KΩ, C = 1μF | | ±2 | 5 | % |
| Drift with Temperature | | | | 30 | 150 | PPM/°C |
| Drift with Supply Voltage | | | | 0.1 | 0.9 | %/V |
| Supply Voltage | $V_{CC}$ | | 4.5 | | 16 | V |
| Supply Current | $I_{CC}$ | $V_{CC}$ = 15V, reset voltage = 15V | | 16 | 36 | mA |
| [1]Trigger Voltage | $V_{TR}$ | $V_{CC}$ = 15V | 0.8 | 1.5 | 2.4 | V |
| [1]Trigger Current | $I_{TR}$ | Trigger voltage = 0V | | 5.0 | 100 | μA |
| [2]Reset Voltage | $V_{RE}$ | Reset | 0.8 | 1.5 | 2.4 | V |
| [2]Reset Current | $I_{RE}$ | Reset | | 50 | 500 | μA |
| Threshold Voltage | $V_{TH}$ | | | 0.63 × $V_{CC}$ | | V |
| Threshold Current | $I_{TL}$ | | | 15 | | nA |
| [3]Output Voltage | $V_{OUT}$ | $I_L$ = 10mA | | 0.1 | 0.4 | V |
| | | $I_L$ = 100mA | | 1.0 | 2.0 | |
| Output Leakage Current | $I_{OL}$ | | | 10 | 500 | nA |
| Propagation Delay Time | $T_P$ | | | 1.0 | | μS |
| Rise Time | $T_r$ | $I_L$ = 100mA | | 100 | | nS |
| Fall Time | $T_f$ | $I_L$ = 100mA | | 100 | | nS |

NOTES:
1. The trigger functions only on the falling edge of the trigger pulse only after previously being high. After reset the trigger must be brought high and then low to implement triggering.
2. For reset below 0.8V, outputs set low and trigger inhibited.
3. Output structure is open collector which requires a pull up resistor to $V_{CC}$ to sink current. The output is nomally low sinking current.

## APPLICATIONS

**Fig. 1 Long-Time Delay**

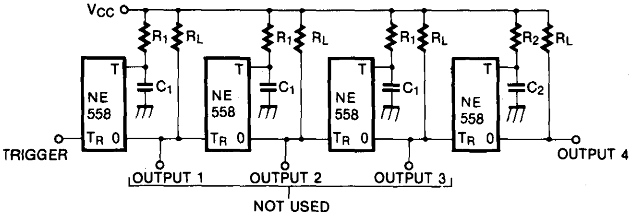


**Fig. 2 Timing Chart**

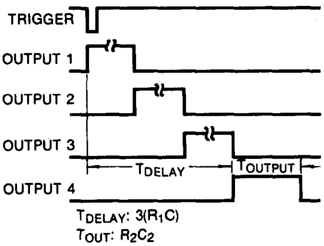


**Fig. 3 Ring Counter**

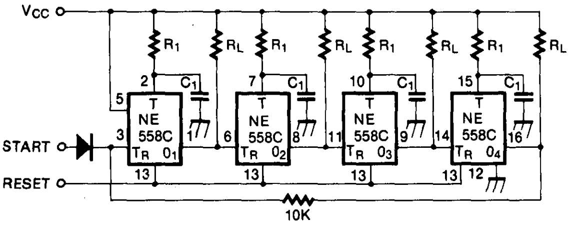
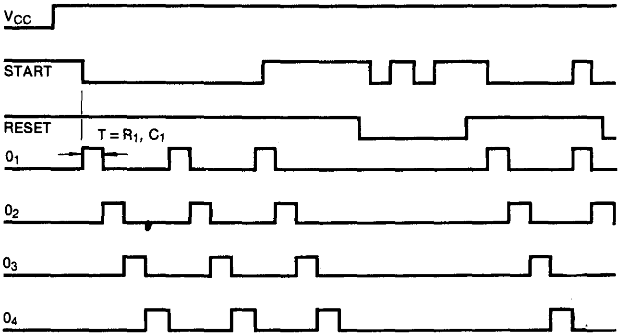


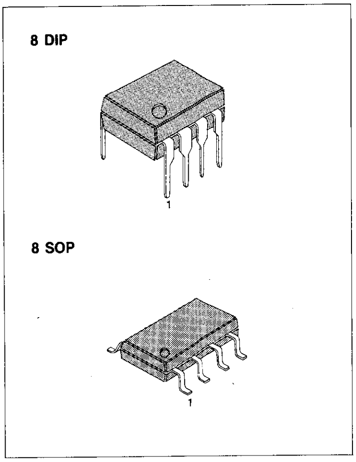
**Fig. 4 Timing Chart**



## CMOS SINGLE TIMER

The KS555 is a CMOS timer with improved performance over a standard bipolar one. Due to its high-impedance inputs, it is capable of producing accurate time delays and oscillations with less expensive (smaller) timing capacitors than a standard bipolar timer.

Its dramatic advantages over bipolar ones are very low power consumption and wide operating voltage range especially during stable low voltage operations.



## FEATURES

- **Low power consumption**
- **Pin to pin operation with bipolar timer in most cases**
- **Extremely low trigger, threshold, and reset pin current**
- **High-speed operation (500KHz)**
- **Stable low voltage operation (possible 1.5V operation with most samples)**
- **Wide operating voltage range: 2 to 18V**
- **High output source/sink driver meet TTL/CMOS**
- **Immunized to static charge with inner protection devices**

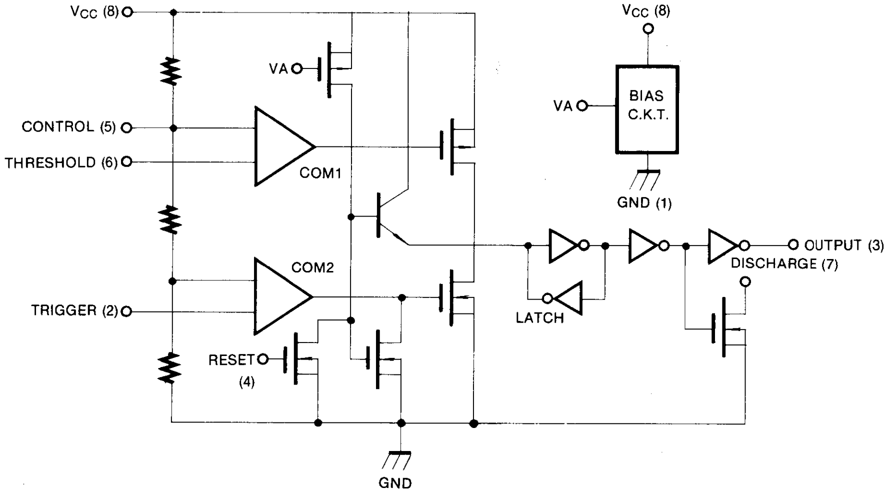
## APPLICATIONS

- Precision Timing
- Pulse Generation
- Sequential Timing
- Time Delay Generation
- Pulse Width Modulation
- Pulse Position Modulation
- Missing Pulse Detector

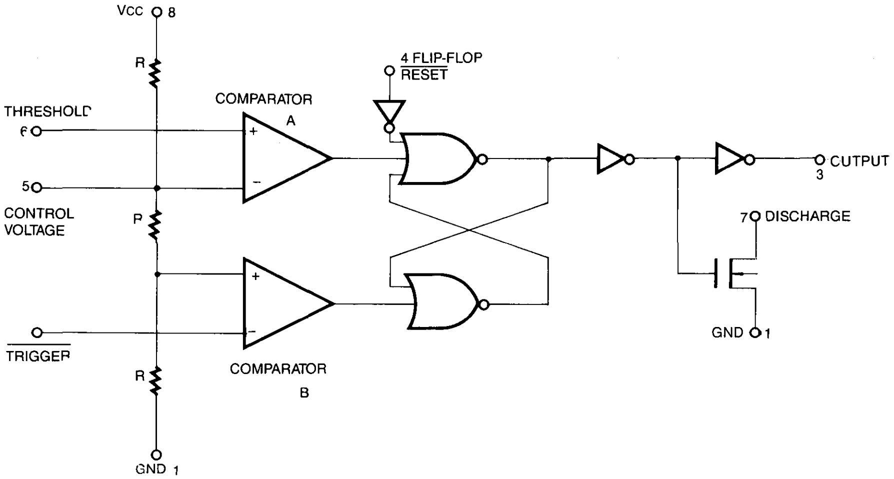
## ORDERING INFORMATION

| Device | Package | Operating Temperature |
|---|---|---|
| KS555N | 8 DIP | − 20 ~ + 85°C |
| KS555D | 8 SOP | |

## SCHEMATIC DIAGRAM



## BLOCK DIAGRAM



This block diagram reduces the circuitry down to its simplest equivalent components. Tie down unused inputs. R = 100KΩ ± 20% Typ.

## TRUTH TABLE

| Threshold Voltage | Trigger Voltage | Reset | Output | Discharge Switch |
|---|---|---|---|---|
| Don't Care | Don't Care | Low | Low | On |
| > 2/3 ($V_{CC}$) | > 1/3 ($V_{CC}$) | High | Low | On |
| < 1/3($V_{CC}$) ~ 2/3($V_{CC}$) | > 1/3($V_{CC}$) ~ 2/3($V_{CC}$) | High | Stable | Stable |
| Don't Care | < 1/3 ($V_{CC}$) | High | High | Off |

Note: $\overline{\text{RESET}}$ will dominate all other input.$\overline{\text{TRIGGER}}$ will dominate over THRESHOLD.

## ABSOLUTE MAXIMUM RATINGS (Note 1)

| Characteristic | Symbol | Value | Unit |
|---|---|---|---|
| Supply Voltage | $V_{CC}$ | 18 | V |
| Input Volage<br>(Trigger, Control Voltage,<br>Threshold and Reset) | $V_{IN}$ | − 0.3 $V_{CC}$ + 0.3 | V |
| Power Dissipation | $P_D$ | 200 | mW |
| Operating Temperature Range | $T_{opr}$ | − 20 ~ + 85 | °C |
| Storage Temperature Range | $T_{stg}$ | − 65 ~ + 150 | °C |

Note 1: Stresses above those listed under absolute maximum rating may cause permanent damage to the device.

## ELECTRICAL CHARACTERISTICS

($T_a$ = 25°C, $V_{CC}$ = 2 to 15V, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Supply Voltage Range | $V_{CC}$ | −20°C < $T_a$ < +70°C | 2 | | 18 | V |
| Supply Current | $I_{CC}$ | $V_{CC}$ = 2V | | 30 | | μA |
| | | $V_{CC}$ = 18V | | 60 | | μA |
| Timing Error<br>Initial Accuracy | MT | $R_a$ = $R_b$ = 1KΩ to 100KΩ<br>C = 0.1μF,<br>5V ≤ $V_{CC}$ ≤ 15V | | 2.0 | 10.0 | % |
| Drift With Temperature | | $V_{CC}$ = 5V | | 50 | | ppm/°C |
| | | $V_{CC}$ = 10V | | 75 | | ppm/°C |
| | | $V_{CC}$ = 15V | | 100 | | ppm/°C |
| Drift With Supply Voltage | | $V_{CC}$ = 5V | | 1.0 | 3.0 | %/V |
| Threshold Voltage | $V_{TH}$ | $V_{CC}$ = 5V | | 0.66 | | $V_{CC}$ |
| Trigger Voltage | $V_{TR}$ | $V_{CC}$ = 5V | | 0.33 | | $V_{CC}$ |
| Trigger Current | $I_{TR}$ | $V_{CC}$ = 18V | | 50 | | pA |
| | | $V_{CC}$ = 5V | | 10 | | pA |
| | | $V_{CC}$ = 2V | | 1 | | pA |
| Threshold Current | $I_{TH}$ | $V_{CC}$ = 18V | | 50 | | pA |
| | | $V_{CC}$ = 5V | | 10 | | pA |
| | | $V_{CC}$ = 2V | | 1 | | pA |
| Reset Current | $I_{RE}$ | $V_{RST}$ = GND $V_{CC}$ = 18V | | 100 | | pA |
| | | $V_{RST}$ = GND $V_{CC}$ = 5V | | 20 | | pA |
| Reset Voltage | $V_{RE}$ | $V_{CC}$ = 18V | 0.4 | 0.7 | 1.0 | V |
| | | $V_{CC}$ = 2V | 0.4 | 0.7 | 1.0 | V |
| Control Voltage | $V_C$ | $V_{CC}$ = 5V | | 0.66 | | $V_{CC}$ |
| Output Voltage Drop | $V_{OL}$ | $V_{CC}$ = 18V, $I_{SINK}$ = 3.2mA | | 0.1 | 0.4 | V |
| | | $V_{CC}$ = 5V, $I_{SINK}$ = 3.2mA | | 0.15 | 0.4 | V |
| | $V_{OH}$ | $V_{CC}$ = 18V, $I_{source}$ = 1.0mA | 17.25 | 17.8 | | V |
| | | $V_{CC}$ = 5V, $I_{source}$ = 1.0mA | 4.0 | 4.5 | | V |
| Rise Time of Output | $T_r$ | $R_L$ = 10MΩ, $C_L$ = 10pF,<br>$V_{CC}$ = 5V | 35 | 40 | 75 | ns |
| Fall Time of Output | $T_f$ | | 35 | 40 | 75 | ns |
| Guaranteed Max Osc. Freq. | $F_{max}$ | Astable Operation | 500 | | | KHz |

# APPLICATION NOTES

## General Description

The KS555 is a CMOS timer and in most cases, may replace bipolar timers such as the NE555 or SE555. It is also possible to reduce component counts. Because the bipolar device can produce large crowbar currents in the output driver, it is necessary to decouple the power supply lines with a good capacitor close to the device. The KS555 device produces no such transients. (See Fig. 1).

