

# Electronic Design

FOR ENGINEERS AND ENGINEERING MANAGERS

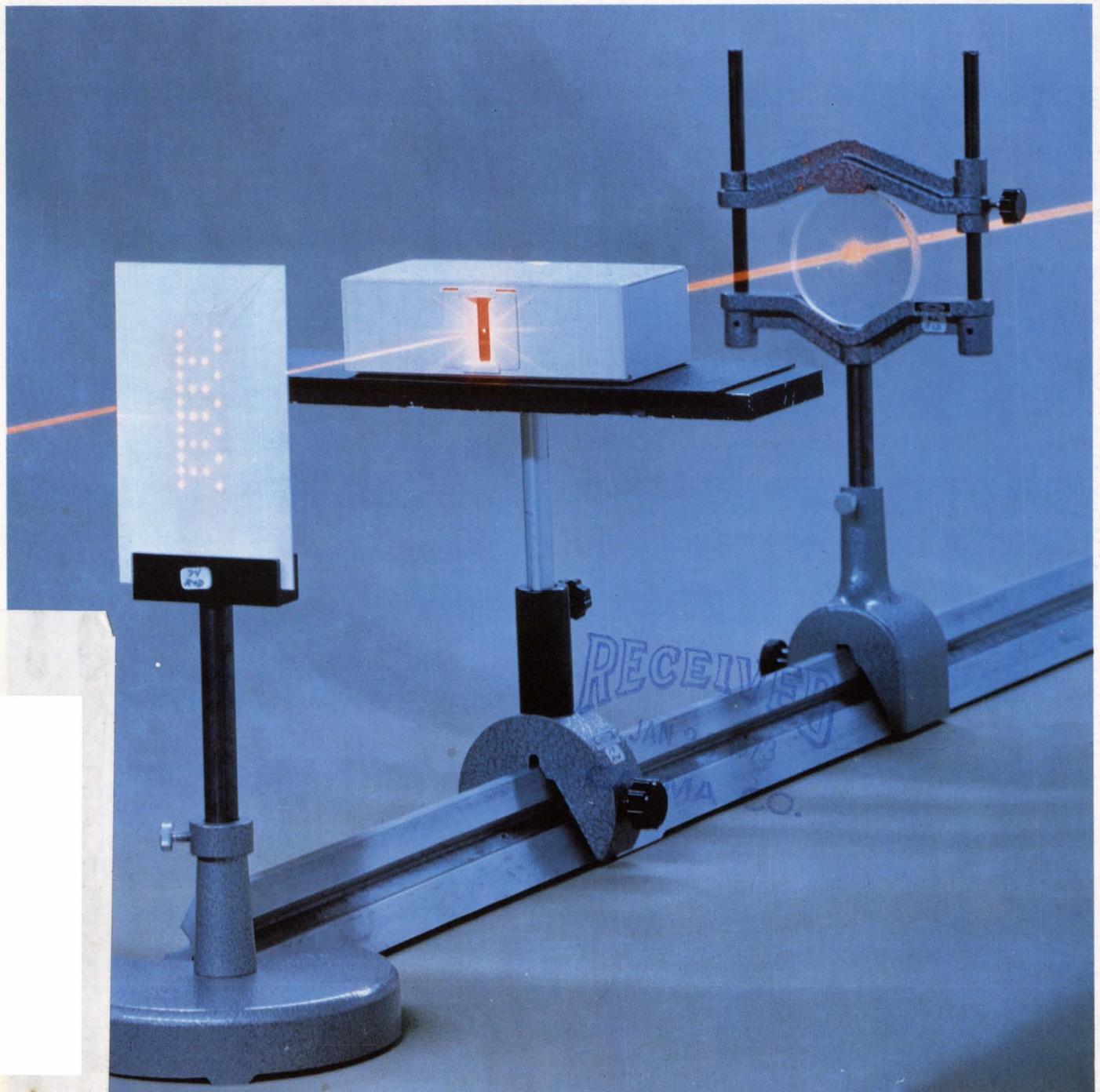
VOL. 21 NO.

# 2

JAN. 18, 1973

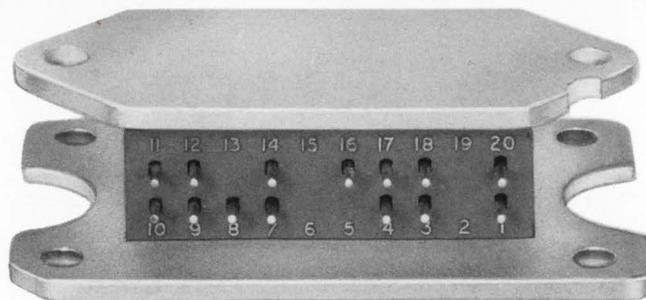
**Low-power, low-cost lasers**, both gas and semiconductor, have moved out of the laboratory and onto the production line. They are finding wide use in areas

like data processing, construction, communications and education. For assistance in using this new class of lasers more effectively, turn to the special report on p.24.



Do you face a make or buy decision on power supplies?

# Announcing Lambda's new 85W negative power hybrid voltage regulator



## 85W, -5.2V, 5A

\$35 ea. (in quantity of 1)      \$20 ea. (in quantity of 100)      \$18 ea. (in quantity of 1000)

also available

**62W positive  
power hybrid  
voltage  
regulators  
62W, 5V, 3A**

\$25 ea. (in quantity of 1)

\$14 ea. (in quantity of 100)

\$11 ea. (in quantity of 1000)

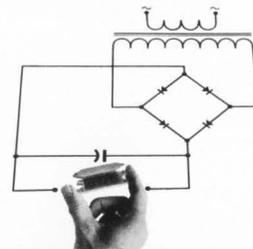
**85W positive  
power hybrid  
voltage  
regulators  
85W, 5V, 5A**

\$30 ea. (in quantity of 1)

\$18 ea. (in quantity of 100)

\$15 ea. (in quantity of 1000)

**Regulation: 0.2% line  
0.2% load  
Ripple: 2mV RMS**



**100,000 hours MTBF demonstrated**

**1-DAY DELIVERY**

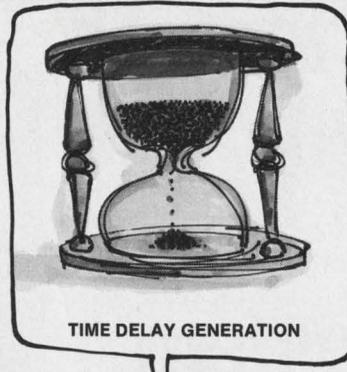
Send for 1973 Power Supply Catalog and Application Handbook

**WHETHER  
YOU MAKE  
OR BUY...**  
**LAMBDA**  
ELECTRONICS CORP.  
A Veeco Company

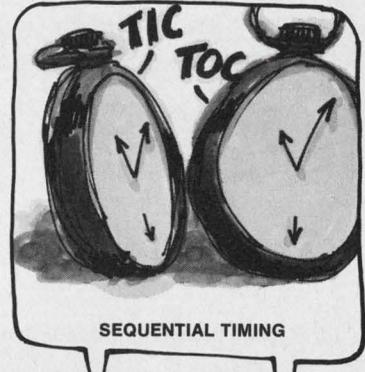
# EXAR'S MONOLITHIC TIMER SPEAKS OUT...



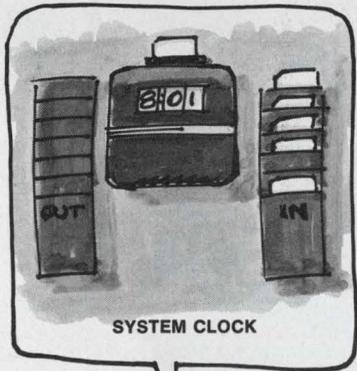
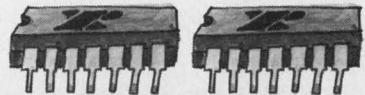
LINEAR SWEEP OUTPUT



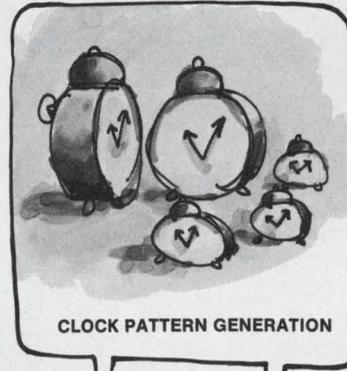
TIME DELAY GENERATION



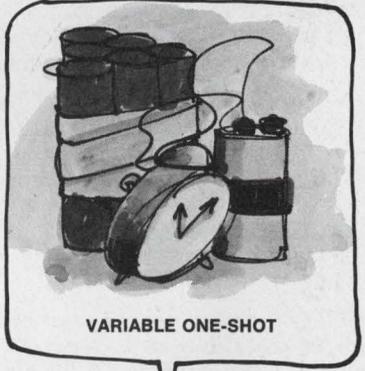
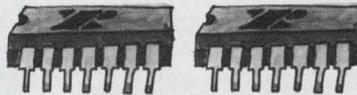
SEQUENTIAL TIMING



SYSTEM CLOCK



CLOCK PATTERN GENERATION



VARIABLE ONE-SHOT



If you're a systems designer stuck with the use of discrete or electro-mechanical timing devices, you should investigate Exar's new monolithic timing circuits.

The XR-220 and XR-320 generate precise pulses and delays variable from one microsecond to one hour, using a single external resistor-capacitor combination to determine the time, 2RC.

They are excellent for monostable or self-triggering timing pulse generation, linear sweep generation, and for pulse-width or pulse-position modulation timing. By combining two or more circuits, you can create an infinite variety of sequential and delayed timing cycles.

These Exar circuits are the only ones in hermetic DIP packages, and the only circuits which accept inverted or non-inverted inputs, and have outputs which are inverted or non-inverted, of high or low level.

You can buy the XR-320 for as little as \$1 in 100-up quantities. It operates from 0°C to 75°C and has a guaranteed accuracy of 5%. The XR-220 is our prime device, with accuracy guaranteed to 0.5%, selling for \$6.50 at 100-up. An XR-220M MIL version operates from -25°C to 125°C and sells for \$10.

Call or write for more information on these new Exar products. Ask for Bill Seibert: Marketing Manager.

## EXAR SPEAKS YOUR LANGUAGE



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INFORMATION RETRIEVAL NUMBER 4

# Here's the perfect DAC-ADC team for your closed loop system

These Burr-Brown Digital-to-Analog and Analog-to-Digital converters are designed to work as an ultra accurate team. Both units have 16 bit resolution, the DAC has guaranteed monotonicity and the ADC has no missing codes. This makes them ideal for your process control, instrumentation, data logging and other closed and open loop systems. They are self-contained in 2" X 4" X 0.4" modular packages.

The ADC 100 features maximum linearity error of only 0.005 % and a maximum accuracy drift as low as 5 ppm / °C. The unit is available with BCD or binary coding and unipolar or bipolar inputs. The binary units have pin programmable resolutions of 12, 14, or 16 bits, while the BCD units offer 4 digit or 4 digit plus sign coding. Conversion time is just 30 msec. Optional card-mount and rackmount packaging is available. Unit price is \$225.00.

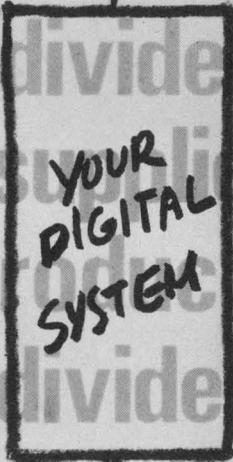
The DAC45 has a linearity error of only 0.003% and a maximum linearity drift of  $\pm 1$ ppm/°C. The unit is TTL/CMOS compatible and accepts 16 bit binary or 4 digit BCD input codes at transfer rates as high as 20 kHz. Conversion speed is just 5 $\mu$ sec for a .6mV step. Optional card-mount and rackmount packaging is also available for the DAC45. Unit price is just \$325.00.

FOR COMPLETE TECHNICAL INFORMATION, use this publication's reader service card or phone Burr-Brown.

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# Burr-Brown conversion products deliver what they promise!

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## NEWS

- 21 **News Scope**
- 24 **More than 100,000 low-cost, low power helium-neon lasers have been sold.** These and other low-cost lasers are finding wide use.
- 32 **A \$4-billion hike in defense spending is expected in 1973,** with little, if any, of it trickling into R&D.
- 35 **Industrial electronics is becoming 'a way of life';** manufacturers see a year of growth ahead.
- 40 **Technology Abroad**
- 43 **Washington Report**

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## TECHNOLOGY

- 48 **Use current-mode IC amplifiers.** New quad versions replace conventional op amps, while avoiding dual-voltage supplies and lowering the cost and package count.
- 58 **Improve single-slope a/d accuracy.** Add a calibration cycle, and you get 0.01% accuracy in a circuit that is suitable for mass production of 4-1/2-digit DVMs.
- 66 **Design versatile d/a converters** by using constant current sources. Custom components are not needed to obtain devices for special applications.
- 70 **Ideas for Design:** Multiplexer technique solves X-out-of-Y bit pattern recognition . . . Analog divider simplifies ac ratio meter and yields  $\pm 0.2$ -dB measurement accuracy . . . Analog sorting network ranks inputs by amplitude and allows selection.

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## PRODUCTS

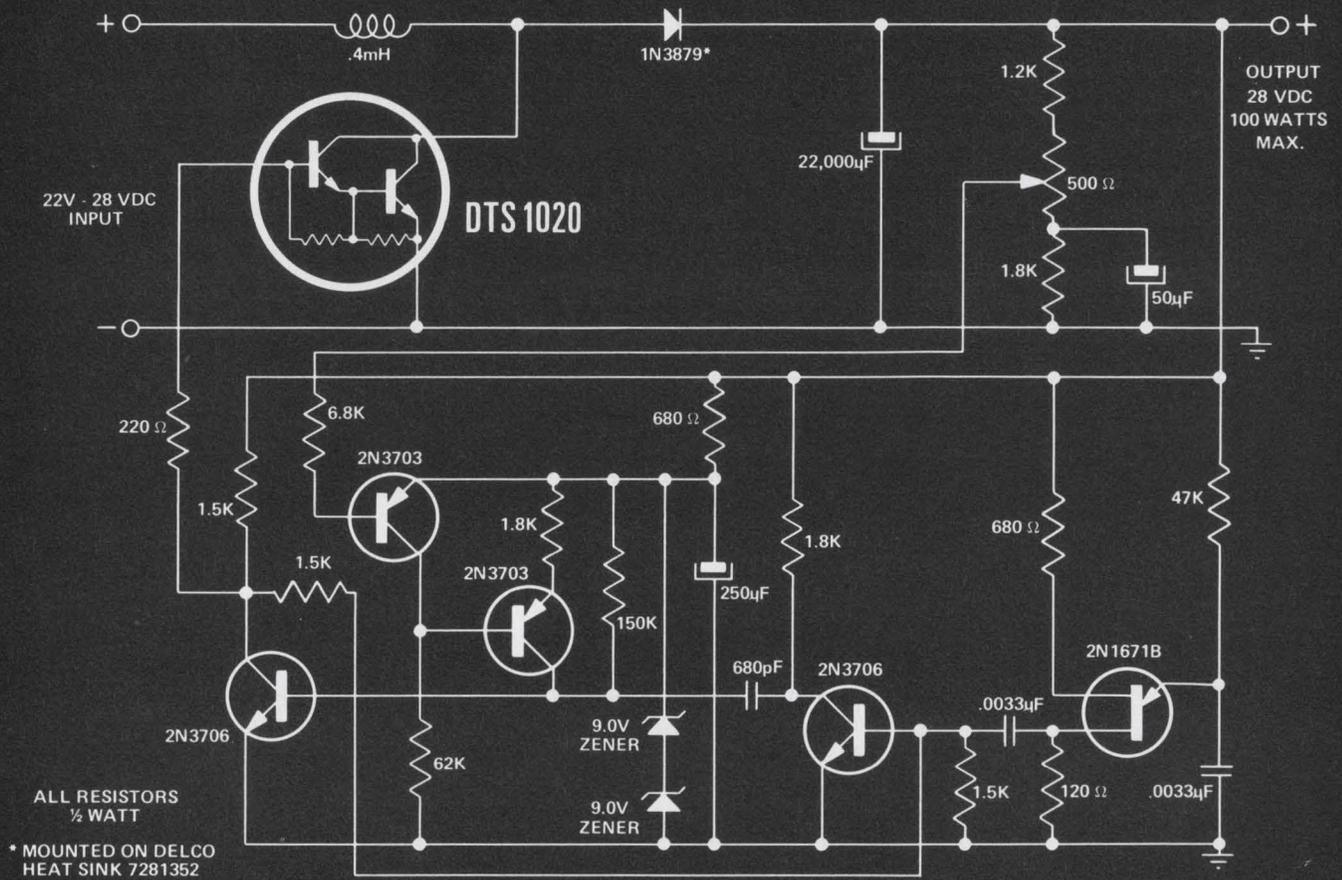
- 77 **Modules & Subassemblies:** 8-bit d/a converter module settles to 0.4% within 15 ns.
- 78 **Modules & Subassemblies:** Nonlinear low-pass filter exhibits zero phase shift.
- 82 **ICs & Semiconductors:** Stereo IC with all functions on chip, simplifies quadrasonic decoding.
- 86 **Instrumentation:** Plug-ons extend versatility of DMM measuring system.
- 80 **Data Processing**

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**Cover:** Photograph by William A. Welch and Kent K. Sutherlin shows the replaceable read-only memory portion of Optical Data System Inc.'s storage and retrieval Holoscan system.

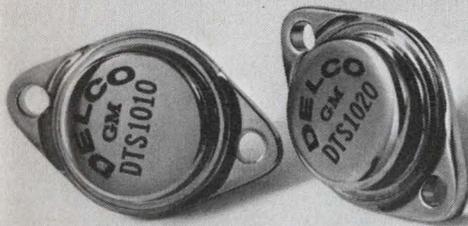


### SWITCHING REGULATOR

	$V_{CEO}$ @ 0.1 mA	$V_{EBO}$ @ 50 mA	$V_{CE(SUS)}$ @ 500 mA	$h_{fe}$ @ 1 MHz ( $V_{CE}=10V,$ $I_C=200 mA$ )	$h_{FE}$ ( $V_{CE}=5V,$ $I_C=10A$ )	$V_{CE(SAT)}$ @ 5.0 A	$I_C$	$P_T$ @ 75°C
DTS-1010	120V	7V	80V	12	200	1.8V	10A	100W*
DTS-1020	120V	7V	80V	12	500	1.5V	10A	100W*

\*100 percent tested at 2.5A, 40V.

# The Kokomoans now give you Darlington Switching Power.



Use a Darlington in place of an ordinary transistor, and you'll realize an additional magnitude of gain plus increased switching power. Use a Delco silicon power Darlington (DTS-1010 or DTS-1020) and you'll also realize a gain in dependability.

Delco's Darlington's are triple diffused mesa units housed in copper TO204MA cases and built for ruggedness. The design gives them high energy capability—the ability to handle surges of current and voltage simultaneously. They are ideal for switching inductive loads in circuits subject to transients or fault conditions.

Design a switching regulator circuit around a Delco Darlington or use it in any 60-100 volt

application to reduce circuit size, weight, and cost. In addition, the Darlington space saving feature allows you more design flexibility. Unlike an ordinary transistor, it's only energy-limited, not beta-limited. You can exploit its full energy capability in your circuit.

Call your nearest Delco distributor. He has them in stock and he's got the data on high energy switching for small spaces.

For details on the switching regulator circuit, ask for Application Note 49.



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# Our Bill Shuart doesn't work for Power/Mate.



**He works only for you...  
and that's the way the new Power/Mate  
wants it.**

Bill is the Power/Mate Quality Assurance Manager and he has 34 supervisors and perfectionists under him.

They also work for you.

The result is unexcelled and consistent quality that we at Power/Mate are genuinely proud of.

Bill does a lot more than making sure our products are produced in accordance with his high standards of workmanship. (He wrote the book on that too.)

Bill has developed a series of courses for all our employees on soldering techniques and workmanship standards.

□ He has developed a computer failure analysis program to insure that our vendors also maintain the consistent high quality you should expect when you use our power supply in your product.

□ He oversees the continuing MTBF studies (by computer of course) and worst case calculations on all our power supplies to insure the long life and trouble free performance you should expect.

□ He has developed a thermally cycled burn-in rack in which we subject *all* of our power supplies for 24 hours before shipment to insure there are no premature field failures.

□ He oversees the random sampling of all production-run power supplies. These are subject to a continuous night and day life test . . . for your continued assurance of a long-lived trouble free product.

We could go on . . . but we at Power/Mate are glad he works for you. That's why we can give a five year no-holds warranty.



THE NEW

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## across the desk

### A cheer for less work

I like most of your editorials, because they're novel and punchy. But the one in the Nov. 9, 1972 issue—"Get Enriched (If Not Rich) With Those High Flyers"—smelled too much of 19th-century optimism and the Protestant work ethic.

The editorial message was: "Get involved in a fledgling company. You'll work like hell. You probably won't get very rich. But the experience will be enriching." The trouble with this message is:

1. There are too many electronics companies right now, and they're competing for scarce business. A more optimum situation is the auto industry with four companies producing all the cars (more optimum for the men in the industry).

2. If 25 hours a day of work does not make you very wealthy, it is to be shunned.

3. Hard work of the sort done by fledgling company executives is not at all enriching (except monetarily); it serves to produce ulcers and coronaries, which are to be shunned.

There's a new movement in America that your editorial is blissfully ignorant of. It's the movement for less work and a better quality of life, with more leisure time. It's a movement that progresses:

1. A man should not be married to his career.

2. America has so much excess productive capacity, that people should work fewer hours, not more. (This produces the four-day work week, which is gradually gaining acceptance.)

3. A man's work should be emotionally rewarding. If it's not, he

should change his work if at all possible.

Like any other industry, electronics has its share of freaks, who thrive on grueling, exhausting, unnerving work. If your editorial is aimed at these few freaks, why print it? If it's aimed at the rest of us also, then please change the tune. It's out of key with the second half of the 20th century.

*Robert Bruce, MSEE*

15 Johnstone Road  
Great Neck, N.Y. 11021

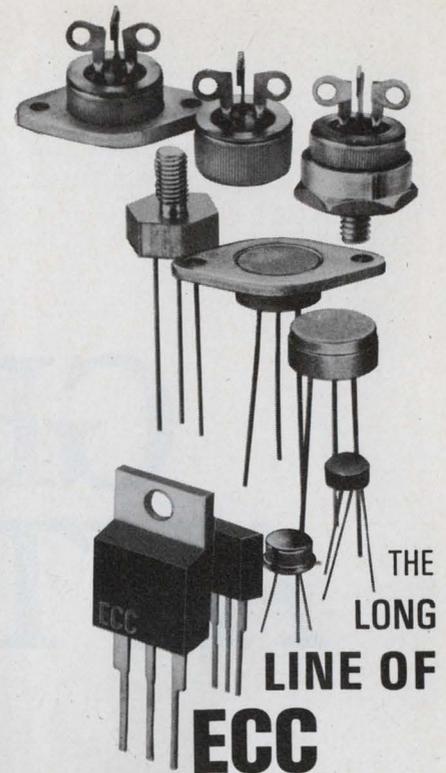
### Wire-AND advice draws a complaint

In Dwight H. Sawin's discussion of wire-AND ("Use the Wired-AND and Implied-OR," ED 20, Sept. 28, 1972, p. 76), he very mistakenly says that up to 10 open-collector TTL gates can be wired together with no adverse effects. He goes on later to state that the wire-AND configuration is not only hazard-free but also provides a significant savings.

The problem with this reasoning is that it assumes unfortunately that the real world ends at the designer's bench. If those who utilize wire-AND connections only for package-count-savings had the onerous task of troubleshooting this design in production, or had the profit responsibility for field repairs, they would find another approach. Only when no other avenue is available does the TTL open-collector, wire-AND connection provide any real savings. The near impossibility of isolating a failure to the bad IC when several are wire-ANDed runs up test costs far exceeding any imagined savings of low-cost, standard TTL

*(continued on page 11)*

Electronic Design welcomes the opinions of its readers on the issues raised in the magazine's editorial columns. Address letters to Managing Editor, Electronic Design, 50 Essex St. Rochelle Park, N. J. 07662. Try to keep letters under 200 words. Letters must be signed. Names will be withheld on request.



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**TRIACS**

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electrical isolation and  
a variety of packages.

LOW CURRENT TRIACS

THERMOTAB® and THERMOPAK\*; Swedge and TO-3; 5/8" Hex Stud, and TO-5 Metal and Plastic Packages

\*trademark of ECC

$I_{T(RMS)}$  0.8 - 16 amps

$I_{gt}$  1, 111 3, 10, 25, 50 ma max;  
with or w/o internal trigger

$I_{TSM}$  20 - 150 amps

$V_{DROM}$  200 - 800 volts

For more information, circle No. 238

HIGH CURRENT TRIACS

3/4" Press-Fit, Stud and TO-3 Packages

$I_{T(RMS)}$  25 - 40 amps

$I_{gt}$  1, 111 50 - 100 ma max

$I_{TSM}$  230 - 300 amps

$V_{DROM}$  200 - 800 volts min

For more information, circle No. 239

All packages are electrically isolated except TO-5 Metal Can. ECC triacs feature heavily glass passivated junctions for high reliability.

Contact your nearest ECC Sales Representative or Authorized Distributor for pricing and technical information.

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**GENERAL  
AUTOMATION  
SAYS  
BUY DEC**

If you're shopping the minicomputer market for raw hardware at rock bottom cost, it's hard to know where to stop. With more than two dozen price lists to choose from, it can get confusing. And time consuming.

We're here to make it easy for you. Buy DEC.

When you cut through all the claims, DEC's priced as low as anyone else. And they have built a business fulfilling the needs of the low-end iron buyer.

We make low cost hardware too. And if you're price shopping, you'll find us competitive. But raw iron is not our primary business.

### **The cheapest machine vs. the cheapest solution:**

Sure, our goal is to save you money too. But our long suit is squeezing these savings out of your total systems cost rather than off of our price list. So if you need more from the machine or the company that sells it to you, we recommend us. General Automation.

Take *the world's most powerful minicomputer*, for instance.

The General Automation SPC-16.

The SPC-16 possesses the most powerful instruction set you can buy in a minicomputer today. Think about that. The *most* powerful. As a result, the SPC-16 does more things in less time. It will actually reduce the total cost of your system.

Depending on your specific needs, you can choose from six different models in the SPC-16 family. Each backed by the best software and peripheral capability in the business. There's another very important reason why you should buy from us.

**It's called involvement.**

All the other big mini manufacturers

today are touting the fact that they're "end-user oriented" or that they're now "in the systems business."

We've been doing exactly that for more than five years now. And it's nice to see that others have begun to recognize our leadership.

We learned a long time ago that the only way to really help our customers in solving their systems problems was to fully understand those problems.

So we got involved with our customers. Both end-users and OEMs. Listened attentively. Learned a lot. Got answers. And wound up building systems to solve some very tough, very complex problems.

Emissions analysis and electrical test systems for the nation's largest automobile manufacturers.

Production machine control systems for some of the biggest companies in the machine tool business.

Telecommunications and message switching systems for the world's leading communications companies, to name just a few.

In short, we've built our company and our reputation by offering answers, not just iron.

### **Who's it gonna be?**

Actually, we've made your choice fairly simple.

If all you need is raw minicomputer hardware at a "rock bottom" price, we recommend DEC.

If you'd like something more—from a mini with more oomph to the total solution of a complex systems problem—we recommend us.

General Automation.

Our phone number is (714) 778-4800.

Or write:

1055 South East St., Anaheim, Calif. 92805

# **General Automation**

INFORMATION RETRIEVAL NUMBER 9

Fluke problem solvers

# Introducing the Fluke 8100B. At \$595, you'll wonder how we did so much in a 4½ Digit Multimeter.



The new version of Fluke's most successful DMM, Model 8100B, gives you the most value for your money ever offered in a quality digital voltmeter.

With a basic dc accuracy of 0.02%, the Fluke 8100B measures ac and dc volts in four ranges from 100 microvolts to 1200 volts and resistance from 100 milliohms to 12 megohms. With an optional ac/dc current shunt accessory, it measures from 10 nanoamperes to 12 amps in six switched ranges.

Features include an active 2-pole switchable filter and automatic polarity indicator. All functions are push-button selectable.

For \$100 extra, a rechargeable battery pack can be

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## ACROSS THE DESK

(continued from page 7)

packages. I shudder to think of 10 gates wired together.

Jesse Pipkin,  
Product Manager,  
Digital Circuit Testing

Hewlett-Packard  
5301 Stevens Creek Blvd.  
Santa Clara, Calif. 95050.

## The author replies

While Mr. Pipkin does make a good point, from the standpoint of reliability diagnosis, there are two sides to the discussion. The comment in the article concerning wiring 10 open-collector TTL gates together with no adverse effects refers to adverse *electronic* effects, if read in context. Specifically it refers to the disastrous results suffered when "totem pole output" TTL gates are wired together.

Furthermore the article offers a general technique that may be applied when any logic family is used to reduce the package count. Likewise power consumption and size are also reduced. Granted, trouble-shooting in large equipment is difficult enough without wire configurations; however, in an extremely simple, high-volume production article, it may be that discarding the faulty circuit entirely is the best course of action economically.

Dwight H. Sawin 3d

University of Idaho  
College of Engineering  
Office of the Dean  
Moscow, Idaho 83843.

## Who makes that cassette transport?

In our FOCUS report on digital cassette and cartridge recorders (ED 18, September 2, 1972, pp. 40-46) we showed a picture of a three-cassette peripheral unit offered by Data General for use with its Nova minicomputers. In the caption, however, we failed to mention that the cassette transports were developed and manufactured by Redac-tron Corp. The cassette transport was developed originally for Redac-tron's editing typewriter system and is currently being used by other firms in typesetting uses.



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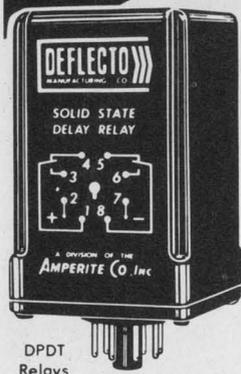
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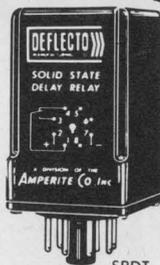
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INFORMATION RETRIEVAL NUMBER 13

ACROSS THE DESK  
(continued from page 11)

## ... And more ways to convert temperature

With respect to temperature conversion (see "A Foolproof Method to Convert Temperature," ED 17, Aug. 17, 1972, p. 7), I would like to suggest an approach that requires only the remembrance of the number 18 instead of any of the C/F or F/C conversion equations.

We all know that water freezes at 0 C, which equals +32 F. For each 10° increase/decrease of C, there is an 18° increase/decrease of F.

Therefore: +10 C = +50 F, +20 C = + 68 F and +30 C = +86 F (note that, fortuitously, 86 is the reverse of 68), etc., -10 C = +14 F, -20 C = -4 F, etc.

Also, for each 1° increase/decrease of C, F increases/decreases 1.8° for interpolating.

Using this approach, you can do most of the conversions mentally. I forgot the 5/9, 9/5, +32, -32, etc., 50 years ago.

Julius Bernstein

118 Rosedale Rd.  
Yonkers, N.Y. 10710

The Aug. 17 issue includes a good method of Fahrenheit/Celsius conversion, but James W. Wrenn could have indicated the background for the use of the "40." It might have made the system a little easier to understand. Simply, both Fahrenheit and Celsius scales are exactly equal at -40° (-40 C = -40 F). Therefore if the known scale is brought to a new origin at -40 (add 40 to a positive degree value) and then converted by the 5:9 ratio of the size of each degree, and finally the 40 subtracted out to get to the 0° level of the new scale, the job is done.

This method described by Mr. Wrenn is so much more logical and understandable, yet is almost never mentioned in the schools.

Robert Fabris  
Research Specialist  
Systems Integration

Lockheed Missiles & Space Co., Inc.  
Sunnyvale, Calif. 94088.

## Correction

In a recent product feature introducing Motorola's dual-tracking voltage regulator, the MC1468 ("Improved Op Amp Regulator," ED 19, Sept. 14, 1972, p. 169) some erroneous statements crept into a comparison with Raytheon's RC-4194 dual-voltage regulator. To set the record straight, we note the following:

■ Both ICs usually require six components (two resistors and four capacitors) for  $\pm 15$ -V operation. However, Motorola's regulator can deliver  $\pm 15$  V with just the four capacitors; the two resistors are needed only to limit load current. For output voltages other than  $\pm 15$ -V, the Motorola IC requires two extra components, while Raytheon's general-purpose device can still operate with six external components.

■ Prices for commercial-temperature-range versions in quantities of 100 up and in a TO-66 package are \$3.90 for Raytheon's 4194 and \$3.75 for Motorola's 1468. In 10-pin metal packages, the MC1468 sells for \$2.80 (100-999), while Raytheon has a 14-pin DIP version of its regulator for \$2.66 (100-999).

For additional information on Raytheon's 4194, see "Dual-Tracking Voltage Regulator Extends Operating Range to 90 V," ED 8, April 13, 1972, p. 97.

## Correction

In the article "Can't Decide Which Instrument to Buy?" (ED 24, Nov. 23, 1972, pp. 162-163), the instructions are garbled in one of the bottom blocks at the left of the Frequency Considerations chart (p. 162). As published, the instructions say: "Consider FG or Digital Dial and RC Osc (To 10 MHz)." They should say: "Consider FS or Digital Dial FG and RC Osc (To 10 MHz)."

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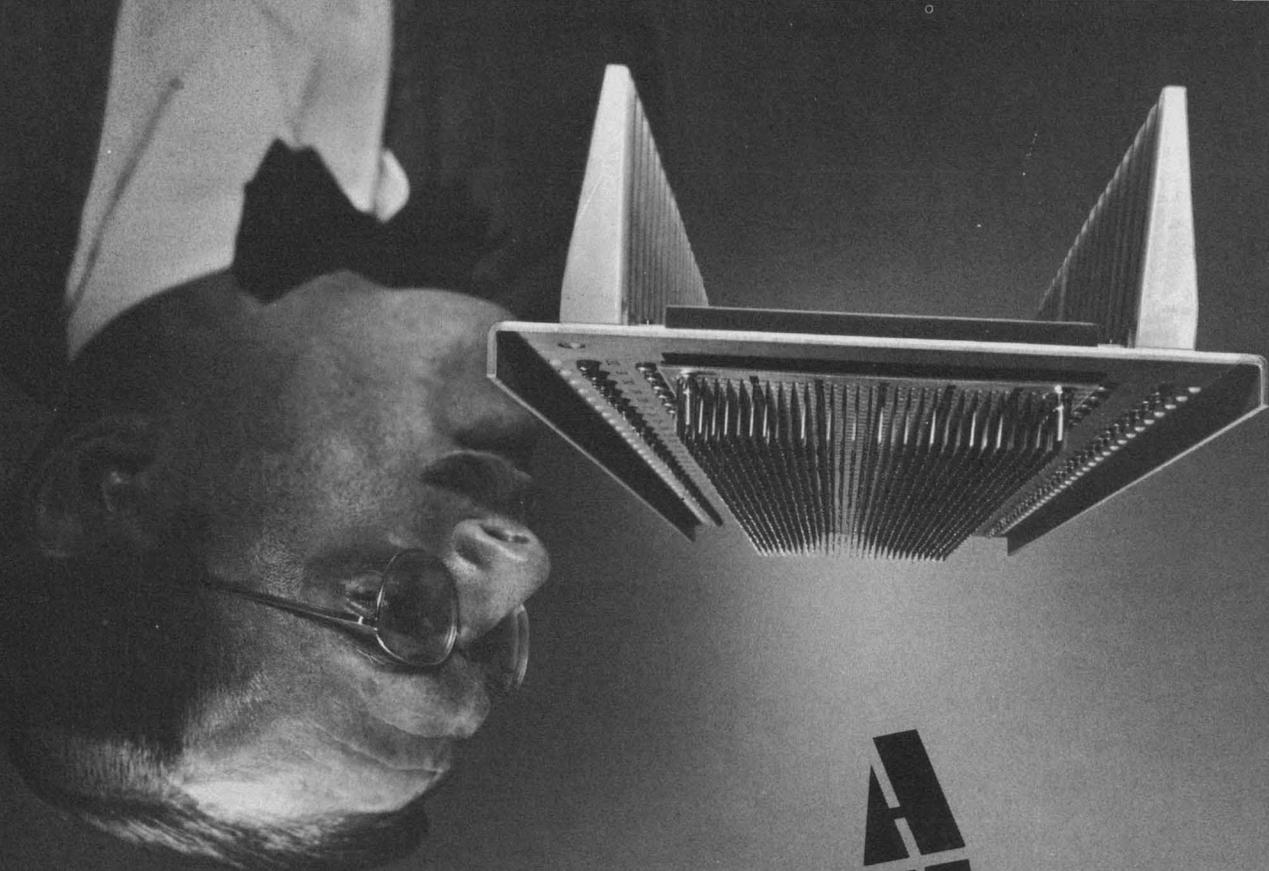
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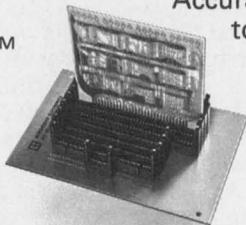
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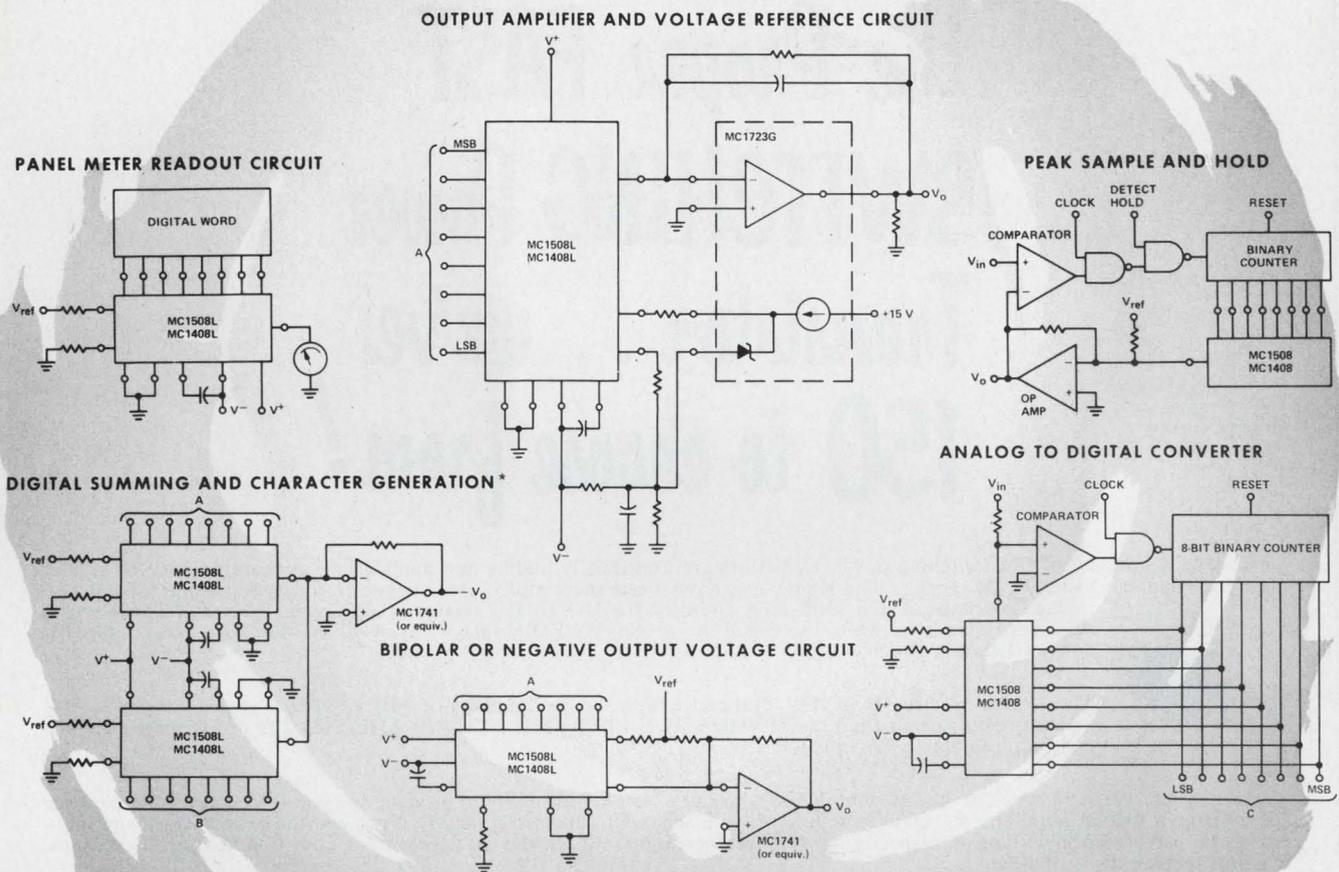
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and the MC1408L-6 have seven and six-bit accuracy, respectively, with eight-bit resolution. All four versions have a fast typical settling time of 300 ns, reference current slew rate of 4 mA/ $\mu$ s, and an extended output voltage swing of +0.5 V to -5 V. The non-inverting digital inputs are both TTL and CMOS compatible. Operating temperature ranges are -55 to +125°C for the MC1508 and 0 to +75°C for all MC1408 versions.

