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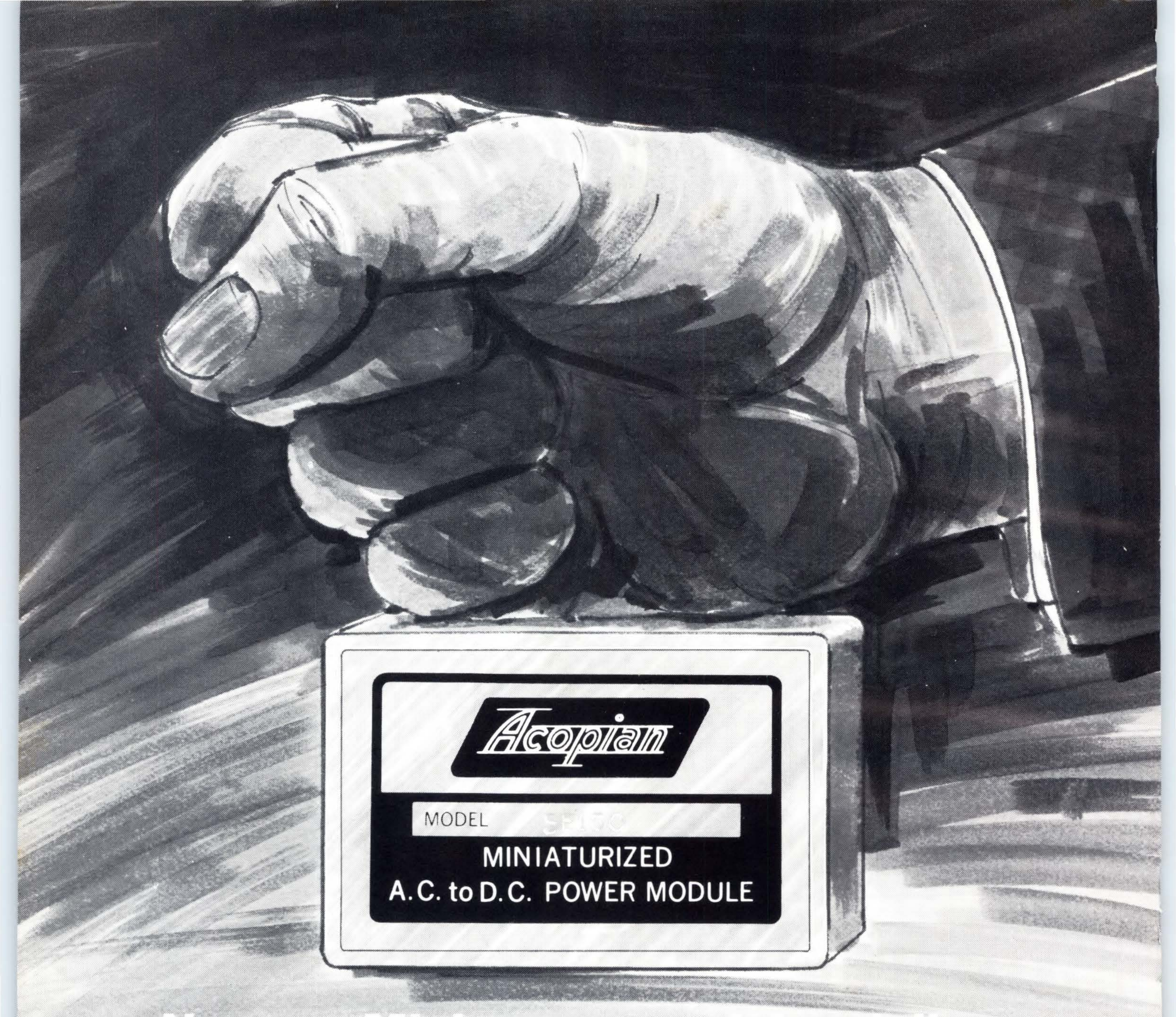
A CAHNERS PUBLICATION

NOVEMBER 1, 1972



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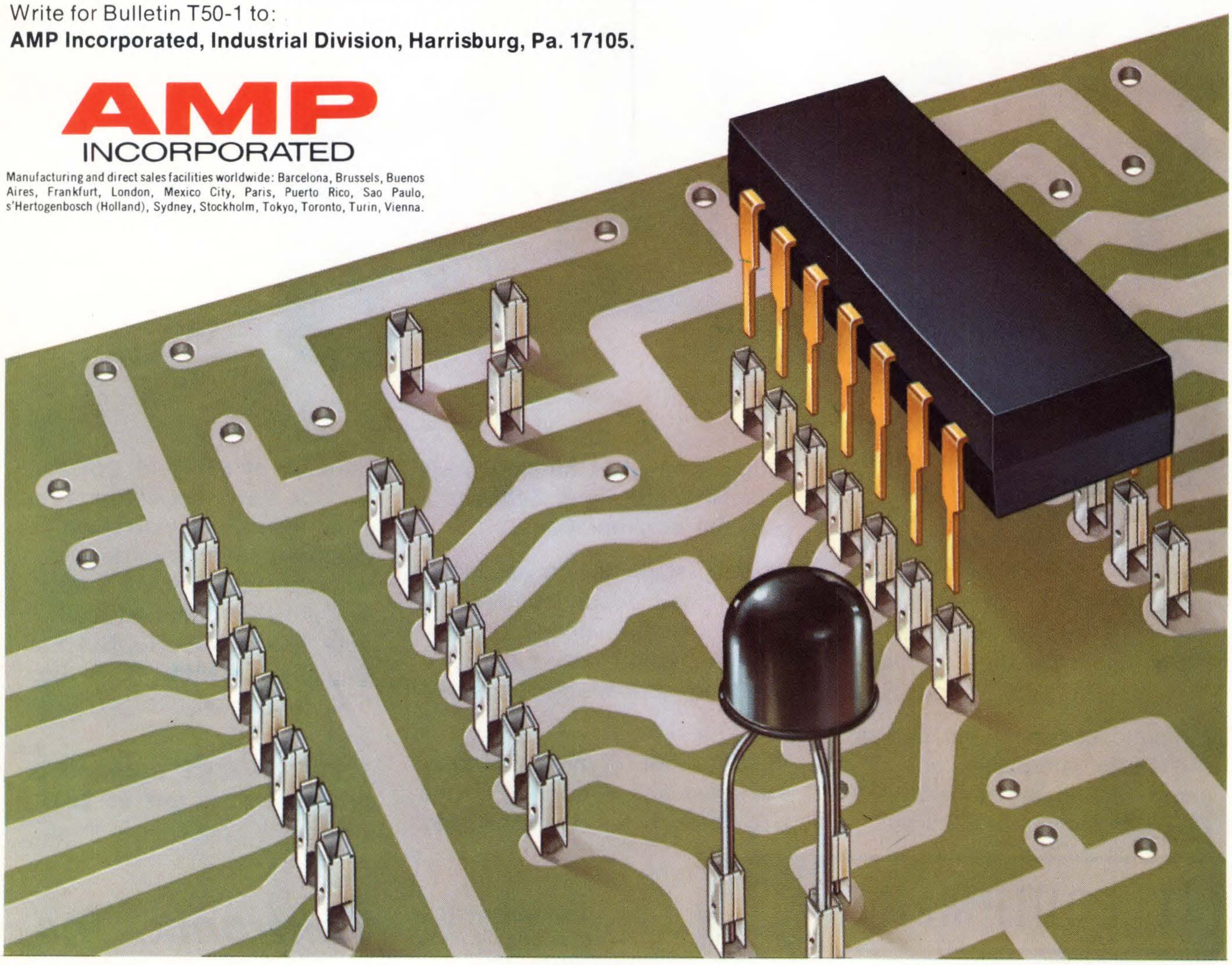

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CORNING
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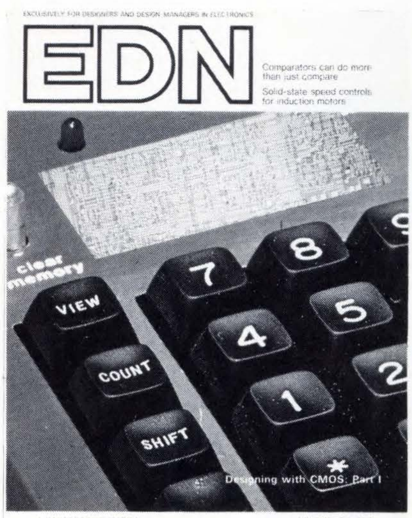
CHECK NO. 7

NOVEMBER 1, 1972
VOLUME 17, NUMBER 21

EDN with EEE

EXCLUSIVELY FOR DESIGNERS AND DESIGN MANAGERS IN ELECTRONICS



COVER

Devices like this 4-bit arithmetic array of RCA and applications like the Data Recorder of Monarch Marking Systems are part of the burgeoning world of CMOS. A 6-part series on designing with CMOS starts on pg. 20.

 Norman L. Cahners; Chairman of the Board; Saul Goldweitz, President; H. V. Drumm, Executive Vice President/Magazines; Ned Johnson, Senior Vice President/Magazines. EDN (formerly Electrical Design News) is published semi-monthly. Editorial, Advertising offices, 221 Columbus Ave., Boston, Mass. 02116 (617) 536-7780. Subscription offices, 270 St. Paul St., Denver, Colo. 80206 (303) 388-4511. Printed at 85 W. Harrison St., Chicago, Ill. 60605. Controlled circulation postage paid at Chicago, Ill. Send form 3579 to Subscription office. EDN is circulated to electronic design engineers and engineering managers in electronic OEM industries. Plants having more than twenty employees and manufacturing electronically operated or controlled equipment of their own design are considered part of this industry. Engineers in such plants responsible for specification of components, materials and test equipment for electronic application may receive EDN without charge. Completed qualification form and company letterhead required. Subscriptions to others in continental United States, $2 per copy. $20 per year. Send requests for qualification forms and changes of address to subscription office in Denver, Colo.

CHECK NO. 9

Do you know enough about CMOS?

If your memory is good and if you were at the Wescon show in 1966, you'll remember that, there in Los Angeles, off-the-shelf CMOS devices were announced and shown for the very first time. In spite of the fact that we, as well as other magazines, reported on the introduction, the impact of the announcement on designers was something less than world-shaking. This was not too surprising, inasmuch as TTL was then just beginning to come into its own, and because the first CMOS circuits and those that followed were rather specialized devices with no second sources available.

What a difference from today. Now, with the makers of electronic equipment and devices looking to penetrate ever deeper into the commercial and consumer fields, interest in CMOS is sky-rocketing. Its inherent characteristics, such as low power requirements and immunity to large supply voltage swings, has forced designers to sit up and take notice—and their enthusiasm is fueled by the many devices available and the numerous companies in the field.

For these and other similar reasons, EDN has prepared a six-part series on "Designing with CMOS." The purpose of the series is to increase the individual designer's appreciation and understanding of this emerging technology as well as his ability to design effectively with it. In effect, the series is an elementary-to-intermediate course on CMOS, which will prepare readers for the wealth of more detailed and advanced literature now being made available.

By publishing the series, we hope to accomplish a number of things. First, of course, is to make designers aware of CMOS and its advantages so that they will consider it when faced with the problem of choosing a logic family.

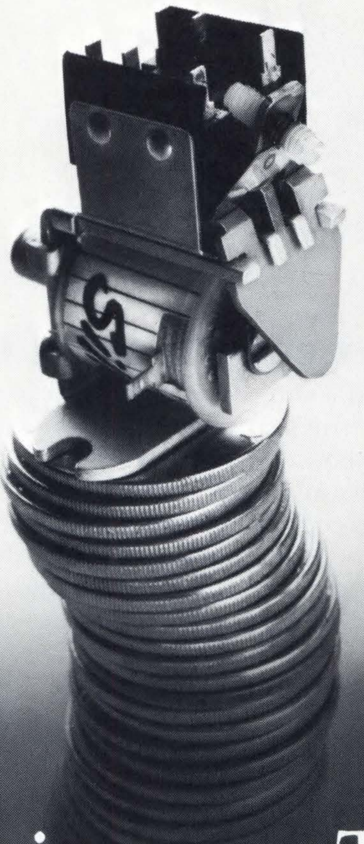
Second, and equally important, by pointing out the limitations and disadvantages of CMOS, the series will prevent designers from trying to apply it, just because it's new, in applications where it doesn't fit.

And third, the series will describe the design rules, considerations and techniques inherent in the CMOS world, with emphasis being given to how they differ from TTL practices. This should help designers avoid the traps and pitfalls that always await them when designing with a new technology.

The first part of the CMOS series begins on page 20. Successive parts will be published on the 1st of each month.

Frank Egan

Editor



STAFF

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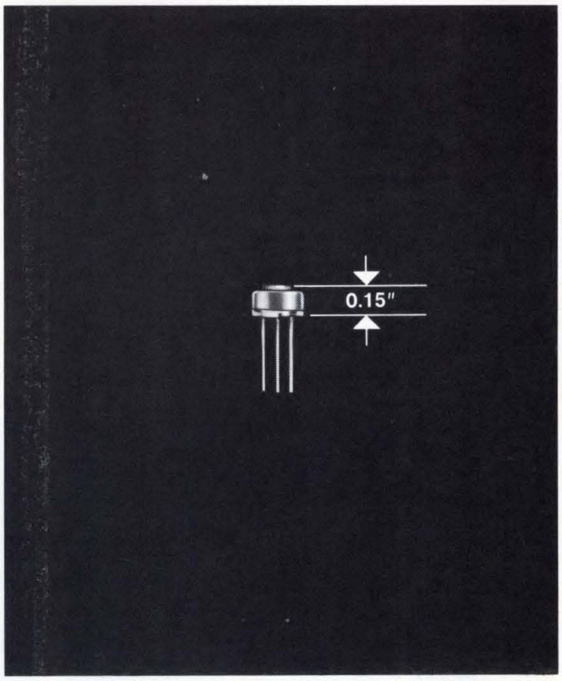

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Harris

Here are the first eight of our new growing DI/CMOS family— the fastest low-power devices of their kind available today.

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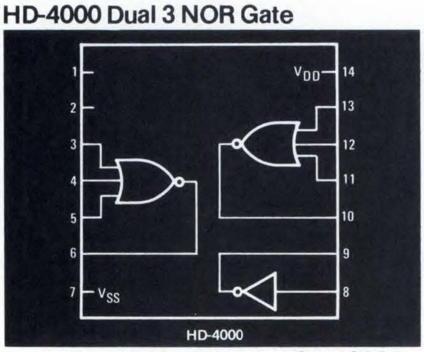
All of the new devices are available in 14-pin dual in-line packages except the HD-4009 and HD-4010, which come in 16-pin packages. Because of their compatible pin-out configurations these circuits will replace or interface with the CD 4000A series. For details see your Harris distributor or representative.

1

HD-4000 Dual 3 NOR Gate



Pin for pin compatible with CD 4000A.

High speed **10ns**
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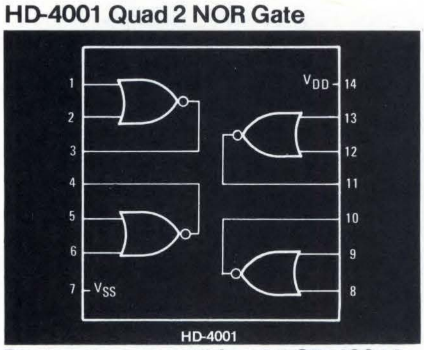
2

HD-4001 Quad 2 NOR Gate



Pin for pin compatible with CD 4001A.

High speed **10ns**
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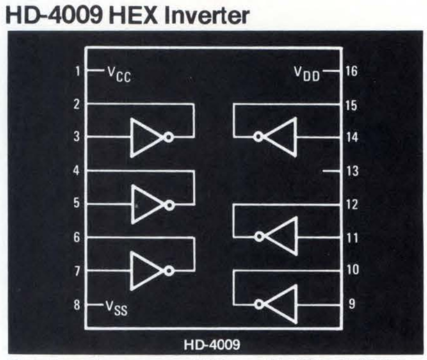
3

HD-4009 HEX Inverter



Pin for pin compatible with CD 4009A.

High speed **10ns**
Low power **50nW**

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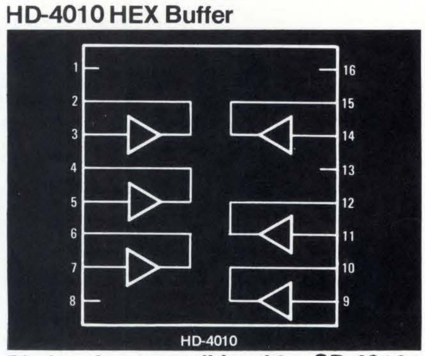
4

HD-4010 HEX Buffer



Pin for pin compatible with CD 4010A.

High speed **10ns**
Low power **50nW**

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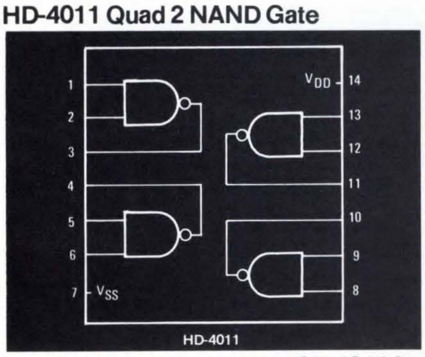
CMOS:

5

HD-4011 Quad 2 NAND Gate



Pin for pin compatible with CD 4011A.

High speed **10ns**
Low power **1nW**

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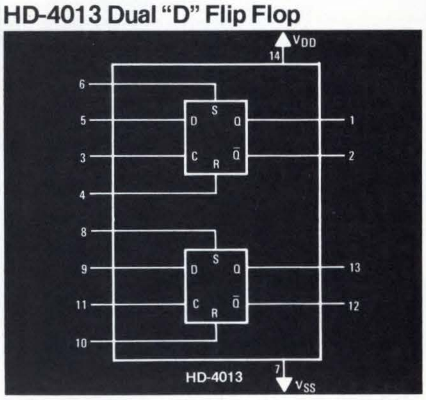
7

HD-4013 Dual "D" Flip Flop



Pin for pin compatible with CD 4013A.

High speed 18MHz typical toggle rate
Low power **50nW**

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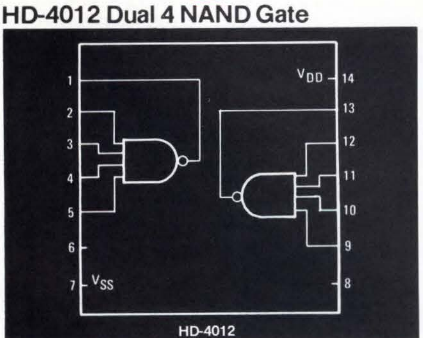
6

HD-4012 Dual 4 NAND Gate



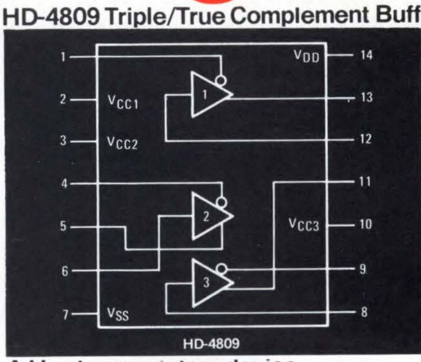
Pin for pin compatible with CD 4012A.

High speed **10ns**
Low power **1nW**

	100-999 units
−40°C to +85°C	**$1.00**
−55°C to +125°C	**$3.45**

8

HD-4809 Triple/True Complement Buffer



A Harris proprietary device.

High speed **10ns**
Low power **50nW**

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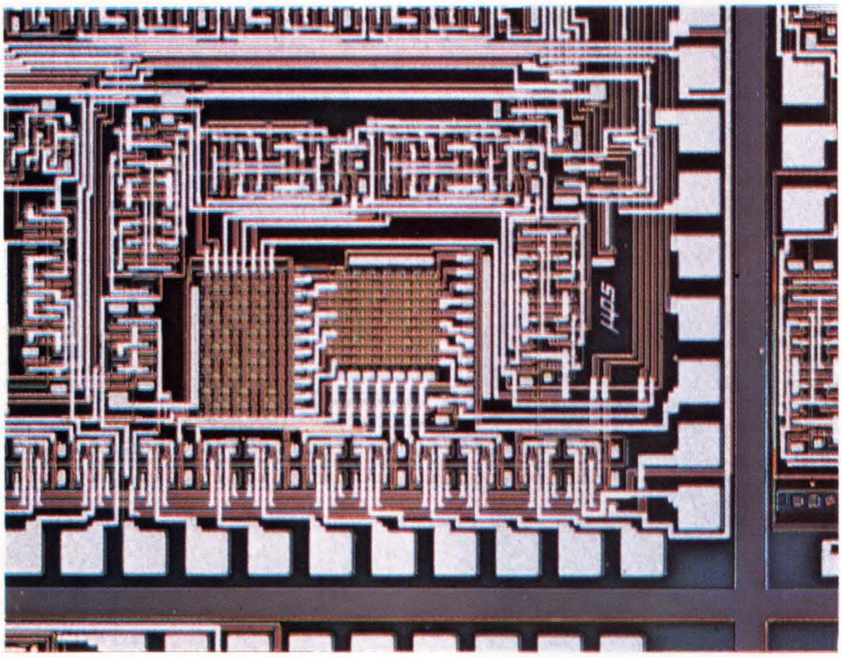
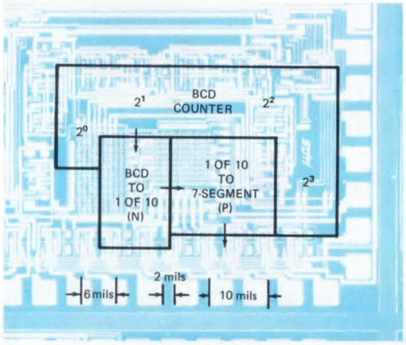
Two-layer metalization yields advantages in CMOS LSI





The decade counter and 7-segment display decoder measures 39 × 30 mils. and is part of a 130- × 130-mil. LSI circuit. The decode logic (17 × 30 mils.) appears as two complementary N- and P-channel matrices. The same decoder designed with conventional CMOS processing would be three or four times larger. While the top layer of metal appears as white traces, the bottom layer shows as purple traces.