The KS555 produces supply current spikes of only 2-3 mA instead of 300 mA to 400 mA and supply decoupling is normally not necessary. In most cases, the CONTROL VOLTAGE decoupling capacitors are required since the input impedance of the CMOS comparators on the chip are very high. Thus, for many applications 2 capacitors can be saved by using the KS555.

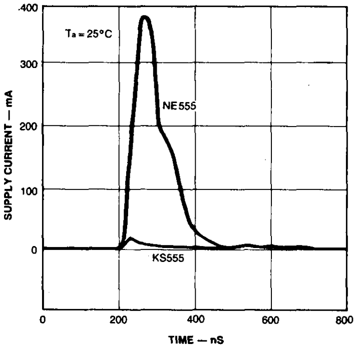


Fig 1. Supply current transient compared with a standard bipolar 555 during an output transition

## Astable Operation

The KS555 can free run as a multivibrator by triggering itself; refer to Fig. 2. The output can swing from $V_{CC}$ to GND and have 50% duty cycle square wave. Less than 1% frequency deviation can be observed, over a voltage range of 2 to 5 V. f = 1/1.4RC

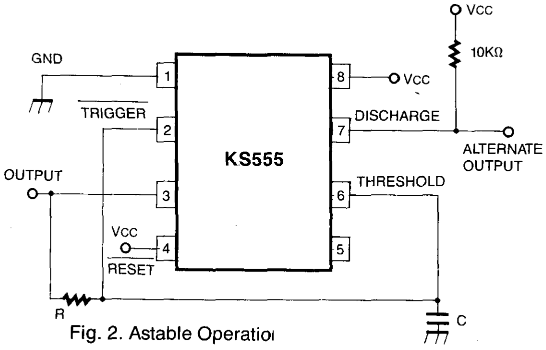


Fig. 2. Astable Operatio

## Monostable Operation

The KS555 can be used as a one-shot, i.e. monostable multivibrator. Initially, because the inside discharge transistor is on state, external timing capacitor is held to GND potential. Upon application of a negative TRIGGER pulse to pin 2, the internal discharge transistor is off state and the voltage across the capacitor increases with time constant t = RaC and OUTPUT goes to high state. When the voltage across the capacitor equals 2/3 $V_{CC}$ the inner comparator is reset by THRESHOLD input and the discharge transistor goes to on state, which in turn discharges the capacitor rapidly and also drives the OUTPUT to its low state.

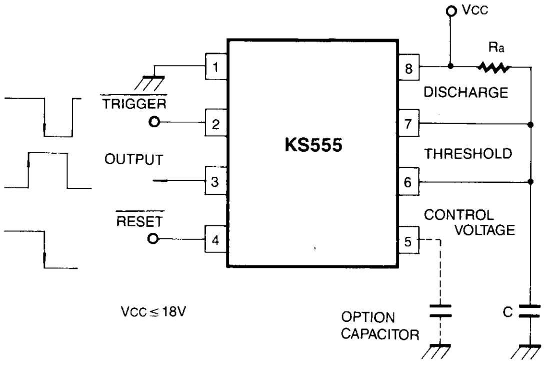
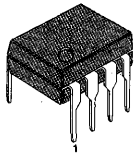


Fig. 3. Monostable Operation

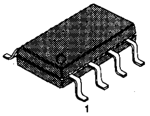
## CMOS SINGLE TIMER

The KS555H is a monolithic integrated circuit fabricated using CMOS process. Due to its high impedance inputs (threshold, trigger, reset), it is capable of producing accurate time delay and oscillation using a less expensive, smaller timing capacitors than the NE555.
Other features are very low power consumption and high-speed astable operation and very low voltage operation.

**8 DIP**



**8 SOP**



## FEATURES

- **Very low power consumption: 1.2mW**
- **Very high-speed operation: 2MHz**
- **Complementary CMOS output capable of switching rail-to-rail**
- **Output fully CMOS-, TTL-, and MOS- compatible**
- **Exactly equivalent in most cases to the NE555 or 556 (dual timer) or the 355**
- **Very convenient reset function**
- **Timing from microseconds through hours**
- **Operates in both astable and monostable modes**
- **Adjustable duty cycle**
- **Highly immuned to static charge**

## ORDERING INFORMATION

| Device | Package | Operating Temperature |
|---|---|---|
| KS555HN | 8 DIP | 0 ~ +70°C |
| KS555HD | 8 SOP | |
| **KS555HIN | 8 DIP | −25 ~ +85°C |
| **KS555HID | 8 SOP | |

** Under development

## APPLICATIONS

- Precision Timing
- Pulse Generation
- Sequential Timing
- Time Delay Generation
- Pulse Width Modulation
- Pulse Position Modulation
- Missing Pulse Detector

## BLOCK DIAGRAM

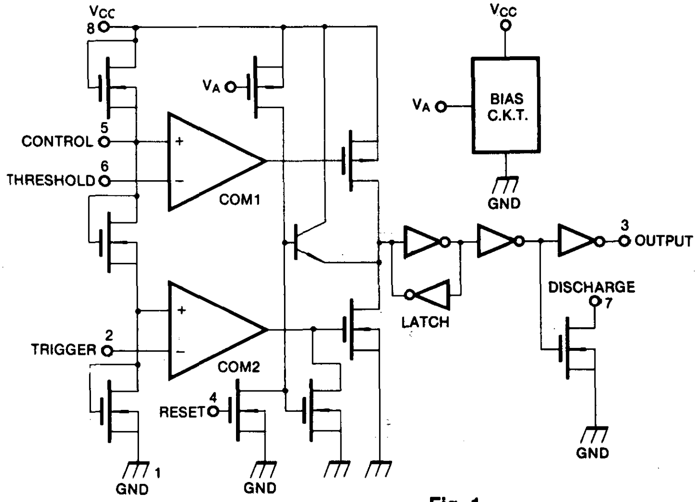


Fig. 1

## ABSOLUTE MAXIMUM RATINGS

| Characteristic | Symbol | Value | Unit |
|---|---|---|---|
| Supply Voltage | $V_{CC}$ | 18 | V |
| Input Voltage (Trigger, Reset, Threshold) | $V_{IN}$ | $-0.3 \sim V_{CC}$ | V |
| Lead Temperature (Soldering 10 sec) | $T_{lead}$ | 300 | °C |
| Power Dissipation | $P_D$ | 600 | mW |
| Operating Temperature Range | $T_{opr}$ | $0 \sim +70$ | °C |
| Storage Temperature Range | $T_{stg}$ | $-65 \sim +150$ | °C |

## ELECTRICAL CHARACTERISTICS

(Ta = 25°C, $V_{CC} = 5V$, refer to application circuit unless otherwise specified)

| Characteristic | Symbol | Test Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Supply Voltage | $V_{CC}$ | | 3 | | 18 | V |
| Supply Current | $I_{CC}$ | | | 140 | | μA |
| | | $V_{CC} = 15V$ | | 180 | | μA |
| Control Voltage | $V_C$ | | | 3.33 | | V |
| | | $V_{CC} = 15V$ | | 10 | | V |
| Threshold Voltage | $V_{TH}$ | | | 3.33 | | V |
| | | $V_{CC} = 15V$ | | 10 | | V |
| Threshold Current | $I_{TH}$ | $V_{CC} = 5V$ | | 50 | | PA |
| Trigger Voltage | $V_{TR}$ | | | 1.67 | | V |
| | | $V_{CC} = 15V$ | | 5 | | V |
| Trigger Current | $I_{TR}$ | | | 50 | | PA |
| Reset Voltage | $V_{RE}$ | | | 0.7 | 1 | V |
| Reset Current | $I_{RE}$ | | | 50 | | PA |
| Low Level Output Voltage | $V_{OL}$ | $I_{OL} = 5mA$ | | 0.1 | | V |
| | | $I_{OL} = 8mA$ | | 0.15 | | V |
| | | $V_{CC} = 15V$ $I_{OL} = 10mA$ | | 0.1 | | V |
| | | $I_{OL} = 50mA$ | | 0.5 | | V |
| | | $I_{OL} = 100mA$ | | 1 | | V |
| High Level Output Voltage | $V_{OH}$ | $I_{OH} = -1mA$ | | 4.5 | | V |
| | | $I_{OH} = -2mA$ | | 4 | | V |
| | | $V_{CC} = 15V$ $I_{OH} = -1mA$ | | 14.8 | | V |
| | | $I_{OH} = -5mA$ | | 14 | | V |
| | | $I_{OH} = -10mA$ | | 12.7 | | V |

## ELECTRICAL CHARACTERISTICS (Continued)

| Characteristic | Symbol | Test Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Initial Error of Timing Interval | $T_{EI}$ | $V_{CC} = 5$ to 15V, $R_A = R_B = 1$ to 100K<br>$C_T = 0.1\mu F$ | | 1 | | % |
| Timing Error Due to Supply Drift | $T_{ES}$ | | | 0.1 | | %/V |
| Rise Time of Output | $T_r$ | $R_l = 10M\Omega$, $C_l = 10pF$ | | 20 | | nS |
| Fall Time of Output | $T_f$ | | | 20 | | nS |
| Maximum Astable Oscillation | $F_{MAX}$ | $R_A = 470\Omega$, $R_B = 200\Omega$, $C_T = 200pF$ | | 2 | | MHz |

## APPLICATION CIRCUIT

### 1) ASTABLE

The circuit can be connected to trigger itself and free run as a mutivibrator. The external capacitor charges through $R_A$ and $R_B$ and discharges through $R_B$ only. Thus, the duty cycle may be precisely set by the raio of these two resistors. In this operation, mode the capacitor charges and discharges between 1/3 $V_{CC}$ and 2/3 $V_{CC}$. As in the trigger mode, the charging and discharging times, and therefore the frequency are essentially independently of the supply voltage.
The oscillation frequency is given by

$f = 1/T = 1.44/(R_A + 2 \times R_B)/C_T$

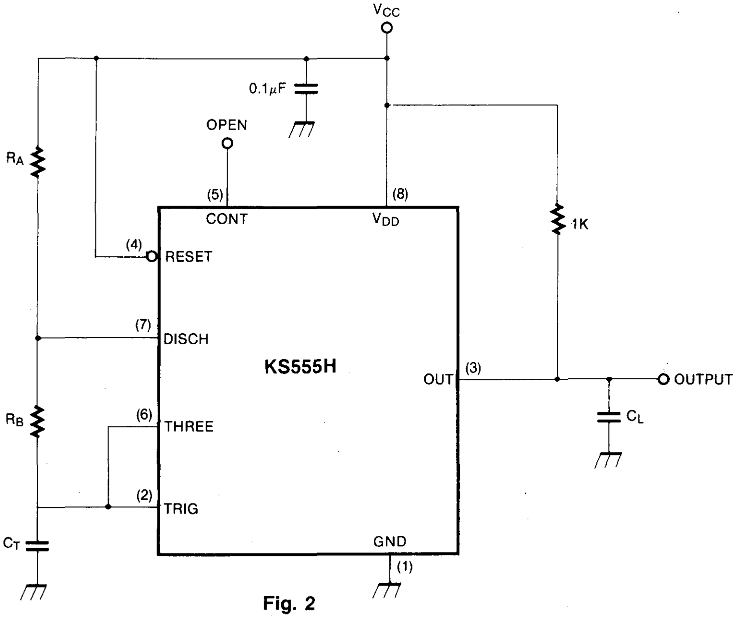


Fig. 2

## 2) MONOSTABLE

In this operation mode, the timer functions as one shot. Initially, the external capacitor C is held discharged by a transistor inside timer. Upon application of a negative trigger pulse to Pin 2, the flip flop is set which releases the short circuit across the external capacitor and drives and output high.

The voltage across the external capacitor now increases exponentially with a time constant $T = R_A \times C$. When the voltage across the external capacitor equals $2/3 \times V_{CC}$, the comparator resets the flip flop, which in turn discharges the capacitor rapidly and also drives the output to its state.