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					$V_{CB}$	$V_{CE}$	$V_{EB}$	$I_C$		$V_{CE}$	$V_{BE}$	$t_{on}$	$t_{off}$	$I_C$			
KS6117 KS6118	KS6217 KS6218	KS6317 KS6318	KS6417 KS6418		100	100	4.5	10A	15	⑤5.0A $I_C=5.0A, I_B=0.5A$		37	120	5.0A			
					60	60	4.5	10A		0.6	1.25				45	140	5.0A
KS6140 KS6120 KS6121	KS6240 KS6220 KS6221	KS6340 KS6320 KS6321	KS6440 KS6420 KS6421	KS6540 KS6520 KS6521	120	120	4.5	15A	15	⑩10A $I_C=10.0A, I_B=1.0A$		37	120	10A			
					100	100	4.5	15A		1.0	1.5				37	120	10A
					60	60	4.5	15A		1.0	1.5				45	140	10A
KS6141 KS6127			KS6441 KS6427	KS6541 KS6527	100	100	4.5	20A	15	⑮15A $I_C=15A, I_B=1.5A$		45	140	15A			
					80	80	4.5	20A		1.8	3.0				45	140	15A
KS6142 KS6129			KS6442 KS6429	KS6542 KS6529	100	100	4.5	25A	15	⑳20A $I_C=20A, I_B=2.0A$		70	180	20A			
					80	80	4.5	25A		1.8	3.0				70	180	20A

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## NASA aims to hold the line with a \$3.4-billion budget

NASA spending in calendar 1973 is expected to remain in stationary orbit. The budget for fiscal 1973 was \$3.4-billion, and the total for fiscal '74 is expected to stay at this level. Even if it drops slightly, spending for calendar 1973 won't be affected too much.

The main effort will be the space shuttle, which the agency will push along as quickly as it can, albeit cautiously. The big fear is that Congress might quash the whole thing if something big went wrong.

Except for a few items that will have to be bought for test purposes, almost all the work on electronic portions of the shuttle will be studies and analyses, says Ronald V. Murad, chief of avionics and ground systems for the shuttle program.

"This year, we'll put the finishing touches on our over-all avionics development plan," Murad says, "making phase-development schedules to tie in with the over-all program milestones. We will also study, with prime contractor North American Rockwell, the types of subcontractors we want."

Other action in the shuttle program this year will include the following:

- The Massachusetts Institute of Technology will begin systems analysis for guidance, navigation and control and performance monitoring. And IBM will begin an analysis of software design.

- Intermetrics in Cambridge, Mass., will begin developing the higher-order language, called Hal, for the shuttle computer, and later will develop the compiler. A computer will be selected by July.

- Honeywell will begin an analysis of the flight-control system and American Airlines an analysis of the problems of maintenance.

"We will also be firming up plans for a shuttle avionics integration

laboratory to be located in Houston," Murad says.

The emphasis in unmanned satellites continues to be for better sensors and instrumentation in the spacecraft to relieve the cost and size of equipment on the ground, according to a spokesman for NASA's Goddard Spacecraft Center in Greenbelt, Md.

Needed are sensors to monitor the earth's resources. Atmospheric and water-pollution monitors are being developed, but "as soon as we've gained some experience with them, we're going to want to improve them," the spokesman said.

Ocean color-monitoring sensors are needed, along with other instrumentation to look at the earth.

An example of the kind of sensor Goddard wants is a microwave instrument for the Nimbus meteorological satellite that will pierce clouds to measure the thermal emission characteristics of the earth. By interpolation, measurements can then be calculated for the temperatures at various altitudes below and above the cloud formations.

"We're asking sensors and instrumentation to do more and more," the spokesman pointed out, "and consequently they're costing more." Because of this, Goddard is asking industry to use existing technology wherever possible, rather than pushing to new, expensive approaches.

Balancing out the cost increase for NASA sensors is a decrease in money needed for ground-tracking facilities, which were recently upgraded and will be adequate for the next few years. Over-all spending at Goddard will remain at about \$500-million a year.

The biggest activity in the continuing exploration of the planets this year will be work on Viking, which is to orbit and land on Mars in 1975. NASA and the Jet Propul-

sion Laboratory will continue work on the camera, the line scanners, instruments to determine the atmospheric composition and pressure, and the nuclear-electric power generator for the lander.

The second Pioneer spacecraft will lift off in April to fly by Jupiter. It will be powered by a nuclear-electric engine. In October, Mariner will take off, powered by solar cells to fly by Venus and Mercury. Both craft will carry radiometers, spectrographs and imaging systems.

NASA's aeronautical work is picking up this year. Efforts are under way to reduce aircraft noise and airway and airport congestion. For noise abatement, a two-segment landing approach is being studied that would require a steeper descent to the final glide slope. Such a technique would require area navigation systems in all planes.

A STOL avionics program is under way to provide a short-takeoff-and-landing plane to operate in bad weather in a conventional aircraft terminal area. An automatic landing system is being developed for a VTOL (vertical take off and landing) plane. And improvements are being sought for landing conventional planes in bad weather.

## A standard predicted for instrument interface

A de facto standard for the interface of programmable instruments will soon be in effect in the U.S., possibly by this summer. So says Robert Faulks, vice president of engineering for the General Radio Co. in Concord, Mass., and chairman of the U.S. Advisory Committee on Instrument-Computer Interfaces, which he helped form.

The standard is being considered for adoption by the International Electrotechnical Commission, the Scientific Apparatus Makers Association, the IEEE and other groups.

If the standard is adopted users of instrument systems will be able to interconnect a variety of instruments—such as signal generators, multimeters, recorders, card readers and computers—simply by plugging in cables. Any of the connected instruments could control or

feed information to up to 14 other connected instruments.

All manufacturers of program-mable or systems-oriented equipment would have to conform to the interface or risk incompatibility between their equipment and that of other manufacturers.

The interface system—as initially proposed—is identical to one designed and developed by Hewlett-Packard, and described in its *Journal*, Vol. 24, No. 2, Oct., 1972. Basically it is a byte-serial, bit-parallel system in which each multiple-bit byte of information is transmitted in parallel and bytes are transmitted serially.

Only 15 lines are required: Eight are reserved for data input/output, three for data transfer control and the remaining four for general bus management.

However, the data-transfer-control portion, called the three-wire handshake, is proprietary to HP. Thus its adoption would require licensing agreements with HP. Don Loughry, corporate interface engineer for HP—and one of the developers of the interface—states that HP will certainly license the technique and make it available to everyone. But the details of the license have yet to be worked out.

Faulks feels that whatever form the interface takes, it will be substantially completed by this summer, although not yet officially adopted. This means, Faulks explains, that there will be very little risk of substantial changes after this summer, and that he'll be confident in recommending that General Radio go ahead with the interface hardware. Other companies, he continues, will probably also follow suit.

## Minicalculator to become 'major market'

The enthusiastic acceptance of the pocket calculator last year is continuing to build at a healthy pace, boosting the miniature electronic device into "one of the hottest consumer markets around—and one in which the Japanese are not yet ready to compete"—according to panelists at the "Outlook 73: Calculators" session of the Winter Consumer Electronics Show in Chicago this week.

"The U.S. market will absorb

eight to 10-million units," according to Herbert Barnett, national marketing manager of Commodore Business Machines, Santa Clara, Calif. "The rest of the world will take another two million."

Both Barnett and Robert Beachler, vice president of operations for Craig Corp., Compton, Calif., predict that most of the 1973 crop of small calculators will cost the consumer from \$59 to \$69.

Variations of the pocket calculator expected to appear this year include a slightly larger, more versatile desk-top minicalculator to cost from \$69 to \$74, Barnett predicts, and calculators with expanded memories for from \$100 to \$120.

The next big development in the minicalculator line, though not expected before 1974, will be a true electronic desk-model printing calculator with standard vertical printout, says Commodore Business Machine's Barnett. The only one available now, which is built by Canon, prints out a non-conventional horizontal serial form similar to ticker tape.

The reason the U.S. won't have to contend with Japanese competition right away is "because they are a year behind the U.S. in their technology," Barnett says. "There's only one chip manufacturer in Japan."

## Users demand and get higher reliability ICs

Increased pressure by manufacturers for more reliable integrated circuits at lower costs has spawned efforts by a number of companies to meet their demands. Signetics' program is called Supr Dip, Texas Instruments has REL II, National Semiconductor calls its program Test, Motorola has Sentry and Raytheon also has a strong program.

## News Briefs

**The American Stock Exchange in New York City has an infrared transmission system** that carries transaction data from the roof above the exchange floor to a computer complex two blocks away. The system, which now handles 5400 characters a second, may be expanded to carry 25,000 this year.

The users desire for guaranteed, factory-made reliability, according to Richard Kramer, National's manager of reliability engineering, is to avoid the expense of having to inspect ICs as they are bought. More important, Kramer notes, is the time and money wasted in reworking printed circuit boards where faulty ICs are used. Also, manufacturers have to worry about warranties and servicing, both expensive and time-consuming.

To overcome these problems, says Kenneth La Barbera, marketing manager for Signetics, Supr Dip was initiated, which resulted in a new category of IC that falls in between the military and commercial devices, both in cost and performance. For an additional 5 to 8¢ per IC, a customer can get a plastic device that has a guaranteed AQL (accepted quality level) of 0.15%, has undergone several visual inspections, thermal shock and electrical and high temperature functional testing.

The program has been so widely accepted, reports La Barbera, that "we plan to come out with a new version of it—Supr Dip II."

National Semiconductor also plans to come out with a new version of its Test program this quarter.

Texas Instruments' distributing arm, TI Supply, has just introduced its high reliability REL II program, which in addition to performing additional tests, provides for a 168-hour power burn-in to eliminate devices that fail early. It provides devices with an AQL of 0.25% and costs an additional 25¢ per unit.

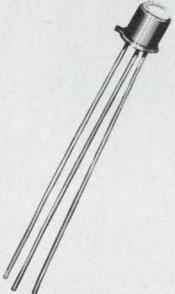
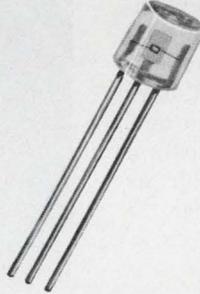
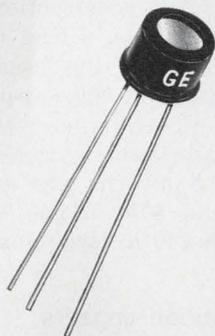
Motorola Semiconductor is about to introduce its Sentry program for consumer ICs. It differs from some of the other efforts in that its main emphasis is on meeting critical environmental requirements.

A publishing company, Gannett of Rochester, N.Y., has invested more than \$2.5-million in R&D on a system for producing printing plates through multiple laser-beam applications. The process would eliminate the need for a photographic negative, line-casting machines or other metal composition procedures.

# GENERAL ELECTRIC

# OPTOELECTRONIC

# DETECTOR LINEUP

				
<p><b>L15A SERIES</b></p> <ul style="list-style-type: none"> <li>● hermetic phototransistor</li> <li>● packaged for printed circuit board mounting</li> </ul>	<p><b>L15E SERIES</b></p> <ul style="list-style-type: none"> <li>● hermetic phototransistor</li> <li>● sensitive, fast switching</li> <li>● for detector arrays</li> </ul>	<p><b>L14A SERIES</b></p> <ul style="list-style-type: none"> <li>● hermetic phototransistor</li> <li>● 3 <math>\mu</math>sec turn on, turn off</li> </ul> <p><b>L14F SERIES</b></p> <ul style="list-style-type: none"> <li>● hermetic photodarlington</li> <li>● high sensitivity</li> </ul> <p><b>L1V SERIES</b></p> <ul style="list-style-type: none"> <li>● hermetic "SCS"</li> </ul>	<p><b>L14D SERIES</b></p> <ul style="list-style-type: none"> <li>● photodarlington configuration</li> <li>● high sensitivity</li> </ul> <p><b>L14E SERIES</b></p> <ul style="list-style-type: none"> <li>● phototransistor</li> <li>● typical 3 <math>\mu</math>sec turn on</li> </ul> <p><b>L14T SERIES</b></p> <ul style="list-style-type: none"> <li>● PNP photo switch</li> </ul>	<p><b>L8, L9 SERIES</b></p> <ul style="list-style-type: none"> <li>● hermetic photosensitive SCR</li> <li>● switches 1.6 amp</li> </ul>

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# The low-cost, low-power laser: It's here, there, everywhere

Some six or seven years ago laser designers convinced the construction engineer to lay aside his \$5 ball of string and try using a gas laser for making straight lines.

The helium-neon laser, with its pencil beam of light might cost a little more, but it is more accurate, saves time and requires fewer people to do the job.

After the construction industry discovered this, a host of new industries joined the laser club, and more than 100,000 low-power, low-cost, CW helium-neon lasers have been sold—lasers with a power output of 5 mW or less and costing less than \$750. Some sell for as little as \$40 in large quantities.

## Competition appears

Low-power lasers are high-power business today, and prospects are that the major growth still lies ahead. The result has been the rise of new laser types and a growing applications struggle between competitors.

About two years ago a low-cost gallium-arsenide semiconductor injection laser became commercially available.

Not able to emit a pencil-like beam, and therefore not suitable as a "straight edge" for alignment jobs, the semiconductor injection laser is finding applications in short haul communications, military ranging devices, security systems, special illumination for battlefield imaging systems and in many jobs in the laboratory.

Ranging in price from \$9.60 to \$950, more than 50,000 low-cost gallium arsenide semiconductor injection lasers have been sold, says



Helium-neon construction lasers, like this Metrologic system, are becoming more versatile.

RCA's product marketing manager for the devices, T. J. Grabowski in Lancaster, Pa.

A third laser, which appeared commercially about four years ago and has sold close to 1000 units, is the helium cadmium. Not quite "low cost" but getting close to that goal, this gas laser emits a blue (4420 Å) or ultraviolet light (3250 Å) that has attracted users who need to write on emulsions and films.

Its advantage over the HeNe laser is that available photosensitive papers are more sensitive—faster—in the blue-green region than in the red, thus making the HeCd laser handier for writing than the HeNe. The HeCd has a big advantage over the Argon laser, because it's cheaper and has better photosensitive paper available for its blue light than the Argon does for its green.

In the jockeying for market position, helium-neon laser has proved it can do far more than define straight lines for highway construction, bricklaying, tunneling, the laying of pipes and—when beamed through a rotating prism—the building of ceilings. HeNe lasers are also being used in the following applications:

- Alignment work. Engineers are using the lasers to align gun positions and antennas on ships and align wheels and other points on automobiles. And now that the devices have become so inexpensive, they are even being bought by small auto-repair shops where damaged car and truck bodies are straightened.

- Testing and precise measurements. Glass and sheet-metal manufacturers find HeNe lasers useful for nondestructive testing—for blemishes as large plates pass down a production line, for example. The lasers are also used for making flow and machine-tool distance measurements, for gauging thickness, for positioning automated machines, for inspecting large prisms and lens and for optical tooling operations.

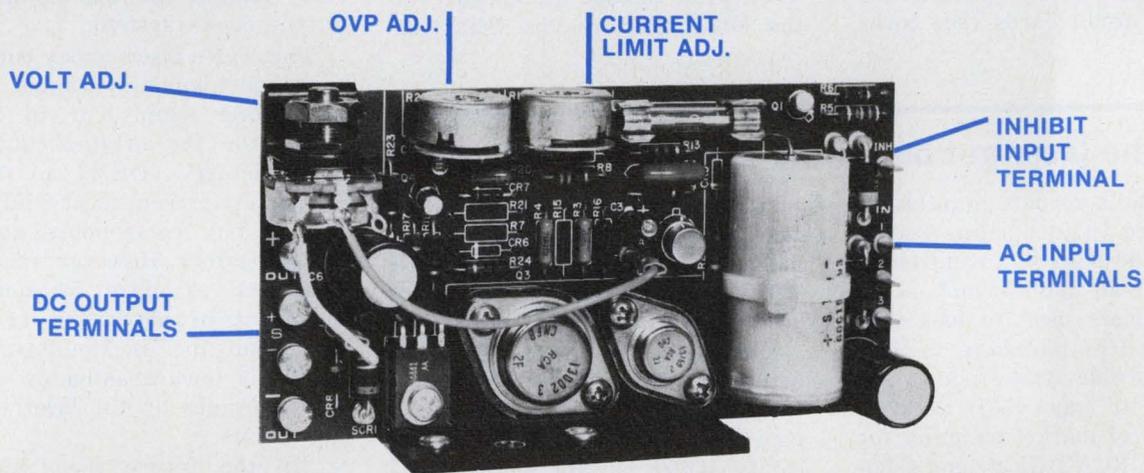
- Scanning. The gas lasers scan production lines to keep quantitative records on output. And they can read bar-code patterns on packages and letters and on supermarket products at the checkout counter, adding up totals and keeping inventories.

- Data processing. Lasers for character recognition for computer readouts "will eventually dwarf the laser market provided by the construction industry," says Philip H. Vokrot, manager of market planning for lasers at RCA's Electronic Components Div. in Lancaster, Pa. And Richard Roemer, manager of laser product sales at the Hughes

John F. Mason  
Associate Editor

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22D	12.0A	10.4A	8.8A	7.6A	6.8A	6.0A	5.6A	5.2A	5.0A	4.7A	35.00
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Aircraft Electronic Dynamics Div. in Torrance, Calif., says: "A single customer might need tens of thousands of such units a year."

■ **Communications.** Gas lasers can carry large amounts of information, audio and video, and they have an excellent potential for short-haul data links, says R. A. Jeuch, engineering leader for RCA's Gas Laser Development in Lancaster, Pa. He points out the advantage of using a laser link at a football stadium to transport television signals to a transmitter van. "At a big game, 25 miles of cable might be needed," he notes. "At \$1 a foot for cable, a laser would do the job for far less money."

Other applications for the HeNe laser include holographic recording for checking filed data—such as the validity of credit cards (see cover

photo)—spectroscopy, particulate sampling in a pollution detection device, ranging systems and optical displays.

"Two applications with promising futures are noncontact printing and, in the home entertainment field, video playback systems to be used with home television sets," says Hughes' Roemer.

### How HeNe lasers are made

The fundamental ingredient in most helium-neon lasers is a tube that is rugged and stable and can be mass-produced. Hughes and Spectra-Physics in Mountain View, Calif., have both substantiated tube lifetimes of more than 15,000 hours.

The tubes are, with a few exceptions, of a coaxial design—one of the key breakthroughs that took

the laser out of the laboratory and into the field. Developed and patented by Hughes, the coaxial construction resulted in a rugged, smaller tube. Another breakthrough, developed by Bell Telephone Laboratories, was the cold cathode-ray tube, which cut the need for heaters and permitted the use of an inexpensive power supply.

Some manufacturers offer tubes that are environmentally sealed in aluminum cylinders with end caps and flexible power cords, ready for operation. The cylindrical configuration of the laser heads permits easy mounting in clamps, V-blocks, rings and other hardware.

Permanent factory alignment of the output beam so it is concentric with the cylindrical mounting surface simplifies alignment of the laser relative to other components in the user's system.

The HeNe laser comes both as a neat and complete package, including power supply, or in components for the original-equipment manufacturer (OEM) to put together. At present most OEMs prefer to buy components and put them together. However, the trend, according to Marc Eliason, vice president of marketing of C W Radiation, Inc., in Mountain View, Calif., is toward assembly of custom packages by the laser makers for OEMs.

"In the future the OEM will know more what he wants and will tell us what the complete package is to be," Eliason says.

Hughes foresees demand for complete systems, including the laser power and optics.

At present there is a wide variety of laser ruggedness that the OEM can choose from. There are units for construction work that are protected from dust and heat and vibration and there are less rugged lasers for use in laboratories.

Available HeNe lasers operate in various modes. One is the TEM<sub>00</sub> mode, which offers the greatest concentration of light in the exact center of the beam. There are also random modes, which concentrate the light anywhere in the beam. According to Hughes, approximately 95% of OEM orders specify TEM<sub>00</sub>. One reason is that this mode has roughly half the beam

*(continued on page 28)*

## How the laser got out of the lab and into the field

How did a revolution in lasers take place in just seven years? Wasn't the laser an invention in search of an application?

"The laser used to look like some kind of plumbing facility with electrode arms sticking out all over it," says P. H. Vokrot, manager of market planning for lasers at RCA's Electronic Components Div., Lancaster, Pa. "It had gas reservoir bottles and a heater for its hot cathode—all of which made it too unwieldy to package."

Two breakthroughs were responsible for the helium neon laser's emergence from the laboratory into the field:

1. In 1965 the cold cathode became available. It eliminated the need for the hot cathode and all its accessories.

2. In 1966 the laser's two cavities—plasma and optical—became one.

Originally the gas laser was built with a plasma tube that was sealed at each end by Brewster windows. Two mirrors were used for the lasing action, but they were placed outside the tube. Then it was discovered that the mirrors could be put directly on the plasma tube,

permanently positioned and aligned, thereby significantly reducing the manufacturing cost.

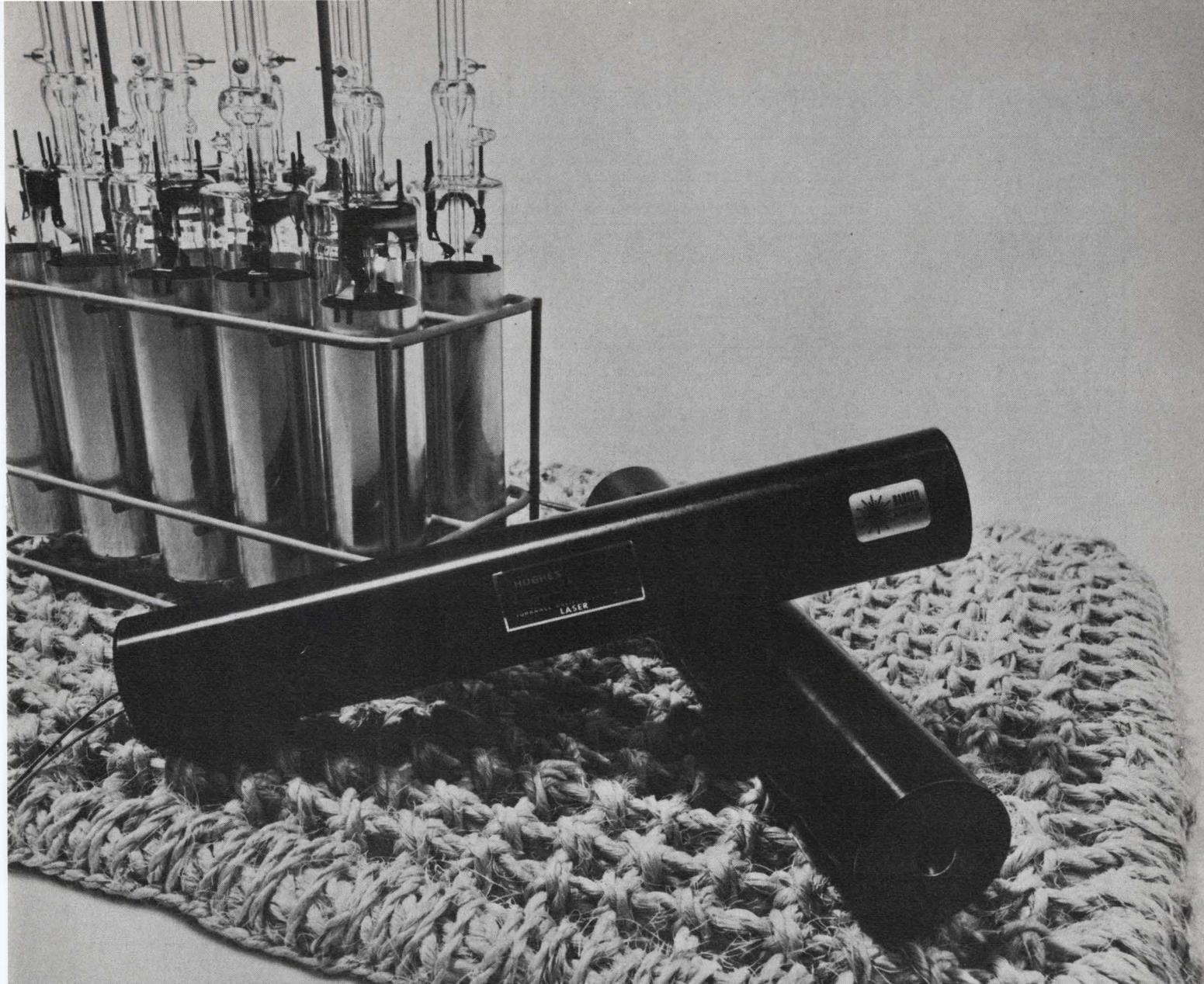
The semiconductor injection laser came into its own in 1970.

"The development of the single heterojunction structure reduced internal losses of the photons generated in the laser diode cavity, which cut the power requirement in half and provided longer life," says Richard Glicksman, RCA's manager of solid-state emitters, in Lancaster, Pa.

End coatings were also developed to reflect the radiation from the rear face of the diode—an area that previously was not utilized. This resulted in increased output of approximately 40% at room temperature and nearly 100% at cryogenic temperature.

GaAs crystal and epitaxy process improvements helped, too. They resulted in prolonged life, uniform radiation from the junction and lower cost through better yields.

The center wavelengths were extended to a range of 8000 to 9000 Å by the use of gallium-aluminum-arsenide diode structures. This permitted greater over-all system sensitivity.



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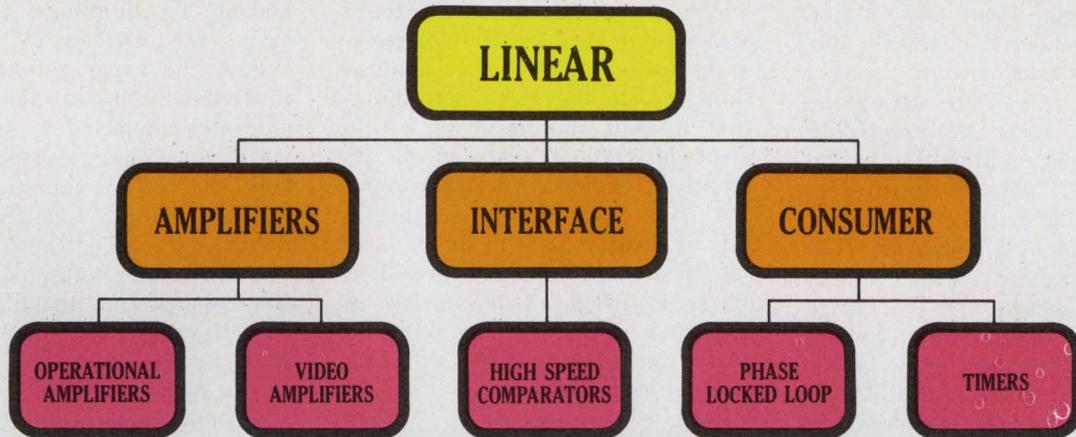


# A sampling of the low-cost, low-power lasers available

Helium neon lasers							
Manufacturer	Power Range	Wavelength	Modes	Output	Power supplies	Packaging	Price range
Coherent Radiation 3210 Porter Dr. Palo Alto, Calif. 94304 (415) 493-2111 Contact: Carl Jordan General Sales Manager	1.5 to 5 mW	6328 Å	TEM <sub>00</sub>	Polarized Unpolarized	12 V dc	Components or complete laser.	\$250 to \$575
C W Radiation 111 Ortega Ave. Mt. View, Calif. 94040 (415) 969-9482 Contact: Marc Eliason Vice President	0.5 to 5 mW	6328 Å 11520 Å 33910 Å	TEM <sub>00</sub>	Polarized	12 V dc 115 V ac 220 V ac	Self-contained, weather-proof, detachable laser heads. Packaged systems.	\$99.50 to \$700
Hughes Aircraft Electron Dynamics Div. Torrance, Calif. 90509 (213) 534-2121 Contact: Dick Roemer, Sales Mgr. Eric Hass, Asst. Sales Mgr.	1 to 5 mW	6328 Å	TEM <sub>00</sub>	Polarized Unpolarized	12 V dc 115 V ac 220 V ac	Laser and power supply separate. Complete laser or components.	\$40 to \$280
Metrologic Instruments 143 Harding Ave. Bellmawr, N.J. 08030 (609) 933-0100 Contact: Larry D. Adams Program Manager	0.5 to 5 mW	6328 Å 11520 Å 33910 Å	TEM <sub>00</sub> Random	Unpolarized	12 V dc 115 V ac 220 V ac	Complete lasers or tubes.	\$87 to \$275
RCA New Holland Avenue Lancaster, Pa. 17604 (717) 397-7661 Contact: P.H. Vokrot	1 to 5 mW	6328 Å	TEM <sub>00</sub> Random	Polarized Unpolarized	12 V dc 120 V ac	Power supply separate or combined.	\$110 to \$440
Spectra-Physics 1250 W. Middlefield Mt. View, Calif. 94040 (415) 961-2550 Contact: Ron Elchesen	0.5 to 5 mW	6328 Å	TEM <sub>00</sub> Highly multi-mode	Polarized Unpolarized	115 V ac 220 V ac	Laser and power supply separate or combined.	\$99.50 to \$675
Helium cadmium lasers							
Coherent Radiation (Same as above)	1 to 10 mW	4416 Å 3250 Å	TEM <sub>00</sub>	Polarized Unpolarized	12 V dc	Components or complete laser.	\$1600 to \$1750
Metrologic (Same as above)	3 to 25 mW	4420 Å 3250 Å	TEM <sub>00</sub>	Polarized Unpolarized	115 V ac 220 V ac	Complete laser.	\$780 to \$1080
RCA (Same as above)	5 mW	4416 Å 3250 Å	TEM <sub>00</sub>	Polarized	108 to 132 V ac	Complete system.	\$1725 to \$2125
Semiconductor injection lasers							
Manufacturer	Peak power	Wavelength	Output	Configurations	Power supplies	Packaging	Price range
Laser Diode Labs 205 Forrest St. Metuchen, N.J. 08840 (201) 549-7700 Contact: Robert Gill Vice President	Diodes 4 W to 60 W  Stacks 25 W to 175 W  Arrays 60 W to 1000 W	GaAs  9040 to 9050 Å  GaAlAs  8000 to 8700 Å	Unpolarized	Discrete diodes Stacks Arrays	28 V dc 120 V dc Pulse generators and converters.	Laser and power supplies separate.  Transistor type packaging.	Discrete diodes \$9.60 to \$95  Stacks \$55 to \$230  Array \$130 to \$2340
RCA Electro Optics Products New Holland Ave. Lancaster, Pa. 17604 (717) 397-7661 Contact: R. Swarbrick	1 W to 1000 W  Diodes 1 W to 50 W  Stacks 25 W to 100 W Arrays 25 W to 1000 W	GaAs  9040 Å at 27 C  GaAlAs  8500 Å at 27 C	Partly polarized	Discrete diodes Stacks Arrays	Power supply not provided.	Transistor type packaging.	Discrete diodes \$10 to \$100  Stacks \$50 to \$250  Array \$50 to \$1000

(continued on page 30)

# Economy: First Class



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**555 IC Timer.** The world's first standard timer has intrigued countless designers with time control on their hands. Low-cost, easy to use, Signetics 555 functions interchangeably as a resettable time delay, sequencer, power modulator or oscillator. So multi-applicable, you can't help turning creative yourself.

**527/529 High Speed Comparator.** A real two-in-one breakthrough, still another Signetics first. The fastest, least cantankerous voltage comparator to hit the market when introduced last year. The biggest improvement in comparators since the 710 (300% faster). By incorporating Schottky technology into 527/529, both high speed and precise input characteristics are maximized. Offering users a new generation of sense amplifiers as an alternate application of these devices.

When it comes to industry standards, Signetics linear shapes them up before we ship them out. So much so, they evolve into new circuits—pin-compatible but considerably

enhanced. So versatile, you can stock fewer parts yet accomplish a great deal more, while lowering total board costs.

**592 Video Amplifier.** Primarily applied as a magnetic head preamp for disc file read circuitry. Pin-for-pin with 733, but offering more refined performance and versatility. Proven useful for high frequency bandpass or highpass filtering because no matched passive components are required. So, less parts are needed—both inventory and board work costs go down.

**531/536 Op Amps.** Salt of the earth, economy-minded op amps for generalized performance requirements. The 536 FET Input Op Amp easily replaces the lower end of the modular op amp market without penalty, and saves up to 50% cost. Low-price 531 High Slew Rate Op Amp is priced under competitive devices, but functions more than adequately over most standard requirements.

**540 Power Amplifier.** Out-performs common power drivers with extra high speed. This Class AB audio amp on a single chip is economy-priced, but saves still more on unnecessary associated components. Output power limiting delivers total power protection and still allows smaller output transistors: less cooling is required.

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(continued from page 28)

divergence of a multimode beam. This is important, because a narrow-beam divergence simplifies the optics for the total system and reduces the package size.

One specification that warrants attention, but not too much concern, is beam width. The beam diameters range from 0.6 to 2 mm, which is considered negligible for most applications.

"An OEM can often run up the cost of his laser by specifying beam divergence and width that he doesn't need," says Richard Gorton, marketing manager at Metrologic Instruments, Bellmawr, N.J.

Angular stability, which is inherent in a laser tube design, is an important specification. Imperfect construction will give lasing action but the angle will shift, so that, under given temperature variations, the beam may wander.

Polarization of the beam is offered in some lasers. This is important for system compatibility if the OEM plans to use a polarized element in the optical system—in a lens, a beam splitter or mirrors.

"If polarization is not necessary, don't ask for it; it costs more," Gorton says. But Hughes' Roemer points out: "Polarization does give better beam purity, and if this is needed, it will be worth the cost."

In general, the advice to the OEM is to tell the laser manufacturer how he plans to use the laser and the performance he requires and then let the laser specialist write the specs.

### Where the semiconductor works

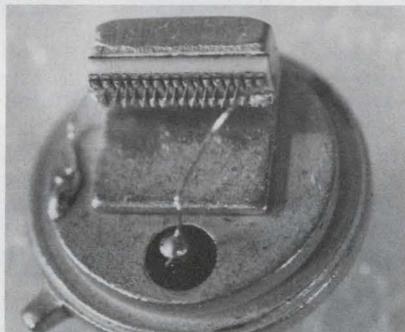
The semiconductor injection laser emits a wide beam of light rather than a pencil beam, and its emission is pulsed rather than continuous. It's surprisingly small—the size of a transistor—and it's finding many uses, particularly in short-distance operations. The applications include these:

- Intrusion alarms, Gallium-arsenide lasers are taking the place of tungsten bulb and filter systems in both military and industrial security systems. When an intruder enters the beam, he reflects light that triggers an alarm. The advantages of the laser system are lower cost, lower power drain and smaller, less detectable systems.

- Communications. Diode lasers are good for short-haul communications—between buildings, for example. And for secure communications for the military, infrared systems are finding application.