Polycrystalline silicon-gate technology has been successfully used in N-channel and P-channel MOS integrated circuits for some time. The capability of two layers of interconnection has been a major advantage of silicon gate to N devices and P devices. However, only recently have manufacturers of CMOS taken steps to adopt silicon-gate technology. Most CMOS parts produced to date have a single layer of interconnecting aluminum.

Micro Power Systems, Inc., of Santa Clara, Calif., is one of the first to employ two-layer metalization for CMOS production. According to John Hall, President of Micro Power, CMOS circuit densities can now be improved by 30% to 40% over conventional one-layer CMOS. This brings the geometries of CMOS circuits down to about the size of P-channel MOS circuits.

The use of two-layer interconnect in CMOS designs is now being evaluated by several IC manufacturers; however, most silicon-gate CMOS has not yet left the laboratory due to poor yields and high production costs.

Micro Power reports good yields and cost advantages using their high-density CMOS in custom LSI production. They decline to give the details of their processing, except to say that it is "similar to silicon-gate."

The use of two metalization layers can substantially reduce the size of CMOS circuit layouts. The greatest advantages come in higher overall interconnection density on the chip and the capability to use matrices to implement random logic arrays.

The advantages in interconnection using two layers of metal are analogous to the density improvements obtainable on pc boards using double sided instead of single sided boards. As an example, Micro Power produces a D-type flip-flop in 8 × 17 mils. (136 sq mils.). Using conventional single-layer metalization techniques, a D-type flip-flop is typically 12 × 20 mils. (240 sq mils.). A four flip-flop decade counter employed in one of Micro Power's custom ICs (see figure) uses only about 430 sq mils. of chip space. The same counter in a one-layer metalization device would need about 760 sq mils. of chip space.

Hall also points out that the reduction of node capacitance using two layers of metal interconnect improves the speed of the device. The speed-power product is reduced about 20%, according to Hall, due to reduction of capacitances associated with smaller geometries.

Another major advantage in density improvement is the capability to do random logic with matrix pairs. The circuit in the figure is a 4-bit decade counter with its 7-segment display decoder. The matrix technique used in the decoder is applicable to any random logic design (any array of gates that serves the function of a read-only memory). The random logic layout is done in a manner similar to matrix layout of a mask programmed ROM. Conventionally, this decoder would be designed with 22 or 27 individual gate structures, interconnected appropriately to generate the 7-segment decode. That approach requires much more chip area than the matrix design possible with two layers of metalization.

The processes used in producing the high-density CMOS (designated HD/CMOS by Micro Power) are for the most part taken from well-known and proven technologies. The breakthrough in density has been achieved by applying these concepts and technologies to CMOS. Two-layer metalization in CMOS is very similar to silicon gate technology used in P-channel devices. The concept applied to CMOS reduces the circuit geometry to dimensions comparable to those of single-channel silicon-gate circuits.

The impact of two metal layers in CMOS is cost reduction, which may enable CMOS to take a substantial portion of the N-channel and P-channel markets. More cost effective now with high-density CMOS are LSI devices for modems, calculators, portable test equipment and watches.

The metalization used by Micro Power is similar to polycrystalline silicon. Thus, the problems associated with oxide formation and step coverage using aluminum are avoided.

Two layers of dielectric are used between the metalization layers. This prevents pin-hole defects, which normally occur in a single layer of dielectric, from impairing yield and reliability. The devices are fully silicon-nitride passivated and finally glass passivated. According to Micro Power, the best known reliability has been directly designed into the new high-density CMOS. □

At the 1st European Electro-Optics Markets and Technology Conference and Exhibition

Geneva, Switzerland: The applications and technology of electro-optics systems and components were discussed today at the first European Electro-Optics Markets and Technology Conference and Exhibition here. Some 500 attendees and 3000 visitors representing over 16 European nations heard three of the latest electro-optical advances, which included the use of a new IR diode for direct control of exhaust emission, a flat-screen display for use as a computer-output terminal and ultimately for use in TV sets, and developments in low-loss fiber optics for laser communication systems.

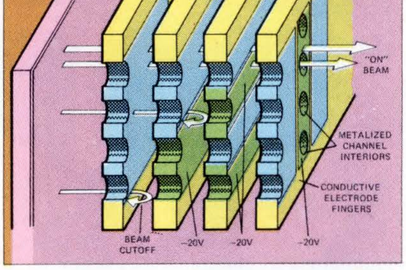


Fig. 1—A new flat-screen display uses a succession of switching plates, each with a matrix of fine holes that permit electron passage from source to phosphor screen. The 512-character display can also produce a gray scale and has a resolution of 40 line/in., with 80-line/in. resolution under evaluation.

Exhaust emission control

An inexpensive way to directly control exhaust emission using a single IR diode source was described by Dr. Egon Loebner of Hewlett-Packard's Research Laboratories.

Composed of an alloy mixture of indium arsenide and indium antimonide, the diode emits energy in the 3-to-6μm band. This band is all important in pollution measurement, according to Dr. Loebner, because carbon monoxide, hydrocarbons, carbon dioxide, water and many nitrous compounds all strongly absorb radiation within this region, transforming radiant energy into molecular vibrational and rotational energy, thus yielding a distinct absorption spectra which clearly indicates the presence and concentration of pollutants.

As a result, the diode can be utilized as a cheap and rugged source of infrared radiation for use in exhaust-emission controllers or "combustionstats". Equally important, it could be used in portable pollution monitors instead of the bulky gas lasers currently being used.

Development work on the new diodes was initiated because existing infrared diode sources are limited to an emission wavelength of 0.9 μm. Indium arsenide and indium antimonide systems are theoretically capable of radiating in the mid-infrared band, but until now, they could only be produced in a polycrystalline form which is unsuited for diode manufacture.

However, using a new technique of crystal growth—liquid transport under isothermal non-equilibrium conditions—Dr. Loebner and his colleagues have succeeded in fabricating single crystals of an indium-arsenide-indium-antimonide alloy. These crystals could produce sufficient photoflux, without cooling, for absorption spectrum analysis by the transform-multiplex technique.

At the same conference, designers heard about a high-definition multi-color flat-screen display which could provide a cheap, compact and rugged replacement for the CRT as a computer-output device. Developed by the Electronics Division of the Northrop Corp., the laboratory prototype could display up to 512 characters (16 rows of 32 characters each). This is a character capacity twice that of rival plasma displays. The display itself packs into a compact glass envelope measuring 5.5 × 7.5 × 1.7 in.

It is constructed—sandwich fashion—from a sheet electron source and a succession of switching plates each drilled with a matrix of fine holes that permit the passage of electrons from source to phosphor screen (see **Fig. 1**). The switching plates act much like punched cards, each successively blanking off electron flow by the application of a retarding voltage until a single elctron spot remains. Then by sequentially addressing selected combinations of switching plates, the electron spot can be made to scan across the phosphor screen the same way an electron beam does in a conventional cathode-ray screen.

The switching plates are constructed from inexpensive glass substrates and contain an array of channels through which the electrons flow. The surfaces of these plates are coated with conductive electrode patterns which connect groups of channels according to predetermined coding scheme.

An additional plate, called the modulation plate, is also inserted to allow the intensity of the electron beam to be adjusted, thus producing a gray scale as in a conventional TV. Alternatively, voltage penetration phosphors can be used on the target, thus permitting multi-color presentations.

Working prototypes of the display are now operating on a 40-line-per-in. resolution. An 80-line-per-in. version is under evaluation. The existing displays cannot yet compare with the 625-line-per-in. TV resolution of today. Nonetheless such a future application is being considered.

Recently, (see "Thin LED display to replace CRT radar pictures for air-traffic controllers", October 1, 1972, EDN, Volume 19,) a display made up of a matrix of GaAsP diodes and measuring less than 1-in. thick was introduced by GEC Marconi Electronics Co. This CRT has its diode matrix mounted in groups and wired directly on PC boards. The diodes are wired in rows and columns, so that each can be energized by supplying a voltage across one row and one column, similar to addressing a memory array.. □

COMPCON '72
Creative ideas in the computer sciences

The sixth annual international conference of the IEEE Computer Society attracted over 700 professionals, eager to exchange ideas and show accomplishments in the computer sciences. The theme of the 18 half-day sessions, conducted at San Francisco's Jack Tar Hotel, was innovative designs in computer architecture.

Speakers came from educational institutions and computer manufacturers in the US, Israel, West Germany, the USSR, Japan, Italy, India and the Republic of China. But the total number of distant travelers to Compcon '72 were few; most of the 80 papers given were from the U.S. Reportedly, attempts to host a delegation from Mainland China failed for lack of an official invitation from Washington.

Hardware cost vs speed

Optimizing the computing machine to the target market is a complex design task, and was widely covered at the conference. The designer must consider both the hardware and the software of the system in order to truly optimize the system's cost/performance ratio.

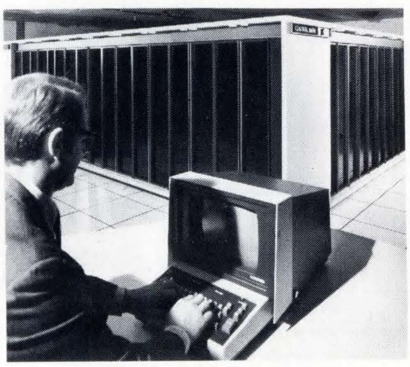
Thomas G. Hallin of Bell Telephone Laboratories and Michael J. Flynn of John Hopkins University gave the results of a study on pipeline implementation (see Box) of arithmetic algorithms. In their paper, "Pipelining of Arithmetic Functions," they numerically define hardware efficiency in order to measure the merits of various pipeline algorithms:

$$\text{Efficiency} = \frac{N}{DG},$$

where N is the number of bits in the operands, D is the delay in each pipeline stage (uniform) and G is the total number of gates, including those used for latching. This definition is essentially bandwidth/cost.

The authors' remark, "As circuit technology approaches the ultimate in high speed, faster circuits alone will not be able to provide significant increases in computing speed and overall system capability."

Hallin and Flynn point out that



Capable of performing 100 million instructions per second, the Control Data Star-100 can handle massive on-line data bases in excess of 10 billion bytes, using pipeline processing techniques.

Pipelines/parallel processors

Pipelining and parallel processing are two ways to increase the speed of a system. A combination of the two techniques in a system may be the optimum solution.

In multiprocessing architectures using pipelining, the processors, or pipeline stages, are arranged in series, with the output of one processor feeding the input of the next. The delay through each processor is uniform and small, allowing a high rate of data flow through the pipeline. Speed is achieved by keeping the pipe full.

In parallel processing computers, such as Burroughs Illiac IV and the Omen-60 computers, several processors function simultaneously and in parallel on different problems or parts of the same problem. Some prime considerations for optimum speed in a parallel organized multiprocessing machine are algorithms for coordination of the independant processors. The task is getting the data to the right place at the right time to keep all processors busy.

the goal of a pipelined system is to have a steady flow through the pipeline. When the stages are all full, the pipeline is operating at optimum speed.

Using their bandwidth/cost measure of efficiency, Hallin and Flynn report that pipelining using the Earle[1] latch increased the efficiency of a conditional-sum adder by 47% over an unpipelined conditional-sum adder. Using three pipeline stages with a delay of four gates per stage, the efficiency is 6.30×10^{-3}. Maximum efficiency for carry look-ahead adders is also realized with a fully pipelined configuration. The carry look-ahead adder's maximum efficiency of 6.0×10^{-3} is still less than the efficiency possible using the conditional-sum algorithm.

In multiplication, three algorithms were studied: unpipelined and fully pipelined. The most efficient multiplier of the three proved to be the tree multiplier (8 stages with 4-gate delays per stage) having an efficiency of 3.48×10^{-4}. This is 50% more efficient than fully pipelined versions of either the iterative array multiplier or the four-pass tree multiplier (used in the IBM 360 Model 91). The study indicated that a 230% increase in efficiency can be achieved by pipelining multipliers.

The authors conclude that, "From the results achieved with adders and multipliers, it appears that pipelining would be applicable to any combinational logic circuit and should increase the efficiency if the Earle latch can be used."

Control Data Corporation's Star-100 computer is a pipeline processor, with instructions that specify variable-length streams of data from memory. This allows full use of the arithmetic pipelines and the memory bandwidth.

The Star-100 processor design was described in a paper by R. G. Hintz and D. P. Tate of Control Data's Advanced Design Laboratory in St. Paul.

The core memory and the data bus configuration support a pipeline rate of 10^8 operations per second, with 32-bit floating-point format.

The Star-100 drew a good deal of interest at the conference. An entire session was devoted to it in which four papers were given, including "Star: A System Programmer's View," by Joseph E. Requa of Lawrence Livermore Laboratory. Requa described LLL's primary concerns encountered in fitting the Star-100 into its computer system.

Case studies of parallel processing computers presented in the sessions featured the PEPE Computer (Parallel Element Processing Ensemble) designed for real-time radar data processing.

PEPE evolved from Bell Laboratories' work in the early 60's, report the authors of "PEPE Computer Architecture" given in session 4. This paper was co-authored by B. A Crane, M. J. Gilmartin, J. H. Huttenhoff, P. T. Rux and R. R. Shively, all of Bell Telephone Laboratories.

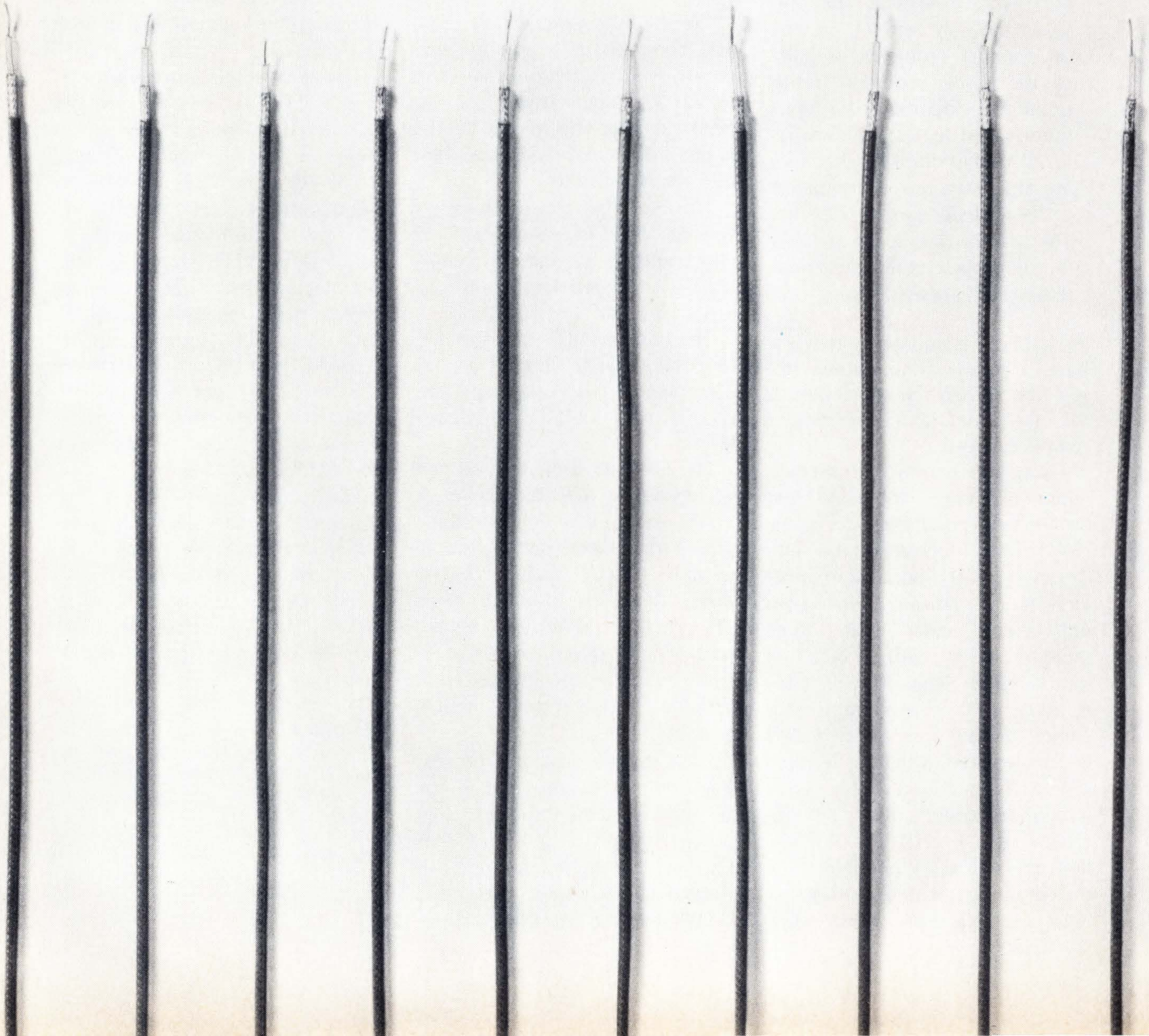
PEPE augments a conventional, host computer in real-time radar processing by taking over the job of maintaining the data representing the objects under track. PEPE's highly parallel architecture allows the simultaneous processing of many object tracks, thus freeing the host computer of this repetitive and time-consuming task and leaving it to perform higher level activities. PEPE's associative organization allows the host computer rapid and convenient access to object data as required in making decisions during these higher level activities.

"System studies have indicated that a PEPE-host combination can handle considerably more objects than is possible with the host computer alone," say the authors. "Economic realization of this increased performance however, requires that PEPE's highly parallel architecture be implemented by MSI and LSI technologies. A detailed feasibility design assuming lowcost MSI logic circuits of around 20 gates per chip and semiconductor memories of around 256 bits per chip has indicated that PEPE is cost effective."

PEPE is an illustration of the dynamics of semiconductor technology and computer architecture. There can be little doubt that new semiconductor products, custom and standard, will have great impact on computer designs of the 70's. ▭

Reference

Earle, J. G. "Latched Carry-Save Adder," IBM Technical Disclosure Bulletin, Vol. 7, No. 10, pg. 909-910, Mar., 1965.



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EDN Design Course
CMOS—Part 1

Why go CMOS? The answer today is a lot different than it was a year ago.

Bill Furlow, Associate Editor

Why would a designer who's been comfortable with TTL for years consider CMOS in a new design? A year or two ago he probably wouldn't unless he was forced to. Talk to an EE who used CMOS several years ago, and chances are you'll find that he became a CMOS user unwillingly. Power consumption was usually the driving force. At a CMOS seminar we attended a few years ago, EDN's question, "Why go CMOS?" elicited an "I've got no other choice" from nine out of ten engineers. Their additional comments were also interesting, though, because almost every excuse they used has fallen by the wayside in 1972.

Reluctance to try CMOS is dissolving rapidly. As more designers learn to use CMOS it is becoming a "glamor issue". These things together with the steadily increasing number of CMOS design articles that we have received, and the enthusiastic response to those we have recently printed persuaded us to begin this Design Course. This is the first of six parts which will run monthly in EDN. That gives you, the reader, the opportunity to participate and actually shape the remainder of the course. Your comments, questions and reactions will play an important part, so don't hesitate to write.

Part I of this course is essentially divided into two sections: one which describes the unique characteristics of CMOS devices and answers the question "why use CMOS?", and a second, which describes the operation and fabrication of the fundamental CMOS device.

What are the advantages?—Let's start by looking at the advantages that CMOS has offered since the very beginning. Using the CD 4000A series, from RCA, as fairly typical of today's devices (there are other families, which will be covered later).

a CMOS gate will have the following properties:

- 10 nW power dissipation (quiescent)
- 3 to 15V operation
- Noise immunity of 45% of the supply voltage

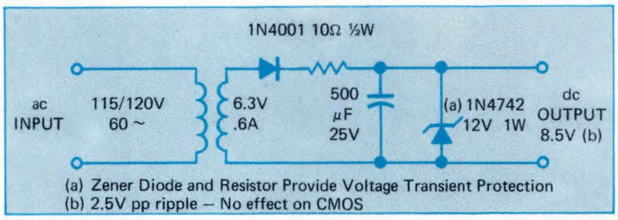


Fig. 1—Simple, inexpensive power supply, from an advertisement by Motorola, can power a 10,000 gate CMOS system. The 2.5 ripple doesn't bother CMOS.

- 5 to 10 MHz operation
- Very high fanout (typically 50)
- $10^{12}\Omega$ input impedance

These six characteristics seem to stack up 5 to 1 as advantages over bipolar logic systems, so let's run through them carefully.

Power consumption—If your system will fly, or operate from a battery, 10 nW per gate should really put a smile on your face. But even if you'll be operating in a fixed location from a 110V line you're still probably wise to the old "What do you care how much power it draws, just plug it into the wall" gambit. Power does cost money, and whether the rule of thumb of "a dollar a Watt" is accurate or not, you can't afford to ignore power consumption in any modern design. You can end up paying for your power twice in most systems—once to use it, and again to cool it.

A recent ad by Motorola, stressing the power supply savings afforded by CMOS, recommended the power supply shown in the schematic of **Fig. 1**. With a $2.5V_{pk\text{-}pk}$ ripple component, it's probably the worst power supply you've seen for a long time, but don't laugh! It will drive a 10,000 gate CMOS system operating at 100 kHz for $3.75 total power supply cost. But what about that 2.5V ripple? That brings us to the next point.