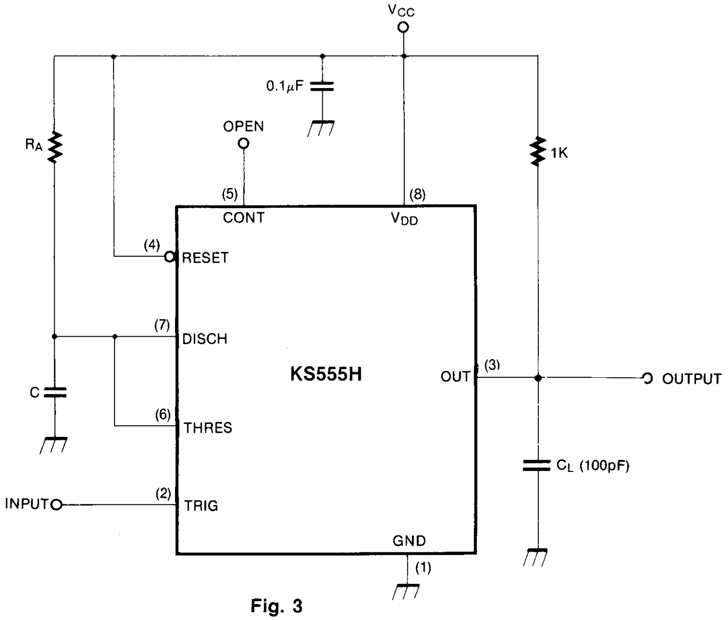
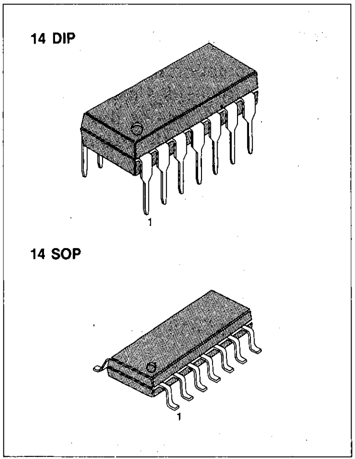


Fig. 3

## CMOS DUAL TIMER

The KS556 is a monolithic integrated circuit fabricated using CMOS process. Due to high impedance inputs (Trigger, Threshold, Reset), it is capable of producing accurate time delay using a less expensive, smaller timing capacitors than the NE556.
Other features are very low power consumption and high-speed astable operation and very low voltage operation.



## FEATURES

- **Very low power consumption: 2.4mW**
- **Very high-speed operation: 2MHz**
- **Output fully CMOS, TTL, and MOS compatible**
- **Timing from microseconds through hours**
- **Adjustable duty cycle**

## APPLICATIONS

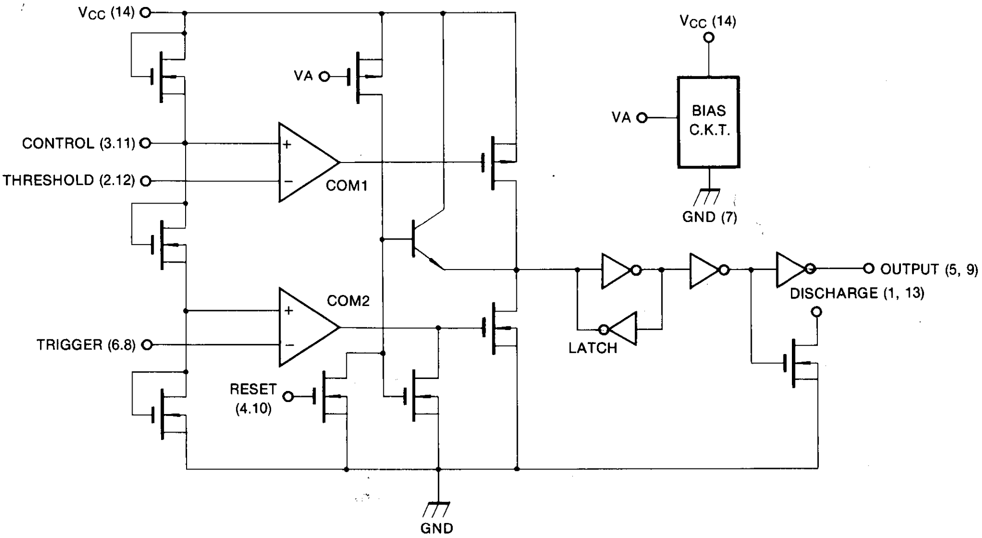
- Precision Timing
- Pulse Generation
- Sequential Timing
- Time Delay Generation
- Pulse Width Modulation

## ORDERING INFORMATION

| Device | Package | Operating Temperature |
|---|---|---|
| KS556N | 14 DIP | 0 ~ +70°C |
| KS556D | 14 SOP | |
| **KS556IN | 8 DIP | −25 ~ +85°C |
| **KS556ID | 8 SOP | |

** Under development

## BLOCK DIAGRAM



## ABSOLUTE MAXIMUM RATINGS (Ta = 25°C)

| Characteristic | Symbol | Value | Unit |
|---|---|---|---|
| Supply Voltage | $V_{CC}$ | 18 | V |
| Input Voltage (Trigger, Reset, Threshold) | $V_{IN}$ | $-0.3 \sim V_{CC}$ | V |
| Lead Temperature (Soldering 10 sec) | $T_{lead}$ | 300 | °C |
| Power Dissipation | $P_D$ | 600 | mW |
| Operating Temperature Range | $T_{opr}$ | $0 \sim +70$ | °C |
| Storage Temperature Range | $T_{stg}$ | $-65 \sim +150$ | °C |

## ELECTRICAL CHARACTERISTICS

(Ta = 25°C, $V_{CC}$ = 5V, refer to application circuit unless otherwise specified)

| Characteristic | Symbol | Test Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Supply Voltage | $V_{CC}$ | | 3 | | 18 | V |
| Supply Current | $I_{CC}$ | | | 240 | | μA |
| | | $V_{CC} = 15V$ | | 480 | | |
| Control Voltage | $V_C$ | | | 3.33 | | V |
| | | $V_{CC} = 15V$ | | 10 | | |
| Threshold Voltage | $V_{TH}$ | | | 3.33 | | V |
| | | $V_{CC} = 15V$ | | 10 | | |
| Threshold Current | $I_{TH}$ | | | 50 | | pA |
| Trigger Voltage | $V_{TR}$ | | | 1.67 | | V |
| | | $V_{CC} = 15V$ | | 5 | | |
| Trigger Current | $I_{TR}$ | | | 50 | | pA |
| Reset Voltage | $V_{RE}$ | | | 0.7 | 1 | V |
| Reset Current | $I_{RE}$ | | | 50 | | pA |
| Low Level Output Voltage | $V_{OL}$ | $I_{OL} = 5mA$ | | 0.1 | | V |
| | | $I_{OL} = 8mA$ | | 0.15 | | |
| | | $V_{CC} = 15V$ $I_{OL} = 10mA$ | | 0.1 | | |
| | | $V_{CC} = 15V$ $I_{OL} = 50mA$ | | 0.5 | | |
| | | $V_{CC} = 15V$ $I_{OL} = 100mA$ | | 1 | | |
| High Level Output Voltage | $V_{OH}$ | $I_{OH} = -1mA$ | | 4.5 | | V |
| | | $I_{OH} = -2mA$ | | 4 | | |
| | | $V_{CC} = 15V$ $I_{OH} = -1mA$<br>$I_{OH} = -5mA$<br>$I_{OH} = -10mA$ | | 14.8<br>14<br>12.7 | | |

## ELECTRICAL CHARACTERISTICS (Continued)

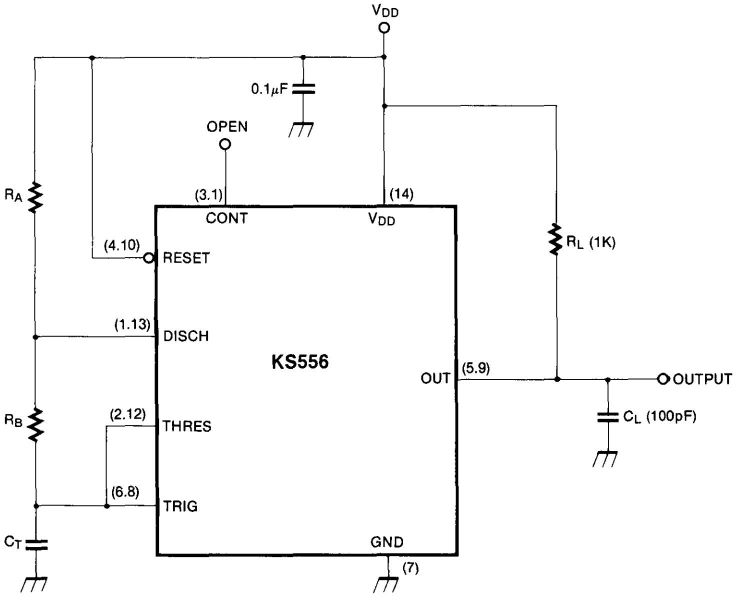
| Characteristic | Symbol | Test Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Initial Error of Timing Interval | $T_{EI}$ | $V_{CC}=5$ to 15V<br>$R_A=R_B=1$ to 100K<br>$C_T=0.1\mu F$ | | 1 | | % |
| Supply Voltage Sensitivity of Timing Interval | $T_{ES}$ | | | 0.1 | | %/V |
| Rise Time | $T_r$ | $R_L=10M\Omega$, $C_L=10pF$ | | 20 | | nS |
| Fall Time | $T_f$ | $R_L=10M\Omega$, $C_L=10pF$ | | 20 | | nS |
| Maximum Astable Oscillation | $F_{max}$ | $R_A=470\Omega$, $R_B=200\Omega$<br>$C_T=200pF$ | | 2 | | MHz |

## APPLICATION CIRCUIT

### 1) Astable

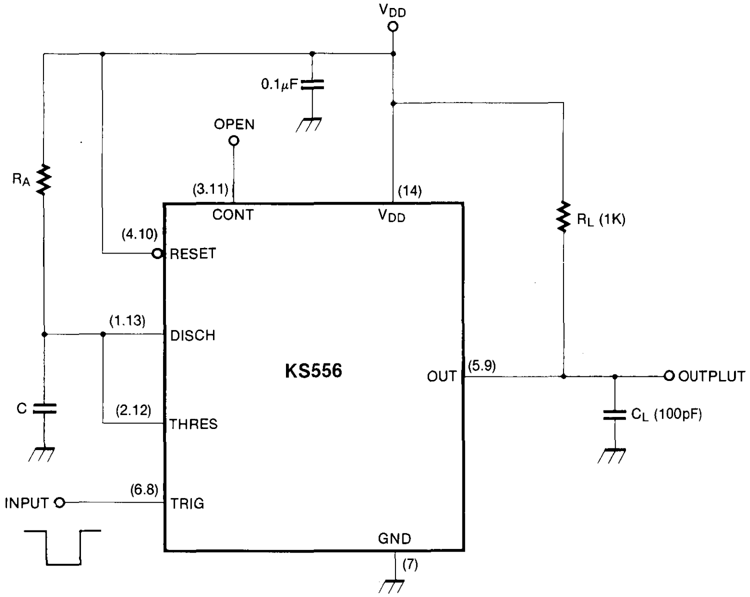
The circuit can be connected to trigger itself and free runs as a mutivibrator. The external capacitor charges through $R_A$ and $R_B$ and discharges through $R_B$ only. Thus, the duty cycle may be precisely set by the raio of these two resistors. In this mode of operation, the capacitor charges and discharges between 1/3 $V_{CC}$ and 2/3 $V_{CC}$. As in the trigger mode, the charging and discharging times, and therefore the frequency are essentially independent of the supply voltage. This oscillation frequency is given by

$$F=1/T=1.44/(R_A+2^*R_B)/C_T$$



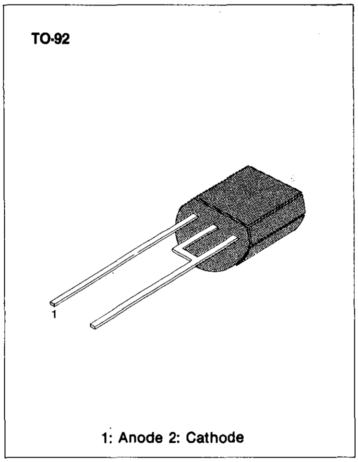
## 2) Monostable

In this operation mode, the timer functions as one shot. Initially, the external capacitor (C) is held discharged by a transistor inside timer. Upon application of a negative trigger pulse to trigger pin the flip flop is set which releases the short circuit across the external capacitor and drives and output high.
The voltage across the external capacitor now increases exponentially with time constant $T = R_A \times C$. When the voltage across the external capacitor equals $2/3 \times V_{CC}$, the comparator resets the flip flop, which in turn discharges the capacitor rapidly and also drives the output to its state.



# SILICON MONOLITHIC BIPOLAR INTEGRATED CIRCUIT VOLTAGE STABILIZAER FOR ELECTRONIC TUNER

The KA33V is a monolithic integrated voltage stabilizer especially designed as voltage supplier for electronic tuners.