- Ranging. The military is buying small diodes for use as altimeters for helicopters, for range-finders to zero in on enemy tanks and similar targets, and for proximity fuses. In the latter applications, when the laser determines that a shell or missile is within a predetermined distance of its target, it explodes the weapon.

- Data processing. Although this application is still in its early stages, Robert Gill, vice president of Laser Diode Laboratories in Metuchen, N.J., sees the semiconductor laser being used as a device for computers.



RCA's 15-diode linear array provides a peak power output of 75 W.

Other applications that RCA and others foresee include real-time readout of holograms, collision avoidance for automobiles, traffic control, weapon simulation and "ceilometers" for measuring the altitude of clouds.

The trick for the OEM in choosing the right semiconductor laser is to order only the power he really needs, Gill says. "Engineers often ask for more power than they need," he notes.

The OEM has a wide variety of semiconductor injection lasers from which to choose. There are single-diode injection lasers, stacked diodes and diode arrays. They are made with gallium arsenide and emit in the 9040-to-9050-Å range.

Gallium-aluminum-arsenide injection lasers are also available for use with near-IR-sensitive (8000 to 9000 Å) image intensifiers and photomultipliers.

The single diodes have a peak

power range from 4 to 60 W. The stacks from 25 to 60 W, and the arrays from 60 to 1000 W. Single diodes are suitable for voice communications over short range. Stacks, which consist of two or more diodes in a stack, emit more power and are suitable for voice over longer links and for intrusion alarms. To illuminate a battlefield target for an IR or TV image converter, the array might be used; it consists of diodes placed side by side and connected by wires.

Though young, and not inexpensive, the helium cadmium laser is also gathering a following because of its ability to do the following:

- Write on photosensitive paper. The applications include information storage, particularly on film; in-flight recorders and data processing readout devices.

- Detect pollutants. Some particles are detected more easily by wavelengths in the blue region than in the HeNe's red.

- Display in full color. By use of a single 4416-Å beam to excite red, blue and green fluorescence, a full color display can be achieved.

- Conduct experiments in spectroscopy. New research in the fluorescence of microscopically small samples is possible, as are new studies of excitation and de-excitation processes of triplet states in organic molecules.

The HeCd laser is usually packaged with its power supply. The total package measures 30 to 40 inches in length and 6 by 6 inches on the sides.

The most inexpensive HeCd laser on the market, Metrologic's ML 442, emits a continuous beam of coherent deep blue light (4420 Å). The beam is randomly polarized and provides a 20-mW output in the TEM<sub>00</sub> mode. The integral mirrors are permanently aligned.

Design features include the laser's use of single isotope cadmium, a diffusion chamber for minimizing noise, and all-fused quartz-glass, sealed optics.

The tube has a directly heated tungsten matrix cathode with long life emission. Warm-up time for the laser is five minutes.

RCA offers a HeCd unit for \$1725. Hughes and Coherent Radiation are doing custom work in this field, and Hughes will soon announce a commercial line. ■■

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## OUTLOOK FOR '73

# A \$4-billion hike in defense spending due, with little if any of it trickling into R&D

Defense spending is expected to increase slightly this year—by \$4-billion for fiscal 1974, if the Defense Dept.'s recommendation goes through. A total of \$80-billion is being sought. But because operating and personnel costs are also rising, it's unlikely that there will be any increase in research and development money.

Only two things would be dramatic enough at this time to cause a war-weary Congress and nation to increase arms spending significantly: a total breakdown of the SALT talks with the Soviet Union, which are intended to curb the arms buildup on both sides, or involvement in another war.

R&D and procurement will continue for what is considered to be the nation's fixed triad of strength: bombers (the B-1), Minuteman

land-based ICBMs, and submarine-launched ICBMs.

### Army stressing versatility

Big Army programs include development of a large transport helicopter, a new attack helicopter, the ground-to-air SAM-D missile and a new tank.

Spending for ground and ship-based radar from the middle of 1972 to July, 1974, will exceed \$1-billion, according to a study by Frost & Sullivan, a New York-based market research firm.

Radar work is under way for the two Safeguard antiballistic missile sites, for the defense of Minuteman sites and for over-the-horizon radars.

The Army has assigned a high priority in 1973 to the improve-

ment of surveillance techniques, electronic warfare, command and control systems and communications.

### Air Force looking ahead

The Air Force's Airborne Warning and Control System (Awaacs) and Advanced Airborne Command Posts will both go into the advanced development stage this year.

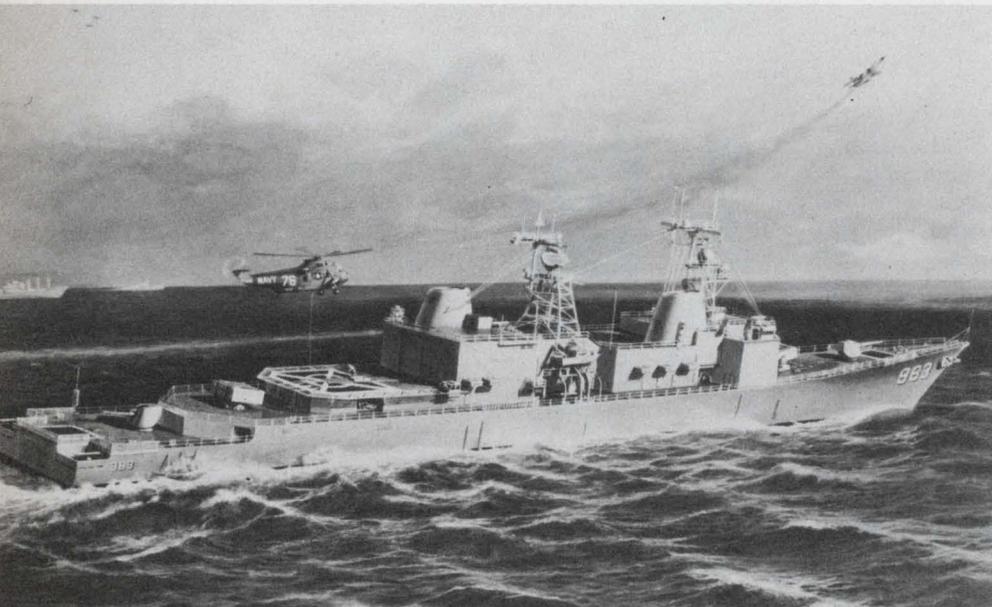
The Air Force will continue efforts to reduce the risks associated with over-the-horizon backscatter radar. It plans to develop automatic tracking and air traffic control for tactical aircraft, a new generation of highly reliable airborne uhf radios, other avionics and landing systems, including a new ground-control approach system.

Also, there will be increased emphasis on the survivability of weapons and equipment exposed to electromagnetic pulses and electromagnetic radiation. Tests are to be made after the development of electromagnetic simulation techniques. New techniques in information transfer systems will be explored, as well as advances in low-frequency communication and base security sensors.

### Navy aiming to economize

For the Navy, the trend in ships is toward more inexpensive ones. Work will also continue on the DD 963 destroyers. Also in the works for 1973 is a fleet communications satellite system and a cruise missile to match the Soviet's Styx missile.

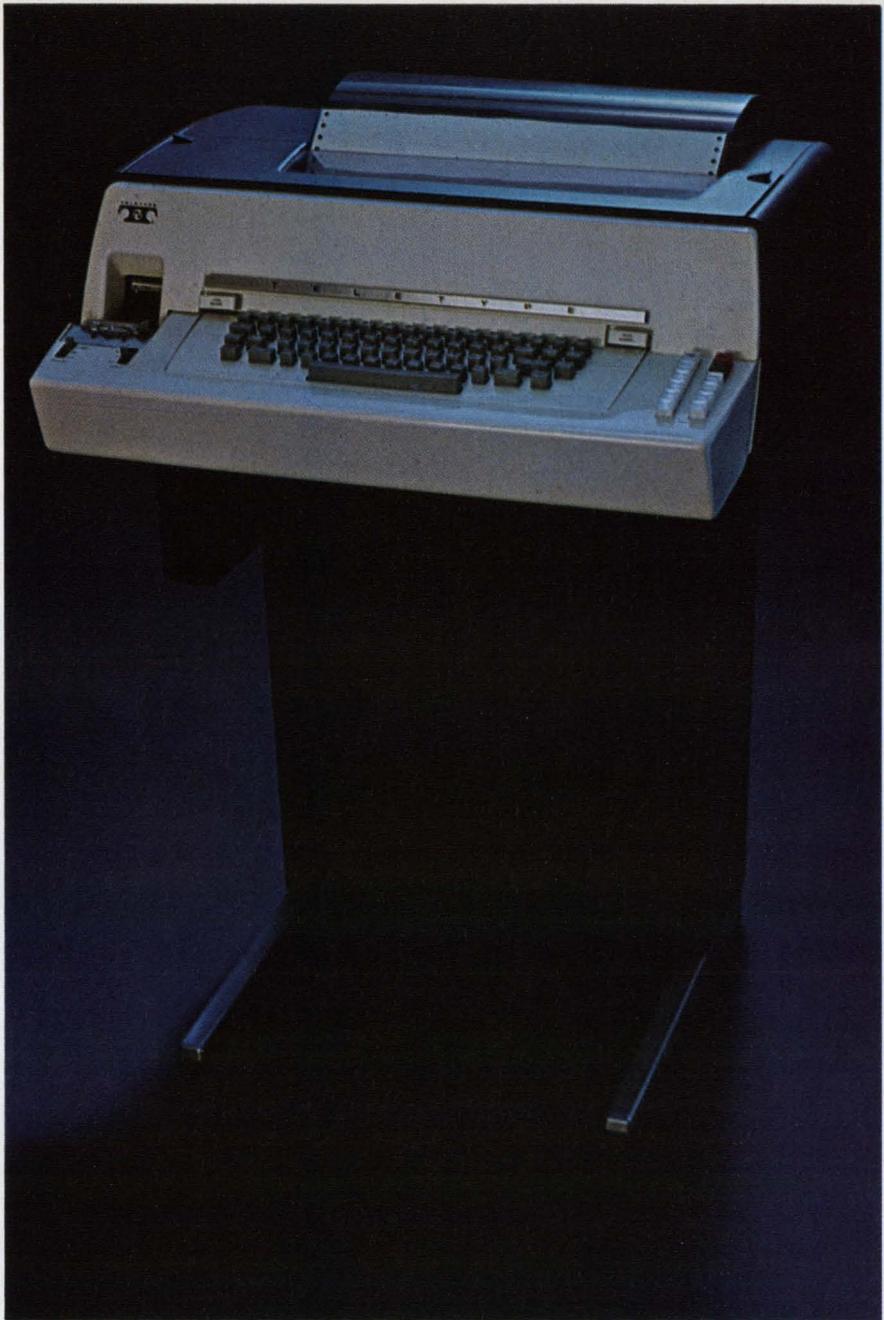
The Office of the Director of Defense Research and Engineering will attempt to overcome a number of technological deficiencies this



The Navy's Spruance class destroyer (DD 963) is being built by Litton Industries as a total system, down to the smallest black box. The contract calls for a design that leaves room for easy modifications, later innovations and new weapon systems.

## Our new model 38 series.

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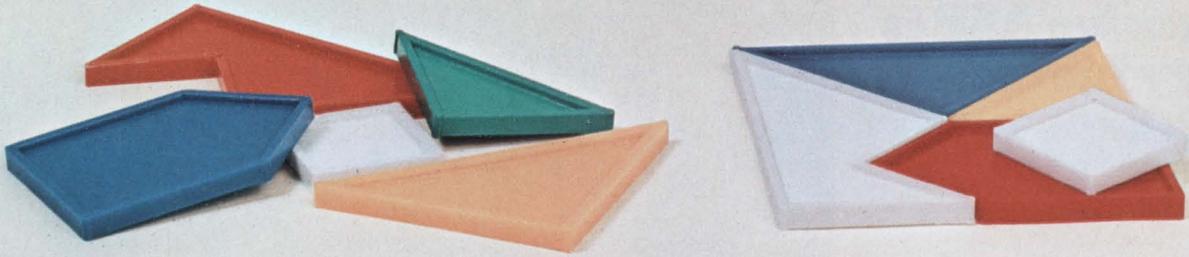


For more information about any Teletype product, write or call: **TERMINAL CENTRAL**; Teletype Corporation, Dept. 89N, 5555 Touhy Avenue, Skokie, Illinois 60076. Phone 312/982-2500

\*Prices subject to change without prior notice.

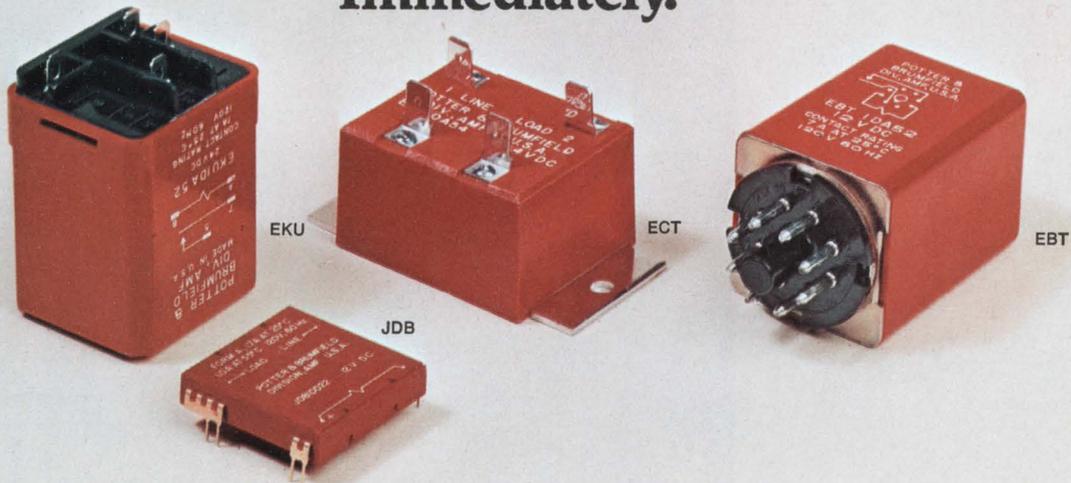
INFORMATION RETRIEVAL NUMBER 25

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of mounting. Coil voltages are from 5 to 48V DC. Power requirements are 290 mW for 120V, 60 Hz operation and 450 mW for 240V, 60 Hz. .250" quick-connect terminals are standard with .187" and .205" also available.

**EBT Series.** The solid-state "contact" is designed to carry a maximum load current of 7A rms, 60 Hz at 25°C ambient. This series provides the convenience of octal plug-in terminals and may be mounted in a socket having screw terminals.

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*\*Like to try your hand at solving the puzzle shown above? Ask your P&B representative for one.*

Solving switching problems is what we're all about.

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year, according to Edwin N. Myers, staff specialist in electronics sciences. Among them are these:

- Microwave tubes. "We got overcommitted in solid state microwave devices, and they won't do all we want them to do," Myers explains. "Meanwhile our laboratories dropped out of the tube business, as did much of industry."

Wanted are tubes with high average and peak power, more bandwidth—into the millimeter-wave region—and more efficiency. A typical application is for countermeasures equipment. "We're looking for new ideas and new techniques to push on into the millimeter regions," Myers says. "We haven't seen many new tube structures, so it appears that the answer will be based on conventional designs. But we'd like to see some breakthroughs."

- CMOS. The high-density package capability of CMOS interests the military, as does its low power consumption, but the devices must first be hardened against radiation.

- Semiconductor technology beyond silicon—"something to give us additional advantages in terms of speed and better infrared detectors," Myers says. "Gallium arsenide isn't the answer now, be-

cause there is no MOS technology feasible in the III to IV groups of the periodic table. What must be found is some compatible insulating material similar to silicon dioxide. We're encouraging our research people to tackle these problems."

- Magnetic bubbles. The Pentagon sees a limited military application for magnetic bubbles as replacements for tape recorders in unattended places. "For high-speed work, however, bubbles are too slow," Myers concedes.

- A nonvolatile memory—one that isn't wiped out when the power fails. The memory being used now is plated wire, "but the power consumption is too great and it is large and heavy, especially for space or airborne use," Myers points out.

- Amorphous semiconductor memories. They're being studied but have not yet been fully checked out, Myers reports. Receiving the most attention is the MNOS (metal nitride oxide semiconductor) memory. "They're attractive but there are still questions on their vulnerability to fatigue," Myers says. "If you design it for more than  $10^9$  write cycles, the device wears out. This limits the pro-

grammer badly. Until we solve the fatigue problem, the MNOS is not a very likely candidate for a true random-access memory."

- Far infrared. Imaging by infrared—including airborne forward-looking infrared (Flir)—has a big future in the military for night-viewing vehicles, sights for weapons, such as the TOW missile, and hand-held thermal viewers. An infrared imaging system gives a picture as good as that produced by television, and it does not require any light.

- Acoustic surface-wave devices. Basically signal-processing devices that work in the low microwave range, these devices, which are about the size of an IC, could replace pulse-compression filters in radars, delay lines and signal correlators. There are, however, still some technology problems. "We need materials that are uniquely tailored to the acoustic-wave needs to eliminate the need for a constant temperature," Myers notes. "Now, performance characteristics change with the temperature."

- Display techniques. "This spring," Myers says, "we're going to decide on the kind of large flat display we think is best and then put a lot of work into it." ■■

## Industrial electronics becoming 'a way of life'; manufacturers see a year of growth ahead

Industrial electronic-equipment sales are climbing and are expected to continue to do so through 1973. This welcome observation is shared by most producers of the equipment and is based on inquiries and proposals received by them late last year.

"We expect a 10 to 20% increase in sales over 1972," says Donald Law, General Electric's manager of numerical-control operations in Waynesboro, Va. "The increase will be more in overseas sales than domestic, because Europe was slower to pull out of its recession than was the U.S. Domestic sales began to pick up in 1972 and will continue to increase, whereas in Europe they are just beginning to move."

There are several other reasons

for the over-all growth. With business in the U.S. much improved, electronics manufacturers are finding that automation equipment built for one industry—automotive or metal-working, for example—has application in other industries, such as textiles, chemical, wood-working and processing. Controls are getting smaller, smarter and cheaper. And people are losing their fear of working with sophisticated equipment. "It's become a way of life, and they're buying it," says Donald Chace, industrial product development manager for the Digital Equipment Corp. in Maynard, Mass.

Allen-Bradley in Cleveland is looking for a wider market for its computer-controlled system, which was introduced at the Ma-

chine Tool Show in Chicago last September. William Ware, the company's marketing manager for industrial controls, reports that inquiries have come in for systems for a wide variety of applications: warehousing, transfer lines, automatic assembly operations and the supervision of programmable controllers. The company is building systems now that will both supervise programmable controllers and control other aspects of the manufacturing operation at the same time.

### Controllers on the move

Programmable controllers have moved out of the factory and into the gas and oil fields, says Edward Holmes, electronics production

manager for Camco, Inc., in Houston, Tex. Controllers are turning up in well-production facilities and pipelines, and Camco plans to extend the memory capacity of its current line.

Analog gas-flow computers are also gaining among gas-distribution companies, as are supervisor control systems. "Because of the energy shortage, people have to do a better accounting job of what's sold and what's available," Holmes says.

He also foresees an over-all upsurge in sales of electronic equipment for the petroleum industry because of an anticipated increase in exploration.

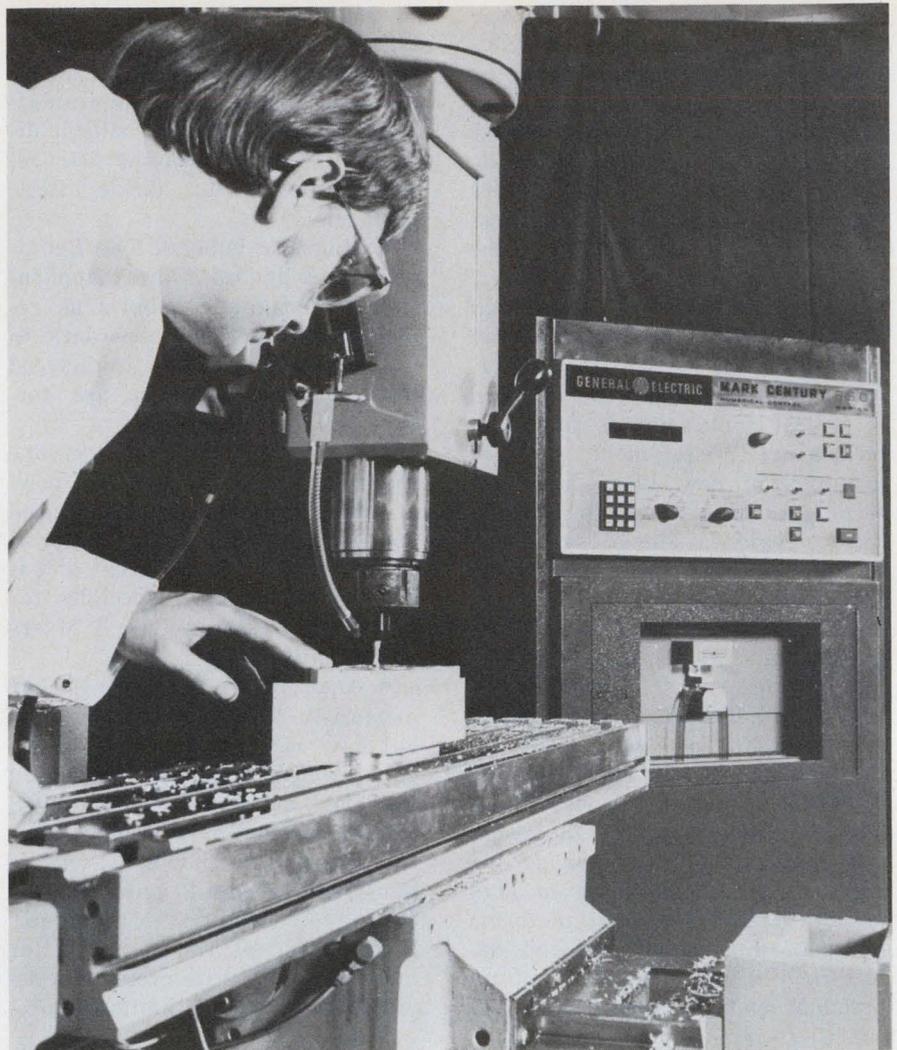
The trend in industrial controls is toward the use of more and more minicomputers and microcomputers—"toward the computer on a chip," Allen-Bradley's Ware says. "This development work will be under way this year," he continues, "with hardware expected in 1975 or 1976."

MOS and LSI are reducing the size and complexity of minicomputers. And programmable controllers are becoming more sophisticated. "Eventually there'll be a boom in small controls for industrial tools, similar to the one now for the hand held electronic minicalculators," Ware says.

Computerized numerical control (CNC) is expected to continue its lead over direct numerical control (DNC), says Allen Bradley's manager of product planning for numerical controls, L.O. Rexrode, in Highland Heights, Ohio. For the distant future, however, the company is developing a DNC system, he says.

### Hardware vs software systems

Law of GE says the mix in demand for hardwired vs softwired systems will depend on how much the customer has been influenced by advertising. He sees a place for both systems. "Hardwired systems will continue to have a place," he says, "until software can be reduced to a chip—until the computer on a chip arrives. In many cases it's better to have hardware than to have to reprogram software in a minicomputer. Advertising this year may influence some people to buy software when they really need hardware."



General Electric's new Mark Century 550 Series numerical control is offered in two versions: 2 or 3-axis controls for contouring and positioning applications and 2-axis contouring controls for turning machines.

Within the automation equipment itself more electronic components will be used. A programmable solid-state interface will replace relay logic in Allen-Bradley's 4000 NC series, and DEC's Chace says that this year solid-state controls will make the biggest inroads to date into relays.

"Solid-state controls," Chace says, "will extend from the lowest level of factory automation up the hierarchy through the higher ones. This trend is coming into vogue very quickly." The reason: Solid-state controls allow machines to operate faster and offer longer life.

"Solid state is coming of age this year in all kinds of industrial equipment," says Robert A. Morgan, marketing manager for the Industrial Systems Div. at Westinghouse Electric in Buffalo, N.Y.

"One example is SCRs, which will go into adjustable speed and adjustable-frequency drive equipment—ac and dc motor controls.

"Installing SCRs in heavy machinery, some of it as large as excavation machines for open-pit mining, means going back to the drawing board.

"We're also using more cycloconverters for applications such as peak-power energy-storage systems and for load-compensation requirements."

A combination of solid-state rectifiers and converters is opening the door to a number of applications, such as fans and pumps, Westinghouse is finding.

Westinghouse agrees with other manufacturers that there is a good immediate future in computerized numerical control but not much for direct numerical control. ■■

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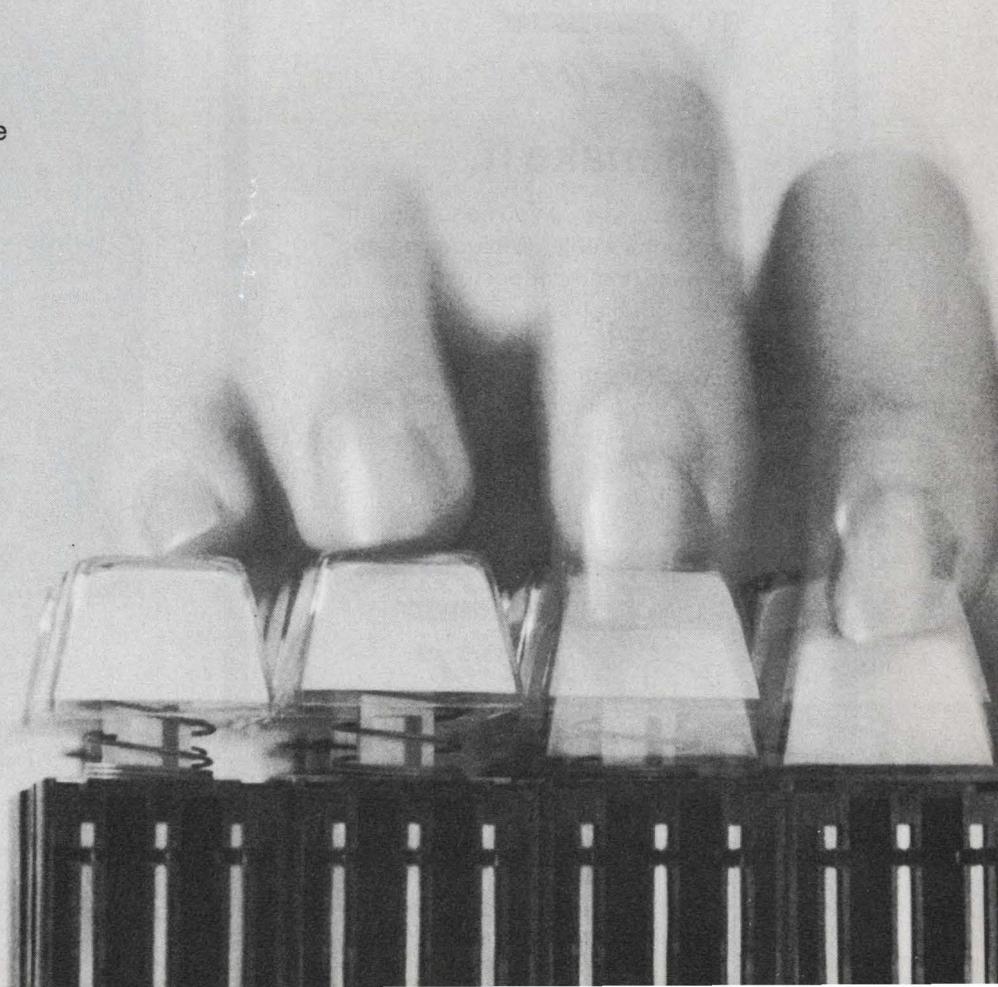
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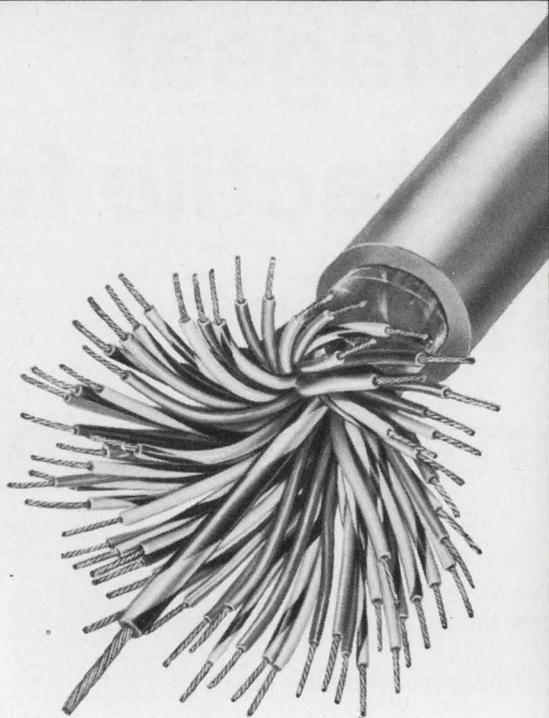
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INFORMATION RETRIEVAL NUMBER 27





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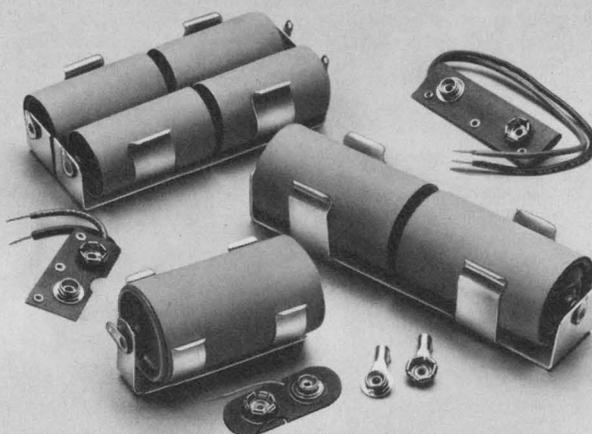
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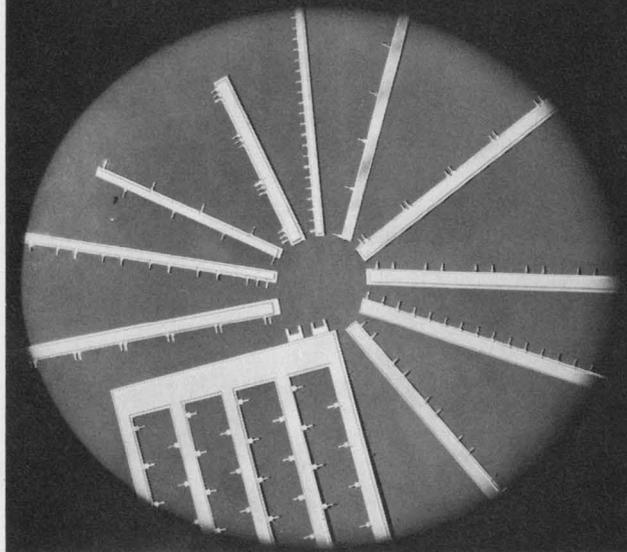
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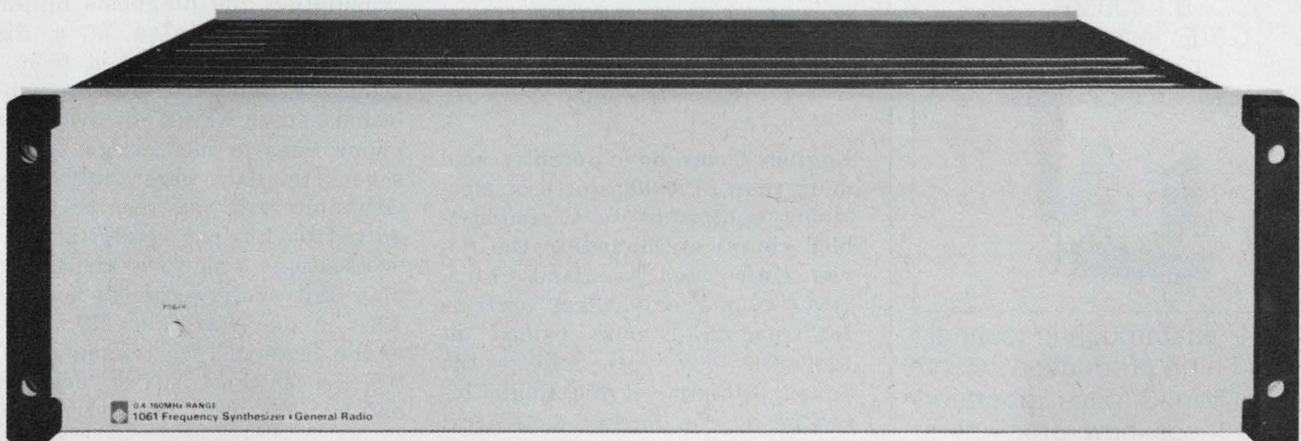


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INFORMATION RETRIEVAL NUMBER 30

ELECTRONIC DESIGN 2, January 18, 1973

# SWIFT\*



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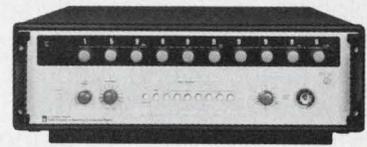
	GR 1061	Runner-up A	Runner-up B
Frequency	dc to 160 MHz	1 MHz to 160 MHz	10 kHz to 110 MHz
Switching Speed	< 100 $\mu$ s	1 ms	5 to 100 ms
Output Level	+20 dBm	+13 dBm	+13 dBm
Spurious	-80 dB	-70 to -100 dB	-80 dB
Phase Noise	-63 dB	-60 dB	-50 dB
Search-Sweep	standard	no	optional

Data current as of December, 1972

\* **swift** \ 'swift \ *adj* ... quick to respond: **READY**  
 Quick response, for example, means stepping the GR 1061 in 10-kHz increments from 100 to 150 MHz in under 500 ms (that's 5000 steps in less than half a second)! Not manually, of course, but by your system's programming signals.

Since your system, not your fingers, controls the synthesizer, we've left off the knobs to save you money. We've also left out the internal reference oscillator and five digits of resolution to save you some more money.

You now may be convinced the 1061 is the best synthesizer for your application, especially since the money you save means it will cost you only \$4700.



Or, you may be equally convinced we've left out too much. In that case, you can have any or all of it back because we offer an array of options to tailor the 1061 to **your** needs: A full control panel, two different reference oscillators, resolution to 10 digits, and phase-modulation capability. Stripped or full-house, the 1061 is unexcelled.



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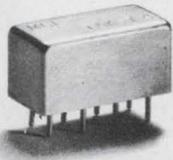
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## technology abroad

A triple-redundant computer system designed to accumulate no more than 30 seconds of downtime in five years is operational at London's Heathrow Airport. The system, called the most advanced fully automatic flight-plan-processing system in Europe, displays to air-traffic controllers the pilot's flight intentions and positions. There are provisions for rapid progressive updating of flight information for all aircraft under control. Designed by Marconi of England, the total system cost is about \$12-million.

CIRCLE NO. 441

English firms have recently sold more than \$700,000 worth of electronic equipment to Communist-bloc countries, including the Soviet Union and mainland China. Seven numerical-control systems for machine tools, valued at \$400,000, have been sold to the Soviet Ministry of the Radio Industry by the Survey & General Instrument Co., Ltd., of Kent. Each system consists of an x-y coordinate table, a television camera, a television monitor and a tape-punching machine. Radio and telecommunications equipment worth \$300,000 for use in Chinese radio and telephone factories has been ordered from Marconi Instruments, Ltd., in Herts.

CIRCLE NO. 442

A fuel cell powered from the glucose and oxygen in arterial blood has been demonstrated by Siemens of West Germany. Catalyst electrodes are embedded in a tissue-compatible porous structure. Hydrophilic membranes around these electrodes maintain catalyst activity and prevent hostile body reactions with the catalyst. In a demonstration, the experimental cell was immersed in a 7-pH glucose solution and saturated with air at 37 C. The cell, with a 12-cm<sup>2</sup> electrode area, de-

livered 100  $\mu$ W at 0.5 V. The ultimate expected use will be as a truly implantable battery for powering such devices as heart pacers.

CIRCLE NO. 443

A medical data link between the Royal College of Surgeons, London, and an exhibition center 1-1/2 miles away recently demonstrated the feasibility of bedside consultation and diagnosis by and with doctors located at a distance. Analog data taken from a demonstration patient at the exhibition center were sent over telephone lines to the college. At the school, the data were analyzed by computer and the results transmitted back along a digital communications link to a visual display unit at the patient's bedside. Also in use was the CRT Viewphone developed for telephones by the British Post Office Telecommunications unit. With the Viewphone the "surgeon" at the bedside could study X-ray charts and other graphics located at the college.

CIRCLE NO. 444

Custom-fabricated LSI arrays are now low-cost enough for low-quantity requirements, says Ferranti of England. Where development costs for LSI in small quantities were previously prohibitive, the English manufacturer has introduced a standard uncommitted logic array of 200 cells. Using the collector-diffusion-isolation technique licensed from Bell Telephone Laboratories, these arrays are prepared and held in stock as a semi-processed unit, complete except for the final aluminum interconnections. Only the final metallizing layer is needed to make each cell operational and to provide connections to external input and output circuits and power.

CIRCLE NO. 445

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Applications for these modules are virtually limitless, especially in process control and data acquisition and communication systems. Specific examples include isolated data conversion, phase detectors, synchronous speed controls, servo loops, flow meter transducers, optical or magnetic pickup amplifiers, and frequency monitors, to name just a few.