Operating voltage—The RCA 4000A series CMOS will operate from power supplies between +3 to +15V (Motorola's 14000A family is rated +3 to

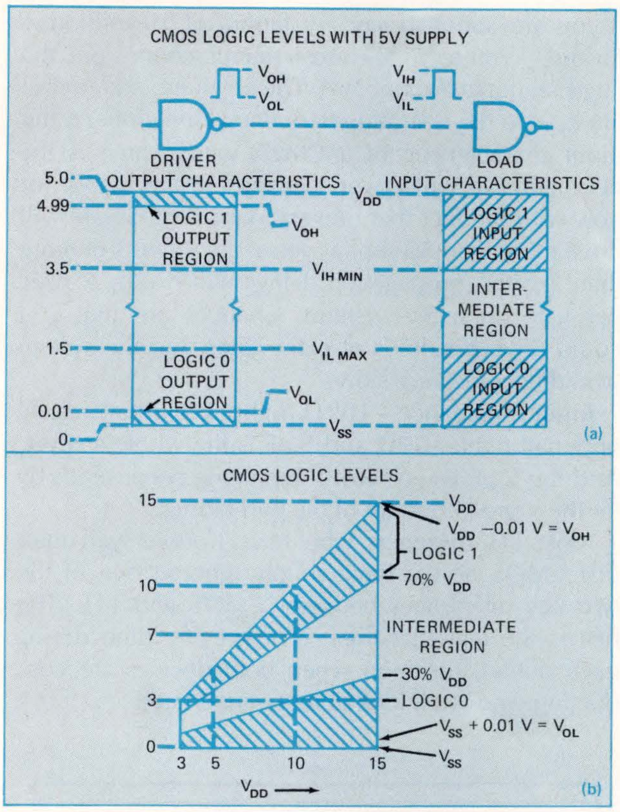


Fig. 2—Excellent noise immunity of CMOS gates (a) for a CMOS system operating at 5V (b) for CMOS operation from 3 to 15V.

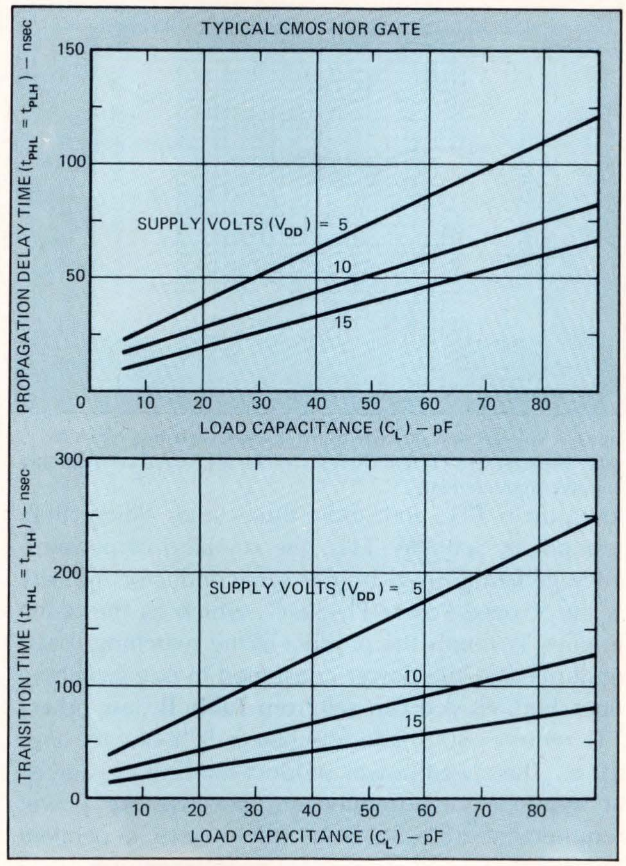


Fig.4—Propagation delays, rise and fall times are all directly dependent on capacitive loading of the gate output.

+18V), so that 2.5V swing on the power supply in **Fig. 1** will have no effect on CMOS, even though it would choke most bipolar logic systems. A wide choice of supply voltages is a tremendous advantage if you're designing an add-on system. It means that the CMOS design can hang on almost any logic or op amp power bus, so there is no expensive voltage conversion required when you add CMOS to the system. This is really a bonus and, as Bob Cushman mentioned in the June 15, 1972 issue of EDN, you have to add a lot of CMOS before you make a noticeable difference in power supply drain.

Noise immunity—as shown in **Fig. 2** and **Table I** the supply voltage level will also define the logic levels at which the CMOS gates will operate. The margin for noise error on the input, 45% typical, 30% guaranteed, is larger than any other logic family—except high threshold logics (HTL or HNIL, and they operate from a fixed 15V supply). The advantage of this noise immunity in automotive and aircraft environments, or for industrial control applications, is enough to sell CMOS to many designers, even if they have to make a lot of tradeoffs. The fact is, they don't have to make very many. But that does bring us to one of the tradeoffs.

Operating frequency—The typical CMOS gate operates to 5 to 10 MHz, and exhibits a propagation delay of about 35 nsec. This is slightly poorer than

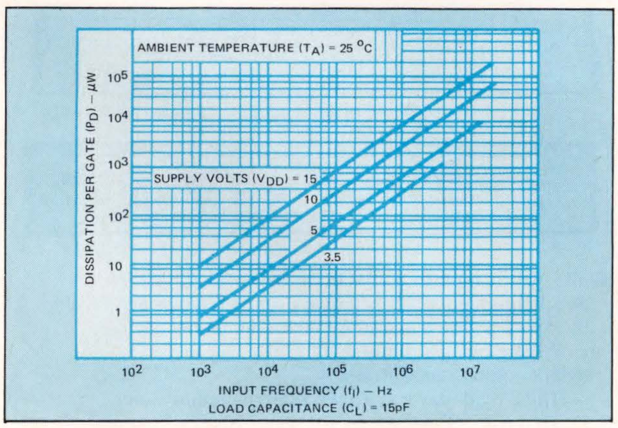


Fig. 3—CMOS power dissipation vs operating frequency. Unlike TTL, CMOS' power consumption varies directly with frequency.

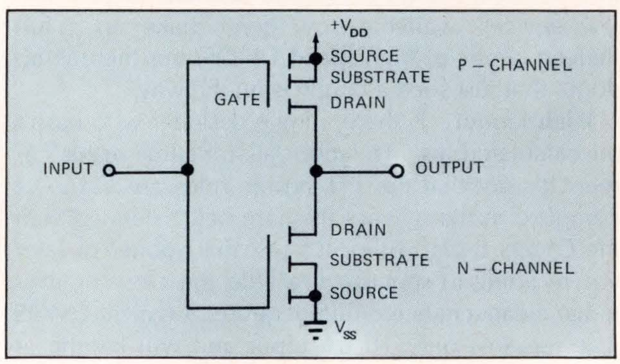


Fig. 5—Basic complimentary inverter, consisting of two MOS transistors, is the heart of the CMOS logic system.

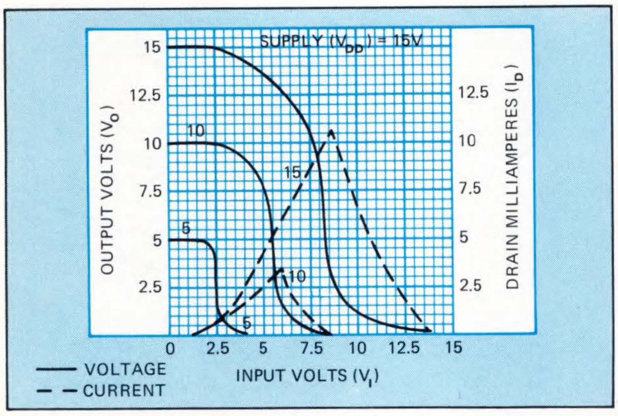


Fig. 6 – Voltage and current transfer characteristics of a CMOS gate. The transient current during switching can add considerably to power requirements.

low power TTL, and about three times slower than low power Schottky TTL. The standard of performance generally used by the semiconductor industry is the "Speed-Power Product", which as the name implies, is simply the product of the switching speed multiplied by the power consumed in one switching operation. As you can see from **Table II**, low power TTL requires 30 pJ and low power Schottky requires 20 pJ. The speed-power product for CMOS is given at two operating frequencies, because the power requirement for CMOS is much more dependent upon frequency than it is for bipolar devices. Low power and low power Schottky TTL remain constant at their rated power levels until they approach the upper limit of their capabilities. There the power requirement begins to rise, but as you can see from **Fig. 3** CMOS power consumption is directly frequency dependent.

Let's not beg the question – CMOS is not as fast as TTL; at 2 to 5 MHz it loses its edge in speed-power product. If higher frequencies are vital, you'd better take another look, especially at low power Schottky. Its speed-power product is very impressive. But if system speed is one of the tradeoffs open to you, CMOS can give you more reward for that tradeoff than any other logic technology available to you today.

Insulated substrates, as presently offered by Harris and Inselek, promise speeds that will compete with the speeds of standard TTL and Schottky LPTTL. The few devices available now don't make up a full fledged family of high speed CMOS, but there is no doubt that just such a family is on the way.

High fanout – Is there a logic designer who hasn't miscalculated his TTL fanout at sometime in his career? It's not that the TTL design rules are vague or complex; in many ways they are better defined than the CMOS design rules. It's just that sooner or later you're going to squeeze it a little too close or misjudge a capacitance or temperature. A typical CMOS gate requires only 10 pA input and will handle at least 0.3 mA output. That gives you a theoretical limit of 10^7 inputs that can be driven by one output. If you are about to say: "a fanout of 10 million is absurd", you're right – most manufacturers put the rated fanout at "about 50." The key here, and one of the keys to the operating frequency limitations, is the input characteristic of a CMOS gate, which is the next item we will cover. Let's just leave fanout for now with the fact that one standard CMOS gate will drive more than 50 similar gates. For fanouts of more than 2 gates, propagation delays will rise by 7 nsec per gate (in a 5V system). Chances are that you could drive hundreds of extra gates, but the system would become *very* slow.

Input impedance – $10^{12}\Omega$, right? Well that's really only half right. $10^{12}\Omega$ and 5 pF is the whole answer. And the 5 pF is well worth repeating because it's by far the more important of the two ratings.

Most TTL designers who have trouble with their first CMOS design have simply ignored one of the two key differences between CMOS and TTL. The first is the fact that there is a specific time during each output transition when both devices are conducting, and we'll look at that a little later.

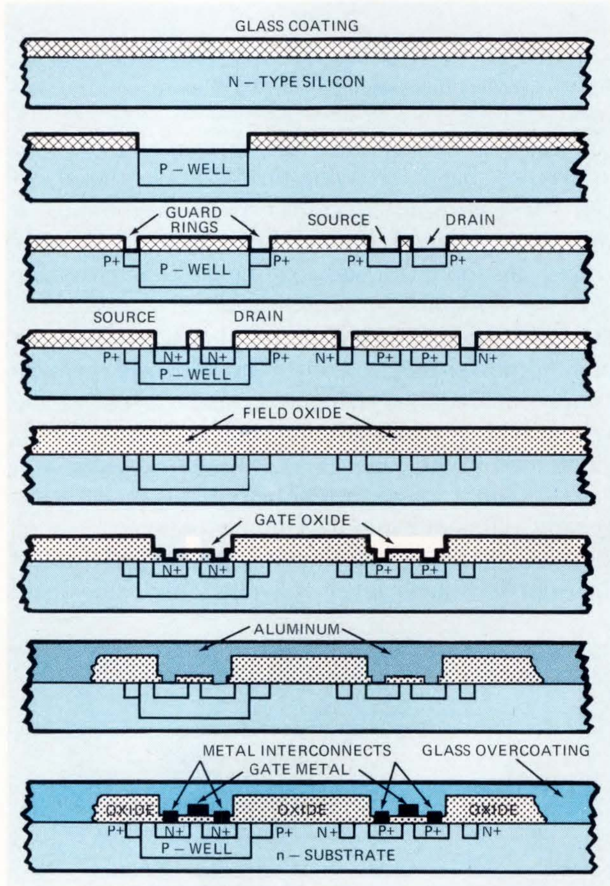


Fig. 7 – Fabrication of a CMOS device.

(a) Silicon-dioxide film is grown over an n-type silicon wafer.
(b) P-well is grown as a substrate for n-channel devices.
(c) P+ regions are diffused.
(d) N+ regions are diffused.
(e) Thick oxide layer is grown over the entire wafer.
(f) Thin gate oxides are grown above channel regions.
(g) Aluminum interconnects are deposited.
(h) Glass overcoating protects the device.

The CMOS trait that we want to look at right now is that 5 pF input capacitance. It is the result of the metal plate which forms the gate, and the silicon which forms the drain, source, channel and substrate of the device. They are in very close proximity with the insulator serving as a dielectric between them. In TTL designs you really only have to worry about sinking or sourcing the required amount of current. But look at **Fig. 4**. In CMOS, the 5 pF per gate load (and you can approximate another 3 to 5 pF as stray and wire capacitance for each 2 gate loads) has a drastic effect on the propagation delay and the transition time of the driving gate. This input capacitance is a direct contribution to the increased power requirement at high frequencies, though it is not the only one. It is the major factor in deciding what your allowable fanout will be.

Don't get the idea that the capacitive input of a CMOS gate is some sort of monster that will grab you when you turn your back. Just remember that it's there and that some engineering evaluation will be required. If you don't demand high speeds and large fanouts from ultra low battery drains you can handle the problem.

Silicon-gate CMOS avoids some of this capacitance. Since the precise alignment of the gate to the channel allows a smaller gate, the overlapping area above the source and drain is eliminated in Si-gate devices.

Motorola will probably be the first to offer Si-gate, with two products scheduled for release in the last quarter of 1972. Si-gate devices are under development by most CMOS manufacturers, and should be coming forth in large volume during 1973.

TABLE II – SPEED AND POWER SPECIFICATIONS

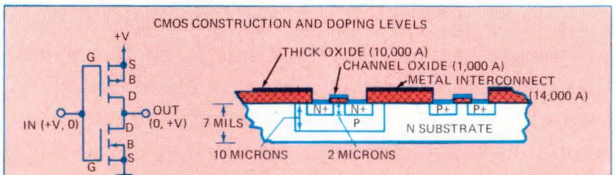
Parameter:	Low Power TTL	Low Power Schottky TTL	CMOS at 2MHz	CMOS at 10kHz
Propoagation Delay (Speed) (nanoseconds)	30	10	35	35
Power (milliwatts)	1	2	1	0.01
Speed-Power Product (pico joules)	30	20	35	0.35

All devices operating from 5V supplies

Good design habits are required

Before we move on, the first half of the input impedance has brought a few, minor problems to some designers. $10^{12}\Omega$ may sound like the greatest thing in the world, but if you're used to the lower input impedance of TTL, keep that high impedance in mind. First of all, you must reference all gate leads to V_{SS} or V_{DD}, whichever applies, even during breadboarding. The second point is that you can't be as casual in handling breadboarded units as you were with TTL. A finger touching a board, lead or socket is a very attractive current path to a circuit looking into $10^{12}\Omega$, and a PC board on a wooden bench top can cause the same problem. The higher the humidity, the worse these side effects become, and some pretty strange things have happened to well engineered units when it was time for prototype evaluation. Good design habits will avoid both of these problems in the final hardware; it's just that a few of us have picked up some rather sloppy breadboarding habits because we got away with it with TTL.

Since this is an evaluation of CMOS covering both its strengths and weaknesses, let's touch on that other potential problem area we alluded to earlier: the fact that both devices can be partially on during switching. **Fig. 5** is a schematic of a basic CMOS inverter and **Fig. 6** is a plot of the voltage transfer characteristic of that inverter gate. Compared to other logic families those transfer curves are very sharp; but there is a period, as you can see, during which the P- and the N-channels are both ON. For example, on the 10V V_{SS} curve, there is evidence of this from V_I = 2.5 to 7.5V. Looking at this in conjunction with the current drain (dotted line) will show you why you want to get through that transition as quickly as possible, especially if current drain is an important part of your design. This effect is the chief culprit in the frequency-vs-power curves of **Fig. 3** and can lead to some other problems, too.



	SUBSTRATE	N+	P+	P – WELL	UNITS
DOPING LEVEL	4×10^{15}			5×10^{16}	ATOMS $/CM^3$
RESISTIVITY	1 – 2	—	—	—	ΩCM
SHEET RESISTANCE	—	5	50	1,000 – 3,000	Ω/□

Fig. 8 – Construction, doping and dimensions of a typical CMOS inverter are shown here. The circuit diagram is also shown for correlation.

For example, one of the nice features of CMOS is that there is no pulse edge requirement; that is, rise and fall times do not have to be a few nanoseconds or less in duration in order for the gates to function. In fact these times can be minutes, or even hours long; but while the input is between 2.5 and 7.5V, power dissipation of the package will be a lot more than anticipated. This linear condition can carry downstream a few gates, too, if everything is just right (or just wrong).

What about price?

Going back to our original question ("Why go CMOS?"), what about the price of CMOS devices?

We don't hear as many of these responses this year. CMOS prices, while not yet as low as TTL, have just been reduced an average of 25%. **Table III** gives a rough estimate of todays pricing picture.

TABLE III – PRICE COMPARISONS – TTL TO CMOS			
Current List Price Levels for a Quad 2-Input NAND Gate			
7400N Standard TTL	74L00N Low Power TTL	74LS00N Schottky LP TTL	CD4011 AE CMOS
$.48 each*	$.64 each	$.96 each	$.78 each
Prices are based on orders of 100 units, in plastic dual-in-line packages			
*Distributors in Boston are offering substantial discounts from this list price, as low as .21 in 100-piece quantities.			

Manufacturers of CMOS have been wildly enthusiastic, when EDN has visited them, about future prices of CMOS devices. CMOS is inherently easier to manufacture than bipolar is. When you talk to the manufacturing and process engineers you don't hear the "black magic" stories that are so common at other semiconductor plants (especially the linear houses). They all agree that the CMOS manufacturing processes are straightforward. This should lead to more price cutting as volumes grow, and should bring CMOS into the TTL ballpark. When?—by the end of 1973 seems to be a target date.

Another complaint EDN used to hear was "it's a little too new for me" or "I can't get a second source". CMOS is at least 8 years old, but in those early years most of the devices were custom aerospace units. RCA introduced the 4000 Series in 1968 and they must have felt very lonely for quite a while. Now there are nine other makers of the 4000 family. Most of these have introduced proprietary circuits in addition to the RCA devices, and in many cases RCA has already, or plans to, second source those new devices. The family is now full fledged, but still growing briskly.

In essence, then, why go CMOS? The answers

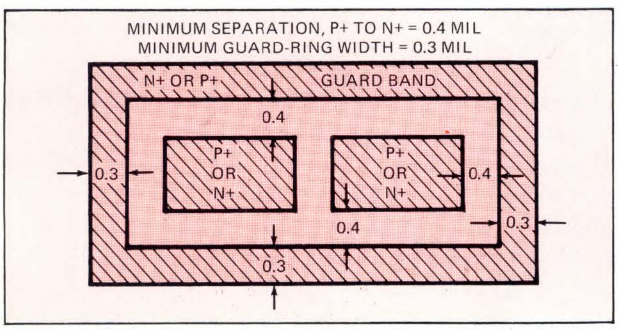


Fig. 9—Minimum spacing between guard band and MOS transistor is the basic constraint on surface area required by a CMOS gate.

today are enthusiastic. Take a look at some of the new products that use CMOS. A pocket pager that wouldn't be possible with other technologies, a heart pacer and an electronic wristwatch. The designers of these products chose CMOS because of the micro power characteristics. The digital automotive clock for Chrysler cars marks the first major inroad made by CMOS into the automotive market. Noise rejection was the selling feature here, because the +12V bus of the automobile is a very noisy power source. Low power wasn't the prime reason, but it was a solid second, because the alternator of a modern auto, already heavily burdened with power options, is not an infinite power source. The future of automotive electronics will rely heavily upon CMOS to solve problems without placing more burdens on the electrical system.

Where will CMOS go? Will it drive TTL and P-MOS from the market place? That is very unlikely. CMOS and Schottky may in time drive standard TTL from the market, but Schottky (especially the low power line) is a very attractive technology. CMOS will be hard pressed to ever replace it. P-MOS is in such volume LSI production that it's hard to believe it can ever be overcome. CMOS will definitely replace P-MOS for some of the portable calculators and other applications, where battery drain is important but speed is secondary. N-channel MOS will gobble up some of the computer applications presently held by P-MOS. In short, two of todays technologies (standard TTL and P-MOS) may fall by the wayside, but that's at least five years away, and they will be replaced by three technologies, not just one.

A look at fabrication

The fabrication of a standard CMOS device, as shown in **Fig. 7**, requires the use of seven photomasks in the following sequence:

1. Beginning with a silicon n-type wafer, a silicon-dioxide (glass) film is grown over the entire sur-

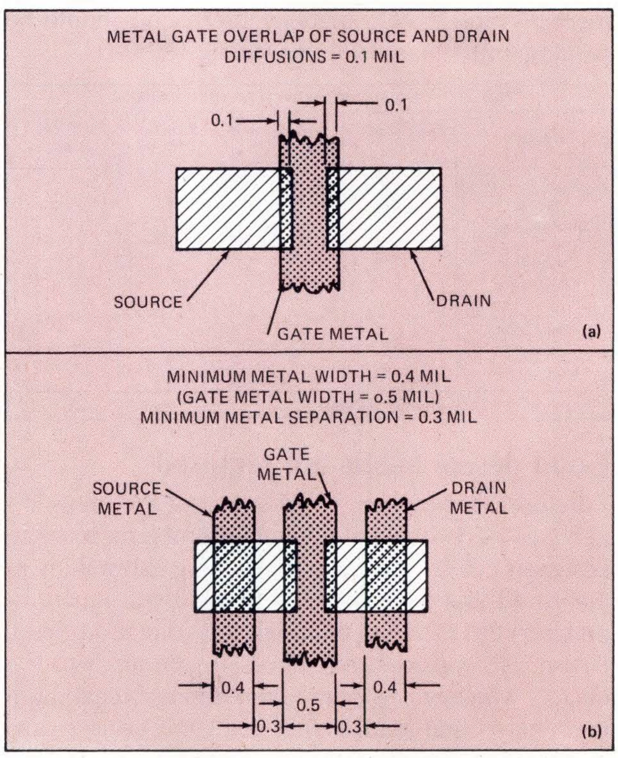


Fig. 10—Minimum metal widths and seperations—the gate metal must overlap source and drain areas to allow realistic manufacturing tolerances.