## FEATURES

- **Low Temperature Coefficient**
- **Low Dynamic Resistance**
- **Typical Reference Voltage of 33V**

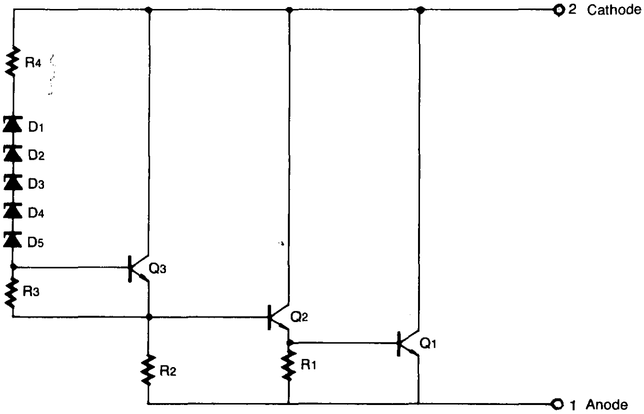
## ABSOLUTE MAXIMUM RATINGS ($T_a$=25°C)

| Characteristic | Symbol | Value | Unit |
|---|---|---|---|
| Zener Current | $I_Z$ | 10 | mA |
| Power Dissipation ($T_a$=75°C) | $P_D$ | 200 | mW |
| Operating Ambient Temperature-Range | $T_{opr}$ | −20 ~ 75 | °C |
| Storage Temperature Range | $T_{stg}$ | −40 ~ 125 | °C |

## ELECTRICAL CHARACTERISTICS ($T_a$=25°C)

| Characteristic | Symbol | Test Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Stabilized Voltage | $V_Z$ | $I_Z$=5mA | 31 | | 35 | V |
| Stabilized Voltage-Temperature Drift | $\triangle V_Z/\triangle T$ | $I_Z$=5mA<br>$T_a$=−20 to 75°C | −1 | 0 | 1 | mV/°C |
| Dynamic Resistance | $r_Z$ | $I_Z$=5mA, f=1KHz | | 10 | 25 | |

## SCHEMATIC DIAGRAM



SAMSUNG Electronics

## MEASURING CIRCUITS

**Fig. 1 Measuring Circuit for Stabilized Voltage $V_Z$**

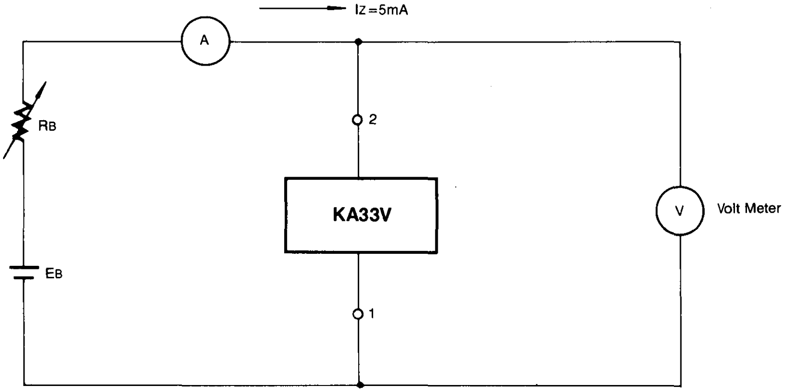


**Fig. 2 Measuring Circuit for Dynamic Resistance**

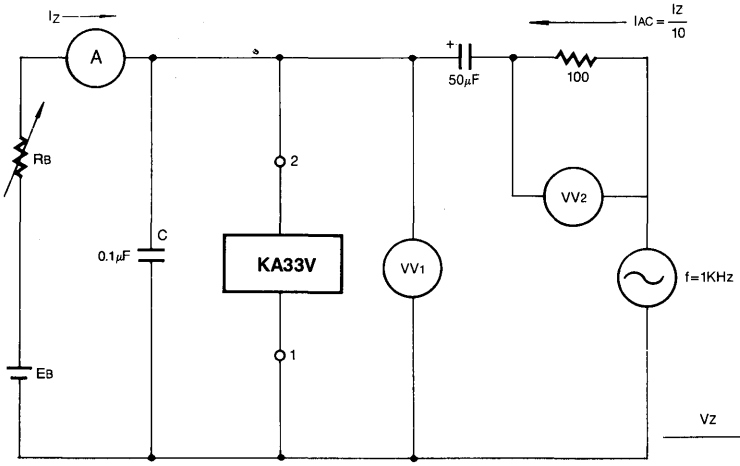
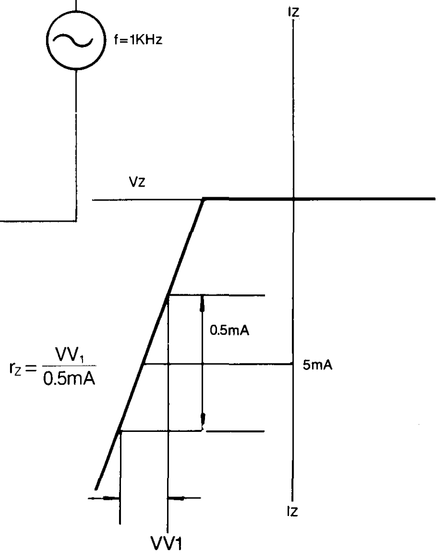
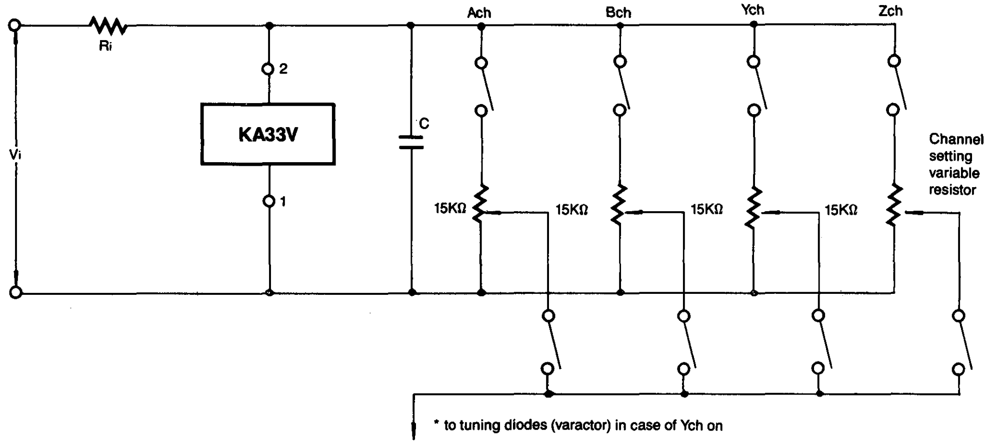


**Fig. 3**

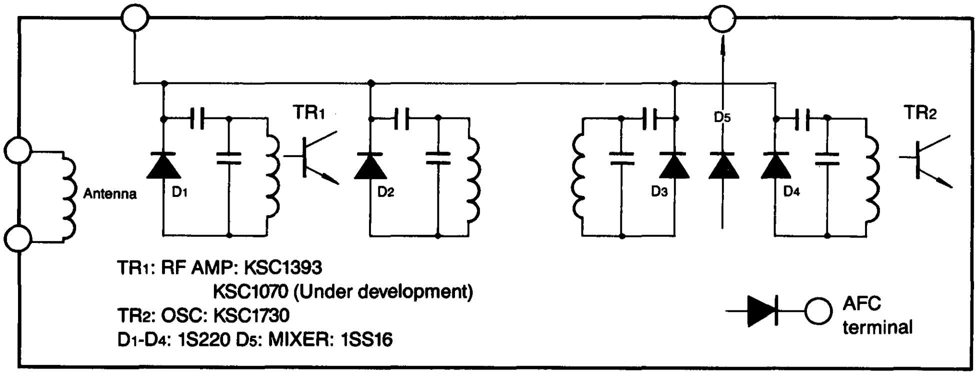


## TYPICAL APPLICATION



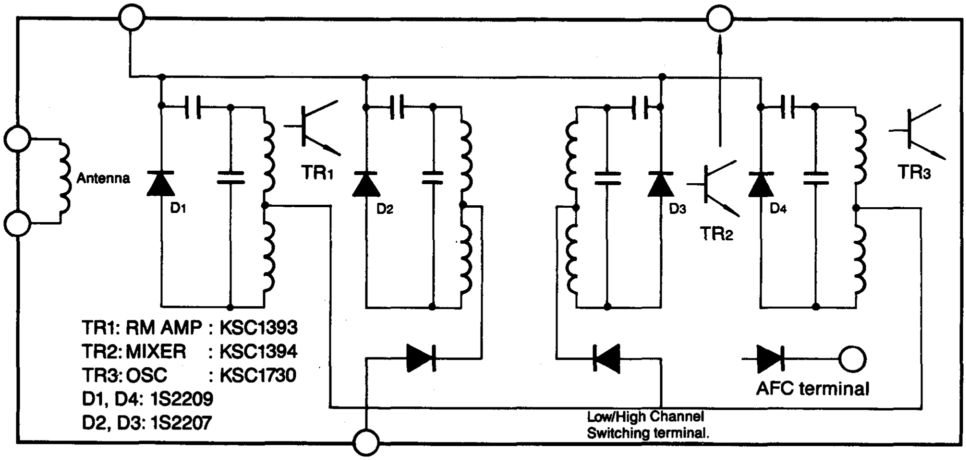
* to tuning diodes (varactor) in case of Ych on

## (1) UHF TUNER



TR1: RF AMP: KSC1393
KSC1070 (Under development)
TR2: OSC: KSC1730
D1-D4: 1S220 D5: MIXER: 1SS16

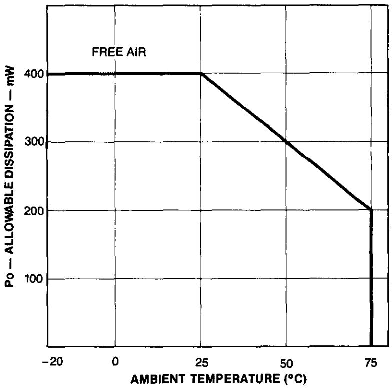
## (2) VHF TUNER



TR1: RM AMP : KSC1393
TR2: MIXER : KSC1394
TR3: OSC : KSC1730
D1, D4: 1S2209
D2, D3: 1S2207

## POWER-TEMPERATURE DERATING CURVE

Fig. 7 ALLOWABLE DISSIPATION vs. AMBIENT TEMPERATURE



## TYPICAL CHARACTERISTIC CURVES (Ta=25°C)

Fig. 8 DYNAMIC RESISTANCE vs. ZENER CURRENT

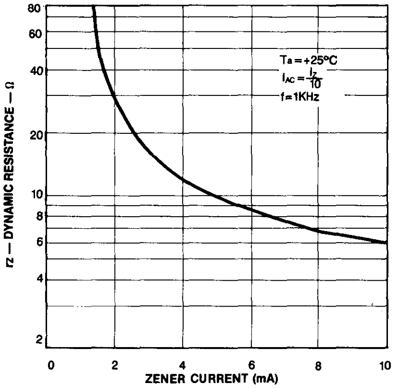


Fig. 9 STABILIZED VOLTAGE TEMPERATURE DRIFT vs. ZENER CURRENT

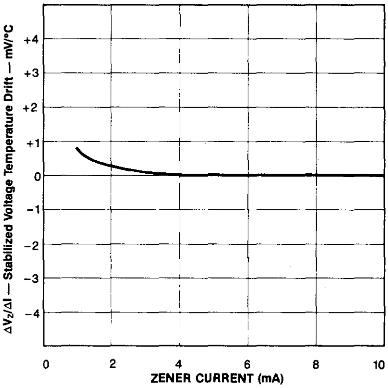


Fig. 10 STABILIZED VOLTAGE VARIATION vs. TIME

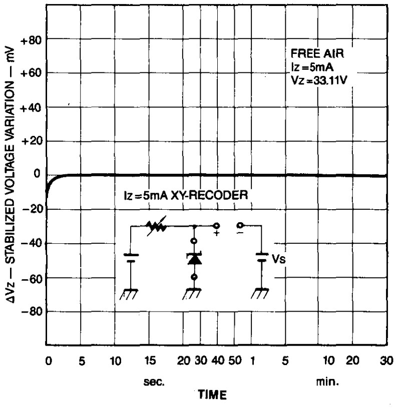
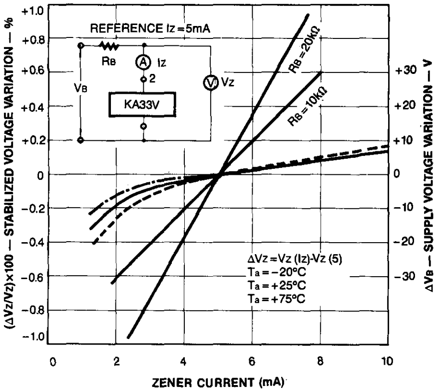


Fig. 11 STABILIZED VOLTAGE VARIATION & SUPPLY VOLTAGE VARIATION vs. ZENER CURRENT



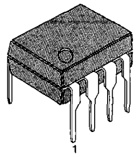
## PRECISION VOLTAGE-TO-FREQUENCY CONVERTER

This voltage-to-frequency converter provides the output pulse train at a frequency precisely proportional to the applied input voltage. The KA331 can operate at power supplies as low as 4.0V and be changed output frequency from 1Hz to 100KHz.
It is ideally suited for use in simple low-cost circuit for analog-to-digital conversion, long-term integration, linear frequency modulation or demodulation, frequency-to-voltage conversion, and many other functions.