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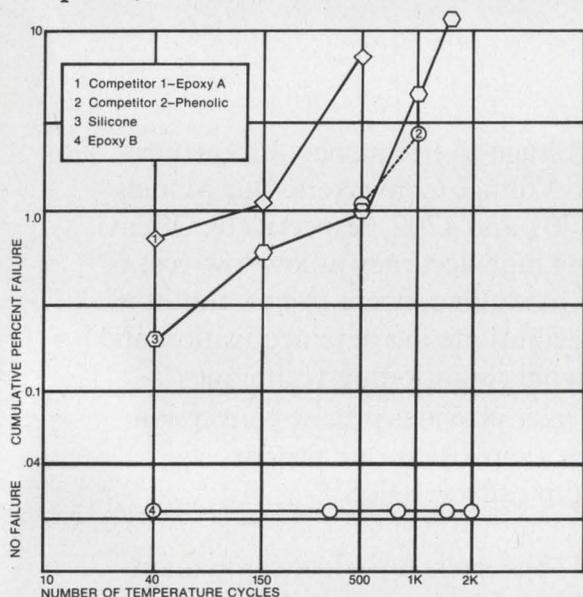
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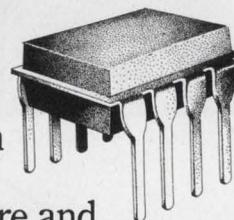


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# washington report



Heather M. David  
Washington Bureau

## Army to improve its electronic camouflage

The Army is looking for industry help to improve its electronic camouflage and countersurveillance techniques. The research and development program will involve sophisticated techniques of disguising, blending and simulating Army weapons and their signatures, so they cannot be detected by ultraviolet or acoustic surveillance. The Army's Mobility Equipment R&D Center is searching for firms with experience in advanced computer-simulation techniques as well as broadband signature analysis and simulation, including visual, infrared, radar and acoustic modes.

## AIA plan spurs talk of SST revival

A source of resuscitation for the supersonic transport program may be contained in a proposal by the Aerospace Industries Association. The AIA is asking the Civil Aeronautics Board, which is drawing up legislation to help airlines finance aircraft purchases, to add a provision for Government loans to companies doing R&D in the commercial aircraft field. Developments such as the SST and short-take-off-and-landing (STOL) craft would be candidates for loans from a \$3-billion fund in the AIA plan. Although considerable opposition to such a proposal could be expected in Congress, the AIA hopes to sell the idea on the basis that the U.S. is losing out in the world aircraft market to foreign, government-financed ventures.

## Ash appointment stirs Senate countermove

Legislation will be introduced in Congress to require Senate confirmation of Presidential appointments for the post of director of the Office of Management and Budget. The move is a result of criticism of President Nixon's appointment to the job of Roy L. Ash, former Litton Industries chief executive. Critics, noting Litton's problems with cost overruns and schedule slippage in its shipbuilding program for the Navy, question whether Ash will perform any better as a Government manager. However, under the present law, Congress has no say in the matter. Attempts to cut funds for Litton's Landing Helicopter Assault (LHA) and DD-963 destroyer programs are expected when new budget proposals come before Congress in the spring.

One Navy procurement official—Gordon Rule, a civilian—testified before a joint economic subcommittee chaired by Sen. William Proxmire (D-Wis.) that the LHA contract should be terminated for default on

Feb. 28, when the Navy is scheduled to make the next decision on the program. As a result of his testimony, Rule was transferred from his job by high Navy officers.

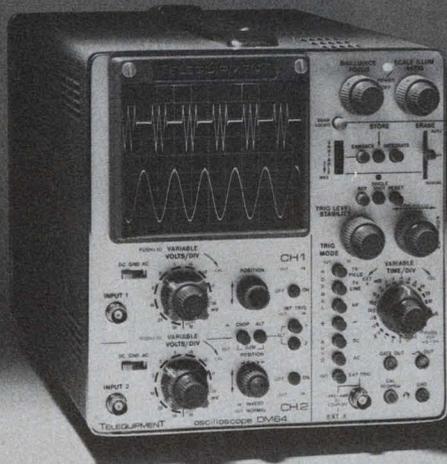
## **More storm clouds for F-14 program**

The Navy's troubled F-14 aircraft program may face its biggest challenge from the powerful House Appropriations Committee, which with its Senate counterpart, are ultimate keepers of the Federal purse. The committee strongly criticized Navy management of the program last year, and some members were reported to be "extremely disgusted" over the service's inability to bring the contractor, Grumman Corp., into agreement on its contract. Unless the Navy does a super sales job explaining why it needs the F-14, the committee may well seek to cancel the program, sources say. The committee asked the Navy to study the possibility of adapting the Air Force's F-15 fighter, now being developed by McDonnell Douglas, but it met a wall of Navy resistance.

**Capital Capsules:** The National Science Foundation is pushing a program to encourage research in optical communications. Some 20 grants have been awarded to support basic studies, mostly in aspects of laser communications. . . . The Labor Dept. says it has placed 6000 professional people in new jobs through its Volunteer Engineers, Scientists and Technicians (DEST) program. The effort was set up 18 months ago to help those who had lost jobs in the defense and space fields. . . . The Electronic Industries Association estimates that U.S. electronics sales last year reached a record \$29.8-billion, almost \$2-billion more than in 1971. Within that total, the EIA says, the communications and industrial electronics segment grew 10% to about \$12.2-billion, consumer electronics reached \$6-billion, and defense and space stayed at about \$11-billion. . . . NASA wants scientists to propose instruments and experiments that can be carried on the Large Space Telescope system planned for launching in the early 1980s. Such instruments as photometers, polarimeters, astrometric instruments, infrared detectors and very high dispersion spectrographs are possible candidates. . . . The Army is planning a new research program on the biological effects of microwave radiation exposure. It will contract for experiments to simulate field exposures of both continuous and pulsed microwaves. . . . The Commerce Dept. has appointed an ombudsman to help businessmen who need assistance in their dealings with the Federal Government. He is Thomas E. Drumm Jr., Special Assistant to the Secretary of Commerce. . . . A new standard that will spell out how much vibration can be tolerated by humans in aircraft, transit systems, ships and near ground machinery of all types is nearing completion after 10 years of preparation at the American National Standards Institute. . . . The Army Combat Developments Experimentation Command is looking for a day and night, passive real-time imaging system sensitive to wavelengths from 0.4 to 10.6 micrometers and capable of reproducing scenes during bright daylight and overcast night at ranges of 5 kilometers or more. . . . A joint State-Federal survey in seven states has found serious shortcomings in safety practices in the use of potentially dangerous lasers in high school and college science classes. A laser operating with a power output of 2 mW has been reported to have produced a burn in the retina of a human eye, according to the Food and Drug Administration in Washington.

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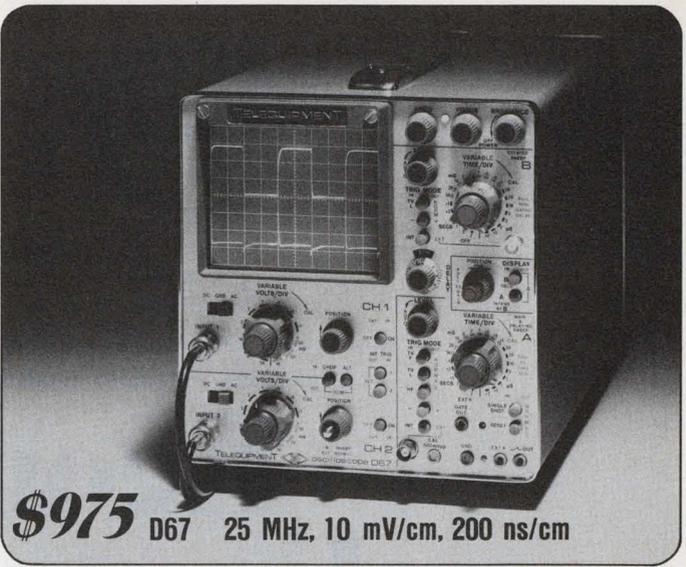


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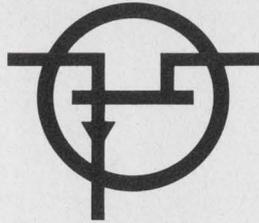


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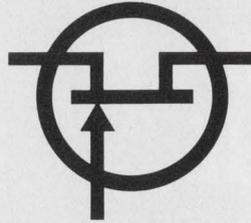
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## Selling is a dirty word.

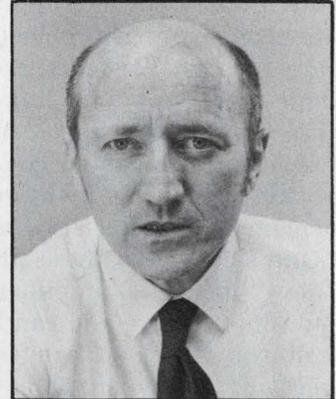
Compared with the major shows in Europe, ours in the U.S. are flops. Exhibits are dull; papers are duller; and attendance shrinks. At least in New York, show management has traditionally been slow to improve the show, though it's been zealous in policing it to see that no holy rules are violated. Some of these rules, exhibitors tell me, are perfectly asinine. One, for example, allows miniskirted girls to *stand* at the booths—but not sit down.

This year a new show management, imported from WESCON, is valiantly trying to pump new life into IEEE Intercon. For a start, the directors shifted the exhibit days to Tuesday through Friday, March 27 to 30, dropping the traditional Monday opening. This should help those who can't break away from the office on Monday. (The technical sessions still start on Monday, but not till 2 p.m.) The directors and Intercon manager Don Larson have planned other innovations. Some will no doubt help the show, others won't. But at least they have the guts and imagination to try things. They're not just watching the shows disintegrate.

It's likely that one of the toughest nuts will be a legal one. An exhibitor is not allowed to sell at the show, lest IEEE's tax status be endangered. So maybe we need to fight for new tax legislation. The furor created when Fluke sold some multimeters at WESCON would be hard to picture in Europe. The Europeans are more sensible. They design their shows for selling and buying in a convivial atmosphere.

Exhibitors there commonly provide a space where a visitor can sit with a company's engineers, enjoy a drink and something to eat, and discuss business. He can talk about technical specifications, delivery schedules and prices. And he can write an order. *WRITE AN ORDER*. What a horrible thought. At American shows we act as if writing business at a show is degrading, as if it's an imposition on an engineer to sell him something. We act as if he builds computers, television sets and communication systems with equations—and never dirties his hands with semiconductors, resistors, relays and test equipment.

Our loftiness and stupidity make our shows duller. While we try to preserve dignity, the Europeans keep looking for new ways to add sparkle, excitement, interest and usefulness. Are we smart enough to learn from them? I think so. The new IEEE Show management is intent on making this year's show a great one. It deserves our support, encouragement and thanks. I look forward to seeing you at the show.



A handwritten signature in dark ink, which appears to read "George Rostky". The signature is fluid and cursive.

GEORGE ROSTKY  
Editor-in-Chief

# Use current-mode IC amplifiers.

New quad versions replace conventional op amps, while avoiding dual-voltage supplies and lowering the cost and package count.

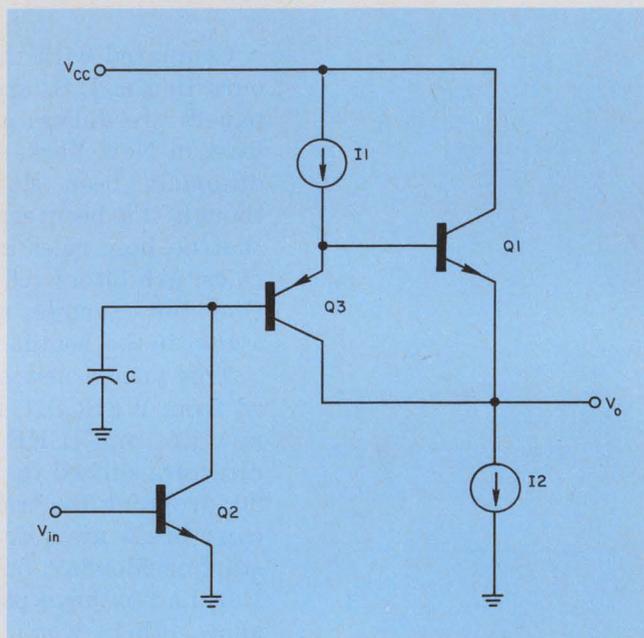
Because conventional operational amplifiers need a dual power supply—typically  $\pm 15$  V—this often poses a problem for system designers. Many systems are designed to operate from a single-power-supply voltage. If an op amp is used with the single supply, limited output voltage swings and unwanted common-mode offsets will probably result. In addition other important performance characteristics may be degraded.

One solution to these problems is provided by a new type of IC amplifier which has a current-mode input stage and can provide characteristics similar to those of conventional op amps while operating from a single power-supply line.

Amplifiers embodying this technique are already commercially available in quad versions—with four amplifiers in a single 14-pin DIP—from two manufacturers. National Semiconductor's version is designated LM3900, while Motorola has a version, the MC3401, which is very similar but not an exact replacement. Other companies are expected to provide alternative sources in the near future.

Both ICs can operate, with little change in performance, from a single voltage supply over a wide range of supply voltages. For the LM3900 the operating range is +4 to +36 V, while the MC3401 spans +5 to +18 V. The output voltage in both cases can swing from nearly ground—typically about 0.1 V—to about 80% of the power-supply voltage.

While, strictly speaking, not op amps, the new amplifiers can do the job of op amps in the vast majority of cases. The basic current-mode operation, therefore the name "Norton" amplifier, is a departure from conventional designs. Instead of using a voltage-differential input, the Norton amplifiers operate on differences in the input currents to their inverting and noninverting inputs. Many biasing advantages are thus realized. Also, because currents can be passed between the two input terminals, some unusual applications are possible. If external, large-value



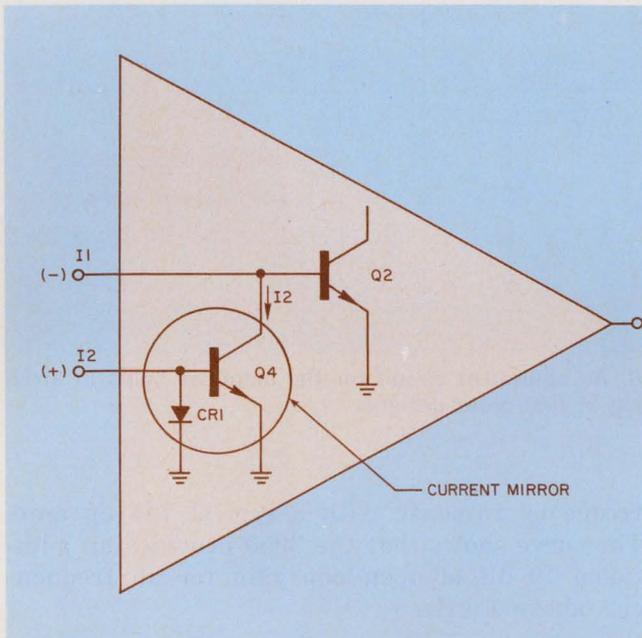
1. The basic gain stage is a common-emitter amplifier with a current-source load and emitter-follower output.

input resistors are used (input signal current can be in the low-tens of nanoamperes), standard op-amp performance can be realized.

## Common emitter supplies gain

The basic gain stage is a common-emitter amplifier (Fig. 1). A large voltage gain is achieved by use of current-source loads, shown as  $I_1$  and  $I_2$ . The gain is stable over a wide temperature range. All of the voltage gain is provided by the gain transistor,  $Q_2$ ; the output emitter-follower transistor,  $Q_1$ , serves as the load driver and  $Q_3$  acts as an interstage buffer. An on-chip capacitor ( $C = 3$  pF) provides the single dominant open-loop pole that helps maintain closed loop stability. The output emitter-follower is biased for class A operation by current source,  $I_2$ .

The gain stage can thus provide an open-loop voltage gain of about 70 dB and a large output voltage swing. However, the input current of this basic configuration tends to be larger than desired. It equals approximately the maximum



2. A differential input, using a current-mode of operation, is achieved with a "current-mirror" circuit.

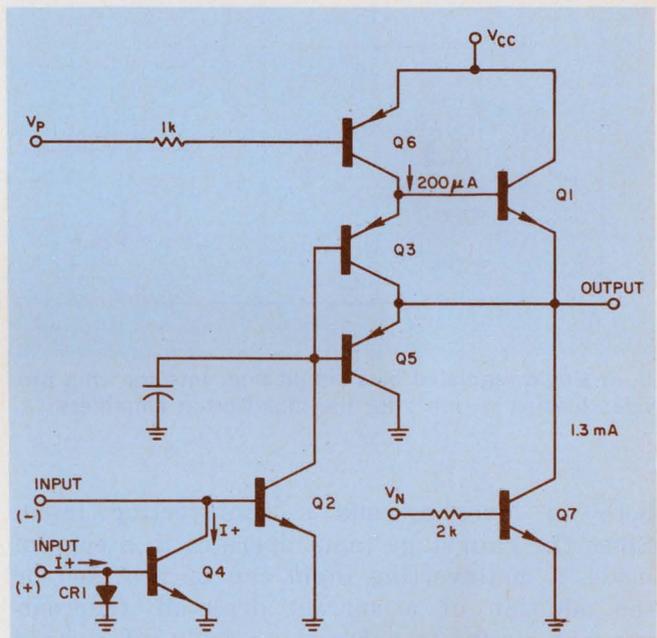
output current divided by  $\beta^2$ , where  $\beta$  is the current gain per device. For an output current of 10 mA, the input current is  $-1\mu\text{A}$ , if  $\beta^2 = 10^4$ .

Input current can be reduced by the addition of a transistor to achieve a  $\beta^3$  current reduction. If the output transistor,  $Q_1$ , is converted to a Darlington pair, the peak-to-peak output-voltage swing is reduced. If, on the other hand, the input,  $Q_2$ , is made into a Darlington pair, the dc voltage level present at the input would be undesirably doubled.

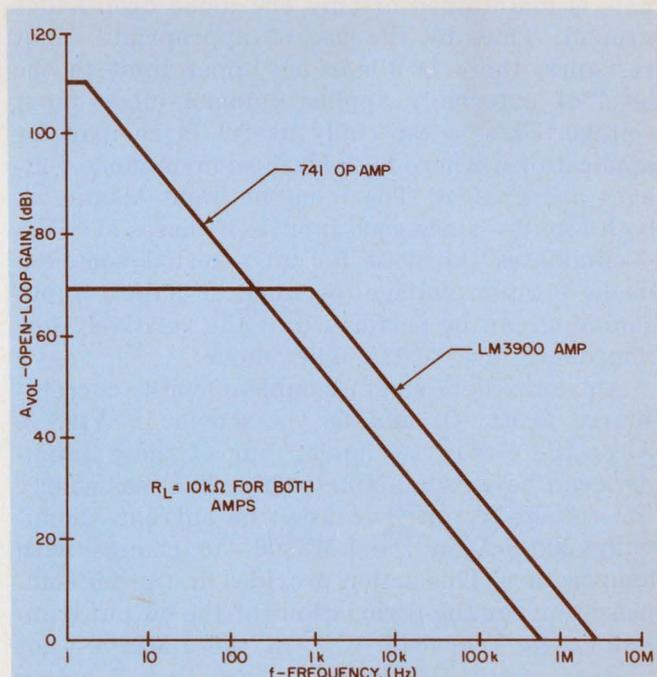
However, a lateral pnp transistor,  $Q_3$ , while neither reducing the output voltage swing nor raising the input voltage, provides the additionally needed  $\beta$ . Note that the collector of  $Q_3$  is connected directly to the output terminal. This bootstrap arrangement reduces the loading at the high-impedance collector of transistor,  $Q_2$ .

#### Current mode provides balanced input

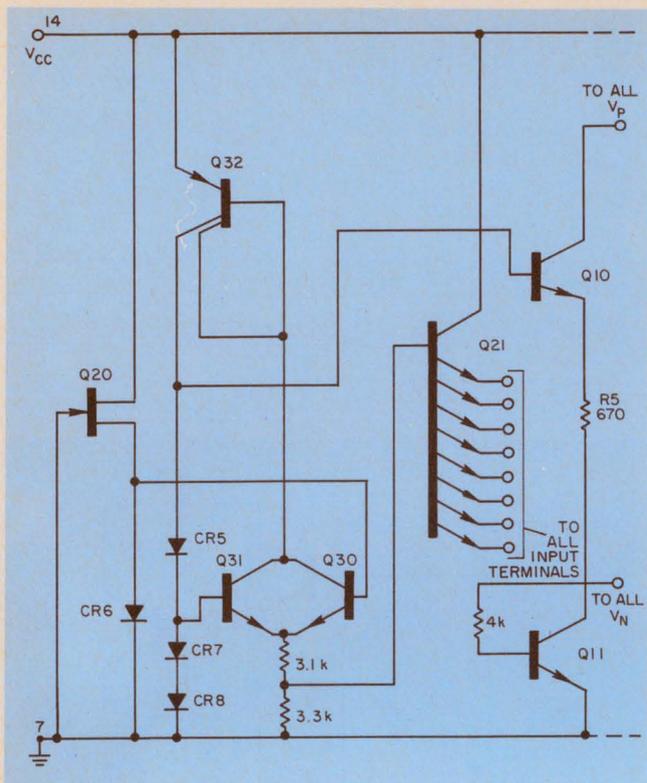
The gain stage of Fig. 1 has only an inverting input. But a general-purpose amplifier requires



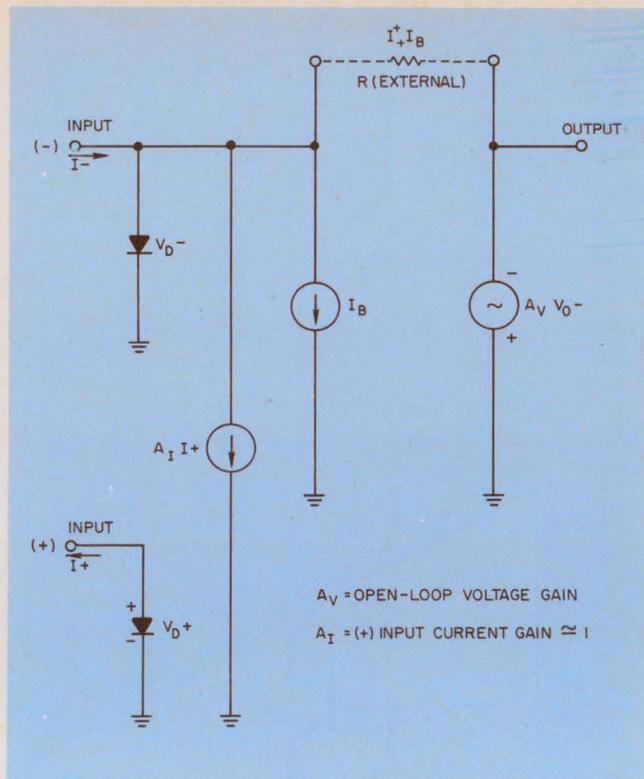
3. The complete amplifier uses transistors  $Q_6$  and  $Q_7$  as current-source loads.



4. The Norton amplifier's open-loop gain is about 10 dB more than the popular 741 op amp above 1 kHz.



5. A single regulated bias circuit built into the chip provides biasing currents for the four Norton amplifiers.



6. An equivalent circuit for the amplifier helps in arriving at first-order designs.

both an inverting and a noninverting input. Since the gain-stage input operates in a current mode, a noninverting input can be provided by the addition of a current drain-off (current-mirror) circuit to subtract or drain off current from the inverting input terminal (Fig. 2). The input common-mode voltage of the input terminals is maintained at only one diode drop above ground. Thus by the use of appropriate input resistors, there is almost no upper limit to the level of externally applied common-mode input voltage. This is especially useful in comparator applications, where high-level common-mode voltages are present. The inherent input biasing at both inputs—since each input self-biases at  $+V_{BE}$ —eliminates the need for an external common-mode biasing voltage network. Further, input summing can be performed at the relatively low impedance level of the input diode.

An amplifier stage complete with current-source loads,  $Q_6$  and  $Q_7$ , is shown in Fig. 3. Since the circuit is simple, four of these amplifiers can be put on a single chip. The bias source for voltage  $V_p$  on  $Q_6$  causes the current—nominally  $200 \mu A$  in the LM3900—to change with temperature. This action provides first-order compensation for the  $\beta$  variations of the output transistor,  $Q_1$ . Transistor  $Q_5$  (in the LM3900—not present in the MC3401) provides class-B action together with  $Q_3$  under large-signal conditions.

Figure 4 compares the LM3900's open-loop

frequency response with a typical 741 op amp. The curve shows that the 3900 provides an additional 10 dB of open-loop gain for all frequencies above 1 kHz.

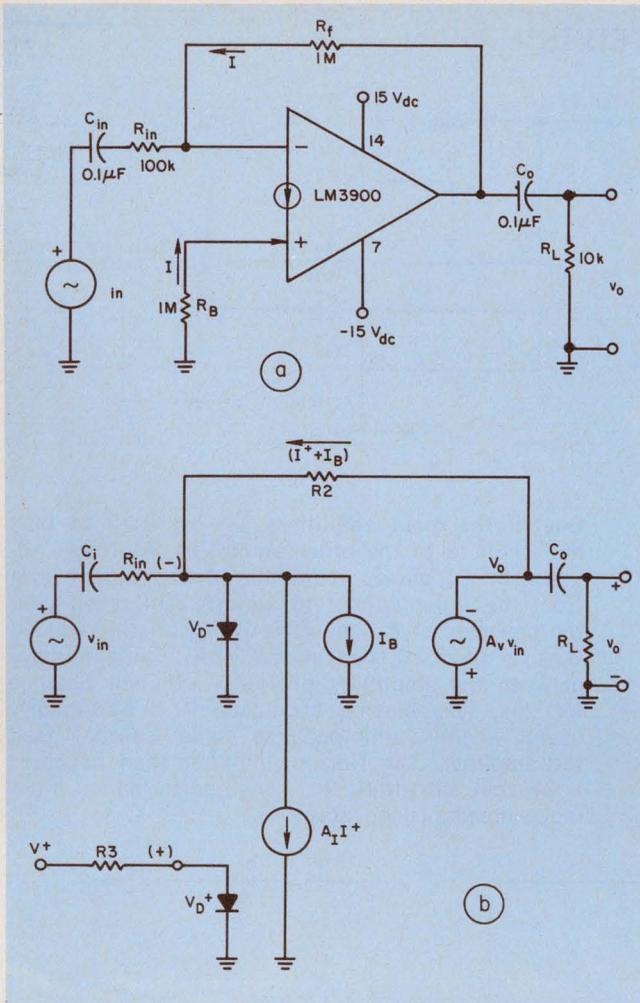
### Regulated supply does the biasing

A single bias circuit (Fig. 5) in the 3900 serves all four amplifiers. The regulator circuit insures that only small changes in bias current occur as the supply voltage changes. Thus the open-loop gain changes only slightly over the wide power-supply range, and it is almost independent of the effects of temperature.

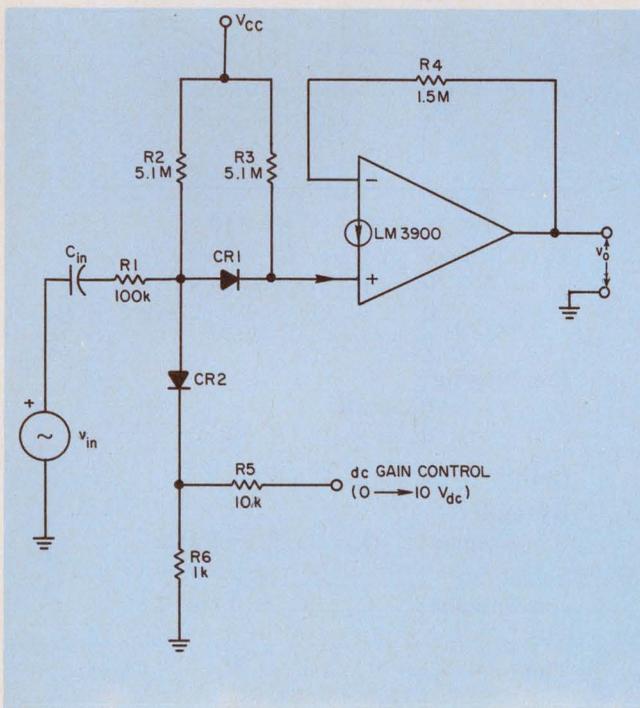
A single resistor,  $R_5$  in Fig. 5, controls the power consumption of the whole chip and establishes the conduction of transistor  $Q_{10}$  in the bias supply. The emitter current of  $Q_{10}$  biases the  $Q_7$  output current sources of all four amplifiers at points  $V_n$  (Fig. 3), and the collector current of  $Q_{10}$  biases the  $Q_1$  current sources at points  $V_p$ .

When power is turned on, the biasing circuit transistors  $Q_{20}$ ,  $Q_{30}$  and  $CR_6$  conduct, thus starting the bias circuit. Current flow through the reference diodes  $CR_5$ ,  $CR_7$  and  $CR_8$  then turns off  $Q_{30}$ , and current through the amplifier circuits thus depends mainly on the  $V_{BE}$  of  $Q_{10}$  divided by  $R_5$ . Power-supply current drain is then essentially independent of the power-supply voltage.

The multi-emitter transistor,  $Q_{21}$ , clamps negative input voltages at each of the eight input



7. This ac-coupled amplifier, operating from a  $\pm 15$  V power source, can also work on a single-voltage source when pin 7 is grounded.



8. Remote voltage-controlled gain is readily attained with the Norton amplifier.

terminals of the chip. One emitter of this transistor is connected to each of the input terminals. This clamping prevents parasitic transistor action if the inputs go negative.

### Designing with the amplifiers

Though these amplifiers can be used instead of a standard op amp, a new design approach is needed. An equivalent circuit for a Norton amplifier is shown in Fig. 6. Both the plus and minus inputs are clamped by diodes, so they can be no more than one-diode drop above ground. Thus the input common-mode voltage at the input terminals is inherently restricted to within a few hundred millivolts of 0.5 V. Therefore, to apply current-mode amplifiers to operate with a voltage-mode input, the external voltages must first be converted to currents by use of series resistors. The use of external input resistors can extend the range of externally applied common-mode inputs almost without limit.

Also, only the minus input needs an externally supplied biasing current,  $I_B$ . As shown in Fig. 6, an external feedback resistor usually can supply the bias.

Though Norton amplifiers accept differential inputs, they are not true differential amplifiers. The output depends on the open-loop voltage gain,  $A_v$ , and only the minus input voltage,  $V^-$ —not the differential input voltage—is effective in generating output. With series input resistors however,  $V^-$  depends upon  $I^+$  as well as  $I^-$ , thus the amplifier provides differential voltage amplification.

Let's analyze the ac-coupled inverting amplifier of Fig. 7a to see how a typical Norton amplifier such as the 3900 is used in a circuit. Figure 7b is an equivalent circuit that includes the biasing current path.

First, consider the dc biasing paths and make a dc analysis. The output quiescent voltage,  $V_o$ , is

$$V_o = V_{D^-} + (I_B + I^+) R_2 \quad (1)$$

and

$$I^+ = \frac{V^+ - V_{D^-}}{R_3}, \quad (2)$$

where

$$V_{D^+} \approx V_{D^-} \approx 0.5 \text{ Volts}$$

and

$$I_B = \text{bias current (30 nA)} \ll I^+.$$

Also, take  $A_1 = 1$

$$\text{and } V^+_{(\text{max})} = V_{cc} \text{ (power-supply voltage).}$$

If Eq. 2 is substituted into Eq. 1,

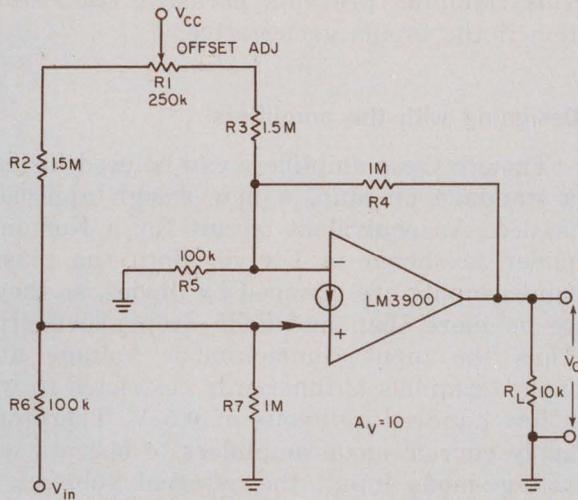
$$V_o = V_{D^-} + \left( I_B + \frac{V^+ - V_{D^+}}{R_3} \right) R_2, \quad (3)$$

which is an exact expression for  $V_o$ . But since

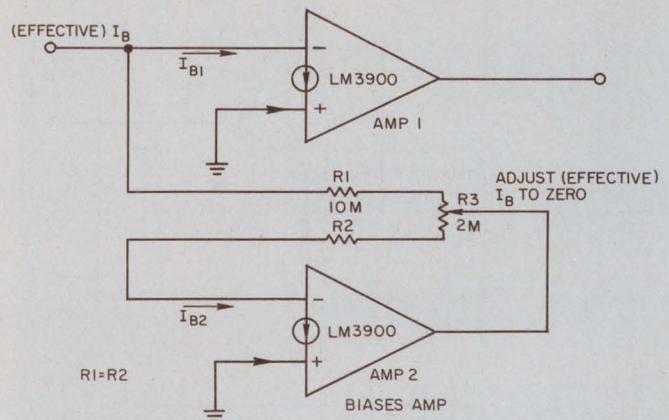
$$V_o \gg V_{D^-} \text{ and } V^+ \gg V_{D^+},$$

we can simplify Eq. 3 to provide a quick design relationship:

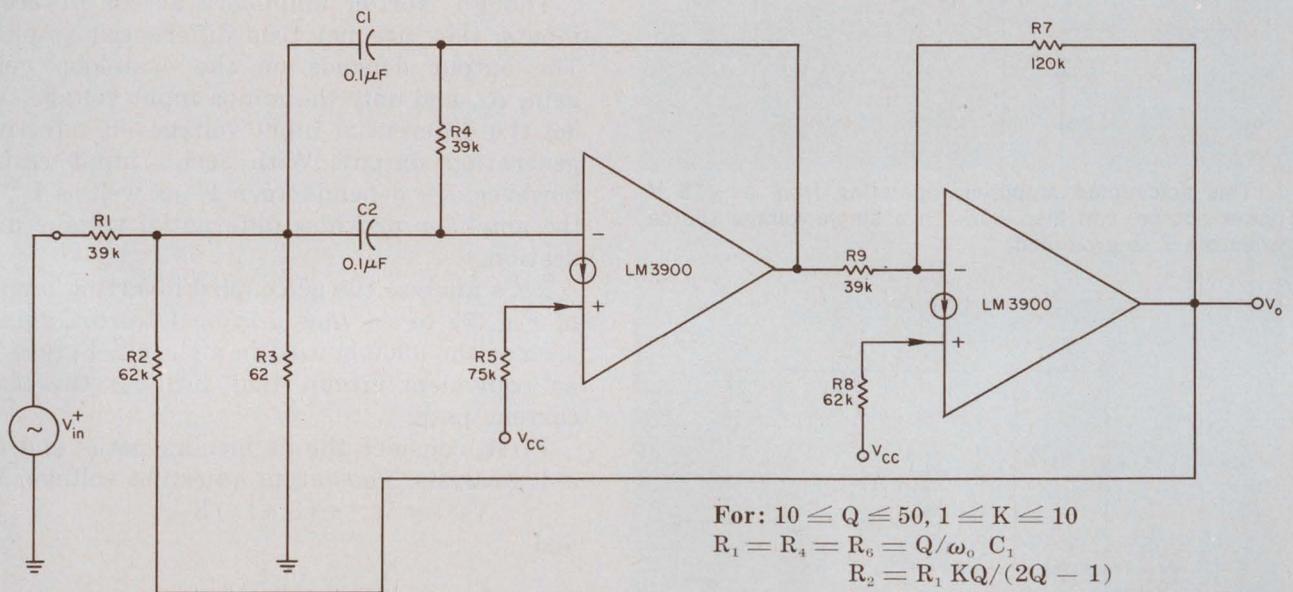
# Analog circuits



When used as a dc amplifier with a single power supply, the Norton amplifier is not as precise as a standard op amp with a split supply. However, single-polarity inputs and noninverted outputs down to zero volts can be readily accommodated with the common-mode input biasing resistors  $R_2$  and  $R_3$  and offset adjustment  $R_1$ . This circuit is adequate for most noncritical applications.



One of the quad amplifiers can be used to bias one or more of the other amplifiers. Although adjustment  $R_3$  allows reduction of the bias drawn from the input source to almost zero, even with the omission of  $R_3$ , the effective  $I_B$  is still reduced by a factor of 10 (typically to 3 nA). The symmetry between the amplifiers provides sufficient balance for this. This biasing arrangement is particularly useful where high-impedance signal sources feed the amplifier. The Norton amplifier then becomes a low-cost substitute for a high-performance high-input-impedance op amp.