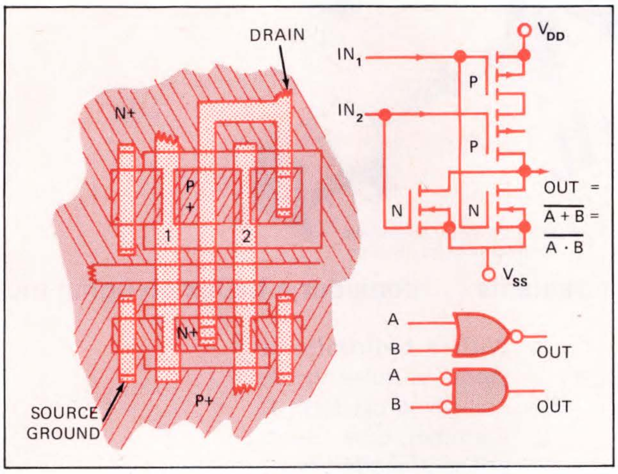


Fig. 11 – Typical layout and circuit diagram for a 2-input CMOS NOR gate. The metallic ribbons labeled 1 & 2 in the surface drawing correspond to the IN_1 and IN_2 lines of the schematic.

face. Photoresist is applied and the first mask is exposed and developed.

2. The glass is etched away, using hydroflouric acid, exposing bare silicon in those areas where the p-wells will be grown. The p-wells are then diffused very deeply into the wafer (at least 10μ) and create an artificial p-substrate within the n-substrate. N-channel MOSFET transistors will be grown within this p-well and p-channel FETs will be grown in the bulk n-type silicon substrate. Again a glass film is grown over the wafer, photomasked with the second mask and etched.

3. The p+ regions are diffused in. These will form the source and drain of the p-channel devices and the guard ring of the n-channel areas.

4. The third mask will expose areas to be etched and doped n+. These areas will provide guard rings for p-channels and source and drain areas for n-channel FETs.

5. The entire surface is etched clean of the glass overcoating and a thick field oxide is grown over the whole wafer. The fourth mask then defines areas which will be etched in order to expose the gates of all transistors.

6. The thin gate-oxide layers are grown and the fifth photomask is used to provide holes through the field oxide to all points where the metalization layer will make contact with the silicon die.

7. The entire surface of the wafer is coated with aluminum. This is done by a vacuum deposition process in exactly the same manner used to aluminize telescope mirrors.

8. Photomask number six is exposed and developed and all of the unwanted aluminum is etched away, leaving the interconnect paths only where required.

9. The wafer surface is completely covered with glass and the seventh, and final, photomask is used to open holes leading to the bonding pads, where lead-wires are to be welded.

10. Extra material is now removed from the back of the wafer and they are scribed, broken apart, wire bonded and packaged.

The process we've just described is the one we were shown first hand at RCA Solid State Division. Most manufacturers use a very similar procedure. Some variations do exist; for example, Motorola grows the thick field-oxide layer first (instead of the glass) and all subsequent steps are done through this layer. Motorola also diffuses p+ and n+ regions in reverse order to that shown here. Also, technologies other than this basic CMOS, such as Si-gate and SOS, will obviously differ from what we've shown.

Some of the physical measurements and doping levels of the production process are shown in **Fig. 8**. This example shows the single two transistor inverter which is the standard building block for CMOS gates.

A top view of a single transistor, shown in **Fig. 9**, shows the size relation of the source and drain to the channel which runs between them. The guard-ring configuration is also more apparent in this view. The guard-rings reduce leakage between adjacent devices and prevent surface currents which can occur beneath the metalization interconnects.

Metal patterns and their dimensions are shown in **Fig. 10**. Note in **Fig. 10 (a)** the 0.1 mil overlap of the gate metalization and the source and drain areas. This is a manufacturing tolerance, required to assure complete coverage of the channel by the metal gate. It is also a contributing factor to the input capacitance of the CMOS gate. Silicon gates, which are self aligning, require no overlap.

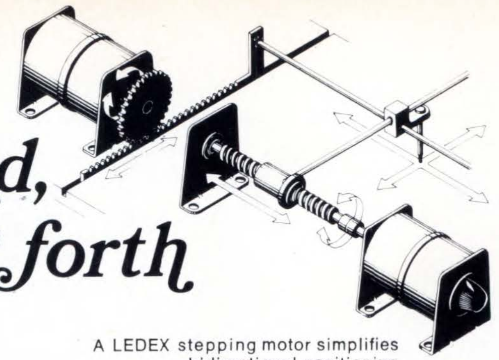
NAND and NOR gates are composed of two or more of the basic inverters arranged as required to perform their particular function. **Fig. 11** shows both the physical orientation on the chip and the schematic diagram of a 2-input NOR gate. The lower, or n-channel, transistors are arranged in parallel so that a HIGH on either of both inputs will turn the device on, and the output will go LOW. The upper, p-channel, devices are in series so that a LOW must appear at both gate inputs to swing the output HIGH. In just the reverse manner a NAND gate will have parallel p-channel transistors and series n-channel transistors as shown in **Fig. 12**.

Those, then, are the very rudiments of CMOS fabrication. Next month CMOS – Part II will discuss the operating characteristics and design considerations of the CD 400A logic family. ▭

A word of thanks

Much of this CMOS Design Course is based on a series of seminars conducted around the country by RCA. EDN would like to express its thanks to both RCA and the individuals involved, who provided us with a wealth of support and assistance.

up, down, around, back & forth



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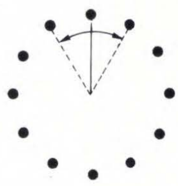

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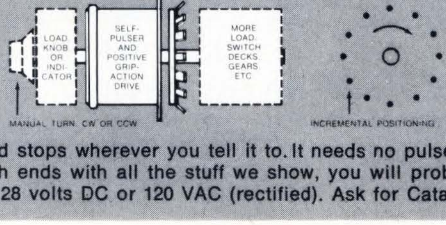

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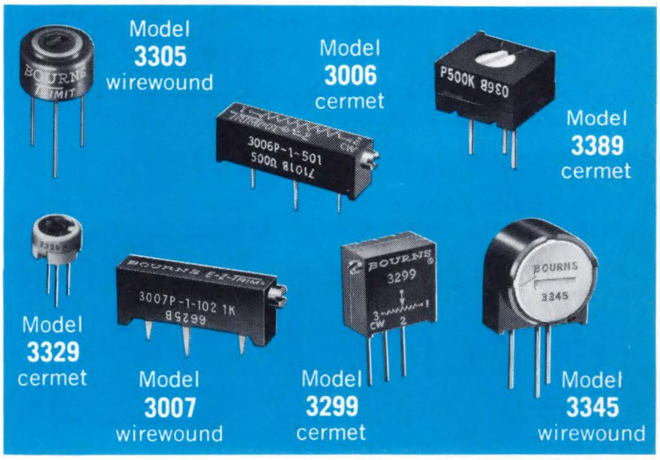

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CHECK NO. 16

Unique semiconductor mix controls induction motor speed

Discrete components, IC packages and optical couplers produce an efficient variable-frequency drive system for fractional-horsepower induction motors.

Thomas Mazur, Motorola Semiconductor Products

The variable-speed induction motor is an attractive solution to many motor drive problems. Although the speed of such a motor can be controlled in various ways, the most effective is to vary the frequency of the applied voltage (see box). A method for doing this for split-capacitor fractional-horsepower induction motors that makes use of the latest semiconductor technology is described in this article.

The control system to be covered is a combination of discrete components and IC logic circuitry. Compatability between these two types of devices is achieved by the use of optical couplers, which provide isolation between the low-power control circuits and the high-power motor drive circuits. The advantage of such a scheme is that the drive section can be modified to accommodate a variety of motors that differ only in their power requirements, without affecting the design of the control section. The optical isolation also inhibits any transient feedback from the drive circuit to the control circuit. The control section is further protected by the use of high noise immunity logic devices.

Quadrature signals required

A permanent split-capacitor induction motor requires two drive signals 90° apart. Normally a capacitor is used in series with one winding to obtain the necessary phase shift when the motor is operated from a single-phase power source. Since the capacitive reactance is inversely proportional to frequency, the capacitor cannot maintain the proper phase shift when operation over a range of frequencies is desired. An initial prerequisite, then, is to eliminate the need for such a capacitor.

A pair of flip-flops, operated in time-quadrature, can perform the same function as the phase-shifting capacitor. As shown in the system block diagram (**Fig. 1**), an oscillator is used to set the frequency of operation. A shaping circuit then converts the oscillator signal to high noise immunity logic levels.

The quadrature generator that follows performs two tasks: first, it provides two complementary pairs of quadrature-phased signals; and second, it distributes a pulse of fixed width to the pulse shapers. The pulse shapers produce asymmetrical drive signals for the LEDs. Due to the asymmetry of the drive signals, the duty cycle of each LED is less than 50 percent. The drive signals are coupled from the LEDs to the detectors, via optical path hf, and then to the power amplifiers. The power stages have a finite

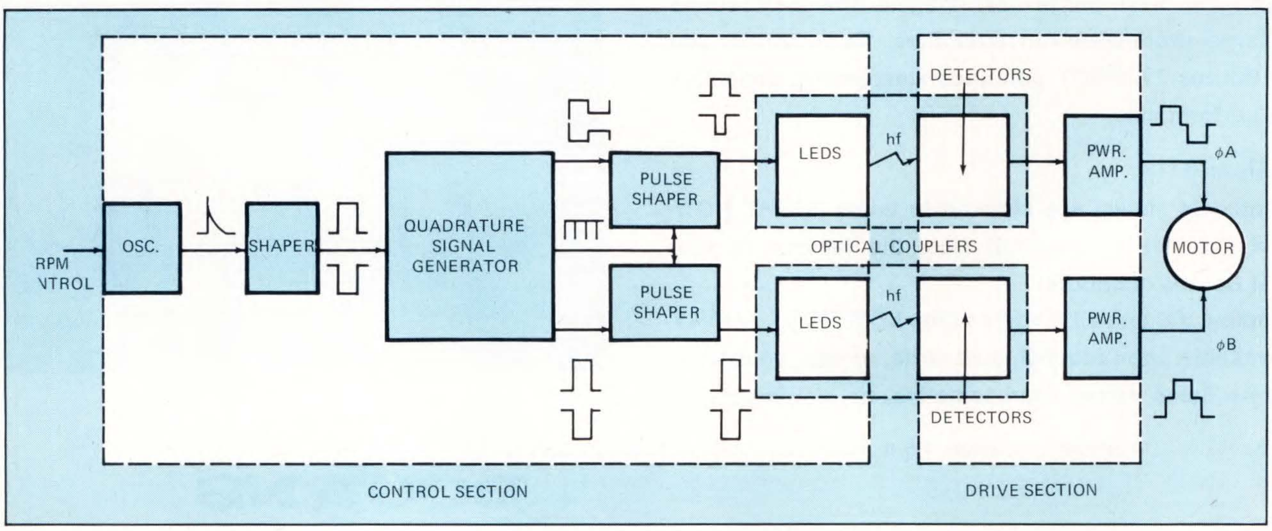

Fig 1 – The speed-control system consists of a low-power control section and a high-power drive section, with the two sections connected by optical couplers.

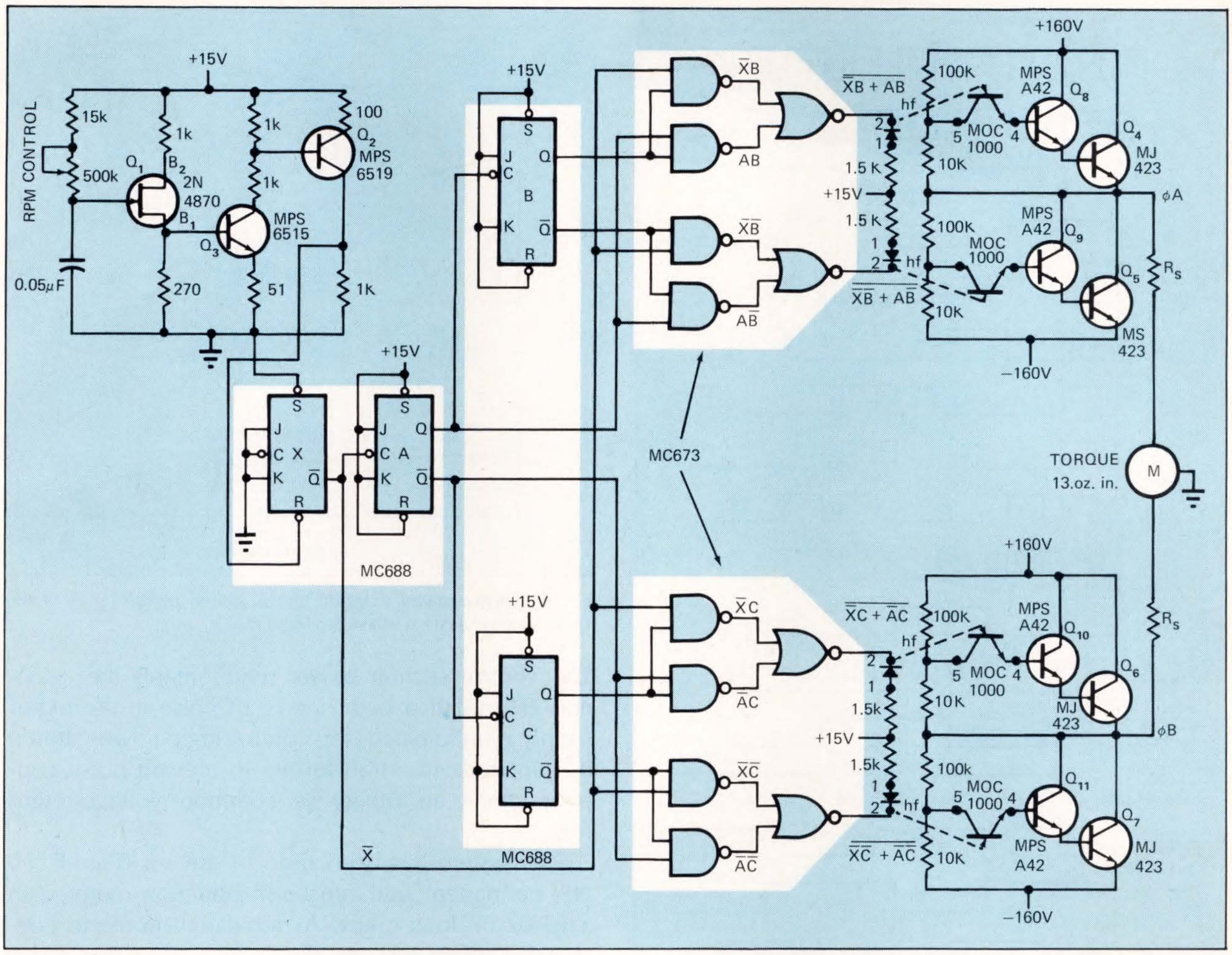

Fig 2—Standard components are used in the variable speed-control circuit. These include IC packages, discrete transistors and optical couplers.

switching speed that is dependent upon the type of power transistor used and the load current. The asymmetrical drive allows each transistor to turn off before its complement is turned on.

The complete schematic of the control system is shown in **Fig. 2**. It should be noted that the specific parts called out, or their equivalents, can be used. From the schematic, it can be seen that a UJT (Q_1) is used as a free running oscillator. The frequency range of this oscillator is 40 Hz to 1200 Hz. Because the logic that follows the oscillator section is in a divide-by-four configuration, the actual drive frequency range applied to the motor is 10 Hz to 300 Hz. This implies a speed range, for an induction motor with two pairs of poles, of 300 rpm to 9000 rpm. In actual practice, however, the speed range will be limited by a variety of losses.

The resistor in the base-1 lead of the UJT controls the width of the oscillator output pulse, while the Q_2 and Q_3 pulse amplifiers translate the oscillator signal to high noise immunity logic levels to drive the set and reset inputs of the X flip-flop. Since this flip-flop is the R-S type, its operation is dependent on the input levels and duration, exclusive of the input rise and fall times.

The $\overline{Q}$ output of X, called $\overline{X}$ on both **Fig. 2** and on the timing diagram (**Fig. 3**) clocks the A flip-flop. This flip-flop, used as a divide-by-two toggle, provides out-of-phase clock signals for the B and C flip-flops, which toggle on the negative transition of their clock signals. Since their clock inputs are 180° apart, the B and C outputs are 90° apart due to their normal divide-by-two operation. In this manner, the need for a phase shifting capacitor in series with one winding of the motor is eliminated.

The MC673 AND-OR-invert gates combine the B and C square waves with the X pulse. This combination results in a zero voltage step in the ∅A and ∅B drive signals to the motor. The output power transistors (Q_4 through Q_7) require about one μsec to shut off. If one of these devices is turning off and its complementary device turns on during this interval, current would flow between the transistors without benefit of any load-limiting impedance. This would result in device overstress. So to insure protection, $\overline{X}$ has been set to produce a 20 μsec dead time during the switching crossover.

The A flip-flop, in addition to providing clock signals for the B and C flip-flops, is also ANDed with B and C's outputs to prevent dead time from occurring

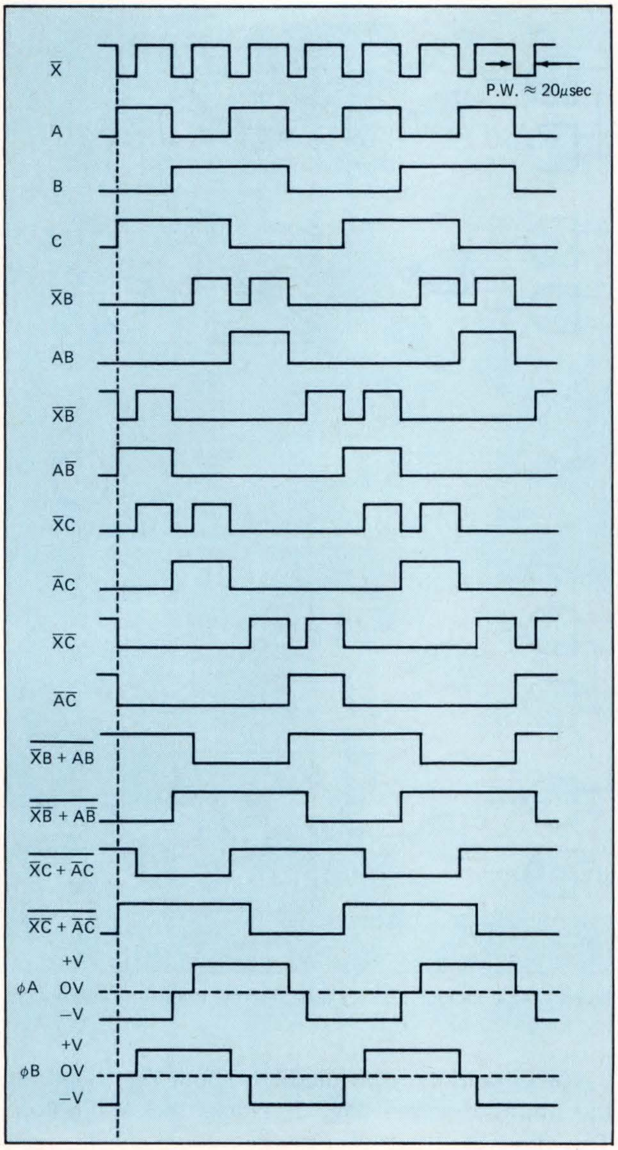

Fig. 3—Interrelationships between the various digital control signals and the output drive signals, ∅A and ∅B, are shown by these waveforms.

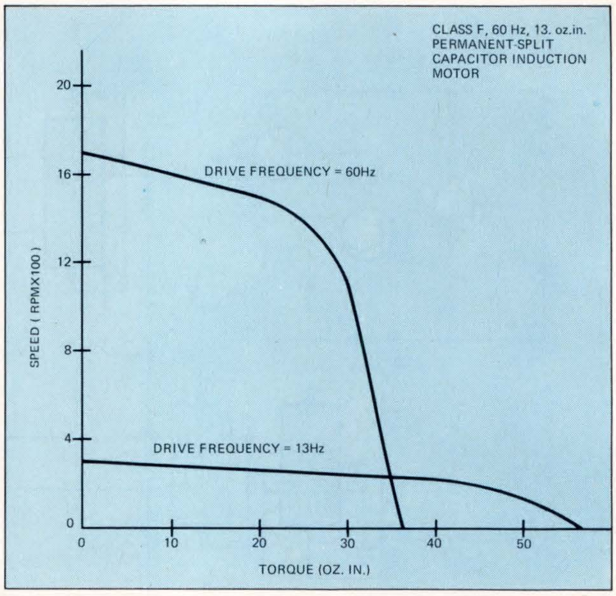

Fig. 4—Torque-speed diagram shows actual performance of the speed-control system when driving a motor.

in the middle of the ∅A and ∅B drive signals.