## FEATURES

- **Guaranteed linearity: 0.01% max**
- **Low power dissipation: 15mW at 5V**
- **Wide range of full scale frequency: 1Hz to 100KHz**
- **Pulse output compatible with all logic forms**
- **Wide dynamic range: 100dB min at 10KHz full scale frequency**

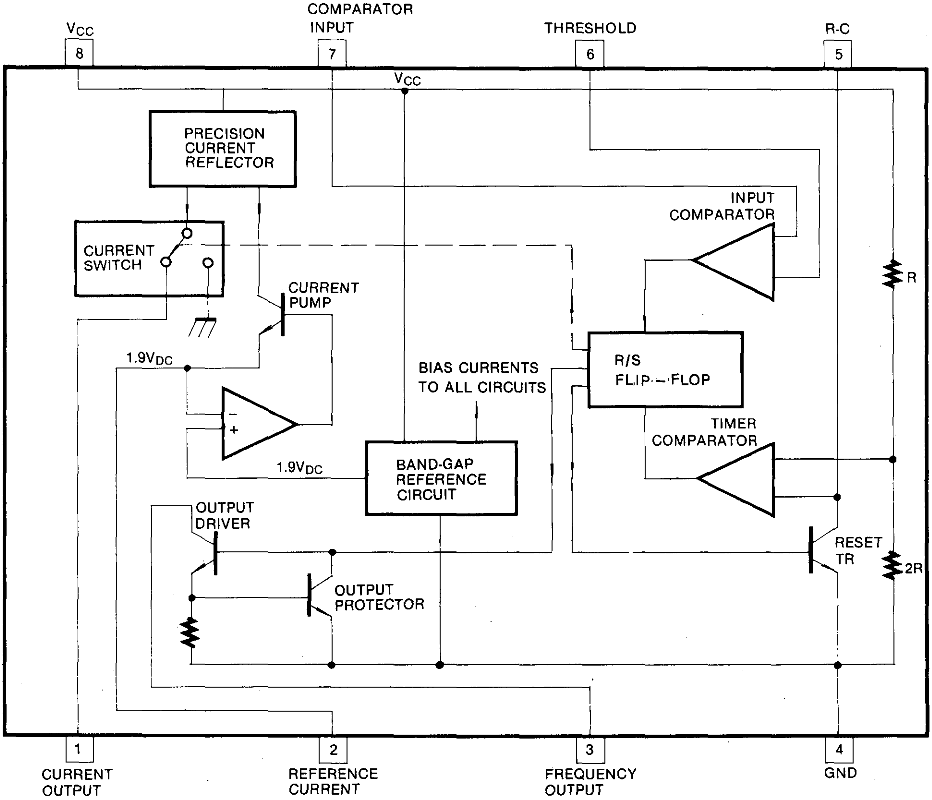
**8 DIP**



## ORDERING INFORMATION

| Device | Package | Operating Temperature |
|---|---|---|
| KA331CN | 8 DIP | 0 ~ +70°C |

## BLOCK DIAGRAM



## ABSOLUTE MAXIMUM RATINGS (Ta=0°C)

| Characteristic | Symbol | Value | Unit |
|---|---|---|---|
| Supply Voltage | $V_S$ | 40 | V |
| Input Voltage | $V_{IN}$ | $-0.2$ to $+V_S$ | V |
| Operating Temperature Range | $T_{opr}$ | 0 to 70 | °C |
| Power Dissipation | $P_D$ | 500 | mW |

## ELECTRICAL CHARACTERISTICS

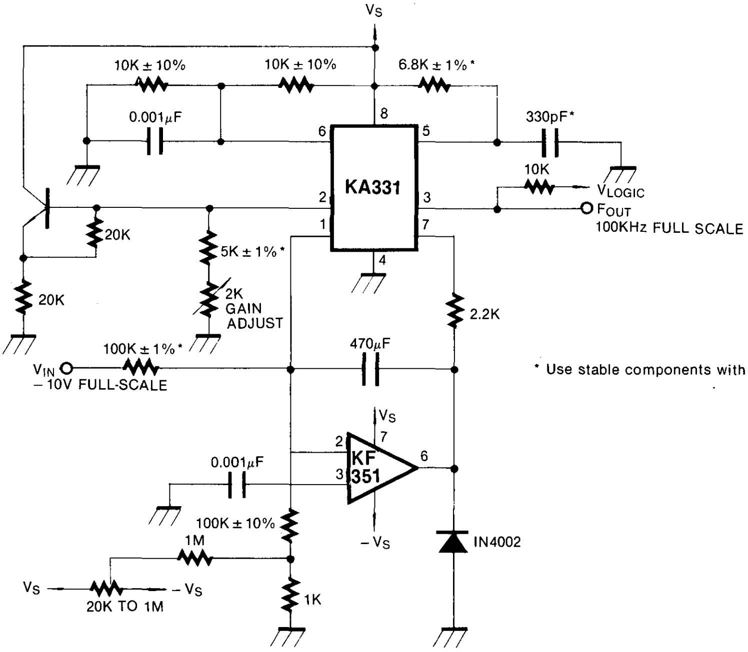
| Characteristics | Symbol | Test Condition | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| VFC Non-Linearity | VFCNL | $4.5V \leq V_S \leq 20V$ | — | ±0.003 | ±0.01 | % Full-Scale |
| Conversion Accuracy Scale Factor | ACCUR | $V_{IN} = -10V$, $R_S = 14K\Omega$ | 0.90 | 1.00 | 1.10 | KHz/V |
| Change of Gain With $V_S$ | $\triangle A$ | $4.5V \leq V_S \leq 10V$ | — | 0.01 | 0.1 | %/V |
| | | $10V \leq V_S \leq 40V$ | — | 0.006 | 0.06 | |
| Rated Full-Scale Frequency | $F_{OUT}$ | $V_{IN} = -10V$ | 10.0 | — | — | KHz |
| **INPUT COMPARATOR** | | | | | | |
| Offset Voltage | $V_{OS}$ | $T_{MIN} \leq T_A \leq T_{MAX}$ | — | ±3 | ±10 | mV |
| Bias Current | $I_B$ | | — | −80 | −300 | nA |
| Offset Current | $I_{OS}$ | | — | ±8 | ±100 | nA |
| Common-Mode Range | $V_{CM}$ | $T_{MIN} \leq T_A \leq T_{MAX}$ | −0.2 | — | $V_{CC}$-2.0 | V |
| **TIMER (PIN 5)** | | | | | | |
| Timer Threshold Voltage | $V_{TH}$ | | 0.63 | 0.667 | 0.70 | $xV_S$ |
| Input Bias Current | $I_{B5}$ | $V_S = 15V$, $0V \leq V_{PIN\ 5} \leq 9.9V$ | — | ±10 | ±100 | nA |
| | | $V_{PIN5} = 10V$ | — | 200 | 1000 | nA |
| Saturation Voltage | $V_{SAT\ 5}$ | $I = 5mA$ | — | 0.22 | 0.5 | V |
| **CURRENT SOURCE (PIN 1)** | | | | | | |
| Output Current | $I_{OI}$ | $R_S = 14K\Omega$, $V_{PIN1} = 0$ | 116 | 136 | 156 | μA |
| Change with Voltage | $\triangle I_O$ | $0V \leq V_{PIN1} \leq 10V$ | — | 0.2 | 1.0 | μA |
| Current Source Off Leakage | $I_{L1}$ | | — | 0.02 | 10.0 | nA |
| **REFERENCE VOLTAGE (PIN 2)** | | | | | | |
| Reference Voltage | $V_{ref}$ | | 1.70 | 1.89 | 2.08 | $V_{DC}$ |
| Stability vs Temperature | $V_{TEMP}$ | | — | ±60 | — | ppm/°C |
| Stability vs Time, 1000 Hours | $V_{TIME}$ | | — | ±0.1 | — | % |

## ELECTRICAL CHARACTERISTICS (Continued)

| Characteristics | Symbol | Test Condition | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| **LOGIC OUTPUT (PIN 3)** | | | | | | |
| Saturation Voltage | $V_{SAT3}$ | I = 5mA | — | 0.15 | 0.50 | V |
| | | I = 3.2mA | — | 0.10 | 0.40 | |
| Off Leakage | $I_{L3}$ | | — | ± 0.05 | 1.0 | μA |
| **SUPPLY CURRENT** | | | | | | |
| Supply Current | $I_S$ | $V_S = 5V$ | 1.5 | 3.0 | 6.0 | mA |
| | | $V_S = 40V$ | 2.0 | 4.0 | 8.0 | |

## TYPICAL APPLICATIONS

**Fig. 1 Precision Voltage-to-Frequency Converter, 100KHz Full-Scale**



* Use stable components with low temperature coefficients

**Fig. 2 Simple Frequency-to-Voltage Converter, 10KHz Full-Scale**

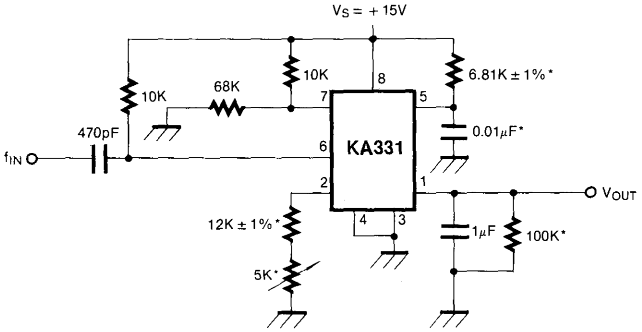
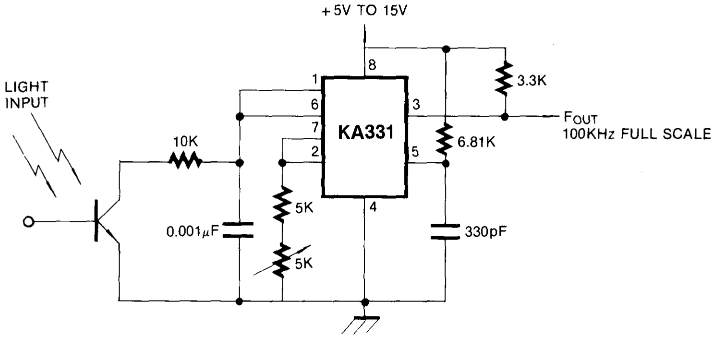
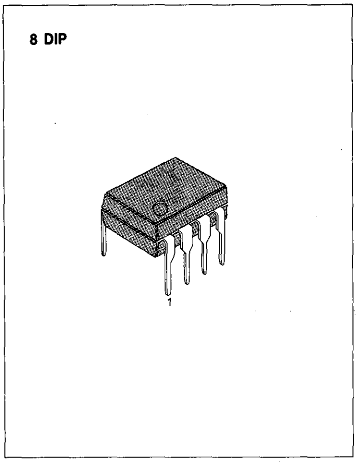


**Fig. 3 Light Intesity to Frequency Converter**



## LOW POWER CONSUMPTION EARTH LEAKAGE DETECTOR



The KA2803 is designed for use in earth leakage circuit interrupters, for operation directly off the AC line in breakers. The input of the differential amplifier is connected to the secondary coil of ZCT (Zero Current Transformer). The amplified output of differential amplifier is integrated at external capacitor to gain adequate time delay that is specified in KSC4613.

The level comparator generates high level when earth leakage current is greater than some level.