A bandpass amplifier with a  $Q$  between 10 and 50 can be constructed with two amplifiers. The circuit uses only two capacitors. Resistors  $R_3$  and  $R_8$  set the bias so that the output voltage of the amplifiers approaches  $V_{cc}/2$ . To do this, resistor  $R_5$  is chosen to equal twice  $R_1$ , and  $R_8$  is chosen to equal  $R_6$  and  $R_7$  in parallel. The value of the constant  $K$  is selected for either control of the spread of resistor values or for optimization of final gain.

$$\begin{aligned} \text{For: } & 10 \leq Q \leq 50, 1 \leq K \leq 10 \\ & R_1 = R_4 = R_6 = Q/\omega_0 C_1 \\ & R_2 = R_1 KQ/(2Q - 1) \\ & R_3 = R_1/(Q^2 - 1 - 2/K + 1/KQ) \\ & R_7 = KR_1 \end{aligned}$$

For biasing:

$$\begin{aligned} R_5 &= 2R_4 \\ R_8 &= R_6 R_7 / (R_6 + R_7) \end{aligned}$$

Gain:  $G = \sqrt{Q} K$

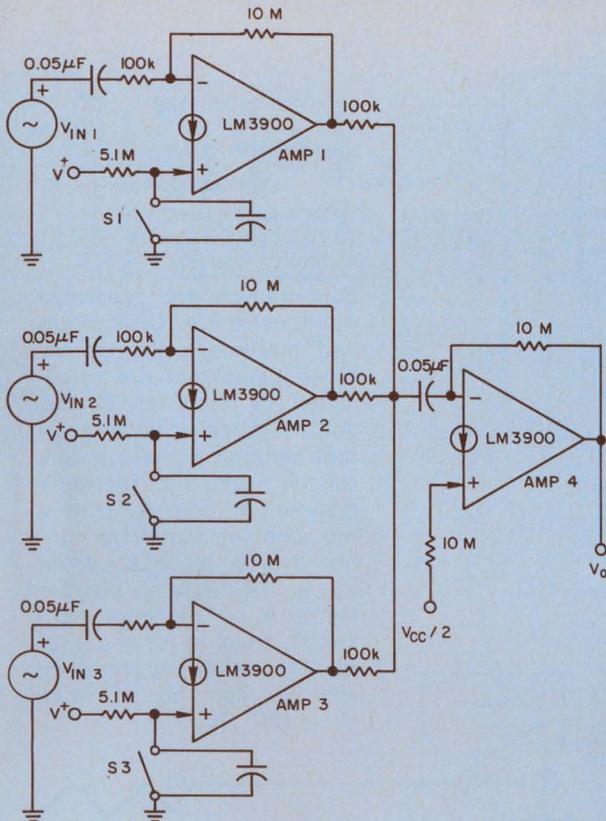
Example:

Requirements:  $Q = 25, f_0 = 1 \text{ kHz}$

Select for

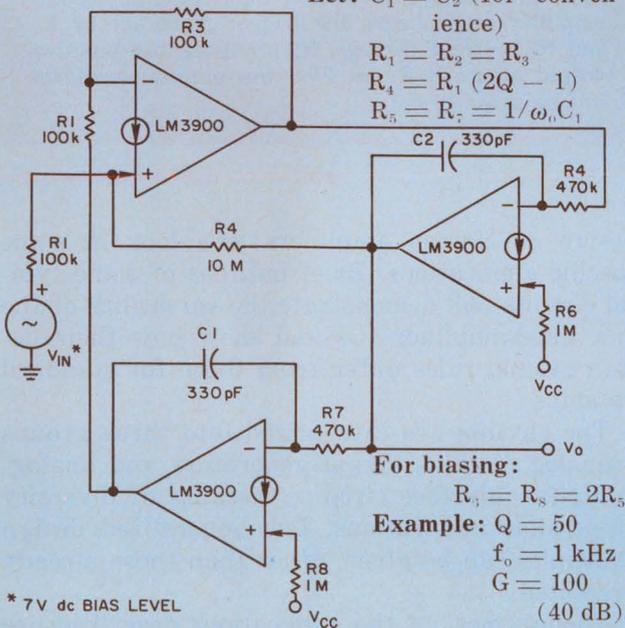
$$\begin{aligned} \text{convenience: } & C_1 = C_2 = 0.1 \mu\text{F} \\ & K = 3 \end{aligned}$$

Then solve for  $R_1$  through  $R_7$   
 $G = 15$  (23 dB)



The Norton quad-amplifier group makes an economical choice for audio mixing and channel selection. Three of the amplifiers summed into the fourth is a convenient arrangement. Individual amplifiers can be turned off when a dc control signal is applied to the plus input. The positive voltage,  $V^+$ , unless shorted by switches  $S_1$ ,  $S_2$  and  $S_3$  saturates the respective amplifiers and they pass no signals.

For:  $Q \geq 50$   
 Let:  $C_1 = C_2$  (for convenience)  
 $R_1 = R_2 = R_3$   
 $R_4 = R_1 (2Q - 1)$   
 $R_5 = R_7 = 1/\omega_c C_1$



A bandpass filter with a  $Q \geq 50$  can be built with three amplifiers. The resulting increase in overall open-loop gain also reduces the effects of component variations.

$$V_o \simeq \left( \frac{R_2}{R_3} \right) V^+ \quad (4)$$

And, if  $R_3$  is made equal to  $2R_2$ , then  $V_o \simeq \frac{V^+}{2}$

The latter result shows that the output can be readily biased to one-half of the power-supply voltage, so that the full peak-to-peak swing can be made symmetrical and almost equal to  $V_{cc}$ .

This simple dc model is adequate for designing switching circuits.

### Design procedure for ac amplifiers

What happens to ac signals? Since the circuit behaves as a standard op amp with its plus input grounded, the closed-loop voltage gain,  $A_{v(CL)}$ , is:

$$A_{v(CL)} = \frac{-V_o}{V_{in}} \simeq \frac{R_2}{R_1}$$

The procedure for designing an ac-coupled inverting amplifier consists therefore of first selecting  $R_1$ ,  $C_1$ ,  $R_2$  and  $C_o$ , as for a standard op amp.

Then  $R_3$  is made equal to  $2R_2$ . Note that  $R_3$  is the only additional resistor needed to complete the biasing requirements. This simplicity contrasts with the complications encountered in dealing with large common-mode voltages when trying to bias standard op amps for operation from a single power supply.

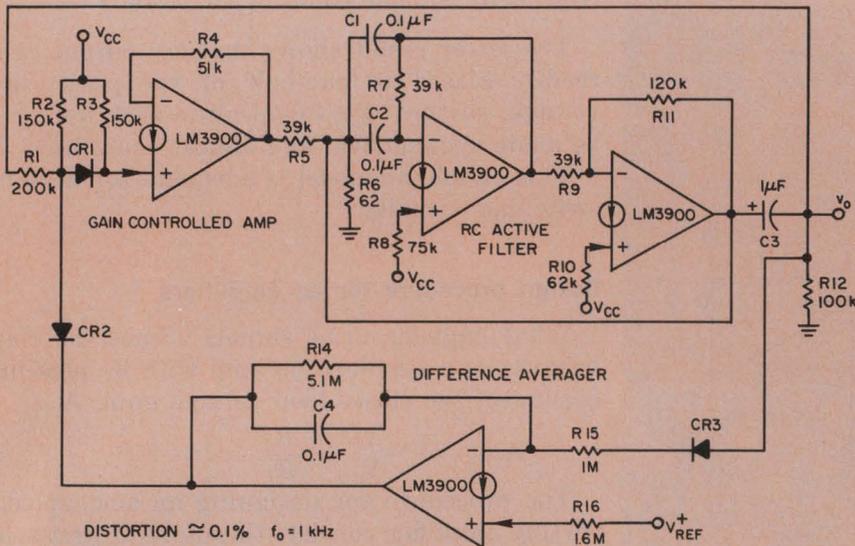
A practical ac amplifier design with remote voltage-controlled gain is shown in Fig. 8. For maximum gain,  $CR_2$  is cut off and the current through  $R_2$  and  $R_3$  provides a bias to set the quiescent output of the amplifier at approximately  $0.6 V_{cc}$ . For minimum gain,  $CR_2$  is turned on, and only the minimum bias current through  $R_3$  enters the input to set the quiescent output at approximately  $0.3 V_{cc}$ . The bias is thus automatically varied to accommodate a large output swing when the gain is set to maximum. The signal swing required for gain control varies from 0 V for minimum gain to less than 10 V for maximum gain.

### A distinctive symbol used

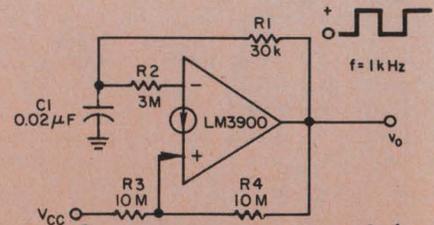
Note the new amplifier symbol that is used in Figs. 7a and 8 to represent this class of current-mode amplifiers. This symbol is recommended to avoid confusion with the standard op amp, since Norton-amplifier operation is quite different in many respects. The current-source symbol between the two inputs represents the new mode of operation. It signifies that current is removed from the minus input terminal. And the current-arrow symbol on the plus input lead indicates that this terminal operates as a current input. This new symbol is thus helpful in both clarifying the behavior of the circuits described here and in doing your own design work.

Armed with an understanding of the internal

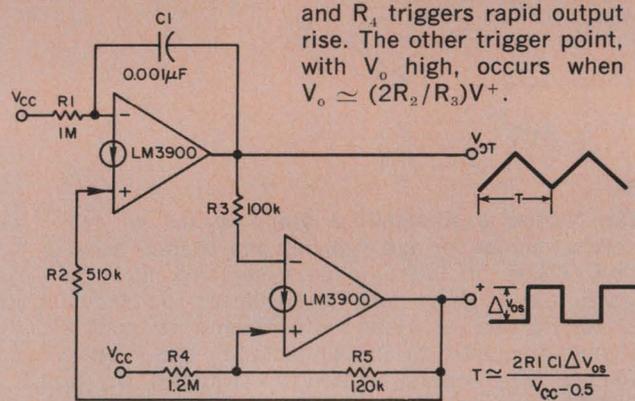
# Signal generator



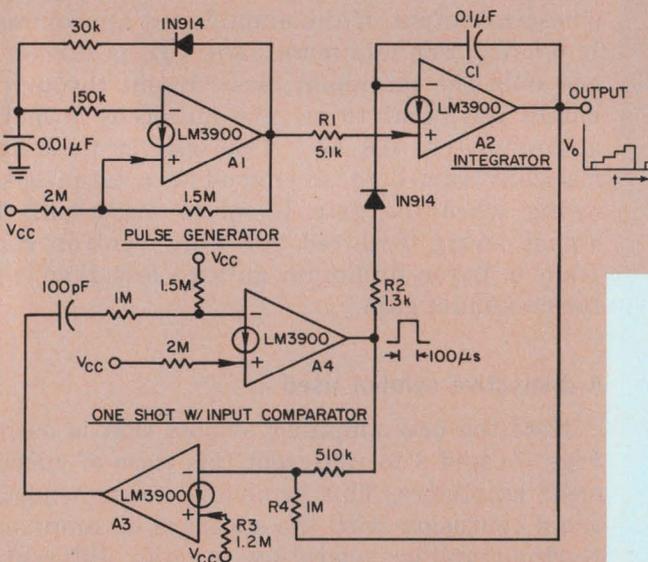
**Sinewave oscillator** using Norton amplifiers achieves amplitude stability and waveform purity. It uses a two-amplifier, RC active filter that requires only two capacitors. A third amplifier controls the gain around the filter. The fourth amplifier compares the sinewave amplitude to a dc-reference voltage and averages the difference. The values selected for  $R_{15}$  and  $R_{16}$  provide first-order temperature compensation for both  $CR_3$  and the internal input diodes. The peak magnitude of the output sinewave is automatically regulated at twice the reference voltage,  $V_{ref}$ .



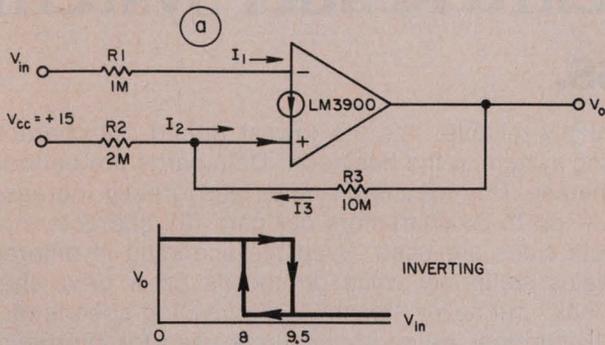
**Squarewaves** are generated when capacitor  $C_1$  charges and discharges via  $R_1$  between limits that are established by resistors  $R_2$ ,  $R_3$  and  $R_4$ . When  $V_o$  is low, current through  $R_4$  is low and can be neglected. Therefore resistors  $R_2$  and  $R_3$  control the point at which the output starts to rise. When  $V_o \approx (R_2/R_3)V^+$ , positive feedback via the plus input and  $R_4$  triggers rapid output rise. The other trigger point, with  $V_o$  high, occurs when  $V_o \approx (2R_2/R_3)V^+$ .



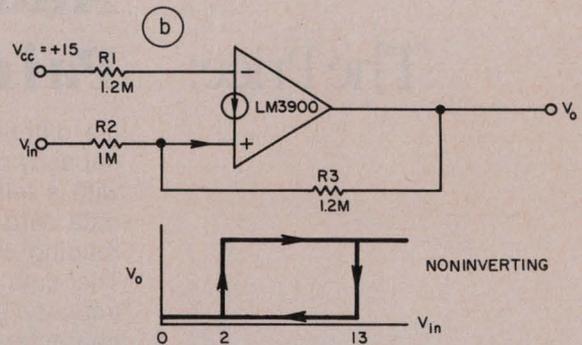
**An integrator configuration** generates triangular waveforms. Current through  $R_1$  produces the negative-output slope. When the input to the second amplifier drops below the trigger point set by  $R_4$  and  $R_5$ , current through  $R_2$  produces the positive output slope. If  $R_1 = 2R_2$ , the output waveform will be symmetrical.



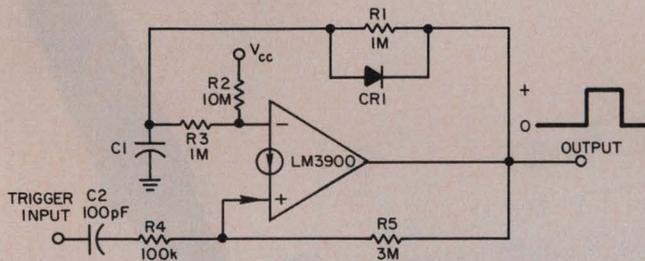
# Analog-to-digital interface circuits



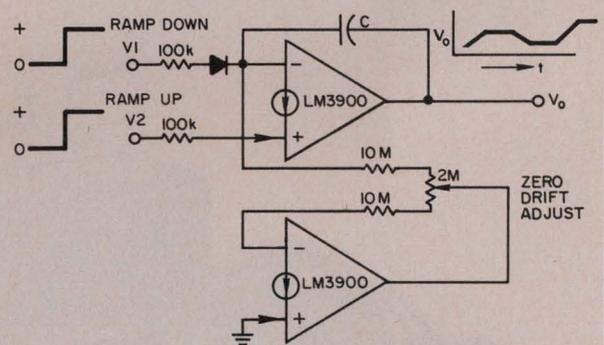
**Hysteresis may be designed into a comparator to form a Schmitt-trigger circuit.** The circuit can be made either inverting or noninverting. The lower switch point for the inverting circuit is determined by the amount of current flowing into  $R_2$ . And since the output voltage is low, current through  $R_3$  can be neglected. As the input current,  $I_1$ , drops below  $I_2$ , the output starts to switch to the high



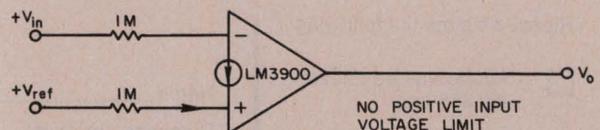
limit. Positive feedback via  $R_3$  rapidly drives the circuit to saturation. With  $V_o$  high, additional current,  $I_3$ , is driven into the plus input through  $R_3$ . Therefore the input current,  $I_1$ , required to switch  $V_o$  down is increased by the amount needed to overcome this additional current. Thus the circuit has different trigger point for high and low outputs—a hysteresis effect.



**One-shot circuit uses only one amplifier.** Resistor  $R_2$  tends to keep the output in the low-voltage state. A positive voltage at the trigger input sufficient to overbalance the current through  $R_2$  causes the output to switch to the high-voltage state. Resistor  $R_5$  latches the amplifier in the high state until capacitor  $C_1$  charges from near ground to a voltage that forces current into the negative input that is almost equal the current into the plus input. At this time the circuit returns to the low state.



**Ramp-and-hold circuits** that can be ramped up or down or allowed to remain at any desired output of dc level use only two Norton amplifiers. If both inputs  $V_1$  and  $V_2$  are at zero volts, the circuit is in a hold mode. Raising either input will cause the dc output voltage to ramp either up or down. The slope is a function of the magnitude of the input voltage. Additional inputs can be fed in parallel through series resistors, if desired, to increase the input control variables. The values of  $R_2$ ,  $R_3$ , and  $R_1$  are selected to set the switching values to the desired levels. The noninverting Schmitt trigger works the same way, except that the input voltage is applied to the plus input.



**Norton amplifiers operate as inverting comparators.** To insure proper operation, the reference voltage must be larger than the internal  $V_{BE} \approx 0.5$  V. But there is no upper limit as long as the input resistors are large enough to limit the input currents to under  $200 \mu\text{A}$ .

Each amplifier can be thought of as a super transistor with a  $\beta$  of 1,000,000 (25-na input produces 25-mA output current). The amplifiers also have a noninverting input feature capable of providing positive feedback that can create sharp trigger points and hysteresis for Schmitt and one-shot circuits. Finally, the low-input currents allow the design of timing circuits with small capacitors and large resistors.

Of course, where the application demands unusually high performance, the designer may be forced to use a more expensive specialized op amp unit. This happens when very wide bandwidths, very high slew-rates, greater gain, very high input or very low output impedances are required. Also, the single source limits dc inputs and outputs to single-polarity excursions. ■■

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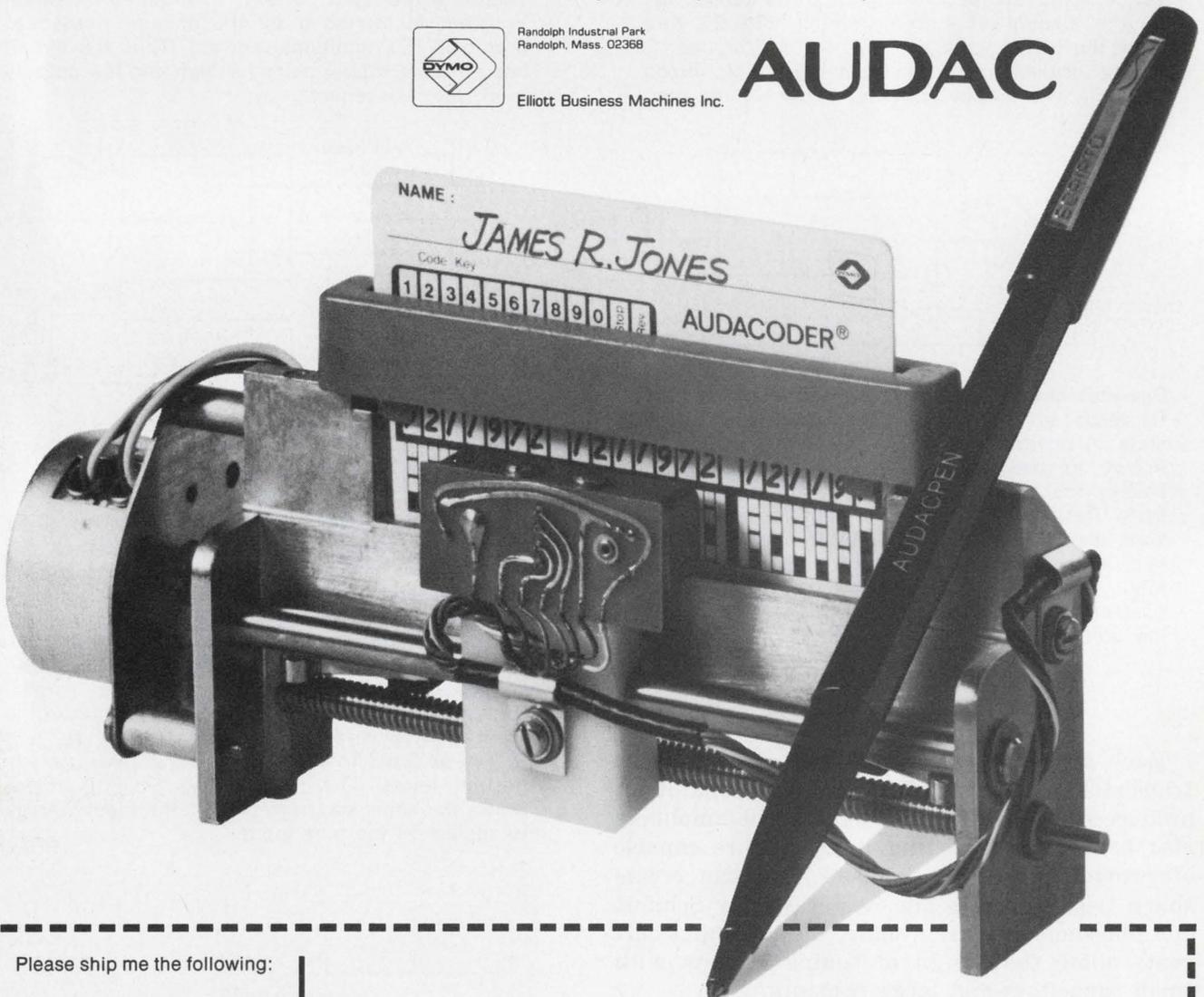
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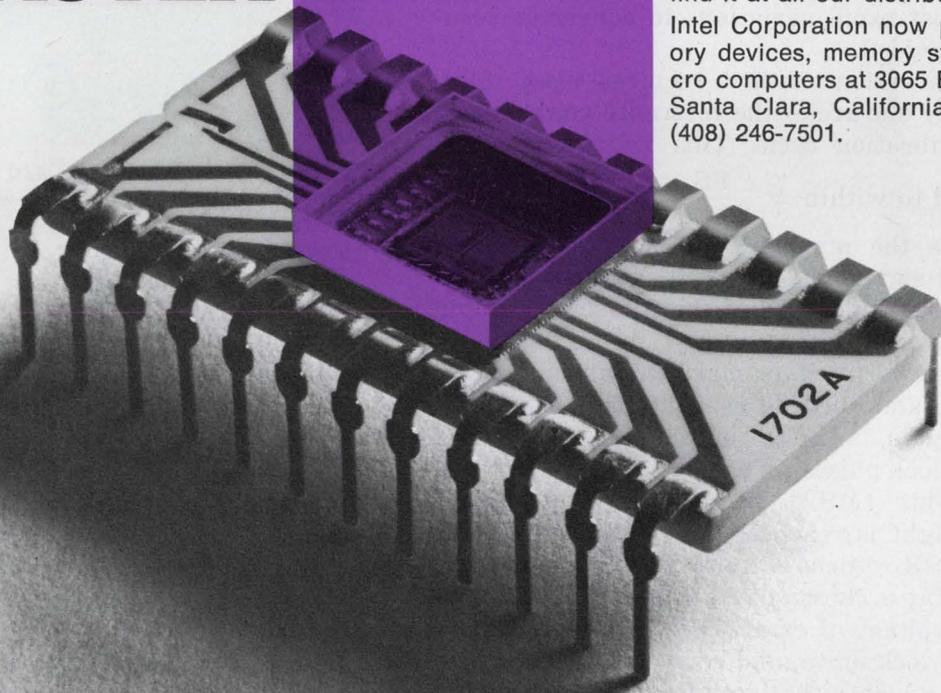
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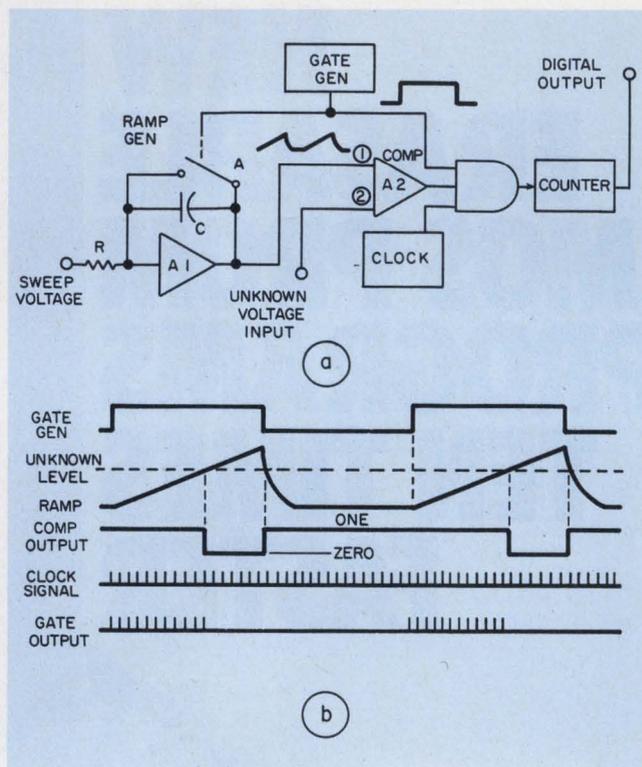
Although the single-ramp technique for a/d conversion is both simple and economical, the accuracy obtained seldom exceeds 1%, or eight bits. By introducing a calibration cycle, along with the normal measurement cycle, the designer can reduce errors to as low as 0.01%, allowing 4-1/2-digit operation without a drastic increase in circuit complexity. The technique, for which a patent is pending, also has many other possible applications in low-cost digital instrumentation.

The converter uses alternate Measure and Calibrate cycles to reduce the measurement error. A known analog input is measured, and the resulting digital number is compared with the correct answer. If this digital number is not correct, the converter is automatically adjusted so the correct answer will be produced. Since the calibration cycle is interlaced with a cycle that measures the unknown analog voltage, compensation for all but the most rapid variations in converter accuracy is provided.

This conversion method requires close tolerance in only one area—the reference voltage used in the calibration cycle. This voltage must be maintained to within  $\pm \frac{FS}{2^{(n+1)}}$ ,

where  $n$  is the number of bits of accuracy if  $\pm 1/2$  least-significant-bit (LSB) accuracy is to be expected. Voltage  $FS$  is the full-scale reading of the converter.

As the converter is primarily intended for use in a DVM and suitable readout devices require a BCD signal, a BCD counter is employed to count the clock pulses. In a BCD counter the most-significant-bit (MSB) is zero until a decimal count of eight is reached. At a decimal count of ten, the MSB returns to zero. Therefore the calibration point is chosen at 80% of full scale, and a reference voltage of exactly 8 V is used. The converter will lock on to, and correct for, error conditions in which either greater or less than an 80% of full-scale count is obtained before the



1. Simplified single-ramp a/d counts clock pulses to determine input voltages. The waveforms (b) show how a voltage-to-time conversion is performed by the ramp generator and comparator.

ramp voltage crosses the reference voltage and stops the count.

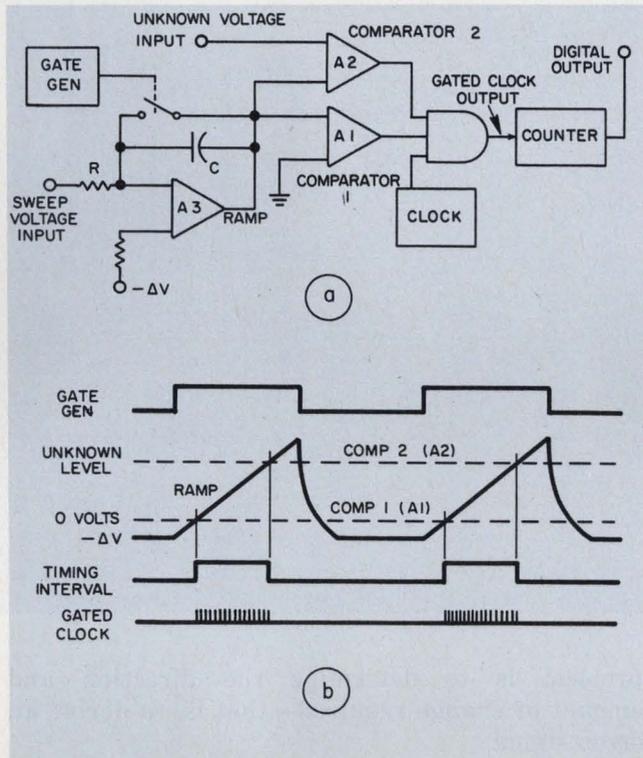
## Basic converter counts clock pulses

The ramp a/d converter uses a linearly rising voltage ramp to convert an unknown voltage into an equivalent time interval. This time interval gates a portion of the output of a clock oscillator. The number of cycles of the oscillator passed by the time gate constitutes a digital number proportional to the unknown voltage. The train of pulses is normally converted to a more usable number system, such as binary, BCD, Gray, etc.

Figure 1 shows the single-ramp a/d converter in a simple form. In general, some time is required for recovery of the ramp after each use, as well as for whatever digital operations may be

required to produce the required type of digital word. Therefore timing gates are needed to separate the various operations. Fig. 1a includes a simple arrangement to accomplish the desired gating, and Fig. 1b shows typical waveshapes. Let's now consider the operation of the various components in the block diagram.

The ramp generator consists of an operational amplifier with a capacitor,  $C$ , in its feedback path. The input is from a constant-amplitude sweep voltage through a resistor,  $R$ . Because the



2. Comparator drift is minimized by use of a two-comparator scheme shown (a). The count begins (b) after the ramp crosses the level set by  $A_1$ , and it ends when the level of  $A_2$  is reached.

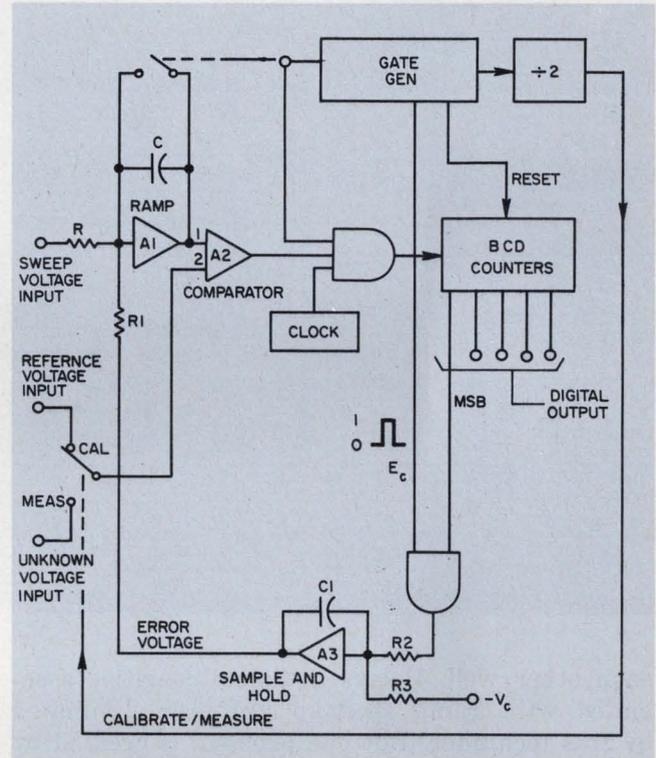
op-amp input terminal remains at virtual ground, the current through  $R$  is constant. This current is available to charge  $C$ , resulting in a linear ramp voltage. It is important that the ramp be linear, because this is the only significant source of error not corrected by the converter's calibration cycle. An op-amp IC performs the comparator function indicated in the block diagram. Its output is high when input 2 exceeds input 1, and low (clamped near ground) otherwise. The gate and clock generators provide the wave shapes shown. The AND-gate output is high when all its inputs are high.

### Ramp and clock errors limit accuracy

The simple a/d converter of Fig. 1a works extremely well if only a few bits of accuracy are

required. However, as more accuracy is demanded, various errors begin to appear. These tend to fall into two major classifications: those associated with the ramp and those caused by clock inaccuracies.

There are two types of ramp errors, other than nonlinearities: those related to slope and those related to starting time. If the ramp starts late, fewer than the correct number of counts will be included. Also, if the slope of the ramp is too steep, it will reach the unknown voltage too soon



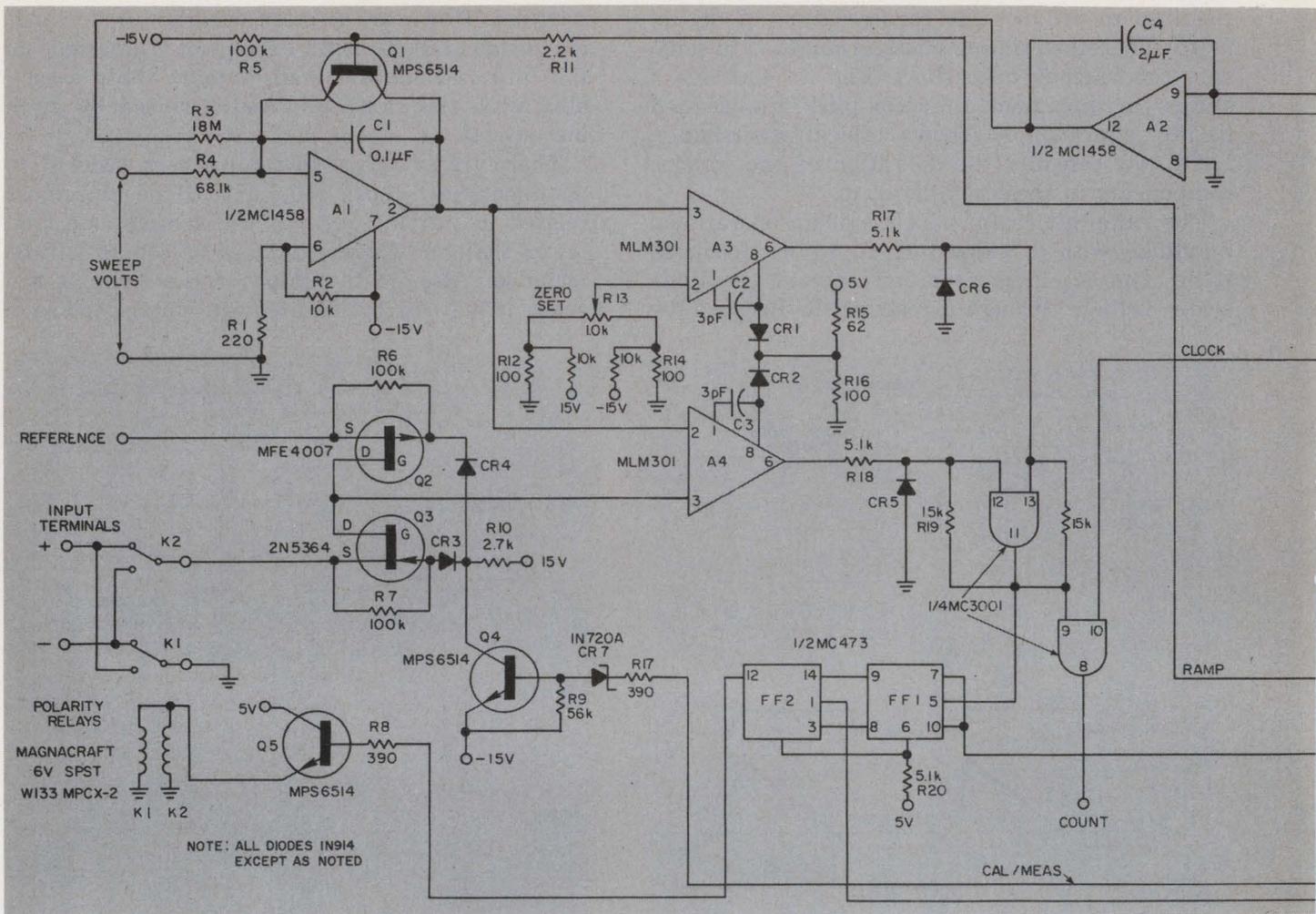
3. A digital feedback loop corrects for clock and ramp errors. During the Calibrate mode the reference voltage is substituted for the unknown. Ramp speed increases with BCD counter readings above 80% of FS.

and, again, the pulse count will be too small.

Comparator voltage offset and delay have effects similar to errors in ramp starting time. If the ramp voltage must exceed the unknown voltage by a given amount to change the state of the comparator, the gate will close late, and too many counts will be included. Likewise comparator propagation delay will cause too many counts to be indicated for a similar reason.

Somehow, ramp-delay errors must be minimized and made to behave predictably with environmental variations. A frequently used method is to start the ramp below the zero-reference voltage (Fig. 2). Then the timing gate is opened when the ramp crosses the zero reference and closed when it crosses the unknown voltage.

The two crossings are detected by identical comparator circuits and should therefore track



each other well. Delays and nonlinearities associated with ramp start-up are also eliminated by this technique. But one problem is created by this technique: It is very difficult to synchronize the clock with the opening of the timing gate, because the gate opening is an analog event not related to the clock. This nonsynchronization can result in a 1/2-LSB error if the gating occurs during the rise time of a clock pulse. With practical clock speeds and standard logic families, this error will normally occur less than 1% of the time.

The clock frequency, of course, has the same effect on count correctness as ramp slope does: If the clock is too slow, it will not produce a sufficient number of pulses during the gate interval. Variations in the clock frequency can be made small by use of a crystal or other high-Q, frequency-determining device.

### Calibration cycle controls ramp slope

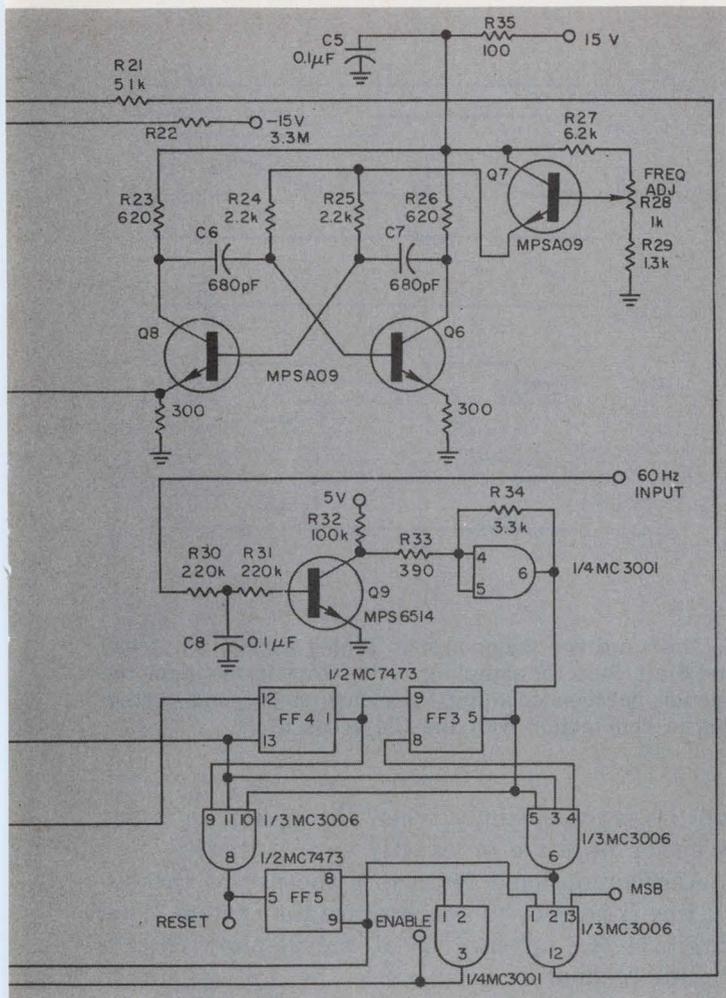
Errors caused by improper ramp slope or improper clock frequency are closely related and are compensated for in the calibration cycle. Both types can be compensated for if the ramp slope is adjusted properly, and this is easy to do. The

problem is to determine the direction and amount of change required—that is, to derive an error signal.