The high noise immunity logic operates from + 15V; the motor drive from ±160V. In order to provide bipolar drive signals from unipolar control signals, the optical couplers are used. With this technique, the drive circuits can be operated down to, and including, dc without the problems inherent in broadband RC coupling. Since photons are the coupling mechanism and input-output isolation is 1500V, transients from the motor drive section up to 1500V will not be transferred to the control section.

Each output drive circuit, consisting of an MJ423, MPSA42 and photo transistor, is normally off and is turned on only when its LED is on. In this manner, if anything happens to the logic power, the drive circuits are disabled, turning off the motor and providing a fail-safe feature.

The input power requirements for the drive section of the system depend on the motor and its load. The control section power requirements are +15V and 50 mA. If a high degree of noise in the motor supply is anticipated, the control logic power should be supplied via a transformer to prevent noise coupling along an otherwise common voltage-return bus.

This system has been used to drive a Class-F, 60 Hz, permanent split-capacitor induction motor with a 13 oz in. load rating. As indicated on the torque-speed diagram (**Fig. 4**), the load capacity increases as the speed is decreased. This is a definite advantage over a voltage-variable control, where the torque falls off with decreasing speed. Resistors were added in series with the windings to limit the current, since the motor reactance is proportional to the drive frequency. The value of R_s for this motor was 25Ω, 50W.

At 1700 rpm, and with a 13 oz in. load, the motor temperature was 40°C when powered by the square-wave drive. A 60-Hz sine wave produced a 32°C case temperature at the same speed-load values. The difference in temperature is attributed to the harmonic components of the square-wave drive signals. Because of the additional heat, care should be taken to insure that adequate ventilation and heat sinking are provided for the motor when it is operated by this circuit.

Alternate circuit is possible

If isolation between the control and drive circuits is not a requirement, as would be the case in a low-noise environment, the scheme shown on **Fig. 5** will generate the same type of drive signals as the system just discussed.

In this circuit, a UJT oscillator toggles a trigger flip-flop designated X which in turn clocks a pair of J-K flip-flops. The quadrature phased Band C outputs are

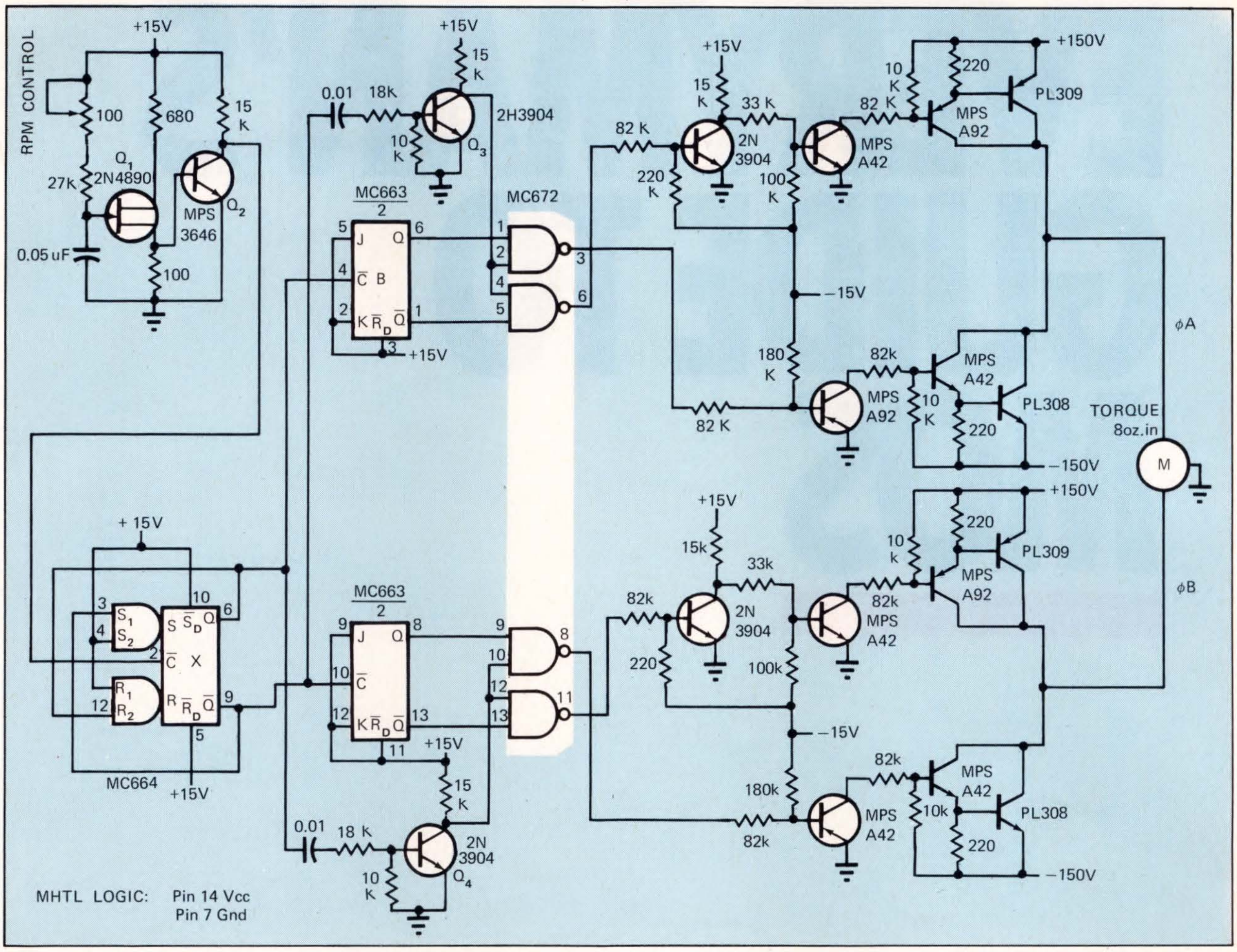

Fig. 5 – Elimination of the optical coupling, as well as other circuit changes, yields a speed-controlcircuit with the performance of the circuit of **Fig 2,** but without its high noise immunity.

Controlling the speed of an induction motor

The speed of an induction motor is determined, in general, by four factors: the number of poles, the frequency and amplitude of the supply voltage and the magnitude of the load. When a fixed-frequency source, such as the 60-Hz power system, is used, the speed may be controlled by varying the applied voltage. This technique has a disadvantage in that the torque of the motor is proportional to the square of the applied voltage; therefore, at slow speeds, the load capacity is reduced. If, instead the voltage is held constant while the frequency is varied, the maximum torque will not decrease as the speed is reduced.

combined with fixed-width pulses, in the MC672, to provide the zero voltage step in the ∅A and ∅B output drive signals. The fixed-width pulses are obtained by differentiating the R-S flip-flop out-puts and amplifying the positive-going transitions with Q_3 and Q_4. The pulse width is approximately 500 msec. The NAND gate outputs are then translated, by means of small signal amplifiers, to levels suitable to drive the final transistors. The final stages are complementary NPN-PNP pairs. □

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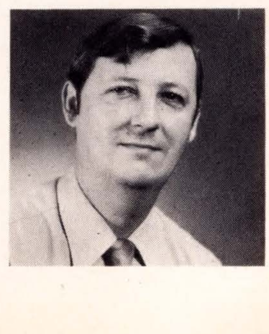
Author's biography



Thomas Mazur is a circuit designer in the industrial controls group of Motorola's Semiconductor Products Div., Phoenix, Arizona. Prior to joining Motorola 9 years ago, Tom worked for Philco Corp.

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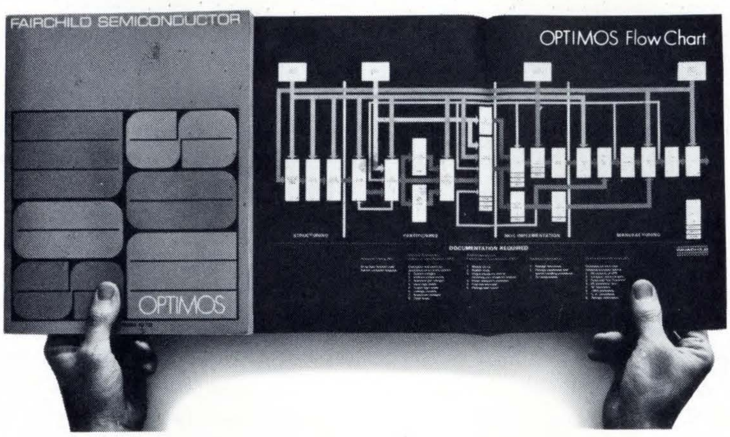

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CHECK NO. 17

Comparators can do more than just compare

When considered as a general-purpose analog component, the comparator becomes an extremely versatile device that can simplify a great many designs.

Robert C. Dobkin, National Semiconductor Corp.

There has been a wealth of design and applications material devoted to the operational amplifier over the past few years. However, the voltage comparator, which is a special-purpose operational amplifier, has not received nearly the attention given to general-purpose op amps. This is regrettable, since the voltage comparator can be used in a wide variety of applications to considerably simplify difficult circuit designs. This article will show the versatility of the voltage comparator in some unusual applications.

The circuits covered do not use the voltage comparator merely as a level detector, but take into account the full capabilities of the device as a general-purpose analog component.

An operational amplifier is a high-gain feedback amplifier, stable with almost any type of feedback network. Like an operational amplifier, a voltage comparator has very high gain; however, it is not designed for use with feedback. The basic idea of voltage comparators is to compare voltages and provide an output as fast as possible. For that reason, no phase or gain compensation, which would slow down its responses, is included in the comparator. Any attempt to apply feedback around the comparator with the same impunity as with an op amp will result in oscillation. Other major differences from an op amp are: the comparator is designed to operate with large differential input voltages, and the output

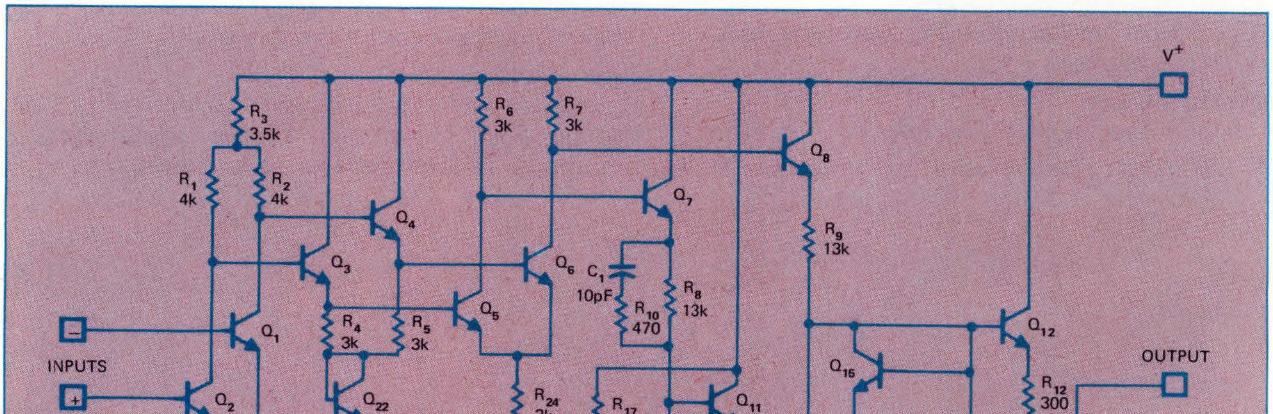


Fig. 1—The LM119 Dual Voltage Comparator, one-half of which is shown here, is representative of the complexity of modern IC comparators.

stage is usually optimized to drive digital logic.

Before linear integrated circuit op amps reached their present level of sophistication, they were well developed as packaged modules. This was not the case with voltage comparators. Comparators that combine high speed and high accuracy have come about only with the development of linear ICs. Discrete op amps are more easily designed than are discrete comparators. Since an op amp is used closed loop, all transistors are operating in a linear mode with their operating points well defined. Differential amplifiers are balanced, which minimizes offset drifts. With a comparator, on the other hand, all stages may be either turned on or turned off. Differences in power dissipation between "on" and "off" transistors give rise to temperature differences, causing shifts in the offset voltage. If high operating currents are used for high speed, the problem is worse. However, in a monolithic IC, all components are at virtually the same temperature and the problem does not exist. Further, IC stray capacitance is greatly reduced from discrete stray capacitance—making the comparator faster.

The basic working of a voltage comparator can be seen from **Fig. 1**, which shows a schematic of a general-purpose comparator. The input signal is applied to differential amplifier pair Q_1 and Q_2. Q_1 and Q_2 are biased so that they do not saturate over the full range of common-mode voltage. The amplified signal is applied through emitter followers Q_3 and Q_4 to a second differential stage, Q_5 and Q_6. The followers have a dual function: they buffer Q_5 and Q_6, increasing the gain of the first stage, and they level shift the signal toward the negative supply. The emitter-base voltage drop of Q_3 and Q_4, in conjunction with the drop across R_3, prevents Q_5 and Q_6 from saturating under worst-case drive.

The signal is amplified by Q_5 and Q_6 and applied to followers Q_7 and Q_8. It is then level shifted toward the negative supply by a resistive level-shift circuit comprised of R_8, R_9, Q_9, Q_{10}, and Q_{11}. The full differential signal from the collectors of Q_5 and Q_6 is both level shifted and converted to single-ended form to drive the output stage. Resistive level shifting is used because it offers more than a factor-of-two increase over the speed of lateral pnp transistors and will operate below the 7V zener voltage needed for zener level shifting. This allows the comparator to operate on a single 5V supply.

The output stage consists of driver Q_{12} and output transistor Q_{13}. Transistors Q_{15} and Q_{16} clamp the output from saturation, while Q_{14} provides limiting.

The rest of the circuit consists of biasing resistor R_{17} and an internal regulator to drive the current sources of the differential amplifiers. The internal operating currents are regulated against supply voltage changes and controlled over temperature to minimize changes in gain. As with many of the new comparators, no gold doping is used. This permits higher transistor current gains.

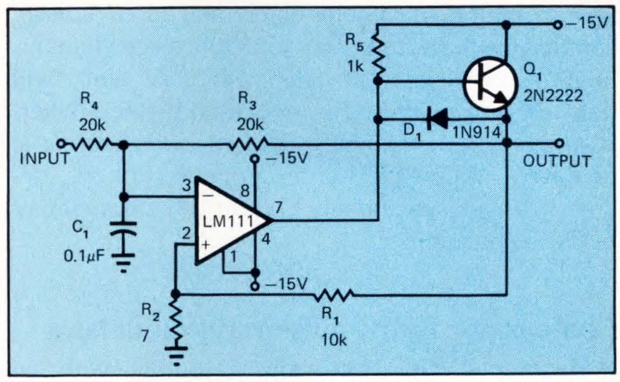


Fig. 2—The pulse ratio modulator delivers a pulse train output linearly proportional to input voltage.

Before describing actual comparator applications it is appropriate to mention some of the problems encountered with comparators.

The problem most often encountered is oscillation. This is not unexpected since comparators have high gain and wide bandwidths. (For example, the LM111 has in excess of 80 dB at 1 MHz.) Stray capacitance from the output back to the input of the comparator is usually the cause. Actually, stray capacitance from the output is not the only problem. If the comparator drives digital logic, the output of the logic can also feed back to the comparators inputs.

There are many approaches for eliminating oscillation. First, the inputs should be isolated from the output as much as possible. Input leads should be short, and routed away from the output. Shielded cable is a preferable method of connecting the input to a distant point. Second, source resistance driving the comparator should be low to minimize the effects of stray capacitance. If maximum speed is not of importance, a small capacitor—1000 pF—across the inputs to the comparator will help greatly. Finally, oscillation can only occur when the comparator is at threshold or in the linear region, so a small amount of positive feedback to induce snap-action and hysteresis will prevent oscillations.

The various types of comparators available have different input stages. Depending on the circuit con-

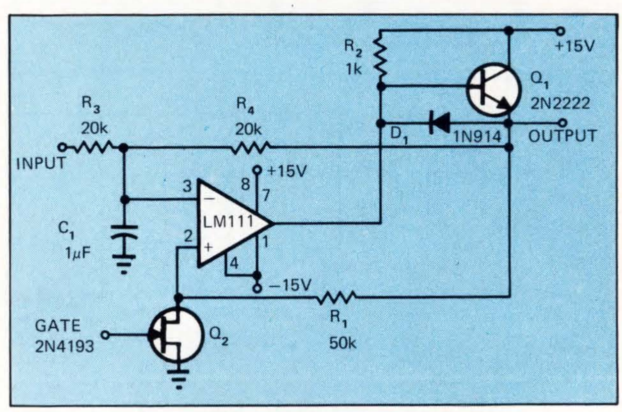


Fig. 3—The delta modulator has its output pulse width and transition time fixed by an external clock via JFET switch Q_2.

figuration, the maximum differential input voltage can be anywhere from ±5V to ±30V. Exceeding this limit, expecially for devices with ±5V limit, will degrade performance. This is caused by the emitter-base junction of the npn input transistor zenering at about 6V. When the transistors zener, the H_{fe} decreases, increasing the bias current and offset current of the comparator.

Comparator forms pulse ratio modulator

This circuit (**Fig. 2**) provides an output, with the average value of the output being proportional to the input signal. The output is a pulse train which varies both in width and frequency. However, over most of the dynamic range, frequency is relatively constant, with large changes occuring at the ends of the range. Pulse ratio accuracy is excellent, with 0.1% easily achieved. The circuit can be used to drive a power stage to make high-efficiency switching amplifiers, or for pulse-width/pulse-height multipliers.

The comparator is set to have about ±10 mV of positive feedback with R_1 and R_2. This insures that the output will be either "on" or "off", with about 20 mV of hysteresis. Negative feedback through R_3 is applied back to the inverting input. With no input signal, the circuit operates as follows: assuming the ouput is positive, the non-inverting input will be at +10 mV. The inverting input is less than +10 mV (or else the output would be negative). Current through R_3 charges C_1 until the voltage at the inverting input reaches +10 mV. At this time the output switches negative. The non-inverting input is then at −10 mV and C_1 begins charging toward −10 mV. When C_1 reaches −10 mV the output will switch again, starting a new cycle. R_5, Q_1 and D_1 provide a symmetrical output drive since the LM111 has an open collector output.

Current into C_1 from an input voltage either adds or subtracts from the charging current through R_3. If the current adds, C_1 will charge faster and the width of the output pulse will shorten. If it subtracts, the width will elongate.

Since the inverting input is always within ±10 mV of ground, it acts as a summing junction of an inverting amplifier. The gain of the amplifier is fixed by the input and feedback resistor (R_3, R_4) at unity, but any gain can be set. If the modulator is used with a power output stage, the feedback resistors, R_3 and R_1, should be connected to the power stage output.

A simple modification of the pulse-ratio modulator makes a delta modulator. With delta modulation, the average value of the output is also proportional to the input; however, the output pulse width and output transition time are fixed by an external clock.

Fig. 3 shows a delta modulator. Resistor R_2 in **Fig. 2** has been replaced by a JFET switch (Q_2). When the clock is negative, the FET is "off" and large positive feedback is applied to the non-inverting input of the comparator. This locks the output either positive or negative. When the clock goes positive, the positive feedback is shorted to ground. The input signal to the comparator is the voltage stored on C_1. This voltage is the integrated error between input signal and the comparator output. If the error is positive the output will switch negative, and if the error is negative the output will switch positive.

The size of C_1 is chosen to keep the error signal at the inverting input in the order of ±20 mV for the chosen clock rate. Thus, the inverting input will act as a summing junction of an inverting amplifier with a pulse train output. Gain is again set by R_3 and R_4.

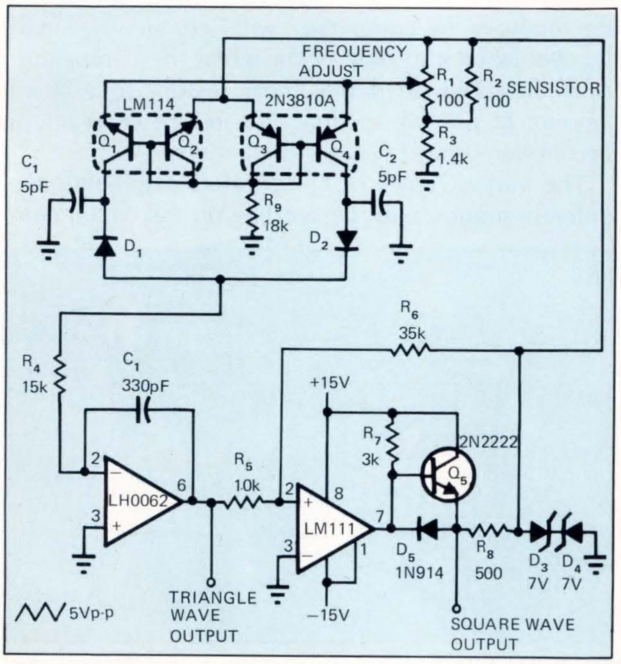


Fig. 4—Wide-range function generator produces square and triangle output waveforms whose frequency can be varied over five decades by potentiometer R_1.

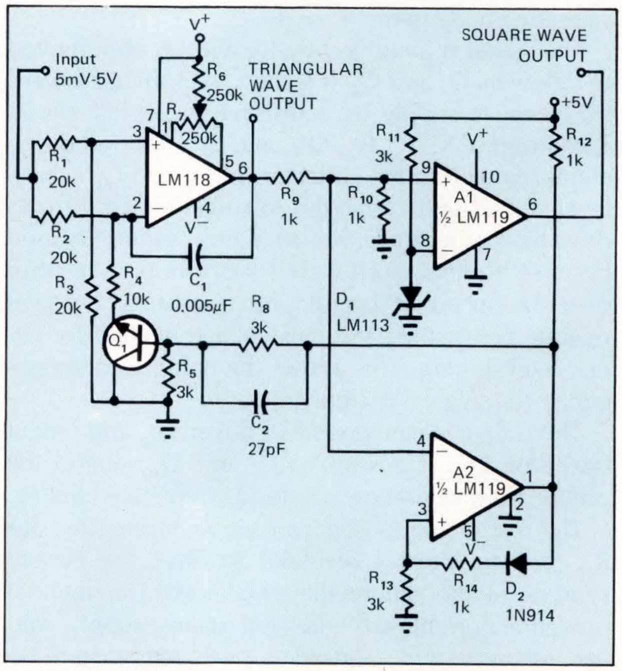


Fig. 5—Voltage controlled oscillator has both square and triangle wave outputs.