## FUNCTIONS

- Differential amplifier
- Level camparator
- Latch circuit

## FEATURES

- **Low power consumption ($P_d$=5mW, 100V/200V)**
- **Built-in voltage regulator**
- **High gain differential amplifier ($V_T$=13.5mV)**
- **1mA output current pulse to trigger SCR'S**
- **Low external part count, economic**
- **Mini-dip package (8 Dip), high packing density**
- **High noise immunity, large surge margin**
- **Super temperature characteristic of input sensitivity**
- **Wide operating temperature range ($T_a$=−25°C ~ +80°C)**

## ORDERING INFORMATION

| Device | Package | Operating Temperature |
|---|---|---|
| KA2803N | 8 DIP | −20 ~ +80°C |

## APPLICATION CIRCUIT

**1. Full Wave Application Circuit**

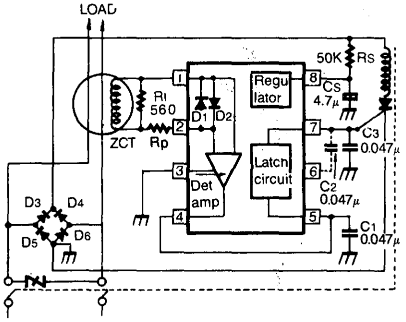


Fig. 1

**2. Half Wave Application Circuit**

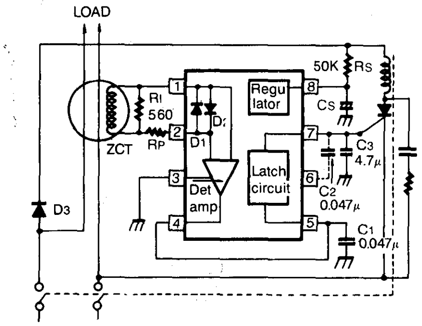


Fig. 2

## ABSOLUTE MAXIMUM RATINGS ($T_a$=25°C)

| Characteristic | Symbol | Value | Unit |
|---|---|---|---|
| Supply Voltage | $V_{CC}/V_{EE}$ | 20 | V |
| Supply Current | $I_S$ | 8 | mA |
| Power Dissipation | $P_D$ | 300 | mW |
| Lead Temperature (soldering 10 sec) | $T_{lead}$ | 260 | °C |
| Operating Temperature | $T_{opr}$ | −25 ~ +80 | °C |
| Storage Temperature | $T_{stg}$ | −65 ~ +150 | °C |

## ELECTRICAL CHARACTERISTICS ($T_a$=25°C)

| Characteristic | Symbol | Test Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Supply Current 1 | $I_{S1}$ | $V_{CC}$=12V (−25°C)<br>$V_R$-$V_I$=300mV (25°C)<br>(80°C) | | 400 | 580<br>530<br>480 | μA<br>μA<br>μA |
| Trip Voltage | | $V_{CC}$=16V (−25°C ~ 80°C)<br>$V_R$-$V_I$=X | 10 | 13.5 | 17 | mVrms |
| Differential Amplifier Output Current 1 | $I_{TD1}$ | $V_{CC}$=16V (25°C)<br>$V_R$-$V_I$=30mV<br>$V_{OD}$=1.2V | 12 | | 30 | μA |
| Differential Amplifier Output Current 2 | $I_{TD2}$ | $V_{CC}$=16V (25°C)<br>$V_{OD}$=0.6V<br>$V_R$, $V_1$ short | 17 | | 37 | μA |
| Output Current | $I_O$ | $V_{SC}$= 1.4V<br>$V_{OS}$=0.8V<br>$V_{CC}$= 12V (−25°C)<br>(+25°C)<br>(+80°C) | −200<br>−100<br>−75 | | | μA<br>μA<br>μA |
| Latch on Voltage | $V_{scon}$ | $V_{CC}$=16V (25°C) | 0.7 | | 1.4 | V |
| Latch Input Current | $I_{scon}$ | $V_{CC}$=12V (25°C) | | | 5 | μA |
| Output Low Current | $I_{OSL}$ | $V_{CC}$=12V (−25 ~ 80°C)<br>$V_{OSL}$=0.2V | 200 | | | μA |
| Diff. Input Clamp Voltage | $V_{IDC}$ | $I_{IDC}$=100mA (−25 ~ 80°C) | 0.4 | | 2 | V |
| Maximum Current Voltage | $V_{SM}$ | $I_{SM}$=7mA (−25°C) | 20 | | 28 | V |
| Supply Current 2 | $I_{S2}$ | $V_R$-$V_I$=X (25 ~ 80°C)<br>$V_{OS}$=0.6 | | | 900 | μA |
| Latch Off Supply Voltage | $V_{soff}$ | $V_{os}$=high (25°C) | 7.0 | | | V |
| Response Time | $T_{on}$ | $V_{CC}$=16V (25°C)<br>$V_R$-$V_I$=0.3V | 2 | | 4 | msec |

## APPLICATION NOTE

(refer to full wave application circuit Fig. 1)

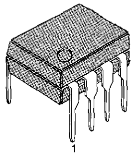
The Fig 1 shows the KA2803 connected in a typical leakage current detector system.
The power is applied to the $V_{CC}$ terminal (Pin 8) of the KA2803 directly from the power line.
The resistor $R_S$ and capacitor $C_S$ are chosen so that pin 8 voltage is at least 12V.
The value of $C_S$ is recommended above 1$\mu$F at this time.
If the leakage current is at the load, it is detected by the zero current transformer (ZCT).
The output voltage signal of ZCT is amplified by the differential amplifier of the KA2803 internal circuit and appears as half-cycle sine wave signal referred to input signal at the output of the amplifier.
The amplifier closed loop gain is fixed about 1000 times with internal feedback resistor to compensate for zero current transformer (ZCT) Variations.
The resistor $R_L$ should be selected so that the breaker satisfies the required sensing current.
The protection resistor $R_P$ is not usually used put when the high current is injected at the breaker, this resistor should be used to protect the earth leakage detector IC the KA2803.
The range of $R_P$ is from several hundred Ω to several kΩ.
The capacitor $C_1$ is for the noise canceller and standard value of $C_1$ is 0.047$\mu$F. Also the capacitor $C_2$ is noise canceller capacitance but it is not usually used.
When high noise is only appeared at this system 0.047$\mu$F capacitor may be connected between pin 6 and pin 7.
The amplified signal is finally appeared to the Pin 7 with pulse signal through the internal latch circuit of the KA2803.
This signal drivies the gate of the external SCR which energizes the trip coil which opens the circuit breaker.
The trip time of breaker is decided by the capacitor $C_3$ and the mechanism breaker.
This capacitor should be selected under 1$\mu$F for the required the trip time.
The full wave bridge supplies power to the KA2803 during both the positive and negative half-cycles of the line voltage.
This allows the hot and neutral lines to be interchanged.
If your application want the detail information, request it on our application circuit designer of KA2803.

## ZERO VOLTAGE SWITCH

The KA2804 is a TRIAC controller providing a complete solution for temperature controlled electric panel heaters, cookers, film processing baths etc.

Switching occurs at the zero voltage point in order to minimize radio frequency interference. The device is suitable for mains-on-line operation and requires minimal components.

**8 DIP**



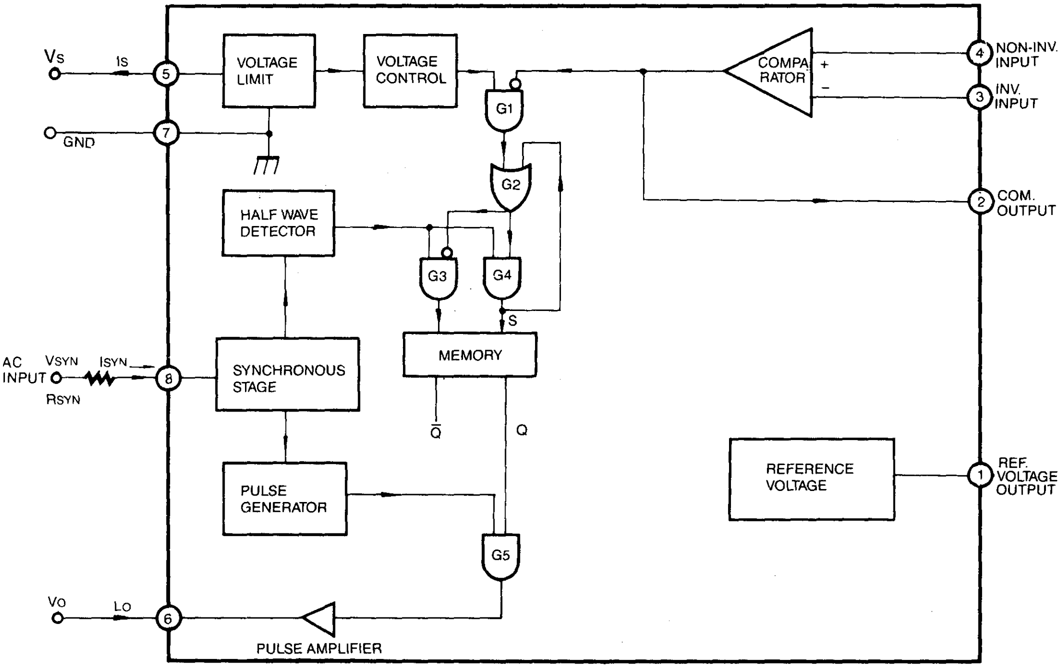
## FEATURES

- **Easy operation either through the AC line or a DC supply.**
- **Supply voltage control.**
- **Very few external components.**
- **Symmetrical burst control — No DC current components in the load circuit.**
- **Negative output current pulse up to 250mA-short circuit protection.**
- **Reference voltage output.**

## ORDERING INFORMATION

| Device | Package | Operating Temperature |
|---|---|---|
| KA2804N | 8 DIP | - 20 ~ + 70°C |

## BLOCK DIAGRAM



## ABSOLUTE MAXIMUM RATINGS ($T_a=25°C$)

| Characteristic | Symbol | Value | Unit |
|---|---|---|---|
| Supply Voltage | $-V_S$ | 8.2 | V |
| Supply Current | $-I_S$ | 40 (average) | mA |
| Synchronous Current | $I_{SYN}$ | 5.0 (rms) | mA |
| Input Voltage | $V_I$ | $\leqq \lvert V_S \rvert$ | V |
| Power Dissipation | $P_D$ | 350 | mW |
| Junction Temperature | $T_J$ | 125 | °C |
| Operating Ambient Temperature | $T_{opr}$ | $-20 \sim +70$ | °C |
| Storage Temperature | $T_{stg}$ | $-65 \sim +150$ | °C |

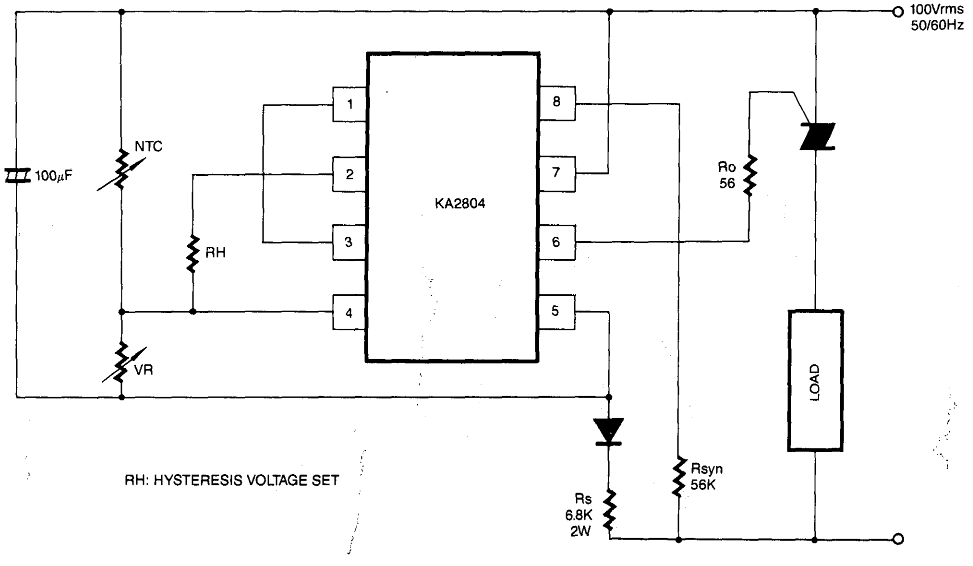
## ELECTRICAL CHARACTERISTICS

($V_S=8.0V$, $V_{SYN}=100$ to $115V_{rms}$, $T_a=25°C$, f=50/60Hz, unless otherwise specified)

| Characteristic | Symbol | Test Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Circuit Current | $-I_S$ | Pin 5, $R_{SYN}=56K$ | — | 2.0 | 2.5 | mA |
| Supply Voltage 1 | $-V_S$ 1 | Pin 5, $I_S=2.5mA$<br>$R_{SYN}=56K$ | 7.2 | — | 8.4 | V |
| Supply Voltage 2 | $-V_S$ 2 | Pin 5, $I_S=20mA$<br>$R_{SYN}=56K$ | 7.2 | — | 8.6 | V |
| Synchronous Current | $I_{SYN}$ | Pin 8 | 0.3 | — | — | mA |
| Output Pulse Width | $T_P$ | Pin 6, $R_{SYN}=56K$ | — | 200 | — | $\mu S$ |
| Output Voltage | $V_O$ | Pin 6, $I_O \leqq 200mA$ | 4.2 | 5.2 | — | V |
| Output Current | $I_O$ | Pin 6, $R_O \leqq 25$ | 200 | 250 | — | mA |
| Output Leakage Current | $I_{LO}$ | Pin 6 | — | — | 2.0 | $\mu A$ |
| Input Offset Voltage | $V_{IO}$ | Pin 3, 4 | — | 2.0 | 5.0 | mV |
| Input Bias Current | $I_I$ | Pin 3, 4 | — | 0.5 | 1.0 | $\mu A$ |
| Common Mode Input Voltage Range | $-V_{ICM}$ | Pin 3, 4 | 0 | — | 5.7 | V |
| Output Leakage Current | $I_{LC}$ | Pin 2 | — | — | 0.2 | $\mu A$ |
| Reference Voltage | $-V_R$ | Pin 1, $I_R \leqq 1uA$ | — | 3.6 | — | V |