A trial-and-error method determines the required direction of the ramp-slope change. The known analog reference voltage is converted to a digital number, and the resulting value is observed. If the digital output is too high, the slope must be increased, and vice versa.

A block diagram of the calibration scheme is shown in Fig. 3. As explained earlier, the voltage reference is selected to be exactly 80% of the full-scale value of the converter. In a BCD counter the MSB is switched only once during the full-scale count—at exactly the 80% value. The comparator is switched to the reference voltage during this cycle. The MSB of the BCD output number is examined once during the calibration cycle by ANDing it with pulse  $E_c$ . The presence of a logical ONE during pulse  $E_c$  indicates that the ramp slope is too shallow, while a logical ZERO indicates the opposite. Since the error voltage is only present during the  $E_c$  pulse, a way must be provided to store the ramp-speed control-voltage value during the absence of this pulse.

In the system shown an op-amp integrator is used as a sample-and-hold circuit. The capacitor



4. The completed converter contains a dual-comparator feature as well as an error-correction loop. Transistors are used to switch between the reference and unknown input voltages, as well as to discharge sweep-integrator capacitor  $C_1$ .

plied only when the gate count is too high, control in the other direction being provided by a fixed bias. With no error pulses, the derived error-control signal to  $A_1$  drifts slowly positive, while with continuous error pulses it moves in negative steps at the same average rate.

Timing and gating functions are derived from an oscillator (or from the 60 Hz line) by a sequence of dividing and decoding operations. The ramp generating signal (Fig. 6) occurs at  $1/4$  the oscillator frequency. Two other signals, an enable pulse and a reset pulse, are generated by decoding the divider wave shapes. The enable pulse, during the calibrate mode, is designated  $E_c$  and gates the error signal into the sample and hold. In the measure mode, this pulse is called Display Enable and it latches the digital equivalent of the unknown analog voltage into the output display.

The reset pulse occurs immediately following the enable pulses, and resets the counters to zero. The trailing edge of the reset pulse also triggers the Cal/Meas signal, the longest of the converter. Within the period of the ramp signal, comparators  $A_3$  and  $A_4$  control the duration of the timing gate in a manner similar to that shown in Fig. 2. The clock pulses are counted only during the timing gate period.

The error control voltage changes rapidly during the  $E_c$  pulse and drifts slowly between pulses. With large errors, such as might be present for a short time when the unit is first turned on, a staircase error wave shape will be produced, but at near zero error the MSB error-decoder output will be toggling between a plus and minus value to produce a sawtooth wave. This toggling during the calibration cycle has no effect on the measuring cycle, because the ramp slope is only being shifted by an amount corresponding to  $LSB/4$ —less than the resolution of the converter.

#### More features can be added

The converter so far described cannot distinguish between a negative input voltage and zero input. It gives a zero output for either. To correct this, additional circuitry is required. If a zero or negative input voltage is applied, we note that in the Measure mode a Stop pulse is generated before or simultaneously with the Start pulse—in other words, no timing gate is generated. In this case, input polarity can be

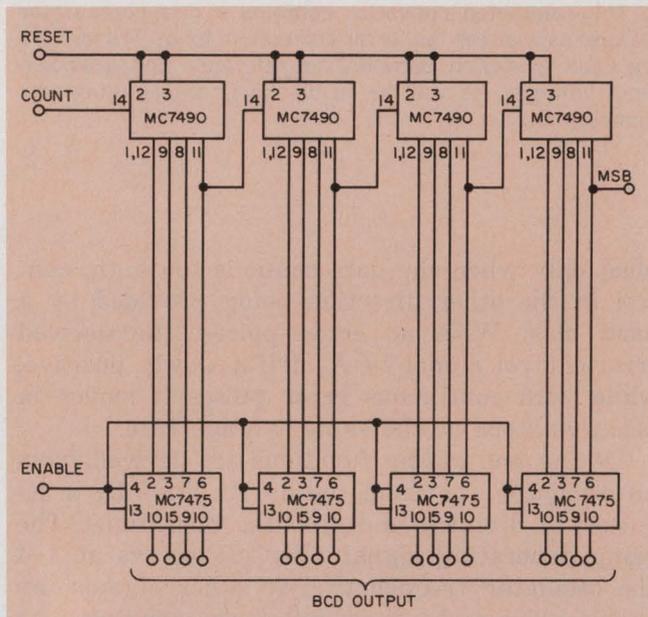
and charging-resistor values are selected so the resulting error control voltage will correct the ramp slope by an amount corresponding to  $LSB/4$ . Error pulses are supplied only when the gated count is high—MSB equal to ONE. Control in the other direction, toward a shallower ramp slope, is provided by the fixed negative bias.

#### Timing and control circuits complete the design

The circuit diagram of a converter using the calibration system just described is shown in Fig. 4. Counters and latches are in Fig. 5. To avoid the necessity for precision parts in the loop, a potentiometer is used to allow adjustment of oscillator frequency. This control is set so that no more than 10,000 counts can be passed in the calibration cycle during the time the ramp, no matter how shallow, reaches the 8-V reference.

From here the ramp-error control signal will always be of the correct polarity to increase the ramp slope, until 8000 pulses have been counted. This occurs at the moment when the ramp crosses the 8-V reference; at this point the loop will lock.

The error input to the integrating amplifier,  $A_2$ , is single-ended—that is, error pulses are sup-



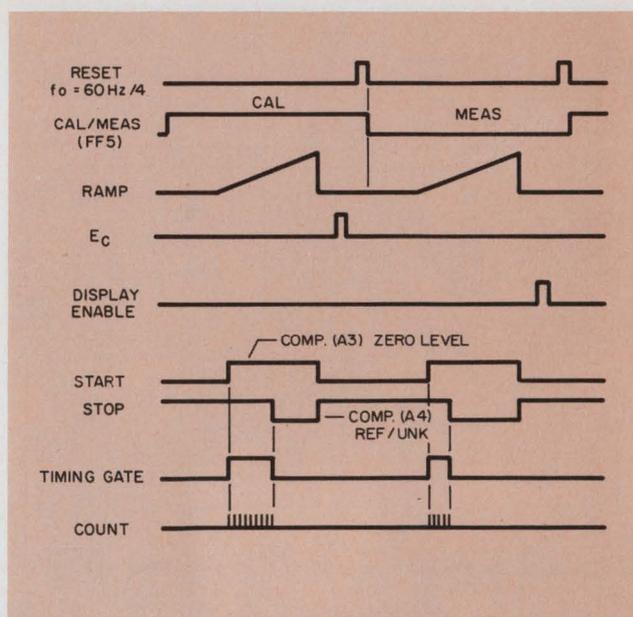
5. The converter output is available as four BCD digits. The Enable signal latches the measured voltage into the output display during the Measure mode. This section also supplies the MSB for ramp speed control.

reversed with a relay. If no timing gate is present during the following Measure mode, as would be the case with zero input, the input should again be reversed. Hence, with an exactly zero input, the input relay is reversed once each Cal/Meas cycle, and the plus-and-minus sign likewise alternates at the cycle rate.

The circuitry to accomplish the above polarity sensing is implemented as follows (Fig. 4): Polarity is indicated by a J-K flip-flop, FF<sub>1</sub>, connected so that it will change state every time it receives a negative-going pulse. The timing-gate signal is connected to its input, so each occurrence of a timing-gate signal will trigger FF<sub>1</sub>. Use of the negative-edge triggering assures that the flip-flop will not trigger until the end of the Timing Gate—that is, after the measurement is completed. Thus the flip-flop triggers when the ramp crosses either the unknown or the Reference voltage level.

During converter operation flip-flop FF<sub>1</sub> changes state at the end of each measurement of a positive voltage. The Timing Gate, which is always present during the Calibrate cycle (because the reference voltage is always positive), returns FF<sub>1</sub> to its original state, ready for the next measurement. However, if the input is negative or zero, the Timing Gate will be present only during the Calibrate mode, so the state of FF<sub>1</sub> will alternate with the mode.

A second J-K flip-flop, FF<sub>2</sub>, is connected to FF<sub>1</sub> in such a way that its state is forced to be the same as that of first flip-flop at the time of the Display-Enable pulse. With two flip-flops connected in this way, the polarity relay (and readout)



6. There are two major system timing cycles: Cal/Meas and Start/Stop (or sampling cycle). Waveforms show the relation between counting for measurement and correction in conjunction with the Cal/Meas cycle.

will be activated only when the unknown input is either negative or exactly zero voltage.

Another optional feature is the use of the 60-Hz line frequency to synchronize the system. This improves the appearance of the display when a digital readout is used, since the voltage under measurement frequently has a small 60-Hz component. When the sampling rate is synchronized with this "hum," the reading is always taken at the same point in the hum wave shape, so the last digit is less likely to fluctuate. The actual reading obtained is, of course, the input voltage at this instant and may not be the rms value of the input signal plus hum.

When the converter is operated at a 60-Hz rate, only about seven corrections per second are made. In a 4-1/2-digit system, LSB/4 is only 1/40,000th of full scale, so if each correction is LSB/4, the correction rate is only 0.0175% per second. Therefore, if the initial error should happen to be 10% of full scale, it will take about 10 minutes for the system to stabilize. This time can be reduced by synchronizing a higher frequency oscillator to the line frequency and using its output to operate the converter.

Another desirable refinement is the use of a potentiometer to vary the offset of one of the comparators. This provides a zero-offset adjustment for the instrument and allows the output to read zero for a nonzero input, a condition sometimes desirable when the input comes from a transducer. Provision for this adjustment also allows the use of a less precise operational amplifier, such as the MLM301A, instead of expensive precision comparators. ■■

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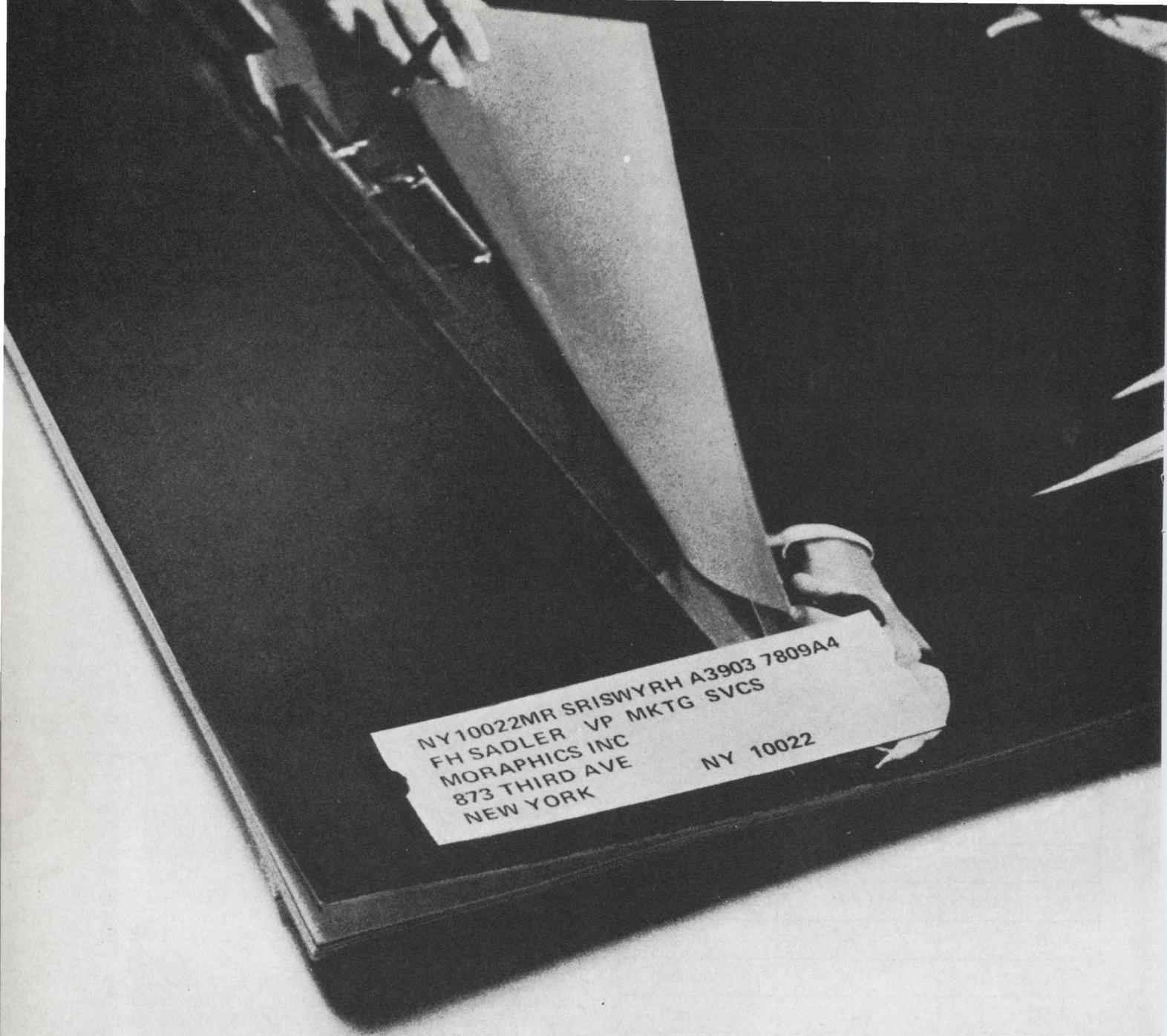
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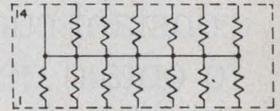
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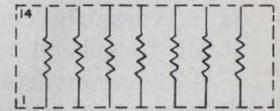
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# Design versatile d/a converters by using constant-current sources. Custom components are not needed to obtain devices for special applications.

Designing "one-of-a-kind" digital-to-analog (d/a) converters presents a formidable problem to the designer. If, for example, the input code is unusual, a suitable off-the-shelf converter may be unobtainable or prohibitively expensive. Yet a completely new in-house design may also involve high expenditures and long delays. What's needed is a versatile conversion technique that lends itself to special applications.

A d/a converter designed with constant current sources can handle a wide range of requirements. Almost any type of digital input coding can be accommodated. Precision resistive ladder networks are not needed, so no time is spent waiting for delivery. Also, most commercially available resistive-weighting networks are restricted to binary inputs.

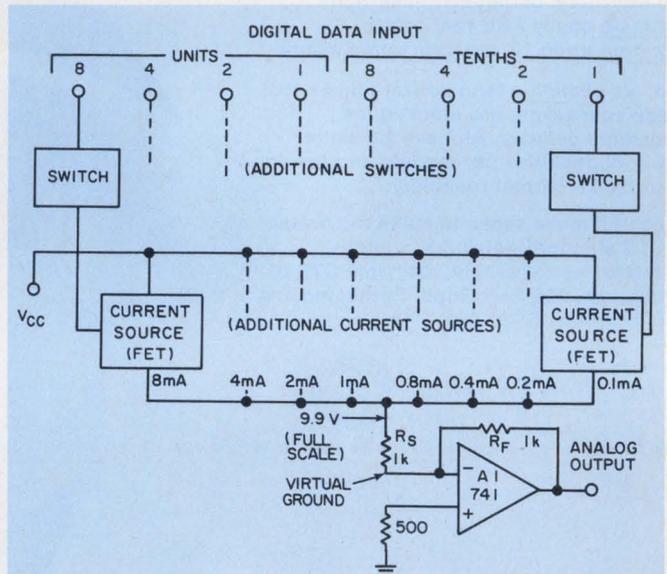
In a constant-current d/a converter, the outputs of all the current sources are connected by a common bus to a constant-impedance load. Each source is individually adjusted so it supplies a steady current value that is equal in weight to the input data bit that controls it. For example, the converter shown in Fig. 1 uses a weighting factor of "one unit equals 1 mA" and the output voltage is developed across an impedance of 1000  $\Omega$ . But any other weighting factor and load impedance can be chosen. Extra digits can be added to this type of converter if additional sources are used. But, of course, there is no reason to design and build a five-digit d/a converter when the output of the analog device has only two-digit resolution.

## Design the switched current source

The heart of the constant-current converter is the current source shown in Fig. 2. The characteristics of the field-effect transistor (FET) and the value of the source resistor,  $R_s$ , determine the value of drain current,  $I_D$ , flowing through the device. The value of  $V_{GS}$  required for a given  $I_D$  can be found with the formula

$$V_{GS} = V_P (1 - \sqrt{I_D/I_{DSS}}),$$

Jon L. Turino, Test Equipment Engineer, Xerox Corp., El Segundo, Calif. 90245.



1. The design concept for a two-digit BCD-to-analog converter. The analog output voltage goes from zero for an input code of (0, 0, 0, 0 - 0, 0, 0, 0) to 9.9 V for a code of (1, 0, 0, 1 - 1, 0, 0, 1).

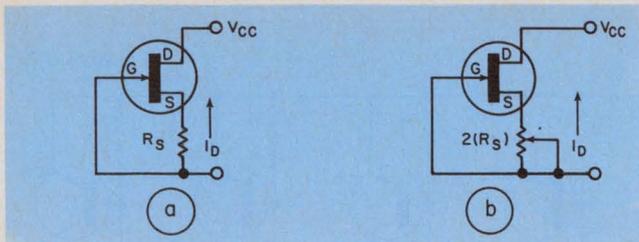
where:  $V_{GS}$  is the required gate-to-source voltage for the FET,

$V_P$  is the pinchoff voltage of the device,  
 $I_D$  is the required drain current, and  
 $I_{DSS}$  is the zero-bias drain current of the transistor.

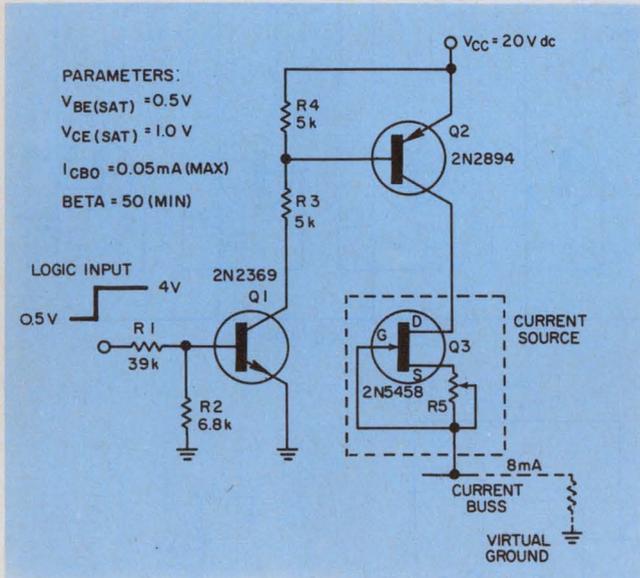
The value of  $R_s$  is then  $R_s = V_{GS}/I_D$ .

Since device parameters vary considerably from their published specifications, it is wise to use a potentiometer with a total resistance of twice the calculated value of  $R_s$  instead of a fixed value. This insures that the required  $I_D$  can be obtained, and it allows the precise adjustment required for accurate calibration of the current source.

The selection of the  $V_{cc}$  for the current sources is very important for proper operation of the converter. It must be large enough to insure that, even with the converter inputs and output at almost full scale, there is enough voltage to keep the least-significant-bit (LSB) current source operating in the constant-current region. A sure way to determine this value is to add the full-scale voltage needed at the current-source output



2. The heart of the d/a converter is the current source (a). A variable resistance (b) is preferred so that each constant-current source can be adjusted exactly to the required values.



3. Complementary transistors,  $Q_1$  and  $Q_2$ , are used in a combination, level-shifting and saturated-switch circuit. A true input (4 V) causes  $Q_1$  and  $Q_2$  to saturate, thereby turning on the preset current source  $Q_3$ .

point to the highest value of  $V_{GS}$  required in any of the current sources. To this value, add about 25% as a safety margin.

This method of selecting  $V_{cc}$  will insure that there is adequate drain-to-source voltage ( $V_{DS}$ ) across each FET. For example, assume that the circuit of Fig. 1, with a full-scale voltage of 9.9 V at the top of  $R_S$ , requires a  $V_{GS}$  of 5 V for the 0.1 mA output. The  $V_{cc}$  supply should then be

$$(9.9 \text{ V} + 5 \text{ V}) + (.25) \cdot (9.9 \text{ V} + 5 \text{ V}) = 18.6 \text{ V}.$$

In practice, a well-regulated voltage of 18-20 V dc will work satisfactorily.

### Interface with the logic levels

With the current-source values and components selected, the remaining part of the circuit to be designed is the input-switching interface. This interface must take the digital input levels and cause them to turn the individual current sources either fully on or fully off. Since the required interface depends on the specific digital device connected to the converter input, no hard and fast rules can be made for its design. An exam-

ple, however, should serve to point to the concepts.

Suppose the interface logic levels are 0.5 V maximum for a ZERO (saturated collector-emitter junction) and 4.0 V minimum for a ONE (a pull-up resistor connected to +5 V dc). A circuit suitable for converting these levels to an on-off control for the current source is shown in Fig. 3. The design procedure starts with the value of the collector current of  $Q_2$  and works back to the input terminal with some rules of thumb.

First, select the  $I_C$  of  $Q_2$  as 16 mA—that is, twice the value of the current source output. (Although no more than 8 mA will flow in the circuit, this rule insures that there will always be enough base current applied to  $Q_2$  to cause saturation.)

Next, find the  $I_B$  of  $Q_2$ , using the minimum  $\beta$  of the transistor. For this example, assume a minimum  $\beta$  of 50, so that  $I_B = 0.32$  mA. Select  $R_4$  so that less than one-half of the  $V_{BE(SAT)}$  of  $Q_2$  can be dropped across it when the  $I_{CBO}$  of  $Q_1$  is at its maximum. Then if

$$(V_{BEQ2})_{SAT} = 0.5 \text{ V}$$

$$\text{and } (I_{CBO})_{Q1} = 0.05 \text{ mA},$$

$R_4$  should be  $0.25 \text{ V} / 0.05 \text{ mA} = 5000 \Omega$ .

Next the value of  $R_3$  can be selected. It should drop

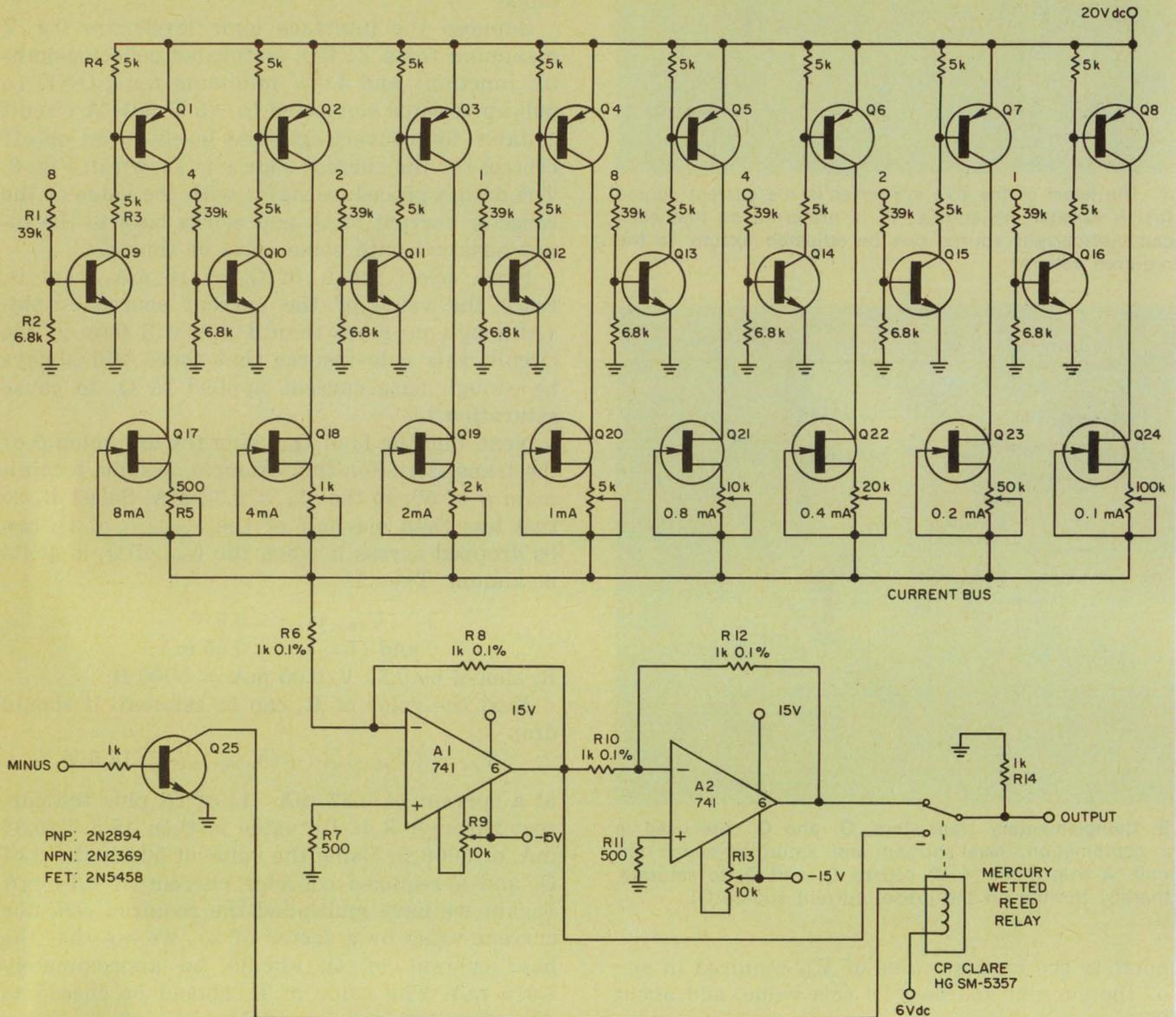
$$V_{cc} = (V_{BEQ2})_{SAT} - (V_{CEQ1})_{SAT} = 18.5 \text{ V}$$

at a current of 0.37 mA ( $I_B$  of  $Q_2$  plus the current through  $R_4$ ). Its value is then  $18.5 \text{ V} / 0.37 \text{ mA}$ , or  $5000 \Omega$ . Using the value of 50 for the  $\beta$  of  $Q_1$  and a required collector current of 0.74 mA (again we have multiplied the required collector current value by a factor of 2), we see that the base current of  $Q_1$  should be approximately 0.015 mA. The value of  $R_2$  should be chosen to drop five times  $I_{B(Q1)}$  at  $V_{BE(SAT)}$ , so its value should be  $R_2 = 0.5 \text{ V} / 0.075 \text{ mA} = 6700 \Omega$ . A resistor with a standard value of 6.8 k $\Omega$  should be close enough. The value of  $R_1$  can then be calculated. It should drop  $4 \text{ V} - 0.5 \text{ V} = 3.5 \text{ V}$  at a current of 0.09 mA. The value is 39 k $\Omega$ .

The schematic of the final version of the two-digit BCD-to-analog converter is shown in Fig. 4. Although a precise dc circuit design procedure may be used when the interface circuits are designed for a specific application, the use of the assumptions and rules of thumb previously discussed insure that the transistors are off when the input is low and on when the input is high.

### Calibrate with external voltages

All that remains is the calibration of the converter. This is done very simply. First, connect all input terminals to a +0.5 V source and adjust the offset control of op-amp  $A_1$  for zero output voltage (pin 6). Then connect each input indi-



4. The complete two-digit BCD-to-analog converter requires only the appropriate power supplies and a simple

calibration routine. A Minus signal from the input device actuates the relay to allow bipolar operation.

vidually to a +4.0 V source and adjust the current-source potentiometers to give the proper output voltages at pin 6 of the op amp (8 V for Units position 8 and 0.4 V for Tenths position 4, etc.).

The output of the converter can drive most analog devices directly. If more driving power is required, it can be obtained in the usual ways (such as with a complimentary-symmetry stage).

Semiconductor-device selection is not critical. The switching portion of the circuit is designed for worst-case operation. A large amount of negative feedback regulates the current-source portions. FETS are used as current-source elements to achieve design simplicity and a low

parts count. The total cost of the components comes to only \$45.

Measurements show that the circuit has a zero drift of less than 0.1 mV from 15 to 50 C. Linearity is better than 0.5%, and the overshoot when codes are changed is less than 1%. The maximum spike duration is less than 50  $\mu$ s, which is much too fast to disrupt the indications of most analog devices.

The only critical voltage is the  $V_{cc}$  for the current sources. This must be regulated so it does not fall below the minimum required voltage. Only the minimum value is important; an increase of 25% affects the converter output by less than 1%. ■■



## Multiplexer technique solves X-out-of-Y bit pattern-recognition

Straightforward application of Boolean techniques becomes unwieldy when the logic designer needs a pattern of X true bits from a field of Y bits. A technique that uses digital-multiplexer ICs easily yields solutions for any range of X and Y. And it is especially useful when Y exceeds six, as often happens with error-correcting codes.

A multiplexer with N addressing (select) bits can produce all Boolean products of N variables. A ONE output results when the selected input line also equals ONE. The input lines are labeled as the decimal equivalent of the N addressing bits. For example, the select addresses of 011, 101 and 110 each produce a ONE output if input lines 3, 5, and 6 are all ONES, as shown for Z<sub>1</sub>.

In this case, a ONE output is produced when two out of the three bits are ONES. Similarly, the inputs can be wired so as to recognize one out of three and three out of three ONES on the select lines.

A three-of-six pattern detector where, X = 3, Y = 6 and N = 3, is shown in the schematic. The output is true whenever three, and only three, of the six inputs are true. The technique used is to work from the output backwards, providing one level of multiplexers for every subset

of N = 3 input variables.

If  $Y_4Y_5Y_6 = 000$  the three-of-three input to the final multiplexer will be selected. Hence the final output will be ONE if  $Y_1Y_2Y_3$  are all true.

If  $Y_4Y_5Y_6 = 001, 010, \text{ or } 100$ , thereby selecting inputs 1, 2 and 4, then the output will be true only if two of the other variables  $Y_1Y_2Y_3$  are true.

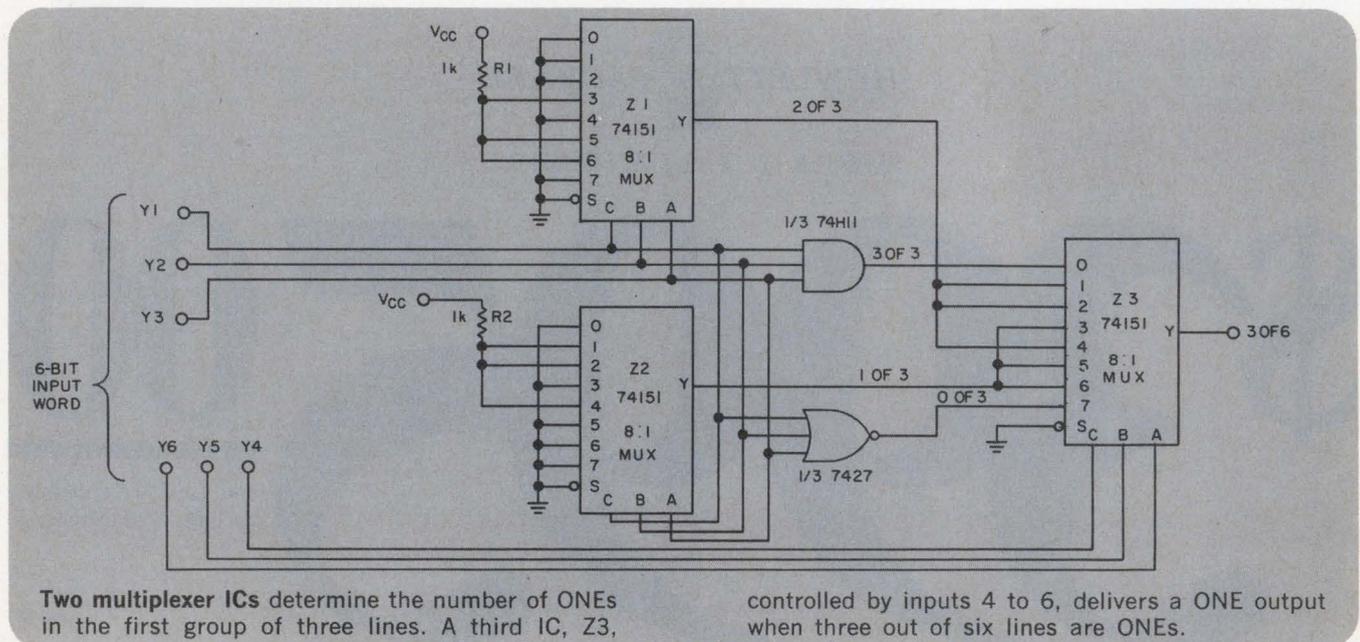
If  $Y_4Y_5Y_6 = 011, 101 \text{ or } 110$  (3, 5, 6), then the output will be true only if one of the other variables,  $Y_1Y_2Y_3$ , is true.

When variables  $Y_4Y_5Y_6 = 111$  (7), the output will be true only if none of the other variables is true.

In the first level the presence of none-of-three, one of three, two of three, and three of three true variables must be detected. Single gates will detect none of three (000) and three of three (111) patterns; multiplexers economically detect one of three and two of three patterns. Note that only one polarity of the Y variables is required.

*Les Furnanz, Development Engineer, Fairchild Systems Technology, 3500 Deer Creek Rd., Palo Alto, Calif. 94304.*

CIRCLE NO. 311



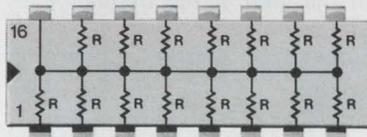
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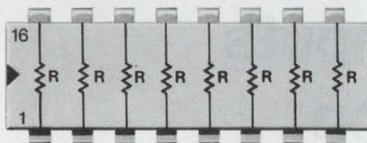
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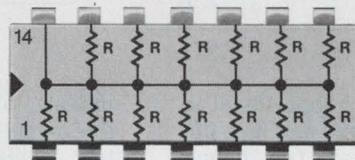


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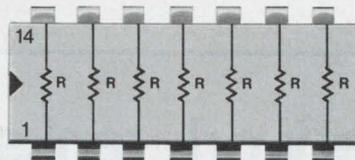
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68	150	470	1.5K	3.3K	6.8K	22.0K
100	220	680	2.0K†	4.7K	10.0K	

\* Standard in 898-3 only.  
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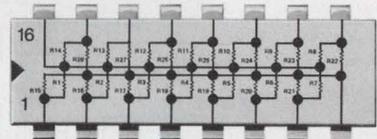
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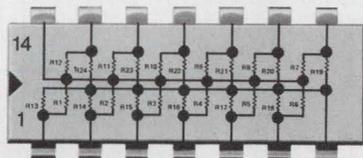
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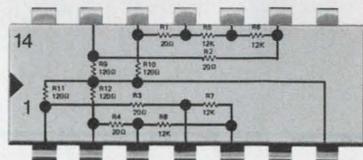
22	62	180	510	1.5K	4.3K	11K
24	68	200	560	1.6K	4.7K	12K
27	75	220	620	1.8K	5.1K	13K
30	82	240	680	2.0K	5.6K	15K
33	91	270	750	2.2K	6.0K	16K
36	100	300	820	2.4K	6.2K	18K
39	110	330	910	2.7K	6.8K	20K
43	120	360	1.0K	3.0K	7.5K	22K
47	130	390	1.1K	3.3K	8.2K	
51	150	430	1.2K	3.6K	9.1K	
56	160	470	1.3K	3.9K	10K	



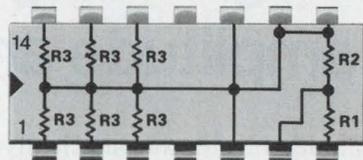
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INFORMATION RETRIEVAL NUMBER 43

# Analog divider simplifies ac ratio meter and yields $\pm 0.2$ -dB measurement accuracy

An ac ratio meter simplifies frequency-response measurements by determining the output-to-input voltage ratio at any given frequency. The circuit shown measures the voltage ratio to within 0.2 dB and has a parts cost of hundreds of dollars instead of the thousands that commercial units cost.

The circuit consists basically of an analog divider and two peak detectors. The latter converts the ac voltages,  $V_1$  and  $V_2$ , to proportional dc magnitudes at the input to the divider. A read-out device such as a DPM, indicates the ratio  $V_2/V_1$  from the output of the divider.

The simple op amp peak detectors shown work adequately at audio frequencies. An uncompensated op amp should be used and preferably should have wide bandwidth.

If capacitors  $C_1$  and  $C_2$  have large values, the op amps should be current-limited at their outputs, to prevent damage when the capacitor

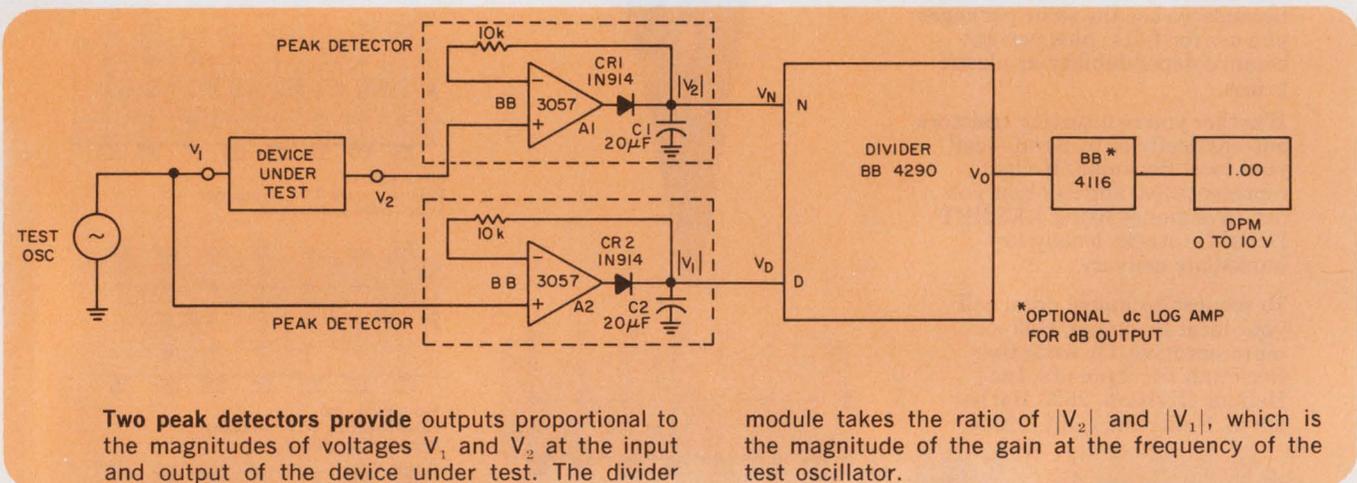
charges toward the peak input voltage.