The clock pulse width must be much less than the clock period to minimize the uncertainty of the output transition time.

A simple analysis will help to understand why both of these circuits (**Fig. 2 and 3**) offer high accuracy. The error between the input and pulse-train output appears at the inverting input of the comparator. Since this error never exceeds 20 mV, the overall steady-state error cannot be greater than 40 mV, or 1% of a 4V signal. This is only a simple approximation showing 1% error; however, the actual error is much less.

Wide range generator is also possible

The circuit of **Fig. 4** shows a wide-range oscillator having both a square and triangle wave output. The operating frequency may be varied over five decades without range switching. Two transistor pairs are used to exponentially vary the charging current to a timing capacitor. The output current from the transistor pairs is controlled by a linear potentiometer, so that rotation of the potentiometer is proportional to the log of the output frequency. With the component values shown, the frequency is smoothly variable over about 1 Hz to 100 kHz.

Since the circuit operates over such a wide dynamic range, the op-amp integrator must have low input current for proper low-frequency operation as well as good 100 kHz response. In this case, a FET hybrid op amp is used. Transistor pair matching is also critical. Offset mismatches between the transistors will cause a non-symmetrical output. This can be somewhat compensated for by using non-symmetrical zeners (D_3 and D_4), or a small resistor in the emitter of Q_1 or Q_2. The best solution though, is to avoid the problem by using good transistor pairs. A sensistor (R_2) is used to compensate for the temperature sensitivity of transconductance of the transistor pairs, thus keeping the frequency constant.

As well as voltage controlled oscillators

Highly-linear voltage controlled oscillators are perhaps one of the more difficult designs encountered by a circuit designer. A relatively simple VCO is shown in **Fig. 5**. The circuit provides good linearity, with about three decades linear range. Additionally, the peak value of the triangle-wave output is precisely set at 2.44V and OV by the reference voltages at the non-inverting inputs of the comparators.

In operation, comparator A_2 drives the load for "low" outputs while A_1 drives the load when the output is "high". With A_2 "low", Q_1 is "off" and the LM118 integrates the input voltage to form a negative going ramp at its output. When the ramp voltage crosses the reference (OV), A_2 goes "high" and latches "high" because of positive feedback through D_2 and R_{14}. Q_1 turns "on" and the ramp goes positive. At a ramp voltage of 2.44V (2 times the 1.22V

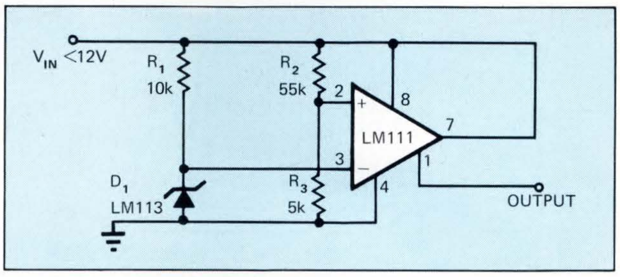


Fig. 6—Power-supply overvoltage limiter can handle load currents up to 50 mA.

reference), the output of A_1 goes negative. A_1 going negative also stops the positive feedback around A_2, so the output stays negative due to A_2. Therefore, the ramp integrates negatively toward zero volts again.

For good results with this circuit, certain precautions must be taken. Due to offsets, it is necessary to balance the LM118. This insures good linearity and symmetry at at low input voltages. The switching transistor Q_1 must be reasonably fast, as well as having low reverse "on" voltage. Actually, a FET would be a better switch, but it is somewhat difficult to find low "on" resistance FETs for use with ±5V supplies.

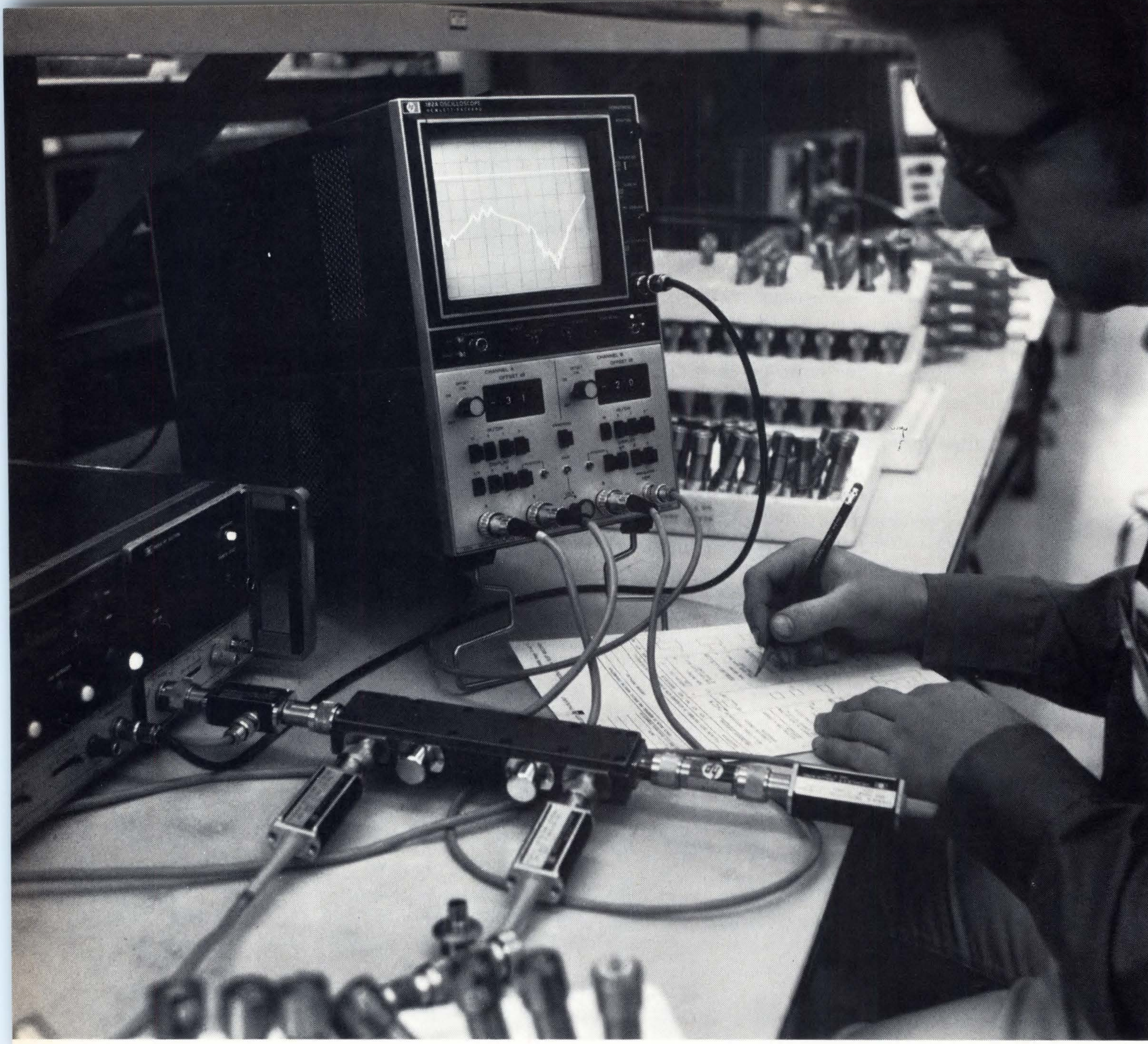
And an overvoltage limiter

A simple overvoltage protection circuit for circuits drawing less than 50 mA can be made with a single comparator. **Fig. 6** shows a limiter circuit for 12V.

In the circuit, a fraction of the input supply is compared to a 1.2V reference by the LM111. When the input exceeds the reference level, power is removed from the output. Since the LM111 has both the emitter and collector of the output transistor available, it can be used as the power switch for currents up to 50 mA. The drop across the internal circuitry of the LM111 when "on" is about 1.8V. If this is unacceptable, an external pass transistor could be used to reduce the drop to a few hundred millivolts. When the circuit is used to limit negative voltage, the drop is only the saturation voltage of the output transistor, or about 0.8V at 50 mA. For application with dual output, a dual comparator, like the LM119, can be used. □

Author's biography

Robert C. Dobkin, Director of Advanced Circuit Development at National Semiconductor Corp., Santa Clara, Calif., heads up a group responsible for developing linear ICs from inception to production. Before traveling cross-country to join National 4 years ago, Bob was employed by Teledyne Philbrick. Bob has attended MIT.



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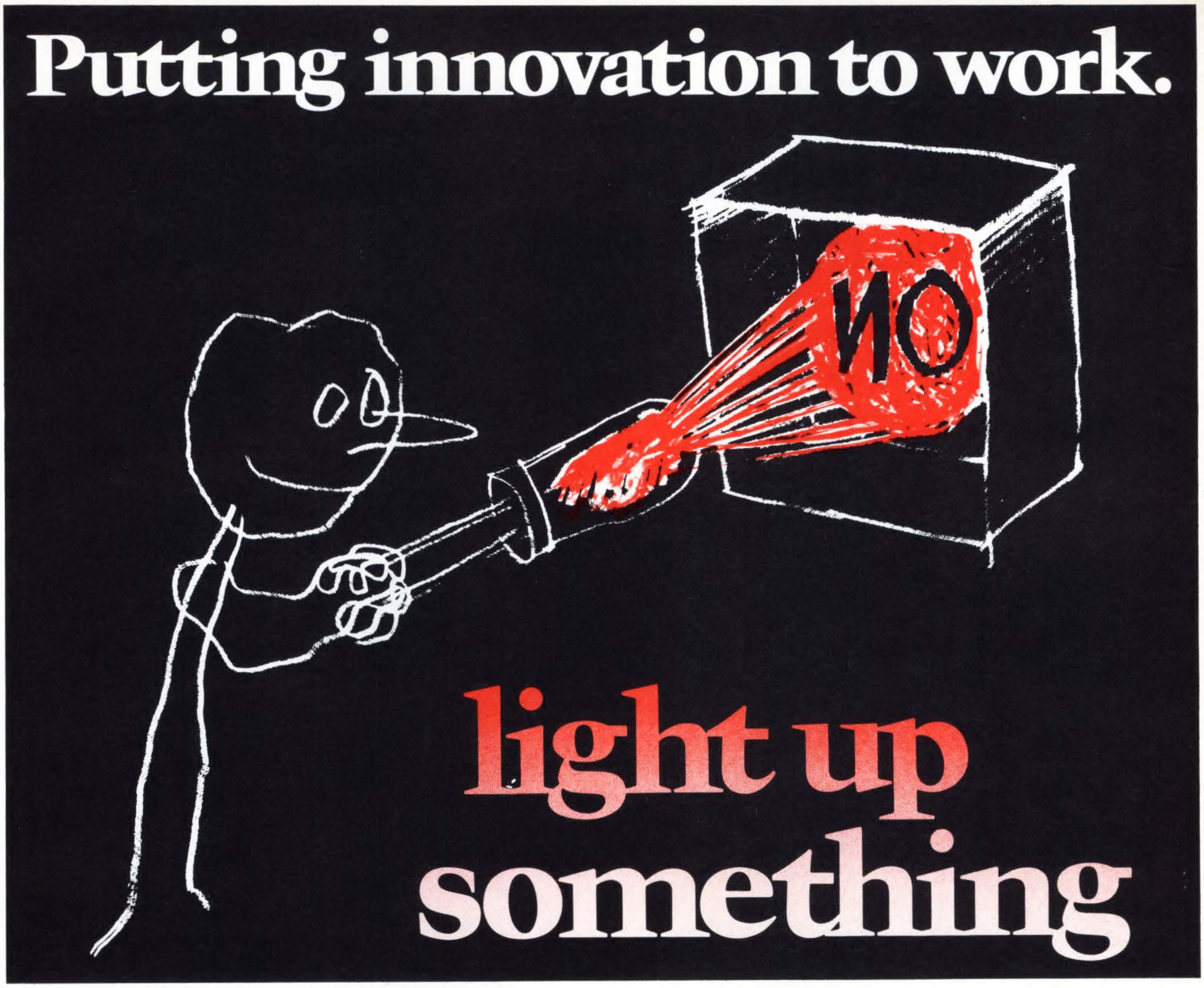

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CHECK NO. 19

Is your work starting to bore you? Beat monotony, and cure boredom!

If you are not careful, monotony and boredom can creep into your work, and productivity will suffer. Here are some ways to prevent it from happening.

Ernest W. Fair

Boredom and monotony are the enemies of every man in business, from engineer to chief executive. They do not necessarily happen during slack periods, but can develop even when he is busy all of the time. A constant effort is required to develop procedures to assure their absence as much as possible.

You can start by paying more attention to the people you are involved with, rather than just their everyday working problems. Business problems are all fairly similar to one another; humans are not. If you deal with customers for example, such attention can open up new interests because attention is directly focused upon them, as well as upon the problems involved in taking care of their needs.

It doesn't hurt to rock the boat

Whenever you feel boredom arising from what you are doing, right then and there is the time to rearrange your work schedules. Do so primarily with the goal of destroying any element of monotony in your work. That element of monotony is a great contributor to boredom in what one is doing, while on the other hand, variety in one's efforts invariably arouses an increased interest. Its absence will destroy interest and much initiative.

Constantly look for something new and different in what you are doing, regardless of where your assignment leads you in the structure of the business operation. Sometimes such things can slip by unnoticed. Each one has the potential of combating boredom. The challenge of anything new and different invariably makes any job more interesting. Set up your own challenges regularly. If you wait for them to originate elsewhere, they are usually slow in coming, if at all. After a certain period of time, you probably feel that you have met most of the challenges connected with your work. If this is the case, it is necessary to search diligently for new ones.

Do as many of the necessary but dull routines involved with your job the first thing each morning.

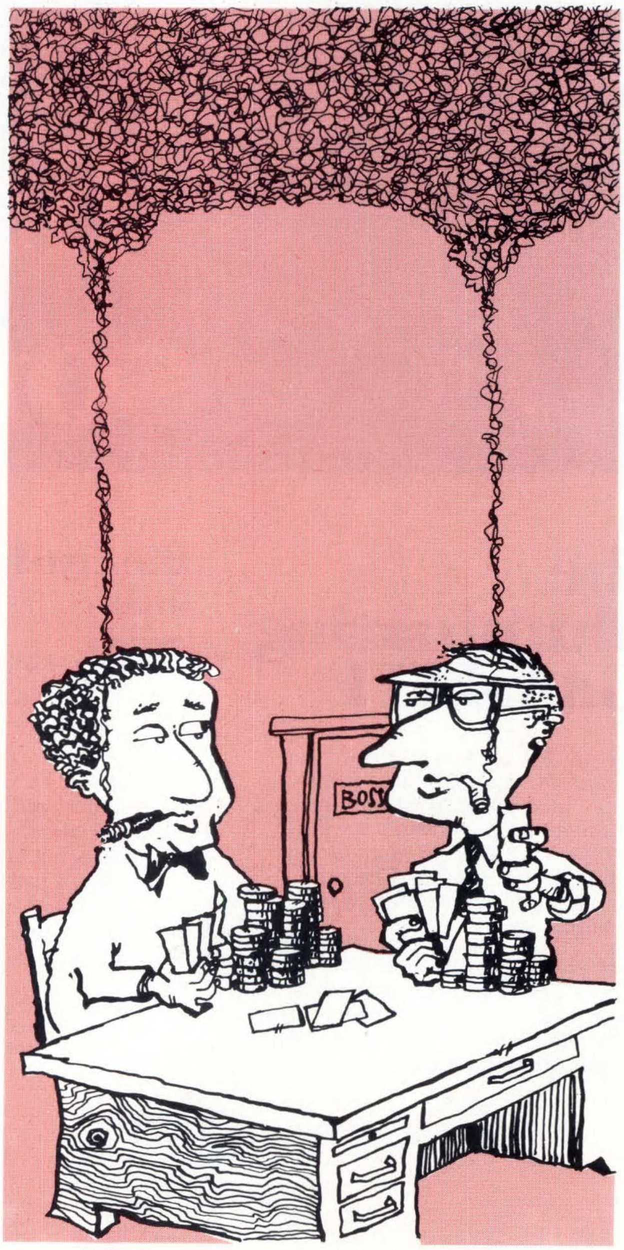


Fig. 1—This is an excellent way to beat boredom, but the boss might object.

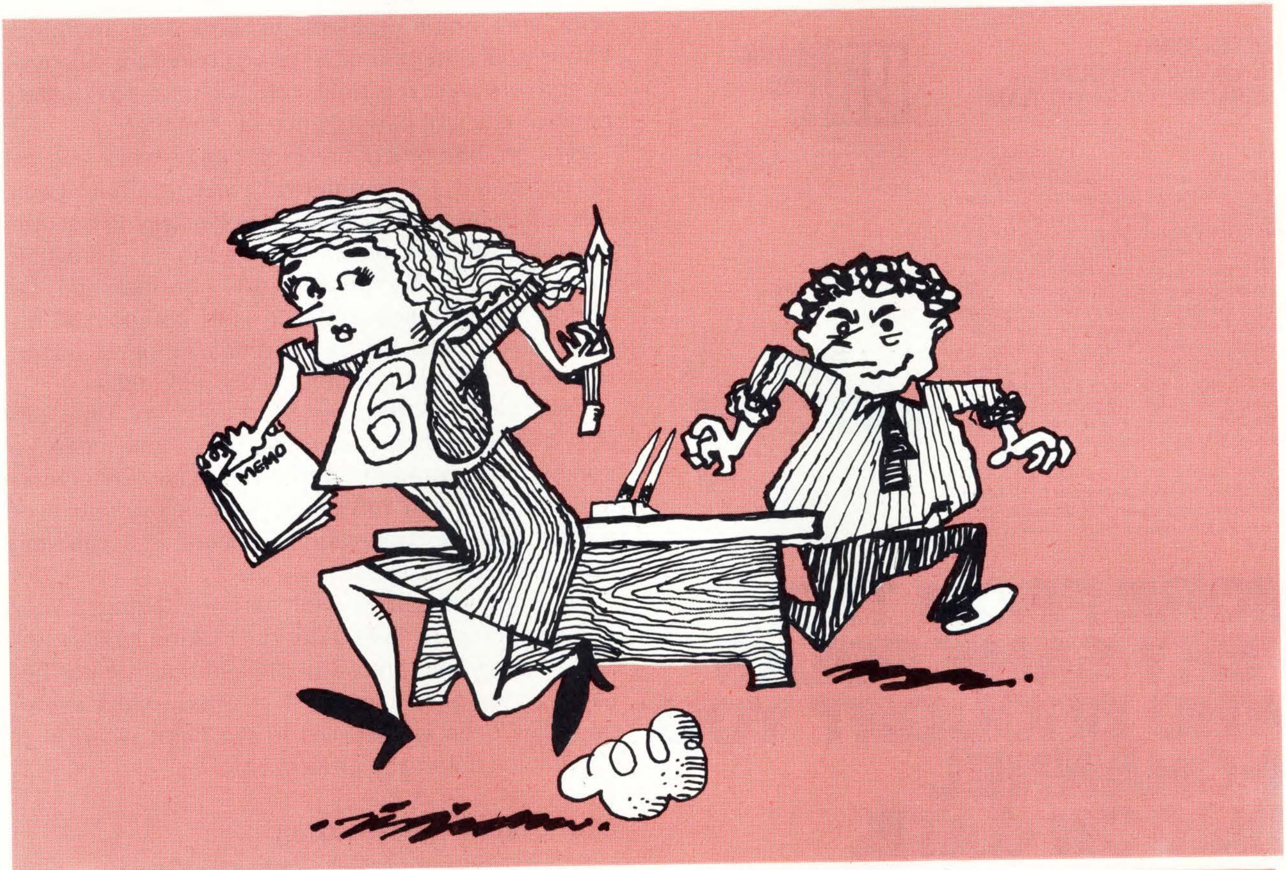


Fig. 2 – There's no monotony in this office, but it's rough on the secretaries.

This is a far better procedure than having them intrude on everything else being done throughout the day. Dull routines are always great cultivators of boredom.

Get out of the rut!

Avoid over-systemizing your work. Too high a degree of such systemization is always one sure way of generating boredom anywhere. When that happens, an individual becomes nothing more than a machine in what he does, and while machines cannot become bored with such circumstances, human beings most certainly will.

Pay more attention to other people's ideas than you have in the past. This listening process will always help to break any existing feelings of boredom that may have arisen. Countless experiences have proven that when this concept is explored in depth, some very useful benefits for the business invariably emerge.

Take a breather from your work every couple of hours. It need only be for three of four minutes at the most. Usually it's best to do something entirely different from what you have been doing previously. This is especially valuable when one becomes bored with an uninteresting task of any nature.