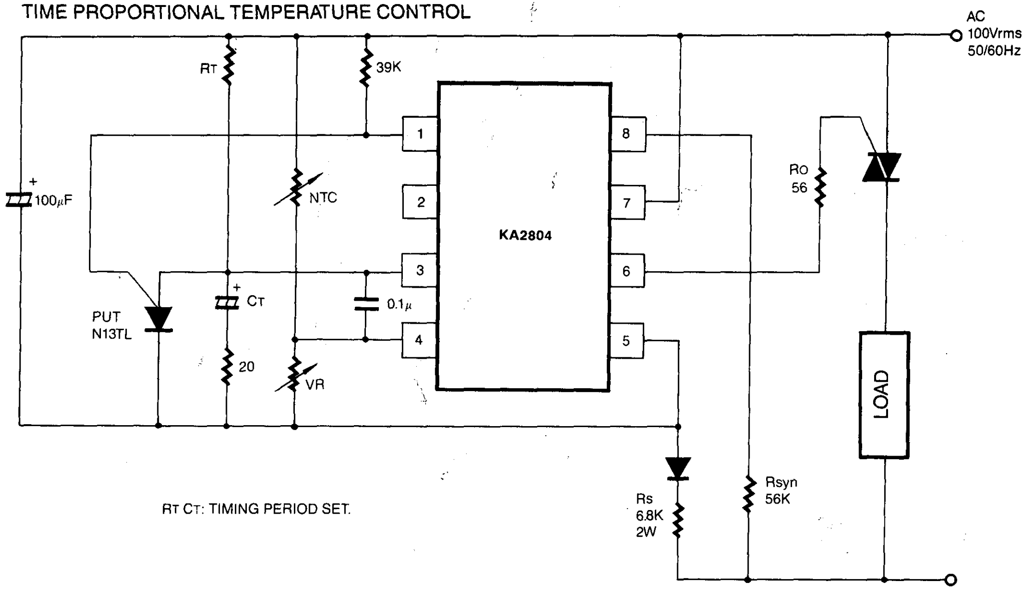
# APPLICATIONS

ON-OFF TEMPERATURE CONTROL



RH: HYSTERESIS VOLTAGE SET

TIME PROPORTIONAL TEMPERATURE CONTROL



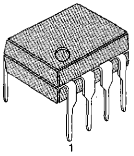
RT CT: TIMING PERIOD SET.

# EARTH LEAKAGE DETECTOR

The KA2807 is designed for use in earth circuit interrupters, for operation directly off the AC line interrupters.

Full advantage of the U.S. UL943 timing specification is taken to insure maximum immunity to false triggering due to line noise.

8 DIP



## FEATURES

- **Full advantage of the UL943**
- **Externally programmable fault current threshold**
- **Direct interface to SCR**
- **Operates under line reversally both load $V_S$ line and hot $V_S$ neutral**
- **Power supply shunt regulator in chip**
- **Sense coil: 1000:1**
- **GND/Neutral coil: 200:1**
- **Normal fault sensitivity current is 5mA typical**
- **Trip time in normal fault and ground neutral fault is 18ms typical**

## ORDERING INFORMATION

| Device | Package | Operating Temperature |
|---|---|---|
| KA2807N | 8 DIP | -40 ~ +70°C |

## BLOCK DIAGRAM

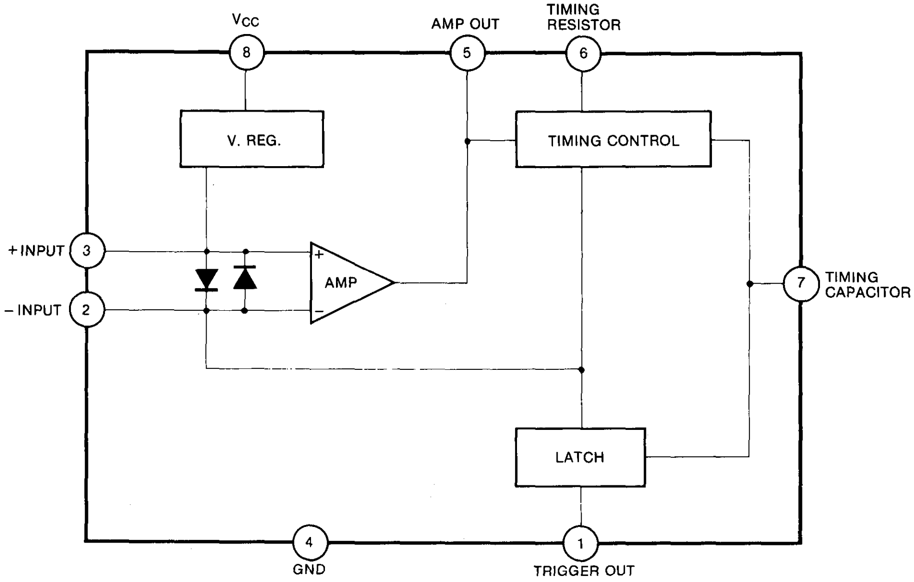


Fig. 1

## ABSOLUTE MAXIMUM RATINGS

| Characteristic | Symbol | Value | Unit |
|---|---|---|---|
| Supply Current | $I_{CC}$ | 19 | mA |
| Power Dissipation | $P_D$ | 1250 | mW |
| Operating Temperature Range | $T_{opr}$ | $-40 \sim +70$ | °C |
| Storage Temperature Range | $T_{stg}$ | $-55 \sim +150$ | °C |

## ELECTRICAL CHARACTERISTICS (Ta = 25°C, $I_{CC}$ = 5mA)

| Characteristics | Symbol | Test Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Shunt Regulator Voltage | $V_{reg}$ | Pin 8, S1:2, S2:OFF | 22 | 26 | 30 | V |
| Amp Reference Voltage | $V_{int}$ | Pin 3, S1:2, S2:OFF | 9 | 10.5 | 12 | V |
| Amp Output High Voltage | $V_{OH}$ | Pin 5, S1:3, S2:ON<br>Sig: 800Hz, 3.0$V_{p\text{-}p}$<br>Sinewave | 17 | 19 | 21 | V |
| Amp Output Low Voltage | $V_{OL}$ | Pin 5, S1:3, S2:ON<br>Sig: 800Hz, 3.0$V_{p\text{-}p}$<br>Sinewave | 1 | 2.5 | 4 | V |
| Amp Sensitivity Current | $I_{SEN}$ | Pin 2, S1:3, S2:ON<br>Sig: 800Hz, 1.0$V_{p\text{-}p}$ ~ 2.5$V_{p\text{-}p}$<br>Sinewave | 3 | 5 | 7 | μArms |
| Latch On Voltage | $V_{ON}$ | Pin 7, S1:3, S2:ON<br>Sig: 800Hz, 3.0$V_{p\text{-}p}$<br>Sinewave | 15 | 17.5 | 20 | V |
| SCR Trigger Current | $I_{TR}$ | Pin 1, S1:3, S2:ON<br>Sig: 800Hz, 3.0$V_{p\text{-}p}$<br>Sinewave | 0.5 | 1 | 2.4 | mA |
| Output Low Voltage | $V_S1$ | Pin 1, S1:2, S2:OFF |  | 100 | 240 | mV |
| Output Impedance | $R_O$ | Pin 1, S1:2, S2:OFF |  | 100 |  | Ω |
| Output Sink Current | $I_{sink}$ | Pin 1, S1:2, S2:OFF | 2.0 | 5 |  | mA |

## TEST CIRCUIT

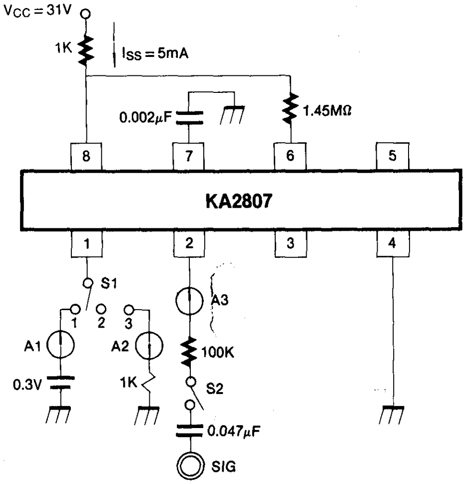
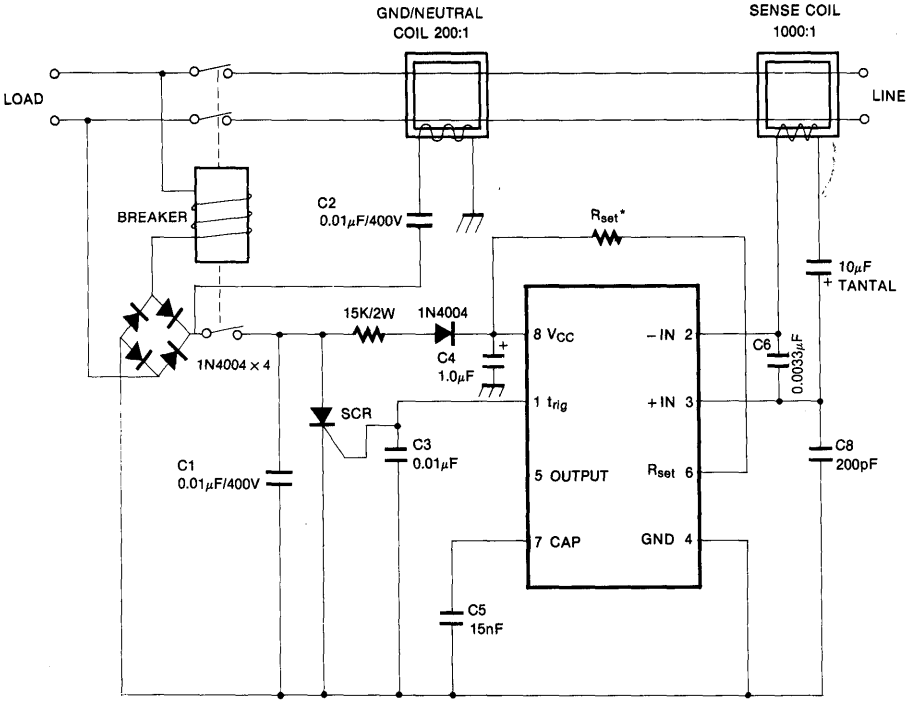


Fig. 2

## APPLICATION CIRCUIT



* Adjust $R_{set}$ for desired sensitivity leakage current.

Fig. 3

Typical earth leakage detector circuit is shown in Fig. 3. This is designed to operate on 120V AC line voltage with 5mA normal fault sensitivity. Full-wave rectifier diode and 15K/2W resistor are used to supply the DC power supply required by the KA2807 C4 (1$\mu$F) is used to filter the ripple of the supply voltage and peak current when fault current generate over 5mA typical, SCR is turned ON and a large current can flow through the breaker coil to pull the contact open. Once opened, the fault condition is removed and the discharge current 3 $I_{th}$ reset both the timing capacitor and output latch causing the SCR to turn off.

A1000:1 Sense coil is used to detect the normal fault. The fault current generated is stepped down by 1000 and fed into the input pins of the OP amp through C7 (10$\mu$F) capacitor.

C6 (0.0033$\mu$F) and C8 (200pF) are added to obtain better noise immunity. The normal fault sensitivity current is determined by discharging current of timing capacitor.

Discharging current $I_{th}$ is $\frac{7V}{R_{set} \times 2}$ ...... (1)

Because the average fault current just equals the threshold current $I_{th}$ at the decision point.

$$I_{th} = \frac{I_{f(rms)} \times 0.91}{2} \text{ ...... (2)}$$

The factor 0.91 converts the rms value to an average value.

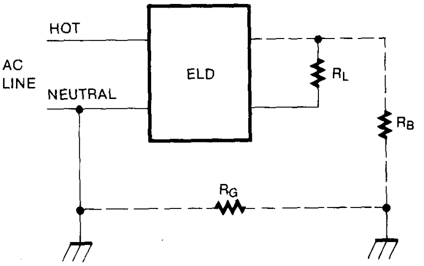
in (1) and (2) $R_{set} = \frac{7V}{I_{f(rms)} \times 0.91}$ ...... (3)

The precision value of $R_{set}$ depends on the specific sense coil used KA2807 tolerances in as much as UL943 specifies a sensitivity "window" of 4mA-6mA, provision should be made to adjust $R_{set}$ on a per-product bisic.

You can be obtained the desired integration time through proper selection of the timing capacitor C5.

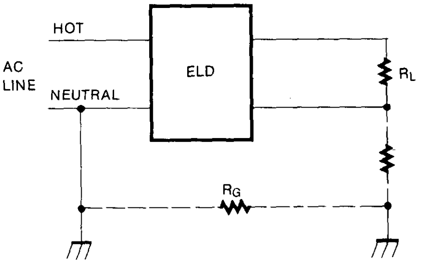
The sense amplifier is capacitively coupled to a 200-turn coil in order to detect the grounded neutral fault.