With the components shown, the ratio meter exhibits a frequency response of  $\pm 0.2$  dB from 20 Hz to 20 kHz, provided the inputs to the divider are near their full-scale value of 10 V. The dynamic range is 0 to  $-40$  dB,  $\pm 0.2$  dB, under the constraint that  $V_D \approx 10$  V, and that  $10 V \cong V_N \cong 0.1$  V.

The inputs  $V_D$  and  $V_N$  to the divider must be scaled so that  $V_o$  is more than 1 V. This limits the divider error to  $\pm 0.1$  dB but restricts the dynamic range to  $-40$  dB. Scaling amplifiers used before the peak detection will extend the dynamic range to  $\pm 60$  dB.

Larry Choice, Product Specialist, Burr-Brown Research Corp., International Airport Industrial Park, Tucson, Ariz. 85706.

CIRCLE No. 312



## Analog sorting network ranks inputs by amplitude and allows selection

An analog circuit automatically selects the  $M$ th largest signal in an arbitrary set of  $N$  analog inputs. The  $N$  analog inputs are ordered from lowest to highest value  $V_{1R} < V_{2R} < V_{3R} \dots < V_{NR}$ ; and the  $M$ th member of the sorted sequence is chosen. Thus,

$$V_o(M) = V_M$$

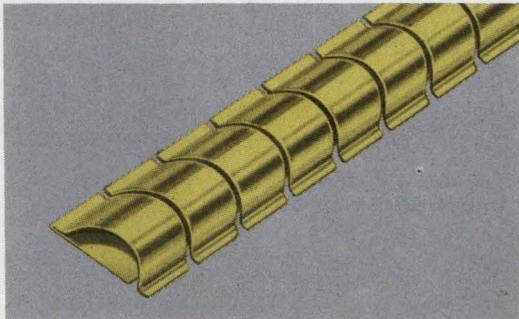
where  $M$  is a variable parameter selected by the

designer and  $R$  denotes sorting. In the special case, where, for example,  $N = 3$  and  $M = 2$ , we have a mid-value selector. In another case where  $N$  is odd and  $M = (N + 1)/2$ , the  $V_o(M)$  represents the median input voltage.

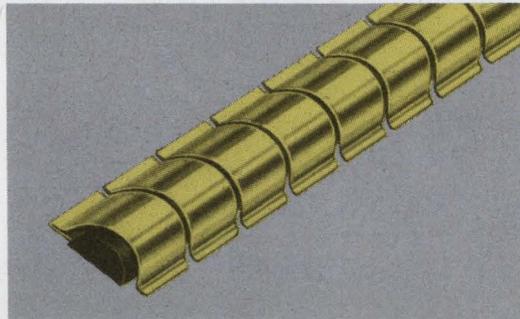
An arbitrary number of voltages,  $N$ , are connected to the noninverting inputs of  $N$  op amps (Fig. 1). Each amplifier output is connected to a

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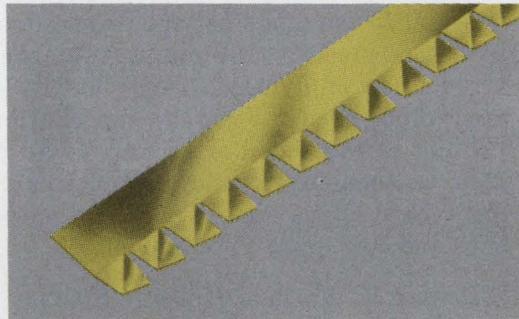
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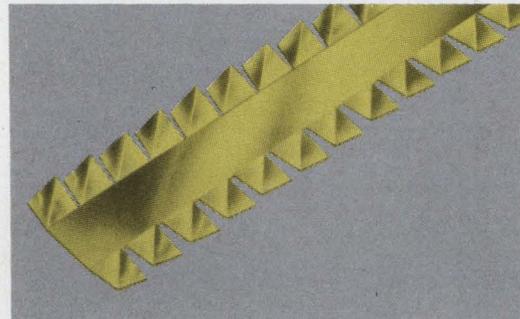
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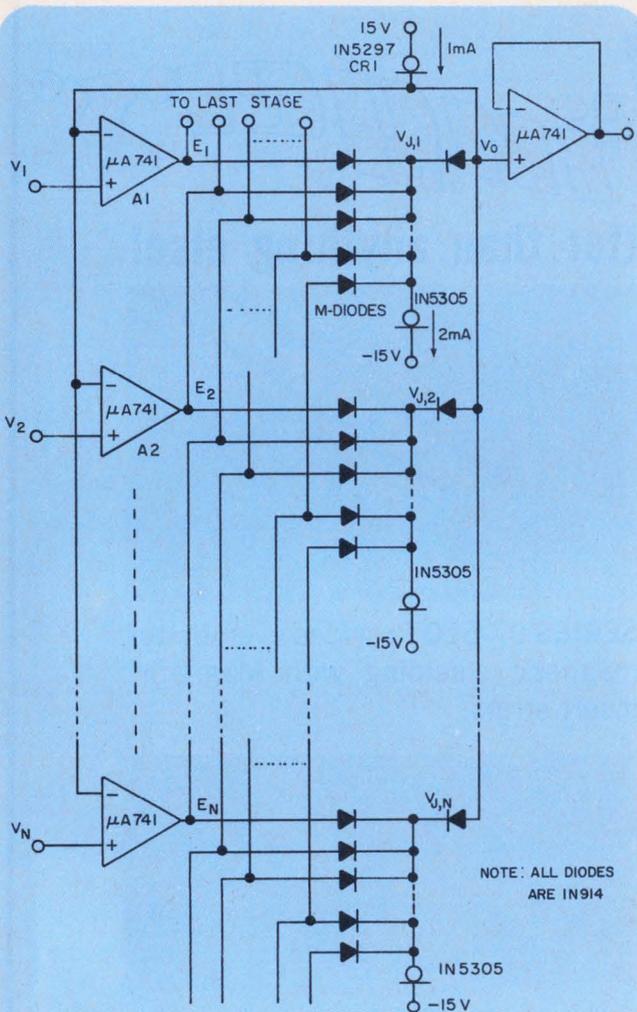
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By making M comparisons per amplifier and by choosing the lowest values found, the analog circuit selects the Mth largest input voltage.

single diode in a cluster of M diodes. The diodes then select the largest voltage from among the next M amplifier output, where  $1 \leq M \leq N$ .

A diode OR-gate circuit, with one input per cluster, causes unity gain feedback of the lowest cluster voltage,  $V_o$ , to the input amplifier inverting terminal bus.  $V_o$  is the minimum of  $V_{J1}$  through  $V_{JN}$ .

Circuit operation can be explained mathematically as follows: Assume (without loss of generality) that  $V_1 < V_2 < \dots < V_N$ . Let  $E_i$  and  $V_{Ji}$  denote the  $i$ th op-amp output and diode voltage respectively, for  $1 \leq i \leq N$ . Also let  $V_D$  be the forward drop of any single diode. Then,  $V_o = \min(V_{J1}, V_{J2}, \dots, V_{JN}) + V_D$ . Also  $V_{J1}$  is defined by the diode clusters  $V_{J1} = \max(E_1, E_{i+1}, \dots, E_N, E_1, E_2, \dots) - V_D$ , where M terms are included in the parenthesis. Since all of the op-amp inverting inputs are common, we have

$$E_1 < E_2 < \dots < E_N.$$

Substituting into the above, we get,

$$(V_{J1}, V_{J2}, \dots, V_{J(N-1)}, V_{JN}) = (E_M, E_{M+1}, \dots, E_N, E_N) - V_D$$

and so  $V_o = E_M$  which implies that  $V_o = V_M$  by virtue of the feedback.

The constant-current sinks (1N5305) are chosen to draw twice the current of the constant-current source (1N5297). This will cause equal currents through the two active diodes and thereby equalize the diode voltage drops. Resistors can be used instead of the diodes. But there will be a reduction of dynamic range and a loss of the exact diode forward-voltage cancellation.

Input voltages to almost  $\pm 15$  V can be handled with reasonable accuracy. The circuit also features high input impedance, low output impedance and low input-to-output offset.

*Dennis R. Morgan, General Electric Co., Electronics Laboratory, Syracuse, N.Y. 13201.*

CIRCLE NO. 313

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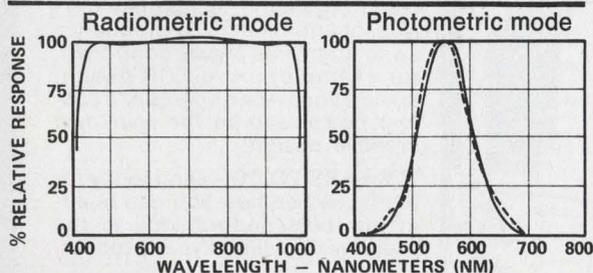
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- $10^{-9}$  joule to  $10^{-3}$  joule (energy)
- $10^{-3}$  ft. cdl. to  $10^4$  ft. cdl. (intensity)
- $10^{-3}$  ft. cdl. sec. to  $10^3$  ft. cdl. sec. (integrated intensity)
- $10^{-2}$  to  $10^3$   $\mu$ W, on one log scale
- Computer designed correction filters

\* to 1 watt with optional beam splitter



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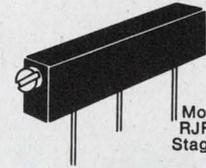
Accutrim™ trimmers RJ12 Styles

**TC: 10 PPM/°C MAX**

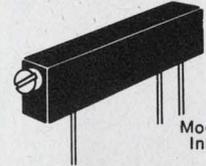
**NOISE: 10 Ω ENR MAX**

**RANGE: DOWN TO 2 Ω**

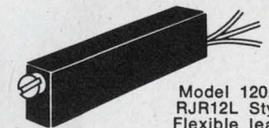
**RESOLUTION 0.05% SETABILITY**



Model 1202Y RJ12Y Style Staggered pins



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Circle 198 on reader service card

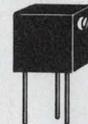
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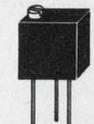
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Model 1240W Style RJR26W



Model 1240P Style RJR26P

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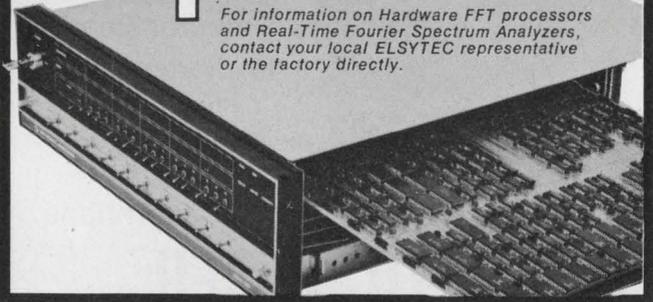
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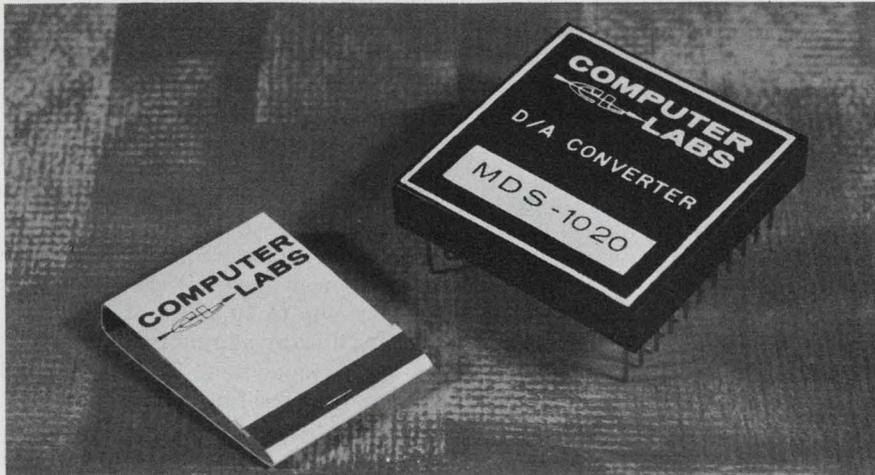


INFORMATION RETRIEVAL NUMBER 49

ELECTRONIC DESIGN 2, January 18, 1973

## new products

# 8-bit d/a converter module settles to 0.4% within 15 ns



Computer Labs, 1109 S. Chapman St., Greensboro, N.C. 27403. (919) 292-6427. See text.

Computer Labs, known for high-performance analog-to-digital converters, has entered the low-cost, miniature converter field. The company's first entry in the low-cost arena is a modular line of 12 ultra-fast current-output d/a converters, with resolution of either eight or 10 bits. The MDS/815 is the fastest of the new units, with a settling time of only 15 ns to 0.4% of full scale (1 LSB). It costs \$109 in unit quantities.

Two other eight-bit units are available, with settling times of 30 ns and 50 ns, respectively, to 0.4% of full scale. These are designated the 830 and the 850. Accuracy of the eight-bit units is adjustable to  $\pm 0.2\%$  (1/2 LSB). In addition three 10-bit converters are offered—the 1020, 1040 and 1080—with respective settling times of 20, 40 and 80 ns to 0.1% of full scale. Accuracy of the 10-bit units is adjustable to  $\pm 0.05\%$ .

Any of the converters can be ordered as the MDS Series, with a temperature coefficient of  $\pm 30$  ppm/ $^{\circ}$ C, or—for an additional \$20—as the MDP series, with a tempo of only  $\pm 15$  ppm/ $^{\circ}$ C. All units operate from  $-20$  to  $+75$  C.

With 15-ns settling time, the MDS/MDP 815 appears to be the

fastest eight-bit modular d/a converter available today. One example of a competitive unit is Datel Systems DAC-HI Series, which comes in either eight or 10 bits, settles to  $\pm 0.1\%$  of full scale in 25 ns and has a tempo of  $\pm 15$  ppm/ $^{\circ}$ C. The eight-bit DAC-HI costs \$149. Another example is the Analog Devices MDA-10F, a 10-bit converter with a settling time of 40 ns to 1/2 LSB.

But it must be pointed out that most companies specify settling time to 1/2 LSB for a full-scale change in the input code—that is, all ONEs to all ZEROs or vice versa. Computer Labs, on the other hand, measures settling time for the major-carry input code transition, in which the MSB switches out of phase with all the other bits.

When this occurs, a d/a's output should theoretically change 1 LSB around the half-scale point. But because transistor turn-on and turn-off times are not equal, a temporary state—or glitch—can occur, in which the output swings toward zero before recovering to the half-scale point. Thus worst-case transients—and hence worst-case settling time—can result. This bit-to-bit, rather than full-scale settling time, is important in tracking applications, such as staircase generation.

The MDS/MDP series offers

more output current than competing modules: Full-scale output is 15 mA at 1.5 V max. for unipolar operation, and  $\pm 7.5$  mA at  $\pm 1$  V for bipolar operation. However, the eight-bit units consume a high 120 mA at 11 to 16 V, and  $-15$  mA at  $-11$  to  $-16$  V; the 10-bit converters require 105 mA and  $-15$  mA at the same voltages. Power-supply rejection is 0.04% per volt. The output impedance of all units is a nominal 165  $\Omega$  and the output zero offset is less than 15 nA. The units can drive five TTL H loads or seven standard TTLs.

The converters accept either straight-binary parallel input coding for unipolar output or offset binary or TWOs complement for bipolar output. Inputs are DTL/TTL-compatible.

The  $2.315 \times 2.315 \times 0.43$ -inch converters weigh 2.5 ounces and are packaged in fiberglass epoxy. Single-quantity prices for the MDS 815, 830 and 850 are \$109, \$99 and \$89, respectively; the MDS 1020, 1040 and 1080 cost \$129, \$119 and \$109. Add \$20 to each unit for the MDP Series.

CIRCLE NO. 250

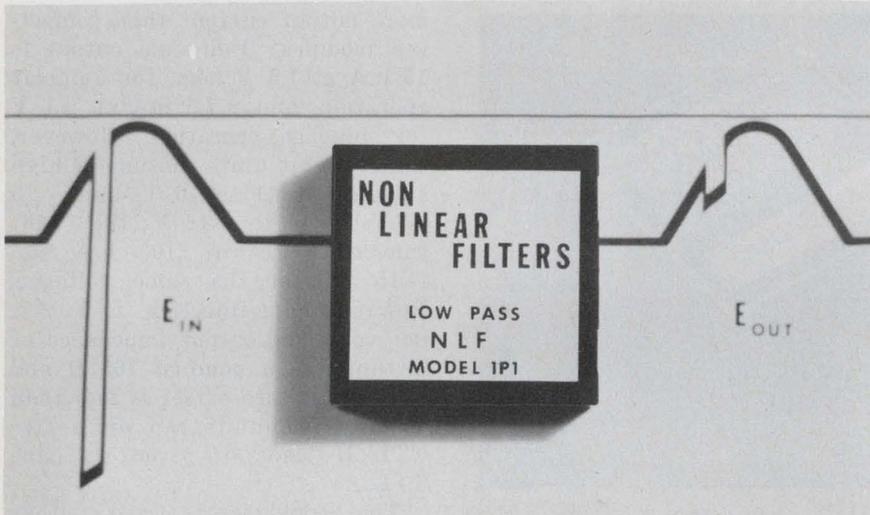
## Module corrects CRT pincushion distortion

Intech Inc., 1220 Coleman Ave., Santa Clara, Calif. 95050. (408) 244-0500. \$495.

The A-740 performs all mathematical operations necessary to correct for the pincushion effect seen on CRTs with flat or semiflat screens. It also corrects dynamic focus distortions and other distortions resulting from nonideal deflection yoke and tube geometries. Correction accuracy is within 99.8%, bw is 10 MHz and slew rate is 40 V/ $\mu$ s in both horizontal and vertical axes. The plug-in module measures  $3.5 \times 2.5 \times 0.87$  inches.

CIRCLE NO. 251

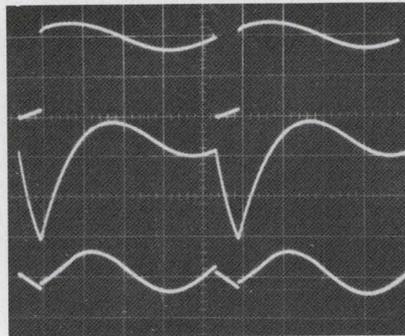
# Nonlinear low-pass filter exhibits zero phase shift



Non Linear Filters, P.O. Box 338, Trumbull, Conn. 06611. (203) 268-6309. \$100 (1-9); \$70 (100s); 30 to 60 days.

Engineers working in digital communications, spectroscopy, voice communication and music reproduction are often plagued by phase-delay distortion and noise spikes. Impulse noise cancellation networks, phase-locked loops and other complex techniques are usually used to reduce such noise. Now, a fledgling company, Non Linear Filters, has come up with an encapsulated  $2.56 \times 2.56 \times 0.8$ -inch module that appears to eliminate noise spikes more effectively than previous methods.

The device—designated the Model 1P—is an active, nonlinear low-



Response of the nonlinear filter to a 10-V, 800- $\mu$ s noise pulse riding on a 3-V pk-pk, 200-Hz sinusoid (top trace). The output of the filter is shown at bottom. The center trace is the response of a single-pole, linear low-pass filter to the same input. The nonlinear filter has no phase shift, while the linear filter gives a 45-degree lag.

pass filter that attenuates frequencies above its corner frequency. This in itself is obviously not earthshaking. What is different, however, is the fact that the device introduces virtually no phase shift either above or below the corner frequency. Thus spikes and other types of noise are reduced without phase-delay distortion.

The user selects corner frequency—up to 10 kHz—of the nonlinear filter by adding two nominally equal capacitors. The capacitor values in microfarads (C) are determined by division of the number 1.7 by the desired corner frequency in Hertz. The  $dV/dt$  of the input is then limited to  $1.65/C$ —the maximum slew rate of the device. Also, three external resistors determine the transfer function.

The Model 1P requires a nominal supply voltage of  $\pm 15$  V at 20 mA. Over the operating range of 0 to 70 C, the unit's input bias current is 3 nA, and input-to-output offset voltage is 750 mV maximum. The linear voltage region of the filter is confined to  $\pm 11$  V for both input and output.

Input resistance, from dc to 100 kHz, is a minimum of 2.7 k $\Omega$ , while output resistance is 1  $\Omega$  max. Voltage gain of the device is nominally 1, but it can vary from 0.8 to 1.2. Both input and output are protected against short-circuits.

CIRCLE NO. 252



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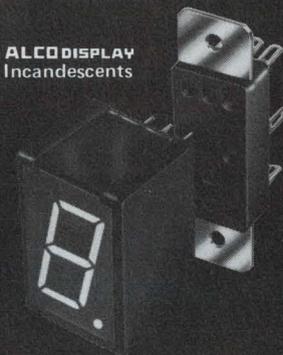
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INFORMATION RETRIEVAL NUMBER 51

## 7-SEGMENT READOUT

New, low-cost, 7-segment incandescent readouts provide large, easy-to-read .8" numerals, plus decimal point. Model MS-5030E (5V 30 mA/seg.) available with choice of red or clear lens filters. Conventional & PC sockets available.

ALCO DISPLAY  
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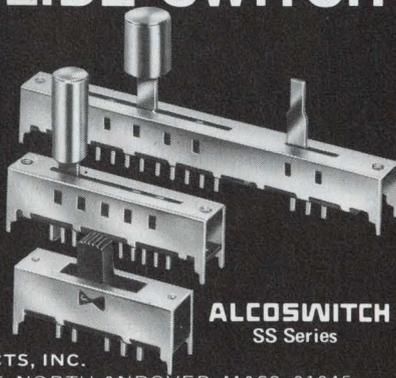


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INFORMATION RETRIEVAL NUMBER 84

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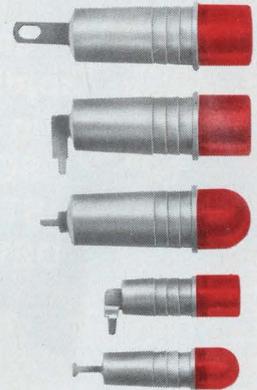


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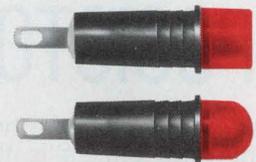
INFORMATION RETRIEVAL NUMBER 52

ELECTRONIC DESIGN 2, January 18, 1973

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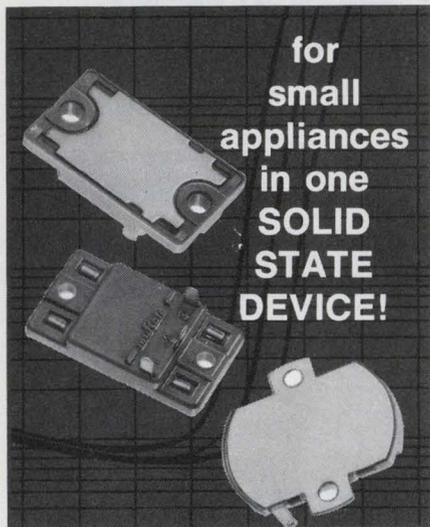
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INFORMATION RETRIEVAL NUMBER 53

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INFORMATION RETRIEVAL NUMBER 54

## DATA PROCESSING

### Unit offers speedier facsimile transmission



*Visicon, Inc., Box 1008, State College, Pa. 16801. (814) 237-6521. See text.*

Model GX-100 is designed to allow high-speed transmission of large size documents over telephone lines. Black-and-white information is transmitted at a resolution of either 100 or 200 lines/in. Letter size documents (8-1/2 by 11 in.) can be transmitted in 30 s or less, "B" size drawings require as little as 70 s. This system is configured around a 16-bit minicomputer. Outputs can be provided in two forms of reconstructed hard-copy, graphic displays or magnetic tape recordings. The system sells for \$100,000, depending on configuration and can be leased for approximately \$3000/mo.

CIRCLE NO. 253

### Video snapshots recorded on cartridges

*Arvin Systems, Inc., 1771 Springfield St., Dayton, Ohio. 45401. (513) 254-1797. \$4000.*

Called the "Discassette," the Arvin video recorder uses a flexible magnetic medium in cassette form to store 300 still frames. The image quality is determined by a 4.2 MHz bandwidth with a 40 dB signal-to-noise ratio and a time-base error of under 400 ns. Pictures can be taken directly from a TV monitor with record/playback rates of 1, 3, 6, 10 or 15 frames/s. Cartridges cost \$25 and can be changed in less than 20 s.

CIRCLE NO. 254

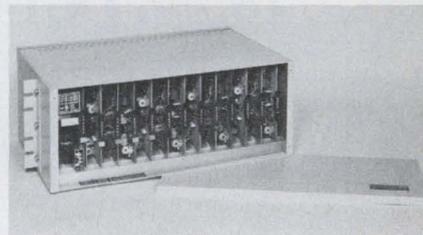
### Fast minicomputer offers interleaved memory

*Interdata, 2 Crescent Pl., Oceanport, N.J. 07757. (201) 229-4040. \$14,900.*

With its MOS solid-state memory, the 16-bit Model 80 has an average cycle time of 270 ns. Typical instruction execution times range between 530 and 1010 ns. Each storage unit consists of two 8000-byte memory modules having separate address circuitry but sharing common sense and data lines. This design reduces memory contention and cycle time. All 16-k bytes of memory are directly addressable. Other features include hardware multiply/divide, hardware floating point and list processing. Both the software and the peripheral interfaces are compatible with the other members of Interdata's "New Series" family of processors.

CIRCLE NO. 255

### Device shunts phone calls to another number

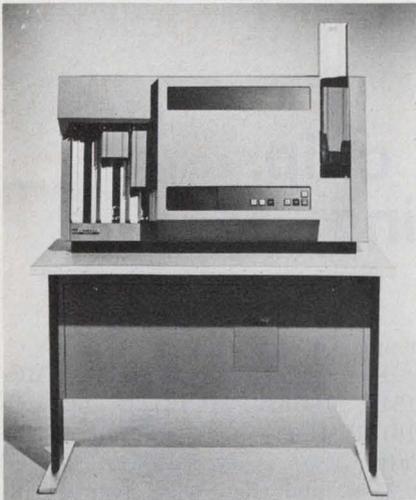


*G-V Controls, 101 Okner Pkwy., Livingston, N.J. 07039. (201) 992-6200. See text; 30 days.*

Designed for installation in a "Central Office" equipment room, the devices will automatically transfer calls from one telephone number to another. Also, no additional amplification will be required to make up for "double-loop" losses incurred by subscriber premise location. Model 907115 is for pulse and Model 907116 for tone signalling. Either unit obviates the "disconnect" problems inherent in other call diverter devices and may be turned on and off from a transfer switch on the subscriber's telephone instrument. Prices range from \$478 for a single unit to \$1675 for a fully equipped shelf of four units.

CIRCLE NO. 256

## Card printer/punch handles 96 columns



Decision Data Computer Corp., 100 Witmer Rd., Horsham, Pa. 19044. (215) 674-3300. \$6900; 4 mos.

Model 9640 is a fully buffered printing punch with an optional card-reading capability. The standard unit features a 2000 card input hopper and three output stackers. It can punch or print 96-column cards at the rate of 120 to 240 cards/min., depending on the number of positions used. At the lowest speed, four rows of 32 positions each can be printed. A stacker overflow condition can be handled automatically or via programming, thereby eliminating the need to halt operations for card unloading. A field installable 1000 cards/min. read-before-punch option is also available. The additional cost is \$850. OEM quantity discounts are available for the Model 940.

CIRCLE NO. 257

## Buffer matches slow devices to fast channel

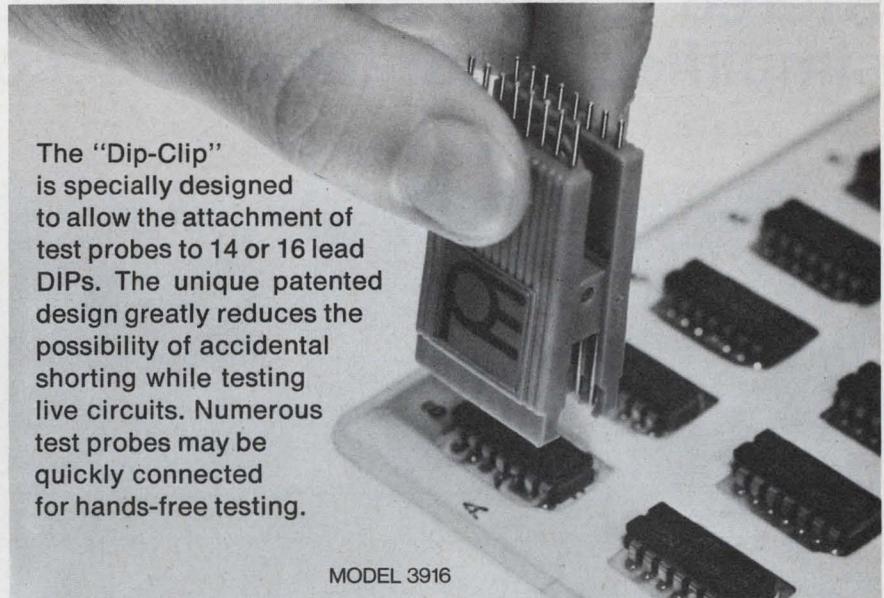
Pulse Communications, Inc., 5714 Columbia Pike, Falls Church, Va. 22041. (703) 820-0652.

Models 7132 are a series of terminal buffers for mating printers such as TTYs with high-speed data links. The buffer units contain 4000-character memories and all the circuits and controls required for editing, automatic transmission, answer-back and control handshaking. Modules are available for memory capacity expansion.

CIRCLE NO. 258

# dip clip

T.M.



The "Dip-Clip" is specially designed to allow the attachment of test probes to 14 or 16 lead DIPs. The unique patented design greatly reduces the possibility of accidental shorting while testing live circuits. Numerous test probes may be quickly connected for hands-free testing.

MODEL 3916



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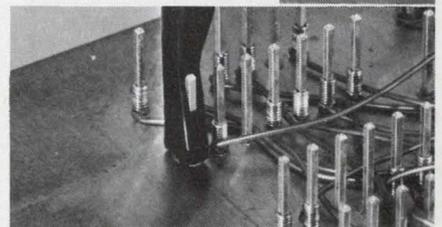
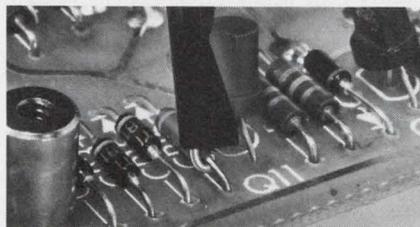
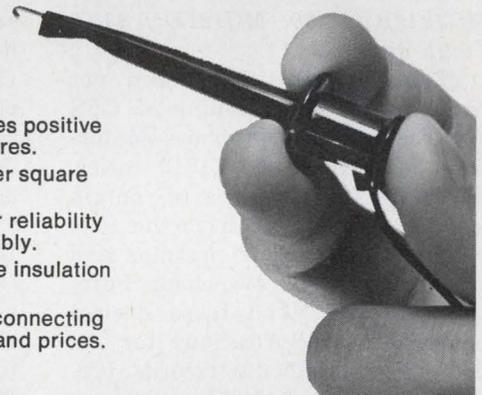
INFORMATION RETRIEVAL NUMBER 55

# the grabber

T.M.

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- Four models offer widest selection of connecting plugs. Write for complete information and prices.



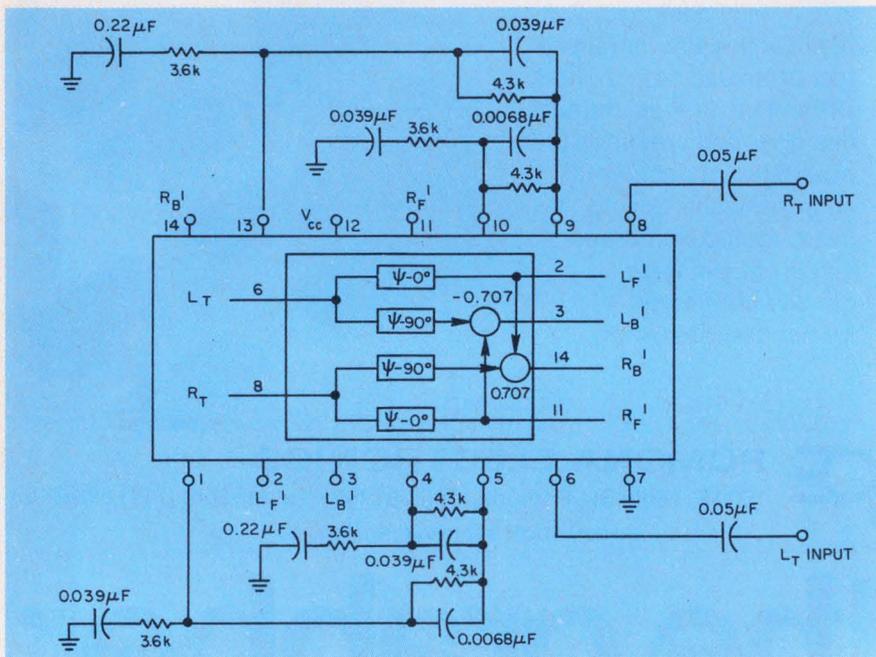
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\*Registered trade-mark of Gardner-Denver Co.

INFORMATION RETRIEVAL NUMBER 56

# Stereo IC with all functions on chip, simplifies quadraphonic decoding



Motorola Semiconductor Products Inc., 5005 E. McDowell Rd., Phoenix, Ariz. 85008. (602) 273-6900. MC1312P: \$2.80; MC1213P: \$3.10 (unit quantity).

Matrix systems have been put on chips for the decoding of CBS SQ four-channel systems—Motorola's MC1312 and MC1313 series. They are the first ICs to contain all the circuitry to drive the four channels, with their preamps and power amps, from two-channel program sources. And these devices conform to specifications for decoding quadraphonic records produced by some of the largest record companies.

Available in 14-pin TO-116 plastic packages, the new ICs consist of two preamps and two all-pass networks of the Wien bridge form. External resistors can be connected between pins 2 and 11 and 3 and 14 to permit blending the four-channel outputs for enhancement of center-front to center-back separation (see diagram).

The quadraphonic signal results from the matrixing of four channels into the two through a special encoder. The two matrixed channels, right total ( $R_T$ ) and left total ( $L_T$ )—obtained after record is played on conventional stereo—are then processed through the decoder and the four original channels are recovered. The circuit consists of two preamps that receive  $L_T$  and  $R_T$  signals. The preamps each feed two all-pass networks to derive two pairs of quadrature signals. The four signals are matrixed to yield left front, left back, right front and right back ( $L_F'$ ,  $L_B'$ ,  $R_F'$  and  $R_B'$ ) output signals.

The resistive arms of the Wien bridge all-pass networks are realized in the IC, but the RC arms are formed by external components. The user can choose values for these components within certain constraints.

With the components shown, bandwidth of 100 Hz to 10 kHz is provided, together with a phase

ripple of  $\pm 8.5\%$ .

Four models are available: MC-1312, MC1313, MC1312P and MC-1313P. Harmonic distortion in the latter two is typically 0.1% and 0.25%, and they have average input impedances of 3 M $\Omega$  and 1.8 M $\Omega$ . Signal-handling capability is at least 2.0 V rms for the MC-1312P and 0.8 V rms for the MC-1313P. The MC1312 is designed for home-entertainment systems and for operation from 0 to 75 C with  $V_{cc} = 20$  V, while the MC-1313 is designed for automotive use at  $V_{cc} = 12$  V and a temperature range of -40 to 85 C.

The only system similar to the CBS SQ is the Electro-Voice EV-4, which uses the EV8-7743 decoder chip. The latter is designed specifically for that system.

CIRCLE NO. 259

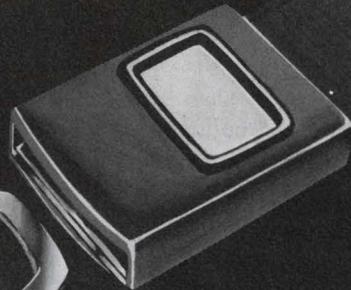
## pROMs assemble programs

Intel Corp., 3065 Bowers Ave., Santa Clara, Calif. 95051. (408) 246-7501. \$364; stock.

A set of pROMs enables an MCS-4 microcomputer prototype to assemble programs for itself. The four pROMs (AO-740, 741, 742 and 743) plug into the prototyping board (S1M4-01 or S1M4-02) and perform all the functions of a Fortran IV assembler, eliminating the need for a general-purpose computer. The pROMs translate symbolic assembly language into bit patterns suitable for entry into the microcomputer's control pROMs. The assembler accepts input source text from a teletypewriter on each of two required passes.