Stop taking your work home with you, and don't

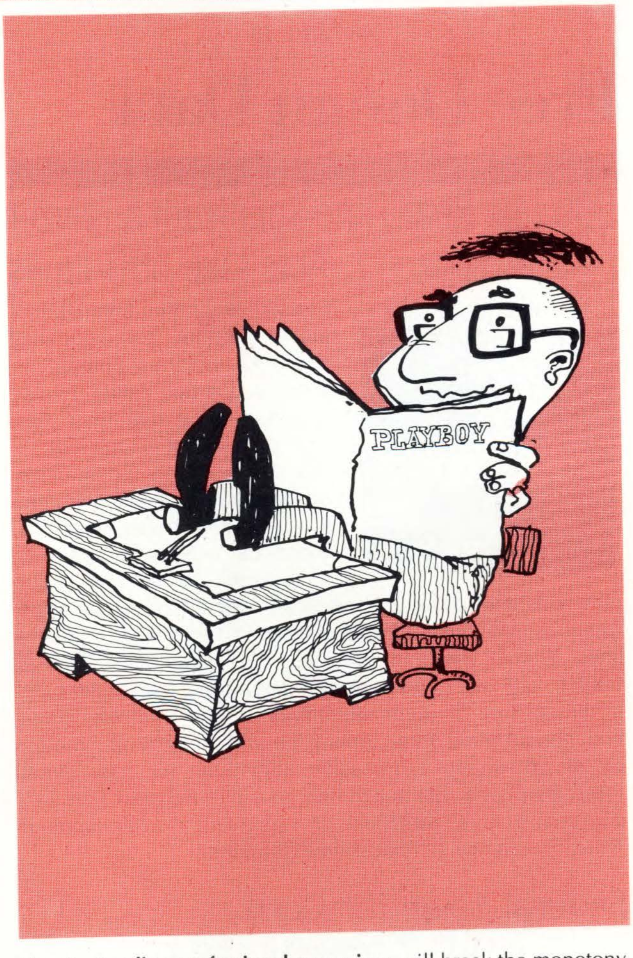


Fig. 3 – Reading professional magazines will break the monotony of every-day routines.

bring your home problems to work each morning. This is a sure method of adding to boredom whenever and wherever it is practiced. Each acts to counterbalance efficient performance of the other.

Pick out one procedure each day or week and try to approach it a little differently than you have been doing it in the past. Look for a better way to accomplish the desired result. When this is a regular method of operation in any man's business life, he seldom has any acquaintance with boredom at his work at any time. Of course, this method of operation won't hurt your professional stature either.

Don't overlook the people around you. They can also use some help to combat this same negative condition of boredom with their work. Otherwise, their attitudes can rub off on you before you ever realize what is happening. Boredom is a catching disease in any business.

Slow down the pace you have been setting in your daily working life. Speed-ups of any kind tend to systemize everything into a boring routine, simply because such speed is seldom attained unless everything has been worked out to the point where it is virtually an automatic procedure.

Don't make work a drag!

Inject a little more fun and humor into your work than you have in the past. The complete absence of this pressure-releaser will make everything that you are doing less attractive; and therefore, more boring.

Remember some of those enthusiastic approaches that you had during your first year or two out of school? Seek them out and use them once again. There was probably no element of boredom in your work at that time. Reuse of these approaches and attitudes toward your work can give them equal value once again.

When you leave each day also leave something interesting to come back to and tackle the next morning. This assures that not even a small degree of boredom will be present at the start of the next business day. □

Author's biography

Ernest W. Fair is one of a rare breed—a free-lance author. For 37 years his by-line has appeared on articles in many of the leading business magazines of the nation. When he's not traveling on assignment or digging out details for a story, he makes his home in Portland, Oregon.

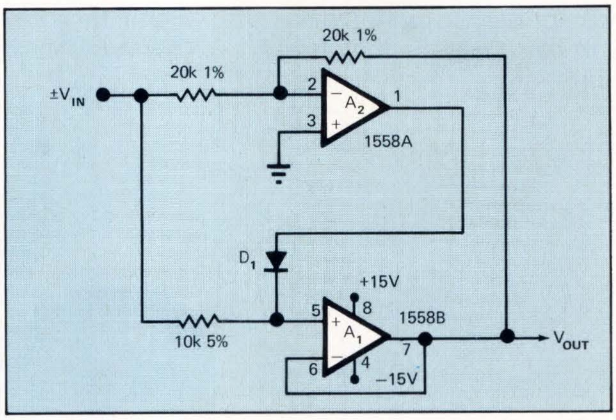
EDN DESIGN AWARDS

Absolute value circuit uses only five parts

Robert J. Wincentsen, King Radio Corp.,
Overland Park, Ka.

Here is an absolute value circuit that uses only five components and requires only three precision parts. The circuit has been tested from −55°C to +85°C and the output had less than 1% change from +25°C measurements. The circuit is useable and linear from zero input to op amp saturation. However, CR1 must be a low-reverse-leakage diode, such as a 1N914A, to have min. effect on the positive transfer and low offset at zero input.

The circuit is basically a voltage follower, A_1, whose input is positive regardless of V_{in}. With a positive V_{in} input, the inverting amplifier, A_2, is disconnected by D_1. With a negative V_{in} input, the inverting amplifier applies a positive input to the voltage follower through D_1 to null the inverting amplifier. □



Voltage follower A_1 is provided with a positive input regardless of the polarity of input signal V_{in}. The circuit transfer function is therefore, $V_{out} = +|V_{in}|$.

**To Vote For This Circuit
Check 150**

Two ICs convert excess-three Gray code to BCD

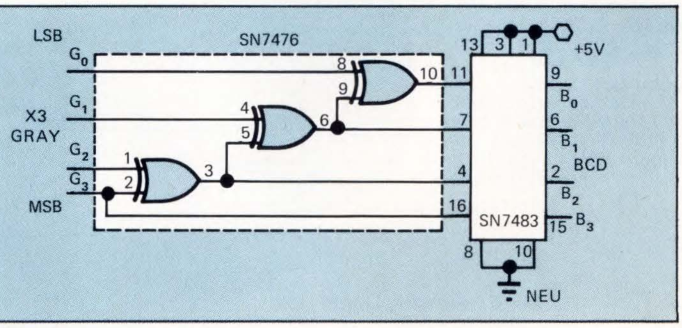
Douglas M. Risch,
Wall Electronics, Albuquerque, N.M.

Often, the output of a shaft encoder is in the form of excess-three Gray code. An easy way to convert this code to BCD using two TTL integrated circuits is shown here. To convert a regular Gray code to BCD, eliminate the 7483 4-bit adder.

Since the Gray code is a distance-one Hamming code it is easily decoded by the parity-checking exclusive-ORs in the 7476. The X-3 Gray code is simply a regular Gray code shifted down by three. Thus, by using the 7483 to subtract three, the desired output is obtained. The scheme is easily expanded by cascading exclusive-ORs and adders. □

**To Vote For This Circuit
Check 151**

BCD	GRAY	X-3 GRAY
0000	0000	0010
0001	0001	0110
0010	0011	0111
0011	0010	0101
0100	0110	0100
0101	0111	1100
0110	0101	1101
0111	0100	1111
1000	1100	1110
1001	1101	1010



Exclusive-ORing followed by a subtraction of three converts the excess-three Gray code to BCD.

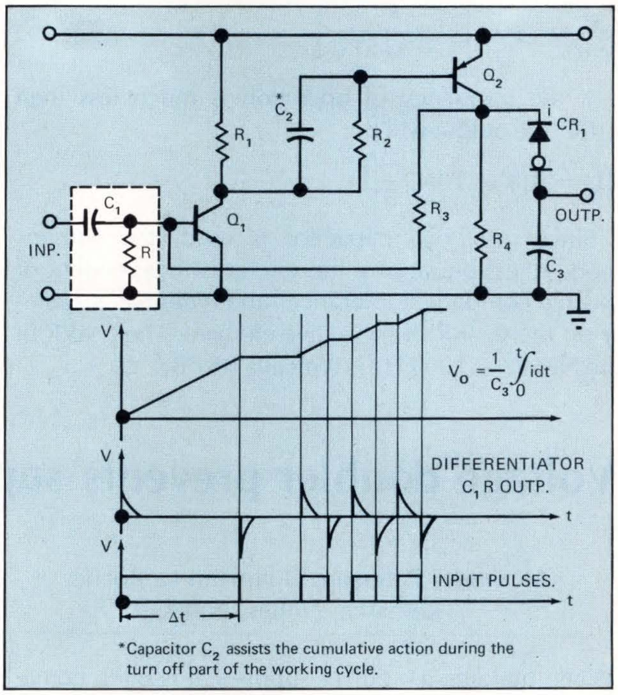
Linear circuit integrates pulse trains

Andres J. Baracz,
Sparta, N. J.

The circuit shown performs linear integration in a very simple manner. The circuit consists of a complimentary transistor which can be turned on and off by means of short pulses of alternate polarity, or by spikes applied to the base of transistor Q_1. A differentiated square pulse will produce a positive spike corresponding to its leading edge, and a negative spike, corresponding to its trailing edge. The positive spike will turn the transistors on, charging the capacitor via the constant current device, a negative spike will turn the transistors off. Thus, the charge on the capacitor C_3 will be controlled by the time interval between positive and negative spikes, or by the duration of the square pulses.

The charging of the capacitor via the constant current device will generate a linear voltage ramp at the terminals of the capacitor C_3. The final magnitude of this voltage will be directly proportional to the time integral of Q. Any subsequent pulse will produce an additional voltage increment proportional to its duration.

A train of pulses will generate a staircase function, with increments proportional to the duration of the pulses. Square pulses in the nsec range will actuate the circuit. ☐



Pulses in the nsec range will actuate this linear integrator. It's output is a linear function of input current and pulse duration. Capacitor C_2 assists the cumulative action during the turn off part of the cycle.

To Vote For This Circuit
Check 152

Video amp solves high-frequency differentiation problems

Dan McCranie, Signetics Corp.,
Sunnyvale, Calif.

Traditionally, differentiation of high-frequency, low-level signals has required closely matched components in order to avoid common-mode noise problems. A typical method of differentiation is shown in **Fig. 1.** The RC networks of each side of the differential amplifier must be matched to within 0.1% in order to exceed 60 dB common-mode rejection. Obviously, the capacitors will have to be selected for both absolute value and temperature tracking equivalence.

By using the NE592 differential video amplifier and a single component, a high-frequency differentiating amplifier with excellent common-mode rejection can be made with no critical tolerance components. This circuit is shown in **Fig. 2**.

The NE592 is a differential-input/differential-output video amplifier with a restructured input. With the modified input, the amount of signal to be differentially amplified is dependent on the amount of signal coupled between pins 4 and 9. If pins 4 and 9 were left open, for instance, the differential gain of the device would be 0. If the two pins were shorted together, the differential gain would be max., or about 400. The capacitor between pins 4 and 9, therefore, will cause the device to function as a high-pass or differentiating amplifier.

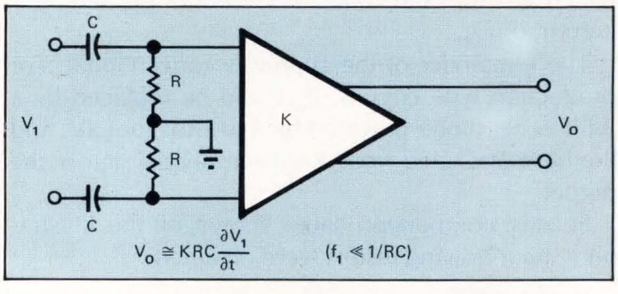


Fig. 1—Conventional differentiation scheme requires matched passive components.

The voltage transfer function for the circuit of **Fig. 2** is:

$$\frac{V_0(s)}{V_1(s)} = 400 \left[\frac{s}{s + 1/40\ C}\right]$$

If the frequency of operation is much less then 1/RC, the output will be:

$$V_0 = 1.4 \times 10^4 C \frac{\partial V_i}{\partial T}$$

Since only one capacitor is used, the comon-mode rejection ratio of the circuit is independent of passive component tolerances and is dependent solely on the CMRR of the active element. The CMRR of the NE592 at 100 kHz is typically 86 dB. □

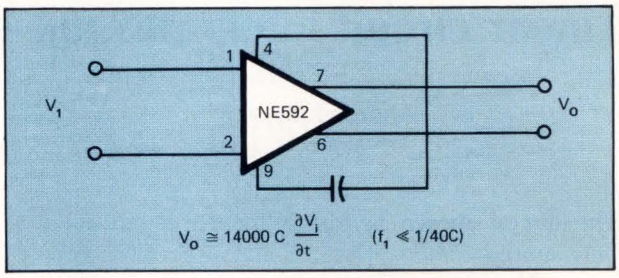


Fig. 2—No component matching is required with the NE592 differential video amplifier.

To Vote For This Circuit Check 153

Voltage doubler prevents supply from losing regulation

Alexander Paterson, Hoffmann La Roche Research, Nutley, N. J.

When building 5V power supplies, it is often convenient (and inexpensive) to use a 6.3V filament transformer. A limitation is imposed, however, since at low line inputs (below about 105V) a conventional supply can lose regulation due to malfunction of the components driving the pass transistor base and the regulator section. This circuit uses a voltage doubler to drive these components so that regulation is maintained down to the saturation voltage of the pass transistor (Q_1 in the circuit).

Operation of the circuit is as follows: On one-half cycle ($V_A > V_B$), C_2 charges to approximately the secondary peak voltage through D_5, and C_3 does likewise via D_5, D_6 and D_3. On the other half cycle ($V_B > V_A$), D_5 is back-biased and C_3 charges to roughly twice the peak secondary voltage via C_2, D_6 and D_1. (Alternatively, referring all voltages to ground, D_6 and C_3 peak-detect the voltage on the positive terminal of C_2; this voltage consisting of a dc component, V_P across C_2, and a half-wave alternating component with peak value V_P existing on the negative terminal of C_2.) The voltage doubler output is used to drive both Q_2, which provides Q_1's base current, and Q_4, a diode connected FET which provides the collector current of Q_3 and base current of Q_2.

The remainder of the supply is conventional. For production type circuits, Z_1 could be replaced by a 3.6V zener diode powered by a resistor to +5V, and the base of Q_3 fed from a voltage divider across the output.

For the component vlaues shown on the illustration, the following results were obtained:

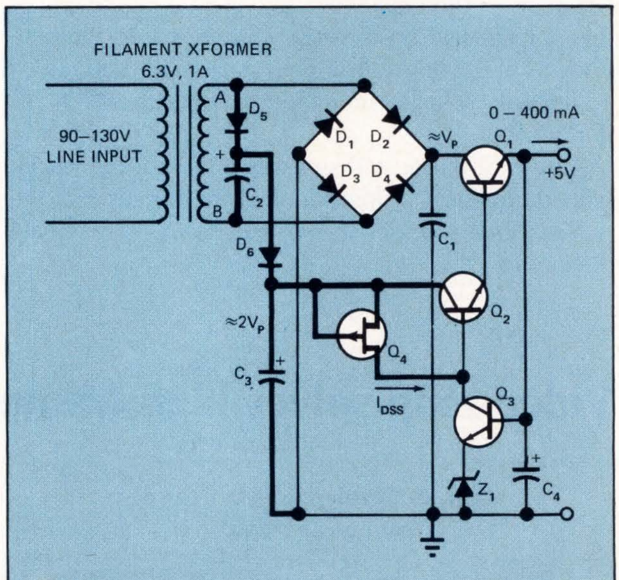
Line regulation

V_{IN}: 95 – 135V ΔV_{OUT}: 6 mV

Load regulation

I_L : 0 – 400 mA ΔV_{OUT}: 3 mV

V_{IN}: 115V □



COMPONENT VALUES

D_1 THRU D_4	1N4001
D_5, D_6	1N914
C_1	8000μF, 15V
C_2	50μF, 25V
C_3	250μF, 25V
C_4	100μF, 10V
Q_1	MJE 521 (HEAT SINK)
Q_2, Q_3	2N3392
Q_4	CONSTANT CURRENT DIODE, (e.g. 2N5033, 2-3 mA)
Z_1	REF. DIODE, 4.3 V @ 2-3 mA (e.g. LVA43A)

Voltage doubling is accomplished by operation of C_2, C_3, D_1, D_3, D_5 and D_6.

To Vote For This Circuit Check 154

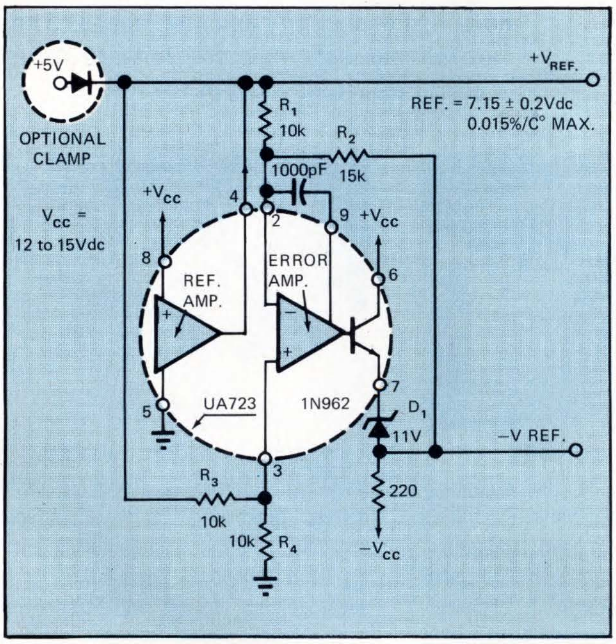
Dual 7V reference developed from a single uA723

David Weigand,
Gulf and Western Research, Swathmore, Penn.

In analog designs, dual polarity references are often required. The temperature stability and regulation capability of the μA723 IC voltage regulator makes it highly useful for such purposes. The circuit shown in the illustration generates both +7V dc and −7V dc from a single μA723 chip. The +7V reference is obtained directly from the 723 temperature stabilized zener reference amplifier. This positive reference is also applied to the internal error amplifier connected as a unity-gain inverting op amp. The resulting output from this error amplifier is the −7V reference.

The trick in using the single-supply error amplifier is to keep both inputs and output within the dynamic range of the amplifier (+2 to +9V). This is done by upward level shifting the output voltage with zener diode D_1 and the input error voltage with the R_1, R_2 voltage divider.

Changing the R_3, R_4 ratio will result in different negative reference values. An optional 5V diode clamp on the plus reference will prevent power-on lockout from the negative power supply.



The negative reference voltage in this dual reference circuit is obtained from the internal error amplifier of the μA723.

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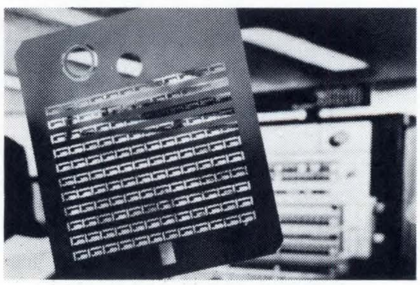

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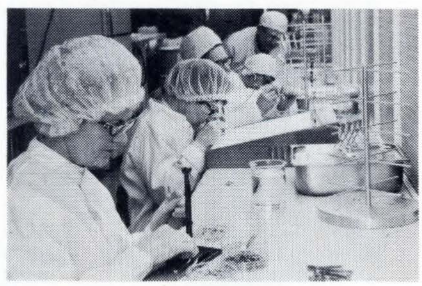