In FIG. 3, grounded neutral detection is accomplished by feeding the neutral coil with 120Hz energy continuously and allowing some of this energy to couple into the sense coil during conditions of neutral fault.



Explain: An unintentional electrical path, $R_B$, between the load terminal of the hot line and the ground, as shown by the dashed lines.

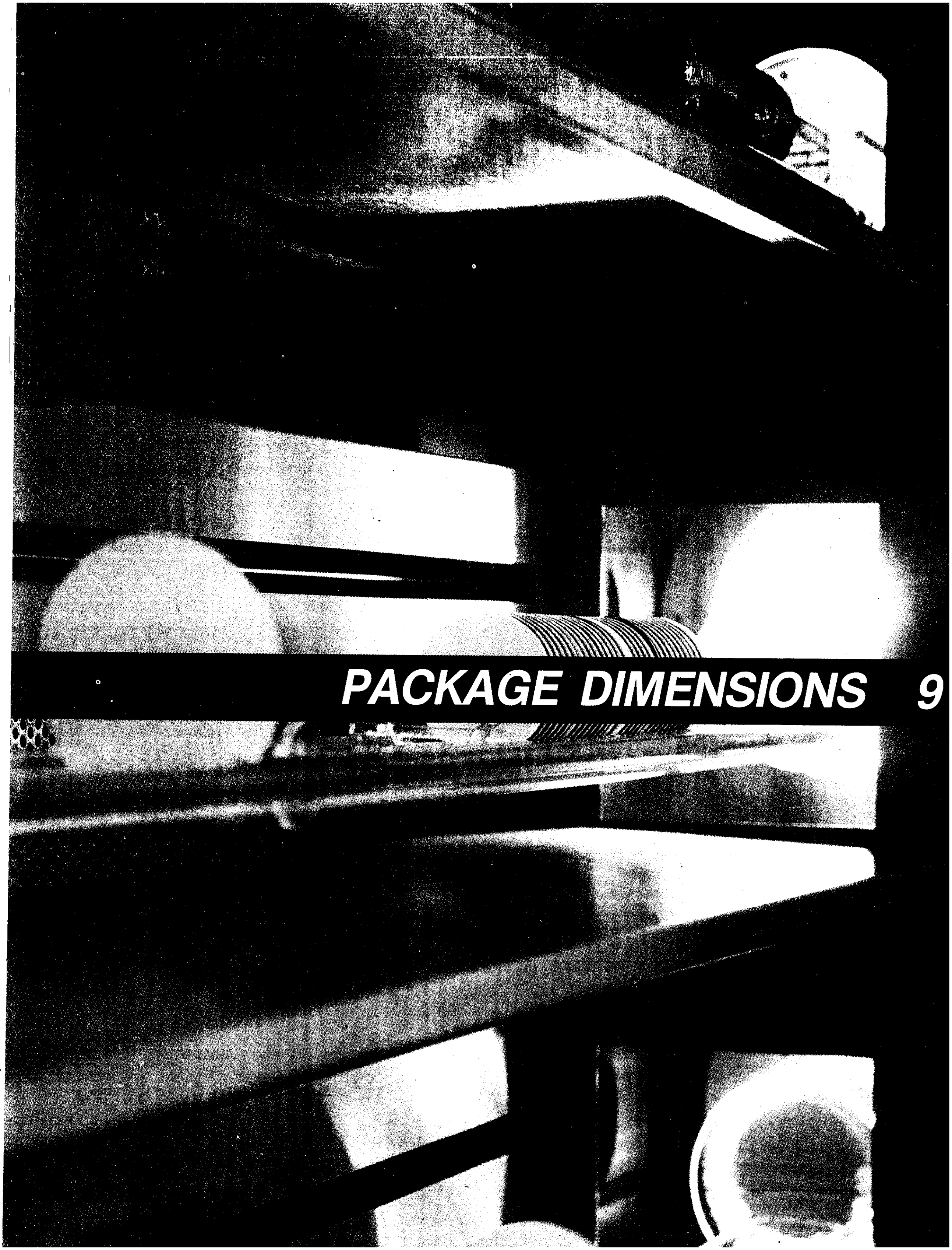
FIG. 4 NORMAL FAULT



Explain: An unintentional electrical path between the load terminal of the neutral line and the ground, as shown by the dashed lines.

FIG. 5 GROUNDED NEUTRAL FAULT

# NOTES

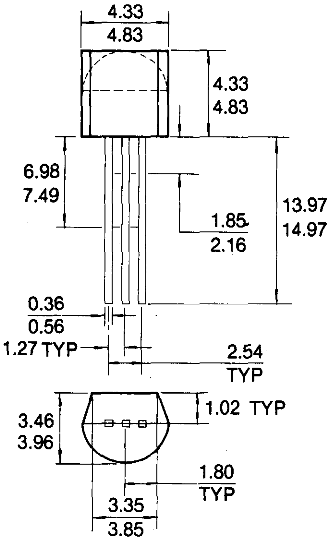


# PACKAGE DIMENSIONS 9

# PACKAGE DIMENSIONS

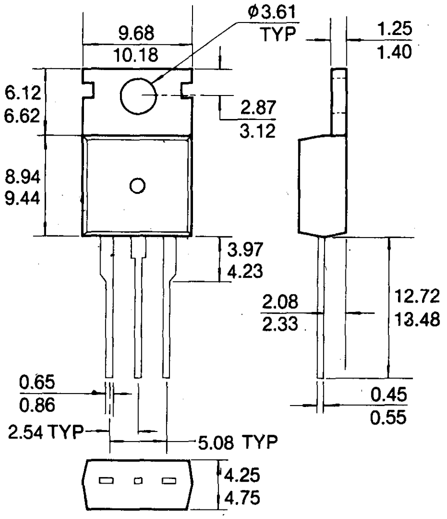
## TO-92

**Unit: mm**



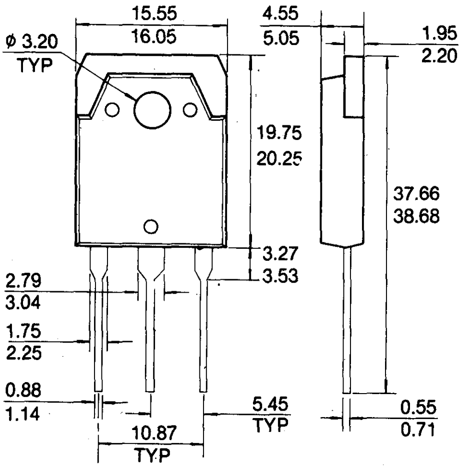
## TO-220

**Unit: mm**



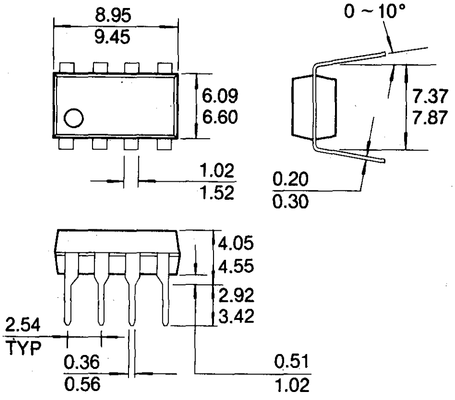
## TO-3P

**Unit: mm**



## 8 DIP

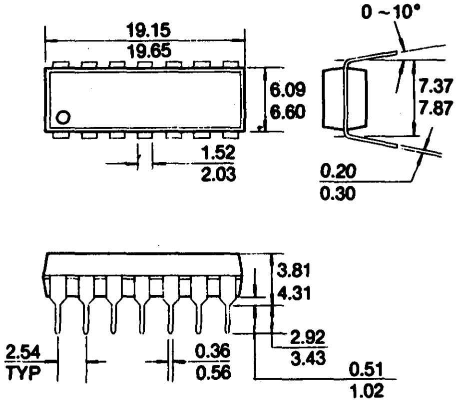
**Unit: mm**



# PACKAGE DIMENSIONS

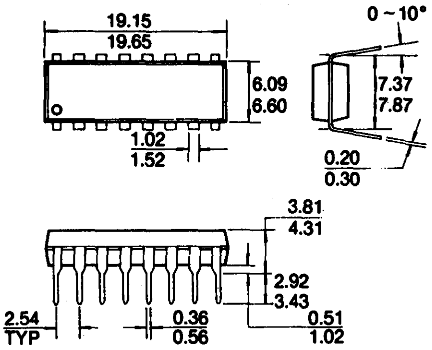
## 14 DIP

**Unit: mm**



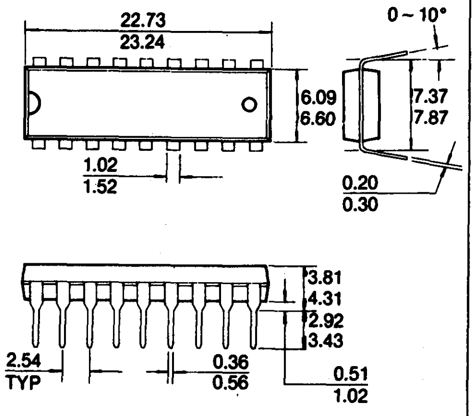
## 16 DIP

**Unit: mm**



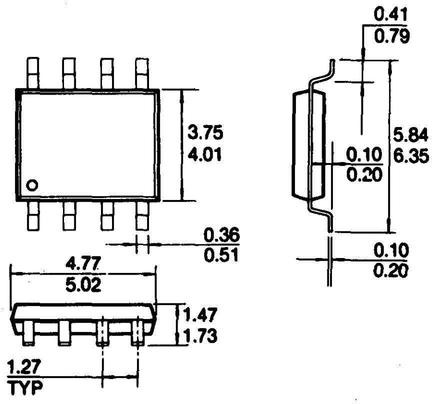
## 18 DIP

**Unit: mm**



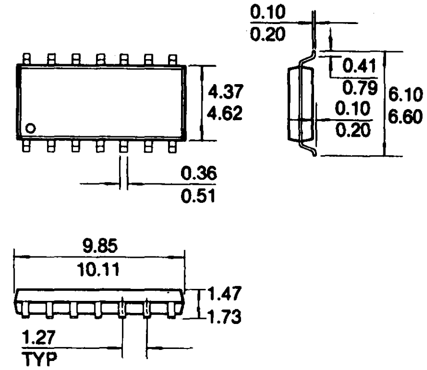
## 8 SOP

**Unit: mm**

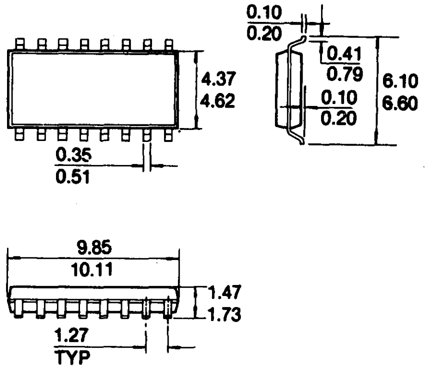


# PACKAGE DIMENSIONS

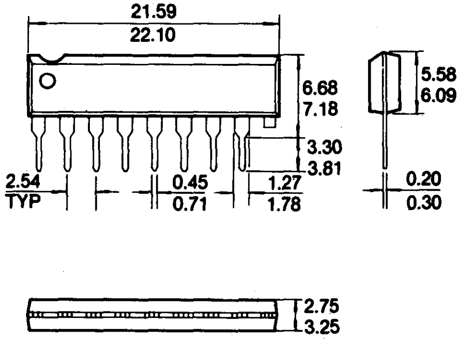
**14 SOP** **Unit: mm**



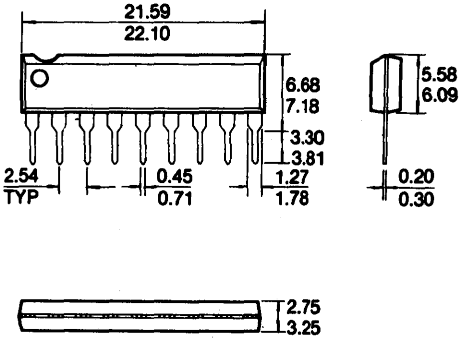
**16 SOP** **Unit: mm**



**8 SIP** **Unit: mm**

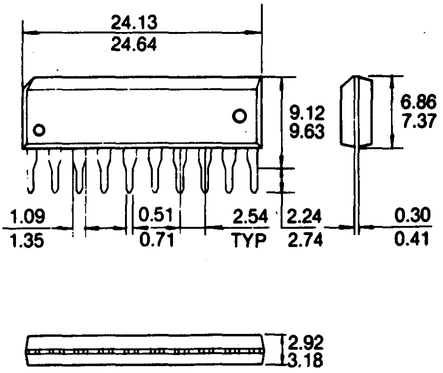


**9 SIP** **Unit: mm**



# PACKAGE DIMENSIONS

**10 SIP** **Unit: mm**



# SALES OFFICES 10

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FAX: 0046-753-75 34 0
TLX: 052-9 77 87

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