CIRCLE NO. 260

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on our side.**



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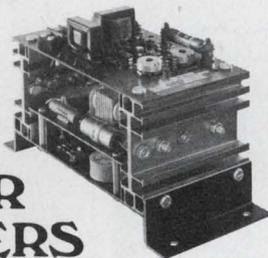
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INFORMATION RETRIEVAL NUMBER 57

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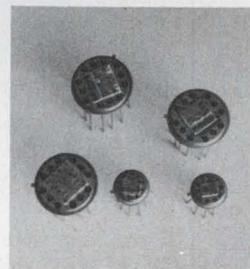
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ELECTRONIC DESIGN 2, January 18, 1973

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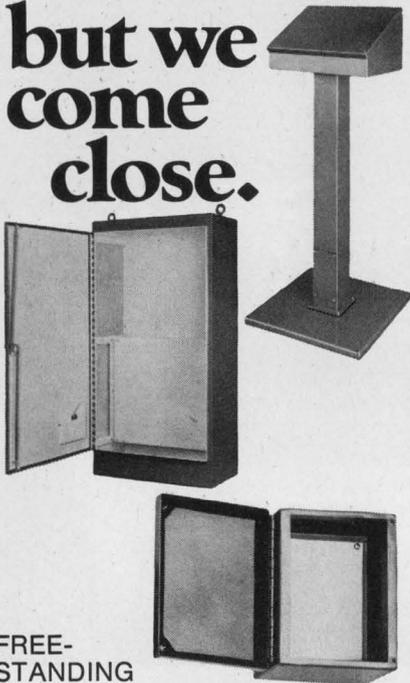
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INFORMATION RETRIEVAL NUMBER 60

ICs & SEMICONDUCTORS

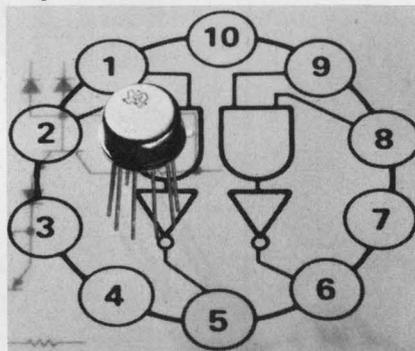
**Op amp upgrades LM118**

Advanced Micro Devices Inc., 901 Thompson Pl., Sunnyvale, Calif. 94086. (408) 732-2400. \$19.95 to \$22.95 (100 up).

The Am118, a high slew rate, internally compensated op amp, offers the highest stability rating in the industry, according to the company. The Am118, which is pin compatible with the like-numbered circuit from National Semiconductor, has a phase margin of 35° and less than 2 dB of peaking at unity closed-loop gain. Other features (all typical) include slew rate of 70 V/μs, input offset voltage of 2 mV, input bias current of 120 nA and offset current of 6 nA. The device has a 15 MHz small signal bandwidth and operates over a ±5 to ±20-V range.

CIRCLE NO. 261

**Dual voltage translator replaces DM7800**

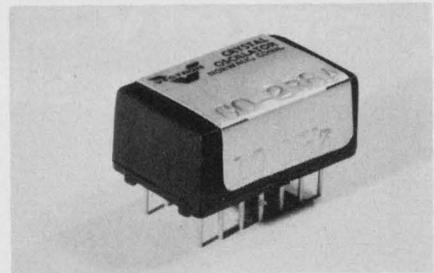


Texas Instruments Inc., P.O. Box 5012, M/S 308, Dallas, Tex. 75222. (214) 238-3741. SN75180: \$2.40 (100 up); stock.

A dual voltage translator, designated the SN55/75180, is a second source IC to the DM7800/DM8800. This device can interface from standard TTL or DTL voltage levels to those levels associated with high impedance junctions or MOSFET-type devices. The SN55 version (for -55 to 125 C temperature applications) replaces the DM7800 while the SN75 version (for industrial temperature range applications) replaces the DM8800.

CIRCLE NO. 262

**Schottky TTL clock comes in DIP**

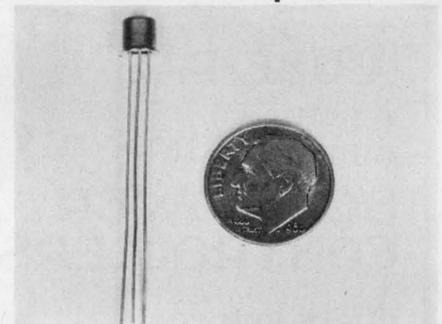


Vectron Laboratories, Inc., 121 Water St., Norwalk, Conn. 06854. (203) 853-4433. 4-6 wks.

The CO-238 crystal oscillator, available in a 14-pin DIP, can drive Schottky TTL circuits at frequencies to 100 MHz. It operates from 5 V dc and drives 10 TTL loads. The standard CO-238 provides stability of ±.0025% over 0-70 C. Options include the MIL range CO-238-2 with stability of ±.005% over the -55 to +125 C and the high stability CO-238-3 with stability of ±.0003% over 0-50 C.

CIRCLE NO. 263

**Radio circuit arrives on a chip**



Ferranti Electric Inc., E. Bethpage Rd., Plainview, N.Y. 11803. (516) 293-8383.

The ZN414, a ten-transistor circuit fabricated with Collector Diffusion Isolation techniques, provides the basis for a complete AM radio circuit. It operates from 1.1 to 1.8 V and requires only battery, earphones and antenna plus a tuning capacitor and two decoupling capacitors to form a radio. Other features include output of typically 30 mV rms, current of 1 mA and harmonic distortion of ≤ 1%. The ZN414 operates over the temperature range of 0 to 70 C and is available in a 3-pin TO-18 package.

CIRCLE NO. 264

## ECL 1024-bit memory uses isoplanar process

Fairchild Camera and Instrument Corp., Semiconductor Components Group, 464 Ellis St., Mountain View, Calif. 94040. (415) 962-3816. \$100 (25-99); 6-8 wks. (large qty.).

An ECL 1024-bit RAM—the industry's first, according to the manufacturer—is fabricated with Fairchild's Isoplanar process. Designated the 95415, it features a 45-ns access time and is packaged in a standard 16-pin ceramic dual-in-line package. It has power dissipation of 0.5 mW/bit and an uncommitted collector output for simple memory expansion.

CIRCLE NO. 265

## Low-cost op amp settles in guaranteed 1 $\mu$ s

Teledyne Philbrick, Allied Dr. at Route 128, Dedham, Mass. 02026. (617) 329-1600. P: See text; stock.

A guaranteed settling time of 1  $\mu$ s to 0.01% at a price of \$7.50 (100 up) are the key features of the Model 1324, a monolithic IC op amp fabricated with standard triple-diffused processing techniques. Other features of the 1324 include excellent bandwidth and slew rate (10 MHz and 35 V/ $\mu$ s, respectively), freedom from latch up and TO-100 packaging with 715-compatible pin-out.

CIRCLE NO. 266

## Silicon-on-sapphire kit for advance designs

Inselek Co., 743 Alexander Rd., Princeton, N.J. 08540. (609) 452-2222. \$1950.

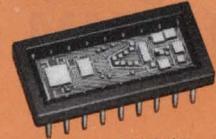
Designers can now build their own integrated circuits using silicon-on-sapphire (SOS) technology with a "do-it-yourself" kit. Called an Instant SOS Kit, the package includes a set of photomasks, instructions and sufficient p-type and n-type SOS wafers for building p-channel, n-channel, deep-depletion and complementary circuits. And these can be built right on present solid-state production lines, according to the manufacturer.

CIRCLE NO. 267

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INFORMATION RETRIEVAL NUMBER 61

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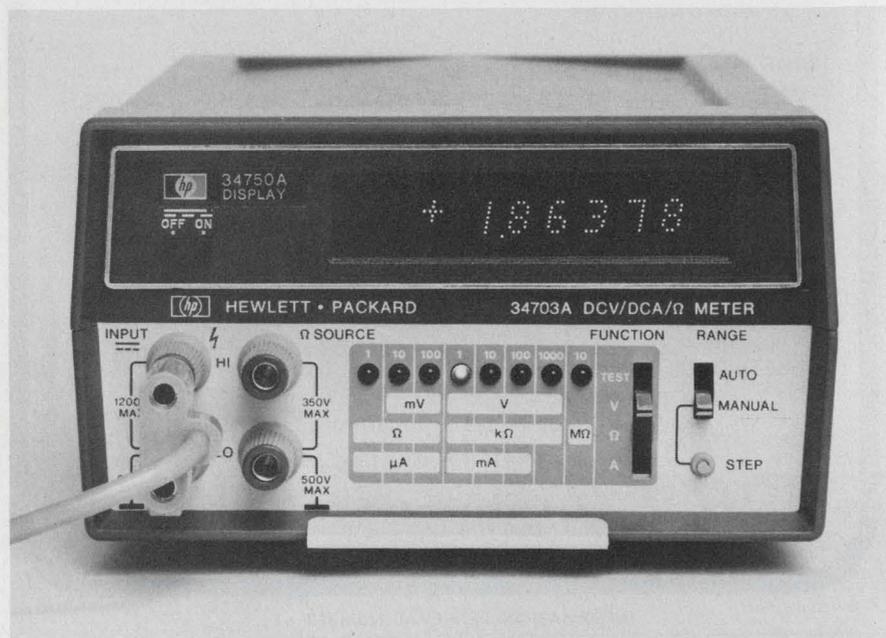


## Vero Electronics Inc.

171 Bridge Road, Hauppauge, N.Y. 11787  
Tel.: 516-234-0400 • TWX510-227-8890

INFORMATION RETRIEVAL NUMBER 62

## Plug-ons extend versatility of DMM measuring system



Hewlett-Packard, 1501 Page Mill Rd., Palo Alto, Calif. 94304. (415) 493-1501. See text; March.

Hewlett-Packard has expanded the capabilities of its snap-on DMM measuring system with three new additions: the 34750A, a 5-1/2-digit mainframe display; the 34703A multifunction module, and the 34722A preamp/ammeter module.

The line now includes six possible instrument combinations, each made up of a top display module and a bottom function module. Any of the six combinations can be converted to portable operation by the addition of a center battery-pack module. Or a BCD output package can be added as a center module to provide printout information.

Except for the additional digit, the 34750A LED display is similar to its 4-1/2-digit predecessor. The second new module—the 34703A multifunction snap-on—can be used with either the 4-1/2 or 5-1/2-digit display, as can its older counterparts, the dc voltmeter and multimeter plug-ons.

The 34703A snap-on measures

resistance (four-wire measurement), dc voltage and dc current. Six voltage ranges from 10 mV to 1000 V are provided, as well as six current ranges from 1  $\mu$ A to 100 mA and eight resistance ranges from 1  $\Omega$  to 10 M $\Omega$ . Full autoranging of the functions is provided, or the user can step through ranges merely by pushing a button. In most cases autoranging is completed within 250  $\mu$ s. And if the user manually selects an improper range, the unit flashes the correct range-annunciator LED.

In addition the 34703A can troubleshoot itself. When the user flips the function switch to the test position, the ROM-based logic controller interrogates its own circuitry for proper operation.

Specifications of the unit include an input resistance of 10 M $\Omega$  on dc volts; 10 k $\Omega$  on the 1- $\mu$ A range, decreasing to 1  $\Omega$  on the 100-mA range; 100% over-range, except for 20% overrange on the 1000-V range; and 120-dB CMR on dc volts. Accuracy holds for 30 days at 23 C and depends on both the range setting and the

particular display used.

Some representative accuracy figures are:  $\pm 0.04\%$  of reading  $\pm 0.01\%$  of range for the 10-V through 1000-V ranges and with a 4-1/2-digit display;  $\pm 0.25\%$  of reading  $\pm 0.025\%$  of range for 10-mA and 100-mA ranges and for the 5-1/2-digit display; and  $\pm 0.04\%$  of reading  $\pm 0.01\%$  of range for 10  $\Omega$  through 1 M $\Omega$  and for the 4-1/2-digit display.

The third new module, the 34722A preamp/ammeter, goes in the center of the assembled instrument, and it can increase the sensitivity of the older voltmeter and multimeter plug-ons and provide current-reading capability. Its preliminary specs include a preamp gain of 10 for ac and dc volts and current ranges (ac and dc) from 100  $\mu$ A to 1 A. The full-scale insertion loss is 100 mV.

The 34750A display and the 34703A V/I/ $\Omega$  meter cost \$550 each, with first deliveries scheduled for March. The 34722A has not been priced yet and will be available at a later date.

CIRCLE NO. 268

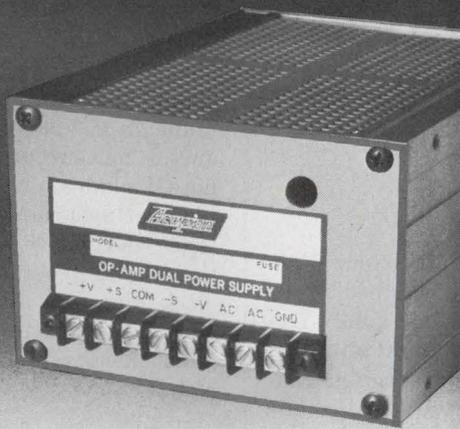
## Spectrum analyzer has variable persistence

Systron Donner Corp., Microwave Div., 14844 Oxnard St., Van Nuys, Calif. 91409. (213) 786-1760. \$2600; 60 days ARO.

A spectrum analyzer mainframe with a variable persistence CRT display is now available from the Microwave Div. of Systron Donner Corp. The S/D Model 711 variable persistence display unit offers a persistence range of 300 ms to 100 s. In addition, the Model 711 can store an image for up to six hours, or be used in a conventional, non-store mode. The unit uses plug-in tuning modules covering the audio, video and baseband frequency ranges.

CIRCLE NO. 269

Best buy  
power  
module  
for  
op amps



$\pm 15$  V (tracking) @ 400 ma...\$85

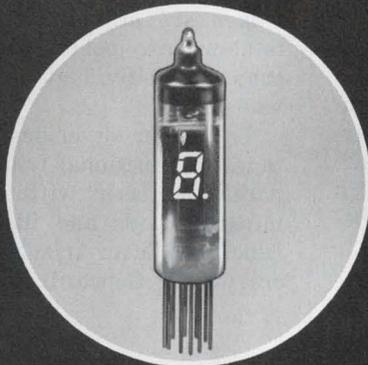
Line/load regulation of  $\pm 0.1\%$  and ripple of 1.5 mv. 3.4" H x 5.1" W x 5.1" D. Order Model TD 15-40. For 1.0 amp outputs, specify TD 15-100. Price \$125. Other great buys are available to power balanced loads drawing from 25 ma to 8.5 amps.

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INFORMATION RETRIEVAL NUMBER 63



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- Segmented Phosphor Display
- Low Cost • Low Power
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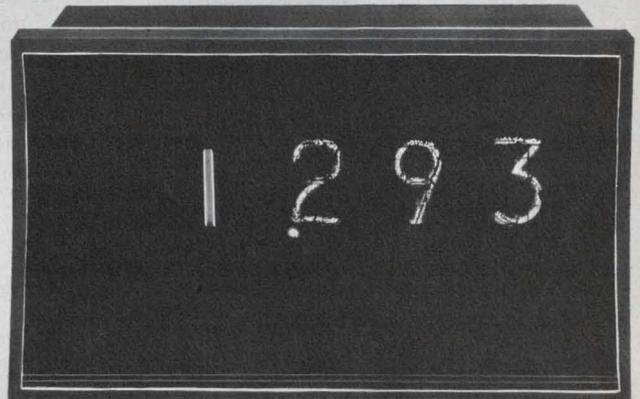
INFORMATION RETRIEVAL NUMBER 64

INFORMATION RETRIEVAL NUMBER 65

# 3½-digit DPMs:



**Ours.**  
**Theirs.**



**When we talk about reliability,  
we put our money where our mouth is.**

**With a full one-year warranty!**

At first glance, our Model 36 looks about the same as most other 3½-digit DPMs (it even fits in the same panel cutout as the AN2532). But that's where the similarity ends:

**RELIABILITY:** In plain language, ours works better and keeps on working longer than theirs. To back up this promise, our Model 36 comes with something you don't get with theirs: a *full service, one year warranty covering parts and labor!*

**PRICE:** Our Model 36 sells for less than \$100 in 100-piece quantities, and gives you a lot more for your money.

**PERFORMANCE:** Ours outperforms theirs. Check our Model 36 specs and features: 0.05% accuracy, 50 ppm/°C stability. 7-segment Sperry non-blinking planar display. Small size, 2.0" H x 3.5" W x 2.8" D. Lower power drain, less than 3.5 watts. Ultra-high input impedance, > 1000 megohms. Standard models include autopolarity, automatic blanking and programmable decimal point at no extra cost.

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INFORMATION RETRIEVAL NUMBER 66

## application notes

### Counter/display

The MK 5002 P MOS four-digit counter decoder is described in an eight-page application note. The note contains information on using the unit, display interfacing, cascading the 5002 (eight-digit application) and annunciator applications. Mostek Corp., Carrollton, Tex.

CIRCLE NO. 270

### Stepping motors

A 60-page Stepping Motor Handbook describes types of stepping motors and their characteristics, drive circuits, use of power amplifiers, heating considerations, operating modes and typical applications. Sigma Instruments Inc., Braintree, Mass.

CIRCLE NO. 271

### Polarimeter, saccharimeter

Technical Bulletin 371 describes the general applications, features, accessories and operating principles of laboratory, precision and high-precision polarimeters and saccharimeters. The generation of a half-shade using polarizing and Lippich prisms is described. Rudolph Research, Fairfield, N.J.

CIRCLE NO. 272

### Lead

"Lead . . . As A Modern Design Material" describes properties, forms and design applications of lead. The uses of lead for soldering and ceramics are also discussed as are lead's lubricating qualities and its solid-state properties. The eight-page booklet includes a listing of the forms in which lead is available. The booklet concludes with a listing of the physical, thermal, low-temperature, electrical and mechanical properties of lead. Lead Industries Association, Inc., New York, N.Y.

CIRCLE NO. 273

### C-V plotting

An illustrated, 10-page technical note, TN-102, discusses the advantages of the lock-in amplifier technique in C-V and related semiconductor measurement analyses. The note includes three sets of curves illustrating typical C-V and capacitance derivative plots made with the lock-in technique and a set of block diagrams illustrating typical measurement setups. Princeton Applied Research Corp., Princeton, N.J.

CIRCLE NO. 274

### CMOS ICs

A six-page brochure describes CMOS integrated circuits in automotive applications. Block diagrams are included. Solid State Scientific, Inc., Montgomeryville, Pa.

CIRCLE NO. 275

### Laser trimming

"Functional Trimming: Discussion of a Problem, Description of a Solution" by Danial Abenaim details the laser's contribution to the coming-of-age of functional trimming, wherein circuit-component values are adjusted for optimum total-circuit performance rather than to individual prescribed values.

The paper describes the advantages of functional trimming, compares the laser with other trimming methods and illustrates one functional laser trim system. General Radio, Concord, Mass.

CIRCLE NO. 276

### IR optical materials

"Kodak IRTRAN Infrared Optical Materials," a 52-page book, describes the selection, application and production of these materials. It also explains uses at discrete wavelengths in the infrared portion of the spectrum. In addition to photographs, diagrams and tables, the book also contains a comprehensive section of transmittance curves, a bibliography and a computation worksheet. Eastman Kodak Co., Kodak Apparatus Div., Rochester, N.Y.

CIRCLE NO. 277

# evaluation samples

## Solderless wrap terminals

Nurl-Loc Wire-Wrap Terminals, used in packaging panels for integrated circuits, feature a knurled cylinder which permits material flow for a better bond, increasing torque resistance and preventing twisting during the wrapping operation. Electronic Molding Corp.

CIRCLE NO. 278

## Terminal clamps

A tipping-type terminal clamp consists of only two pieces—the screw and a coined clamp plate—and provides virtually identical load on two different size wires. Called Teeter Terminal, it comes in the following sizes: 4-40 × 9/32-in., 6-32 × 5/16-in. and 10-32 × 3/8-in. A fourth size will be added soon. Elco Industries, Inc.

CIRCLE NO. 279

## Solder pads

Tin-plated and flux-coated donut pads offer solderability for PC board construction or repair applications. The pads are etched copper on 2.5-mil epoxy glass film backed with a pressure sensitive adhesive and quickly laminate to any circuit board. They are available in five sizes from 0.062 × 0.025 in. up to 0.250 × 0.040 in. and each size is packaged in precisely spaced multiple rows. Circuit-Stik.

CIRCLE NO. 280

## Test panel

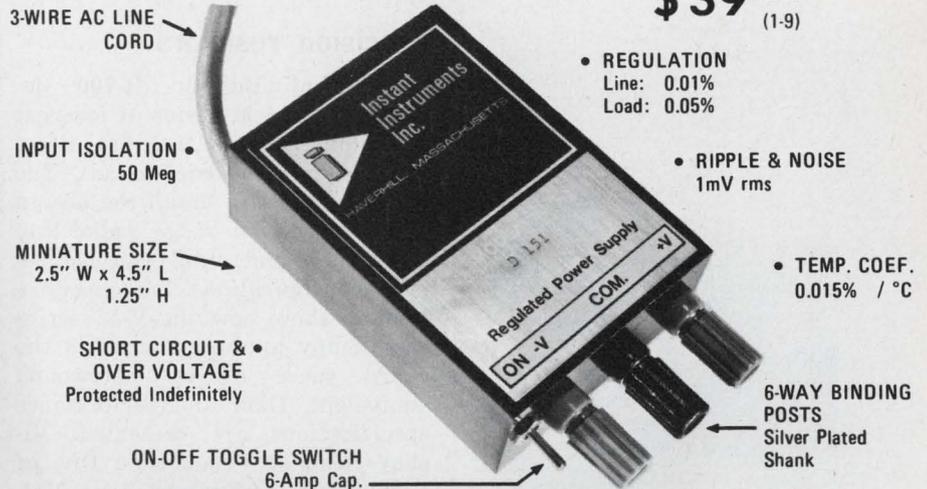
Mounted in a test panel are samples of nylon Heyco hole plugs, snap bushings, universal bushings, strain relief bushings, miniature bushings, open/closed bushings, terminal bushings and snub bushings. Data relative to sizes available and typical applications are included. Heyman Manufacturing Co.

CIRCLE NO. 281

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6-Amp Cap.

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MODEL	VOLTAGE	CURRENT	PRICE
M55	5.0	500 mA	\$ 49
M510	5.0	1000 mA	\$ 69

DUAL OUTPUT			
MODEL	VOLTAGE	CURRENT	PRICE
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D151	± 15.0	100mA	\$ 49
D152	± 15.0	200mA	\$ 69



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INFORMATION RETRIEVAL NUMBER 67

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INFORMATION RETRIEVAL NUMBER 69

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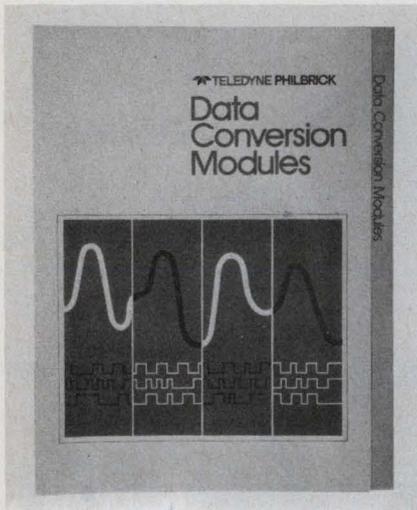
Suggested minimum retention periods and when to destroy important papers

the **SHREDMASTER** CORPORATION

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INFORMATION RETRIEVAL NUMBER 68

## new literature



### Data conversion

A fold-out data-conversion short-form catalog features a line of data converters. Analog-to-digital and digital-to-analog converter specifications are arranged for quick selection by key parameters. Also included in the two-color brochure are accessory modules. Teledyne Philbrick, Dedham, Mass.

CIRCLE NO. 320

### Status indicator

LED and resistor construction have been integrated in a solid state status indicator which is described in a data sheet. The indicator is designed in a mini-DIP size flat pack for PC board mounting and is compatible with DTL or TTL logic. Eldema Div., Genisico Technology Corp., Compton, Calif.

CIRCLE NO. 321

### Instrument rentals

A catalog features an expanded line of instruments offered on a rental basis from General Electric. The catalog lists the nationwide network of rental agencies and inventory centers. Related services performed include measurement consulting services, environmental quality testing and instrument repair and calibration. GE, Schenectady, N.Y.

CIRCLE NO. 322

### Precision resistors

Technical Bulletin R-700 describes V and M series of low-cost precision resistors that are direct replacements for wirewounds. The bulletin shows in detail the design and construction of the radial lead (V series) and axial lead (M series) configurations. Drawings are used to show how the V-53 series can occupy approximately 1/8 the board space of its wirewound equivalent. Data and performance specifications are presented. Vishay Resistor Products, a Div. of Vishay Intertechnology, Inc., Malvern, Pa.

CIRCLE NO. 323

### Push-button switches

A full-color, 12-page catalog with an accompanying color-coordinating kit describes and illustrates push-button rotary switches. The switches come in green, red, yellow, blue, white and grey. Janco Corp., Burbank, Calif.

CIRCLE NO. 324

### Impulse generators

Two data sheets describe three impulse generators. Singer Instrumentation, Los Angeles, Calif.

CIRCLE NO. 325

### Component recorders

The Flying Spot component recorders, for producing pattern, plot or picture records, are described in a 16-page catalog. The catalog contains specification information. Featured applications contained include frequency-spectrum analysis. Recordings of "whistlers" i.e. low radio-frequency emanations from lighting and other electromagnetic phenomena of interest in communications studies are clearly illustrated along with recordings of ionospheric back scatter made during long range communications studies by radar in real time. Alden Electronic & Impulse Recording Equipment Co., Inc., Westboro, Mass.

CIRCLE NO. 326

### Modular terminal blocks

A complete line of modular terminal blocks, terminal strips and specialty items is described in a 12-page, quick-reference catalog. Drawings and photos illustrate the features and design of these products. Product categories are: control and power circuit terminal blocks, high-capacity terminal blocks; test terminals; fuse terminals; compensating terminals; slide-on connection terminals; ground terminals; micro terminals and a complete line of terminal strips. Applications, material specifications, ratings, accommodating wire sizes, mounting dimensions and physical dimensions are also included. Electrovert Inc., Mount Vernon, N.Y.

CIRCLE NO. 327

### Precision decade capacitor

An engineering bulletin features a precision decade capacitor. Sprague Electric Co., N. Adams, Mass.

CIRCLE NO. 328

### Line printer

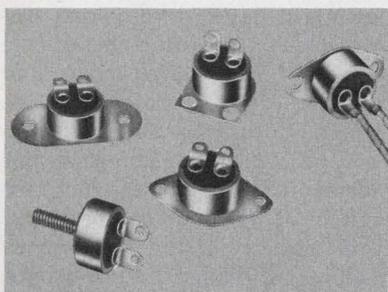
Features of the Model 200 line printer are described in a six-page brochure. Included are detailed specifications on font sets and codes; the use of the multifont buffer and font belt to provide increased speed, interface information and forms handling capabilities. Iomec, Inc., Digitronics Div., Southboro, Mass.

CIRCLE NO. 329

### Vacuum equipment

A catalog of vacuum equipment includes data sheets and prices on all current products. The catalog presents vacuum pumps, hardware, systems and accessories. In convenient loose-leaf form, the catalog documents equipment for high vacuum and ultra-high vacuum work. Other products described are processing equipment for semiconductor manufacturers, evaporation and sputtering equipment, leak detectors, gas analyzers, Marshall furnaces and surface analysis instruments as well as vacuum flanges, valves and gauges. Varian Vacuum Div., Palo Alto, Calif.

CIRCLE NO. 330



Prototypes of precision snap-action thermostats from Elmwood, widely specified for quick, reliable response; proven industrial and military performance record. Environ. expos. -65° to 550°F; narrow or wide diff.; rated to 15 amps. Wide choice of brackets, terminals. Elmwood Sensors, Inc. (401) 781-6500. TWX 710-381-6413.

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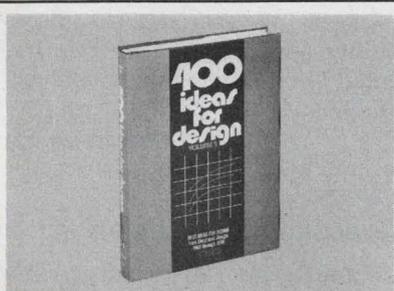
Dietzgen's new 12-digit electronic slide rule does even more than your slide rule. All trig. and exponential functions—including hyperbolics and natural log—with a single function key. Converts degrees, minutes, seconds to decimal; degrees to radians or vice versa. Dietzgen Corp., 2425 N. Sheffield, Chicago, 60614. (312) 549-3300.

INFORMATION RETRIEVAL NUMBER 185



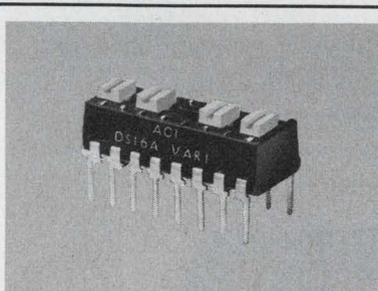
Thin-Trim® variable capacitors are designed to replace fixed tuning techniques. Applications include crystal oscillators, CATV amplifiers, communication and test equipment. Series 9410 has high Q's with five capacitance ranges from 1.0 - 4.5 pf to 10.0 - 50.0 pf. Johanson Manufacturing Corporation, Boonton, N. J. (201) 334-2676

INFORMATION RETRIEVAL NUMBER 183



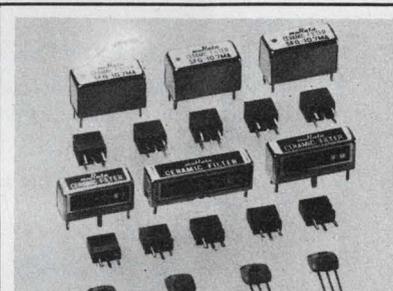
400 Ideas for Design, Vol. 2, Edited by Frank Egan. Ready to borrow, modify, or adapt, the top recent contributions to Electronic Design's popular "Ideas for Design" column range from amplifiers to switching circuits. 288 pp., illus., cloth, \$11.95. Circle below for 15-day examination copies. Hayden Book Co., New York, N.Y. 10011.

INFORMATION RETRIEVAL NUMBER 186



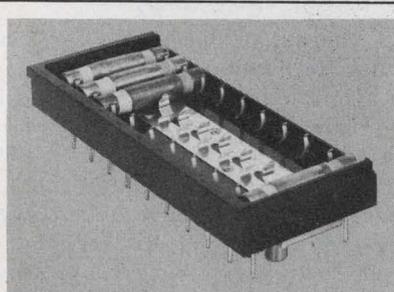
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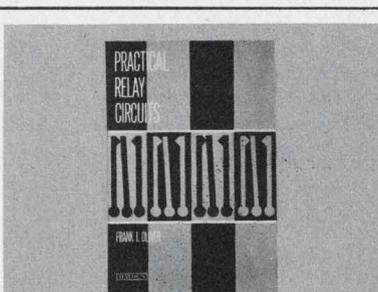
Murata ceramic filters provide solid state reliability for AM, FM, TV and com. receiver IF strips. 455 KHz, 10.7 MHz and 4.5 MHz filters including ladder types are offered. Narrow and "flat top" bandwidths allow maximum design versatility. Most types shipped from stock. Murata, 2 Westchester Plaza, Elmsford, N.Y. 10523. (914) 592-9180.

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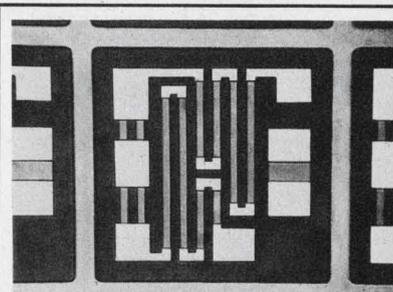
TII-700 series multiple pair arrester assemblies — available up to 30 arresters in wire-wrap pin, coated for solder, high density package. For use in signaling, data processing, carrier and security equipment. Telecommunications Industries Inc., Copiague, N.Y. (516) 842-5000.

INFORMATION RETRIEVAL NUMBER 181



Practical Relay Circuits, by Frank J. Oliver. Time-saving guide classifies relays by function, presenting a rapid overview of the circuits that can solve the problem at hand. 384 pp., illus., cloth, \$14.95. Circle below for 15-day examination copies. Hayden Book Co., New York, N.Y. 10011.

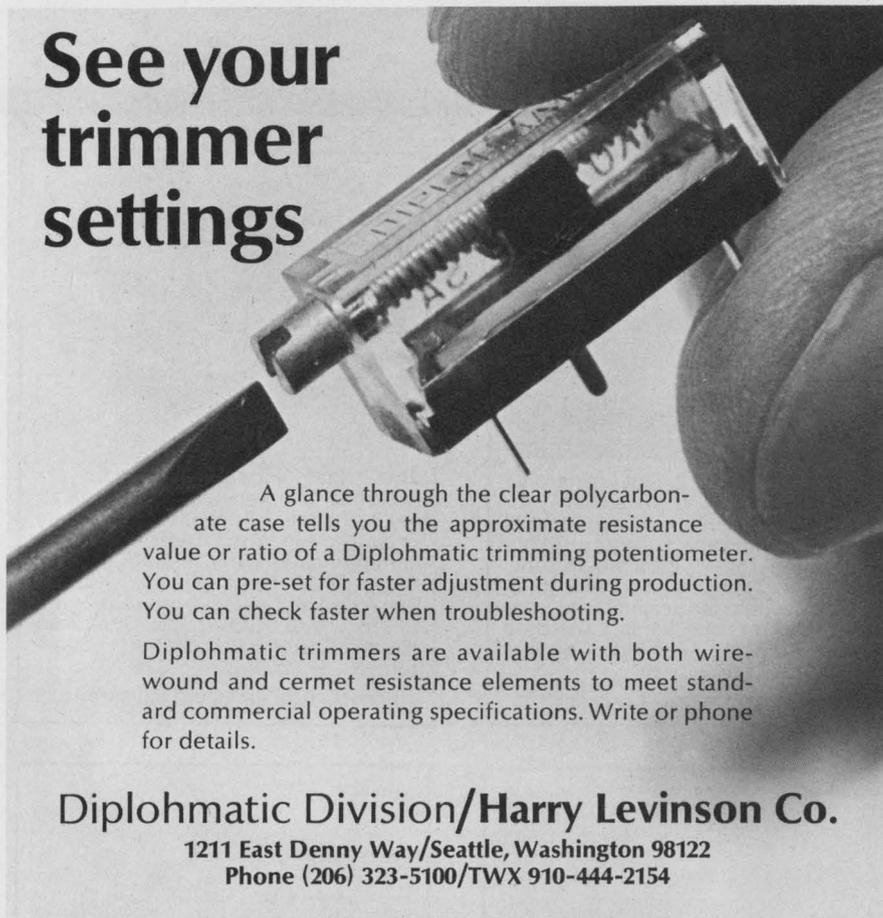
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INFORMATION RETRIEVAL NUMBER 189

# See your trimmer settings



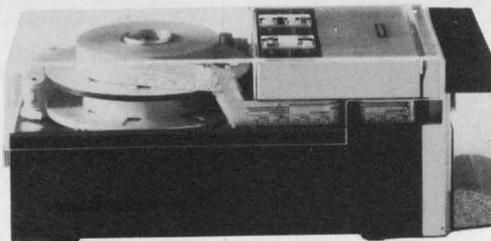
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INFORMATION RETRIEVAL NUMBER 71

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CIRCLE NO. 331

### Stereoscopic television

A four-page illustrated technical paper surveys various three-dimensional television systems and describes the company's system which optically converts normally flat closed-circuit television to 3D. Stereotronics Television Co., Sherman Oaks, Calif.

CIRCLE NO. 332

### Terminal specifying aid

A Terminal Specifying Aid, a four-page brochure, is designed as an aid in determining the physical and functional characteristics for the company's tailor-made CRT terminals. Approximately 200 characteristics are listed under the headings of general, display, character codes, cursor, keyboard layout, editing functions, tabulator format, communications functions and peripherals. The aid includes diagrams of three sample keyboard layouts plus a blank master diagram for the customer to use in specifying his requirements. SYS Computer Corp., Hackensack, N.J.

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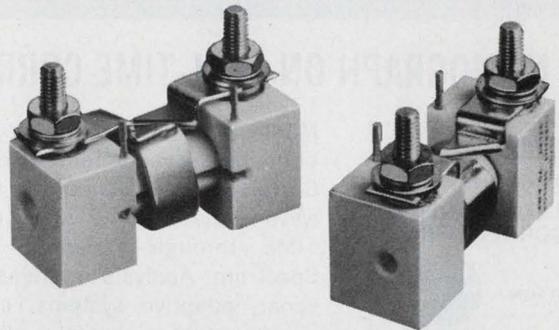
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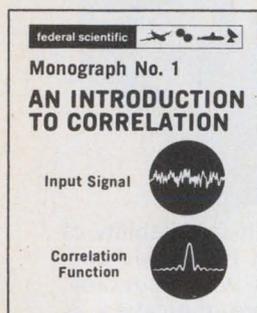
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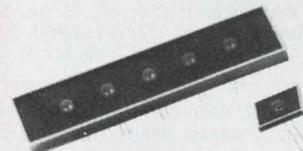
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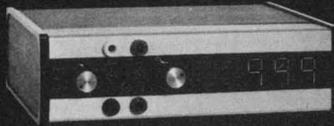
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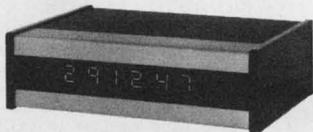


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Complete information and rules appeared in the Jan. 4 issue. Dig out your Jan. 4 copy and enter the contest now. (If the entry cards are all torn out, you can use the form that is printed below.) Entries must be postmarked before midnight, February 15.

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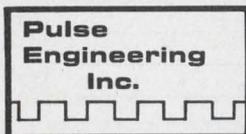
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**Information Retrieval Service.** New Products, Evaluation Samples (ES), Design Aids (DA), Application Notes (AN), and New Literature (NL) in this issue are listed here with page and Information Retrieval numbers. Reader requests will be promptly processed by computer and mailed to the manufacturer within three days.

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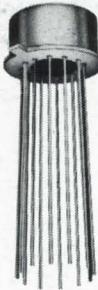
Actually, it may turn your system off. Or turn it on. Because the new CA3094 linear amplifier is also a very effective Power Switch that can operate off a single power supply. That's right!...a programmable Power Switch/Amplifier all in one TO-5 package. And this makes it one of the most flexible devices available to you today.

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CA3094T	24V	100dB typ.	±12	300 ma	100 ma
CA3094AT	36V	100dB typ.	±18	300 ma	100 ma
CA3094BT	44V	100dB typ.	±22	300 ma	100 ma

\*These three types are also available in formed-lead TO-5 for dual-in-line socket configuration, as CA3094S, CA3094AS, and CA3094BS.

Interested? Let us send you a Data Sheet and Application Note (ICAN-6048). Write: RCA Solid State, Section, 57A-18 Box 3200 Somerville, N.J. Phone: (201) 722-3200

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