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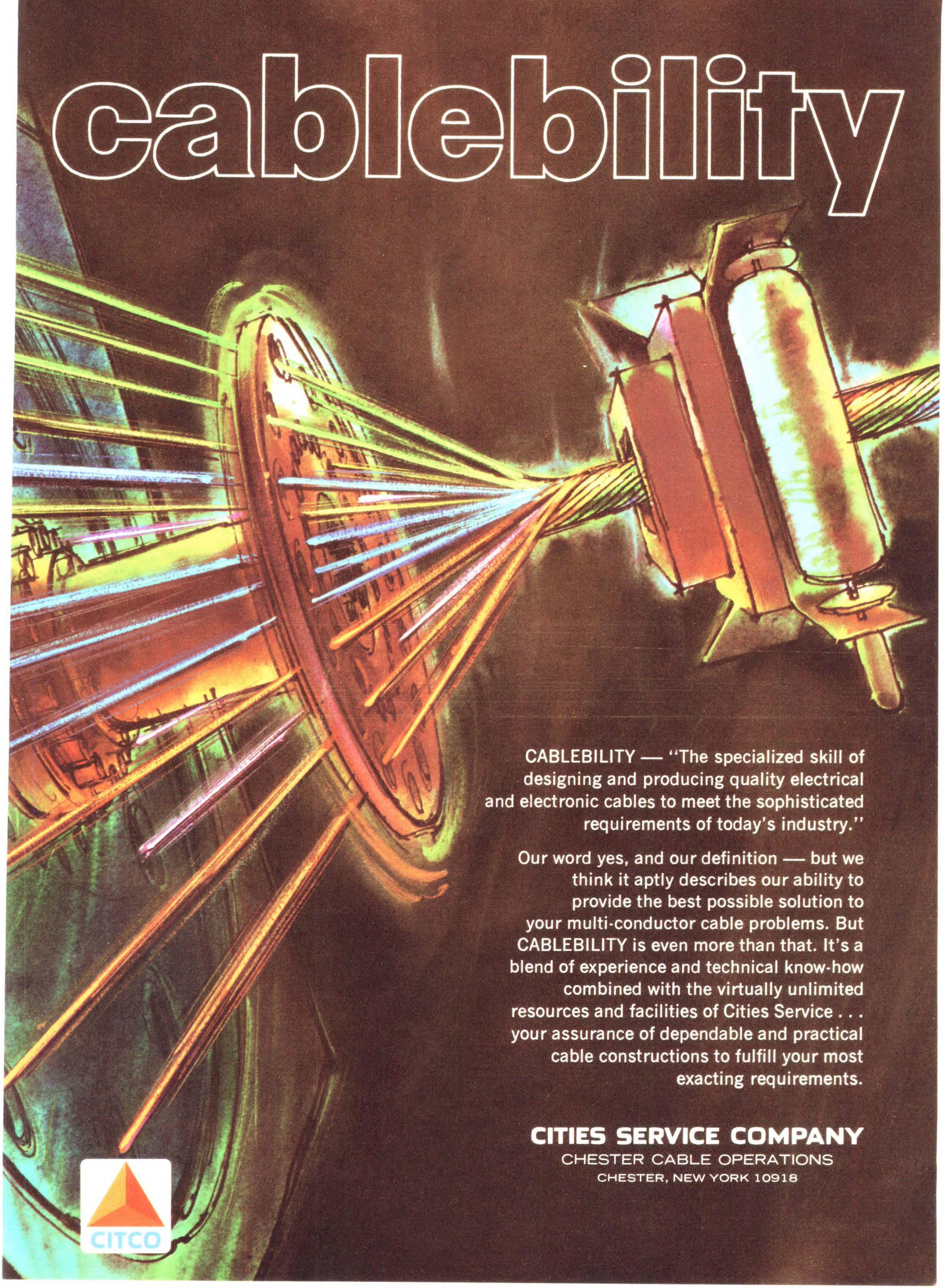
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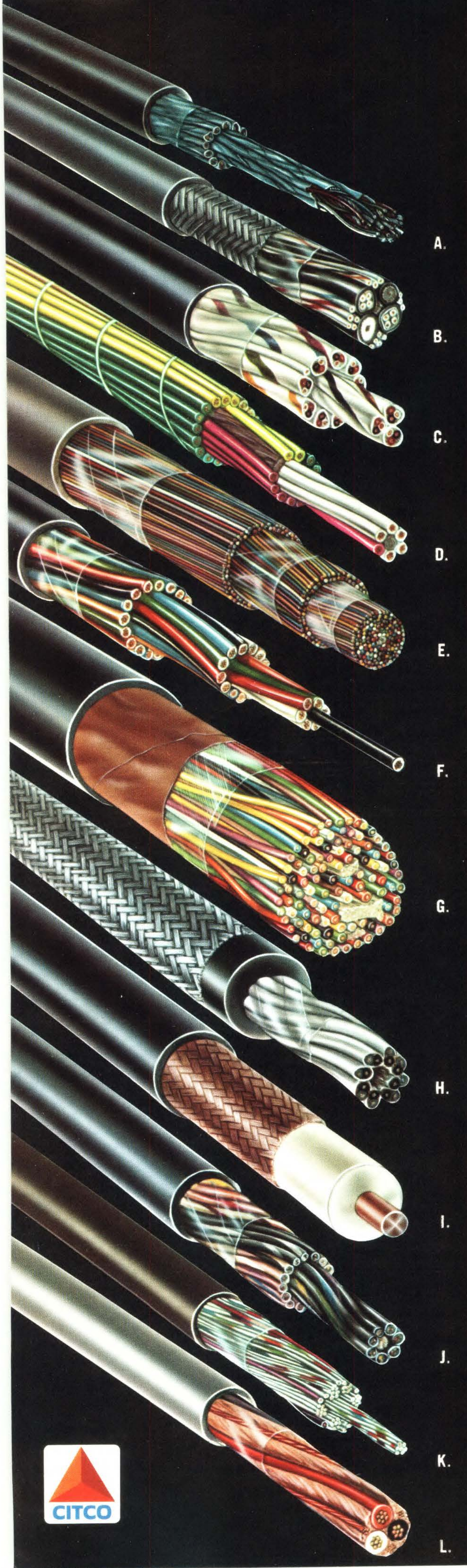

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H. **CITCO SHIPBOARD CABLE:** Stranded conductors, nylon-jacketed PVC insulation, pairs shielded and jacketed, cabled, PVC jacket, and aluminum braid armor overall; per spec. MIL-C-915.

I. **CITCO COAXIAL CABLE:** Type RG-218/U, solid copper conductor, polyethylene insulated, copper braid shield, PVC jacket; per spec. MIL-C-17/79.

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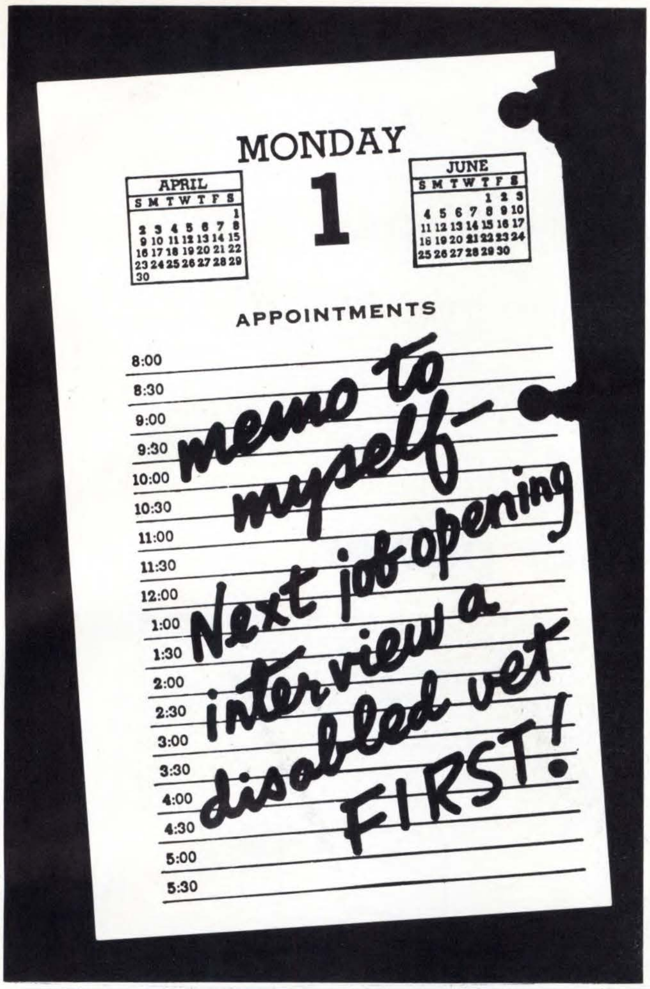

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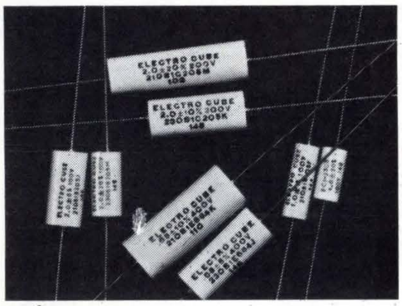

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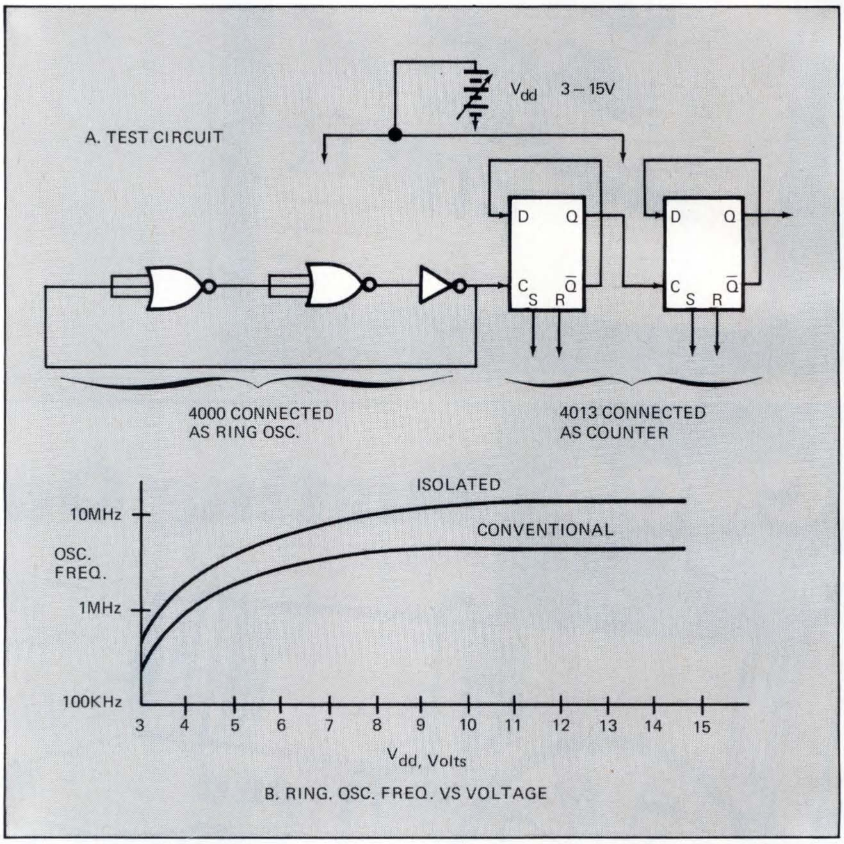
CHECK NO. 46

"Isolated" CMOS has higher speed and lower power

PROGRESS IN SEMICONDUCTORS

Two IC manufacturers—Harris Semiconductor and Inselek—have come out with higher-speed versions of some of the 4000A CMOS logic family. The 1-1/2 to 3 times higher speeds are the result of dielectric isolation that cuts down the output capacitances of the CMOS gate stages to essentially zero plus a few pF for output pin wiring rather than the 5 pF (or more) for the conventional junction isolated CMOS from RCA, Motorola, Solitron and others. Harris achieves this isolation by surrounding the device tubs with polycrystalline silicon while Inselek forms its devices as islands on a sapphire substrate.

Comparing the two processes, the Harris approach appears to give a larger speed advantage and a lower static leakage. Harris claims speeds 2-3 times as fast as the standard CMOS while Inselek is only claiming a 50 percent speed advantage. Harris claims an order of magnitude lower quiescent current while Inselek is claiming no particular advantage here. But both say that the first devices they are offering do not begin to tap the performance potential of dielectric isolation. This seems reasonable because RCA Research Laboratory at Princeton, N. J., has already demonstrated that speeds as high as 50MHz are possible with isolation. Right now, the thrust of Harris and Inselek appears to be the production of conservative, manufacturable devices that can be sold at the same prices as standard CMOS.



Quick and dirty circuit (a) used by EDN to compare the new dielectrically isolated CMOS to previous junction isolated units. The three gates formed a self-oscillating ring that exercised the flip-flop counter. Values in curves (b) do not accurately indicate full speed potential of either type as ring oscillators tend to produce sloppy sinewaves rather than sharp squarewaves. Incidentally, it can be seen that CMOS circuits with their wide operating voltage ranges produce useful VCOs. This circuit could span the entire AM broadcast band with just a few volts variation on Vdd.

As neither Harris nor Inselek will have the complete 4000A line for a while, most designers will be considering these higher-speed devices in systems mainly made up of the existing slower junction isolated CMOS 4000 (or National's CMOS replacement for low-powered TTL). Here the degree of advantage gained becomes a tricky question. The Harris gates, for example, use larger transistors to reduce the ON-resistance from the standard CMOS levels of 500-to-750 ohms or higher down to 200 ohms. This is possible because with dielectric isolation, Harris doesn't pick up additional output capacitance with larger devices. However, the increased device size means some of the Harris gates have higher input capacitance—7 pF vs 5 pF. This presents no problem as long as the Harris devices are being used with each other, for the significantly lower ON resistance more than makes up for the slight increase in input capacitance. But if Harris gates are being driven by regular CMOS devices, this increase in capacitance could actually slow down the system! If, on the other hand, Harris (or Inselek) devices were driving regular CMOS devices, the logic fanout and speed could be increased, again because of the lower ON resistances feasible with isolation.

Where both the Harris and Inselek technologies will really shine, however, is not at the gate level of the first announced units, but at the complex level of future MSI units. Then there will be enough stacked-up on-chip delays, coupled with controllable low on-chip capacitances, that the performance gain will really leave standard junction isolated CMOS in the dust. EDN noted this when it plugged a Harris 4013 dual D flip flop in place of an RCA 4013 in a counter circuit. The Harris unit would continue to toggle at speeds in the 6 MHz and above region after the RCA unit had started to skip. As explained by Harris designer Bill White, the isolated unit could propagate the signal through the five gate delays in this master-slave flip flop and get the $\bar{Q}$ output back to the D input in time for the next clock pulse, while the RCA unit could not.

Our comparison-by-substitution tests indicated that speeds of standard CMOS (from RCA and Motorola) and the isolated CMOS (Harris) are equally sensitive to supply voltage. At the low-voltage end—3V—the circuits slow down to just the 1 MHz level (though the isolated unit still retained its 2:1 to 3:1 speed advantage). White explained that this was due to the reduced drive margin (over the 1-1-1/2V device thresholds) for turning the channels hard ON. At lower voltages the channel ON resistance is higher.

Comparison of CMOS Family Types

Parameter \ Mfg.	RCA	Motorola	Harris	Inselek
Form of Isolation	Junction	Junction	Dielectric	Dielectric (SOS)
Supply Range (V)	3-15	3-18	3-18	5-15
Gate Output Resistance (Ohms)	750	500	200	200-300
Gate Output Cap. (pF)	5	5	2 (stray)	2 (stray)
Gate Input Cap. (pF)	5	5	7	5
Propagation Delay (nS) (at 10V supply)	25	25	10	
FF Clock Rep. Rate (MHz at 10V supply)	10	10	15	
Gate Quiescent Power (uW)	0.025	0.025	0.001	0.025

Isolated CMOS Devices Now Available

(in terms of 4000 family numbers)

From Harris: 4000, 4001, 4009, 4010, 4011, 4012, 4013 plus 4809, a Harris addition to the family. (35 total 4000 units within a year)

From Inselek: 4012 (Two more units, 4027 and 4030 to be available soon).

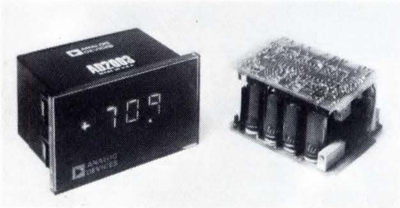
The standard 4000A family test measurements do not do the faster isolated units justice at higher voltages where they can operate quite fast. The standard test waveforms have slow 20-nsec rise times and are not really representative of the operating waveforms a 10-nsec propagation delay isolated gate system would experience. White says this is one explanation for the fact that Harris 4000-type spec sheets showing diminishing increases in speeds for supplies over 10V. With sharp step test inputs, the Harris devices will show continued improvements in speed as the supply voltage is raised to the full 18V limit (military units), White says.

EDN has not had the opportunity to examine any of the Inselek units. Carl Rapp of Inselek told EDN that Inselek will introduce the 4000A series with their SOS technology at a slower rate than Harris. He agrees with Harris that these first gate-level units do not begin to show off the full speed and power-saving ability of dielectric isolation technology. He believes that future improvements such as self aligned gates and ion implantation (which Harris is phasing into its production line) will allow speeds up to 50-100 MHz. But these future improvements will only be meaningful at the LSI level.

One question that will not be answered until Harris and Inselek get into volume production is whether they can really meet the ever-lower pricing of junction isolated CMOS. Harris obviously is banking its hopes on its ability to produce high yields of 3-in diameter wafers. . . and it appears to be hedging its bets by also coming out soon with a fine geometry junction isolated version of CMOS, (using the poly-iso-planar process). Harris projects costs as low as 0.06¢/gate by 1975 if it can achieve 10 percent overall yields. It will probably need these yields if it is to achieve its targeted 15-25 percent share of the CMOS market by 1975—a market that Harris projects at $130 million.

Harris Semiconductor Div. of Harris-Intertype Corp., Melbourne, FL 32901. (305) 727-5430 **164**

Inselek, 743 Alexander Road, Princeton, N J 08540. (609) 452-2222 **165**



3-1/2-DIGIT SYSTEM DPM Model AD2003 features a true-differential-instrumentation-amplifier input, fully latched BCD outputs and a $93 price in 100's. The 5V dc powered AD2003's input amplifier provides CMR of 80 dB minimum, NMR of 40 dB and minimum common-mode voltage of ±2.5V. It accepts bipolar and differential signals over 0 to ±199.9 mV with a maximum error of 0.05% ± 1 digit. Polarity and overload indications are provided. The AD2003 has a seven-segment green filtered incandescent Numitron display and is housed in a 1.8 × 3 × 2-in. aluminum case. Analog Devices, Inc., Route 1 Industrial Park, Norwood, MA 02062. Phone (617)329-4700. **200**

C-V SYSTEM FOR MOS-WAFER AND VARACTOR-DIODE EVALUATION. The Model 179A is a low-excitation-level, 1-MHz "turn-key" system for producing C-V data on MOS wafers and varactor diodes. It consists of a Boonton Model 72A, 1-MHz capacitance meter, a Boonton Model 16A ramp voltage generator and an 8-1/2-×-11-in. X-Y pen recorder to automatically produce capacitance vs dc-voltage data in the form of X-Y plots. Ramp voltages are programmable over a ±100V range and ramp rates may be set from 0.1V/sec to 2.0V/sec. The system including enclosure costs $3650. Boonton Electronics Corp., 1279 US Route 46, Parsippany, N J 07054. Phone (201)887-5110. **201**

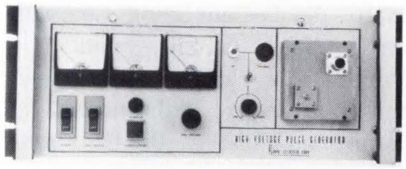
MINIMUM/MAXIMUM DIGITAL INDICATOR SHOWS PROCESS LIMIT CONDITIONS. The new meter enables a designer to inexpensively record actual process extreme conditions encountered during a test period. Any Digilin 1000, 2000 or 3000 Series instrument can be used with the meter; BCD information is fed from the measurement meter to the minimum/maximum meter. Depending on whether minimum or maximum has been selected, the display is updated only when the new reading is lower or higher than the old reading. The measurement meter displays show the actual reading while the minimum/maximum meter shows the extreme variations. Both three ($204) and four-digit ($240) units are available. Digilin, Inc., 1007 Air Way, Glendale, CA 91201. Phone(213)240-1200. **202**

PANEL-MOUNTED DIGITAL TIMING INSTRUMENTS for use in manufacturing test and process-control applications. The LT20B Series digital timing instruments provide accurate measurements of fractional time periods in 30 different models that provide the selection of any range and configuration from microseconds to minutes. Used as a replacement for many electromechanical devices, all 30 models use start and stop action that can be triggered separately or from a single line. A choice of 2 to 5-1/2 digits with prices starting at $106 in single quantities is available. Durgin & Browne, Inc., 80 Allen Rd., S. Burlington, VT 05401. Phone(802)863-6873. **203**

SINGLE AND DUAL-OUTPUT POWER SUPPLIES AVAILABLE IN LX-EE PACKAGES. Lambda has expanded its LX line to include seven new single-output voltage power supplies and one dual-output voltage power supply in the "EE" package size—7-1/2 × 16-1/2 × 4-15/16 in. All the supplies are guaranteed for all labor and parts for 5 years. Some prices and ratings are as follows: LXS-EE-5-OV (5V at 25 to 45A, depending on temperature) at $425; LXS-EE-15 (15V at 14 to 28A) at $400; and LXD-EE-152 (±15V to ±12V at 7-12.5A to 6-10A) at $435. Lambda Electronics Corp., 515 Broad Hollw Rd., Melville, NY 11746. Phone(516)694-4200. **204**

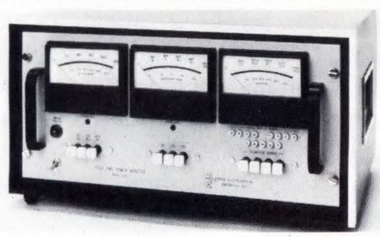
512-MHZ COUNTER GIVES 9-DIGIT RESOLUTION MEASUREMENTS IN 1/10TH NORMAL TIME. The $895 Model 5700A counts directly to 220 MHz and only pre-scales by two for its 512-MHz operation. It measures from 5 Hz to 512 MHz and offers a sensitivity of 10 mV rms at 512 MHz. It also incorporates an optional $75 frequency offset capability; hence, its desgination as the Autoconvert frequency counter. Other features are a quick-recognition display achieved by logical grouping of the display numerics, and front-panel pushbutton blanking of unused or unwanted digits. Ballantine Laboratories, Inc., Box 97, Boonton, N J 07005. Phone (201) 335-0900. **205**

IMPULSE GENERATOR GIVES ±1-dB OUTPUT FROM 500 Hz to 35 MHz. The output of the Model 93453-1 generator is useful from dc to 400 MHz. The output level is adjustable in 1/4-dB steps from 0 dB above 1 μV/MHz to 121 dB above 1 μV/MHz. Pulse repetition rate is variable from 2 to 100 pps while a single pulse can also be obtained from a manual switch. Pulse width is 10 nsec. Model 93454-1 is intended for making receiver bandwidth measurements, rapid gain checking of tuners, test noise suppression filters and receiver alignment. Singer Instrumentation, Los Angeles Operation, 3211 S. LaCienega Blvd., Los Angeles, CA 90016. Phone(213) 870-2761. **206**

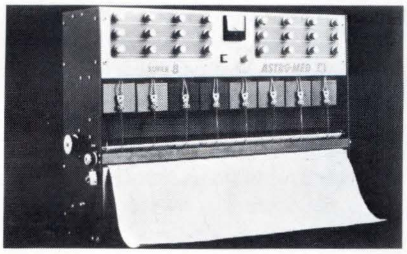


HIGH-VOLTAGE PULSE GENERATOR Model PG-030 features variable-output pulses to 30 kV, nominal rise time of 6 nsec, negligible time jitter and total trigger-to-output delay of less than 100 nsec. It can be triggered either by a minimum 5V pulse input or by an internal variable repetition rate or by a single-shot trigger generator. Output pulse widths from 5 nsec to 10 μsec are available by using auxiliary plug-in pulse-forming networks. The PG-030 is used in light-modulation and laser-control applications. Kappa Scientific Corp., Box 30585, Santa Barbara, CA 93105. Phone(805)967-2396. **208**

3-1/2-DIGIT MULTIMETER COMBINES WITH 10 MHZ FREQUENCY COUNTER. By combining a frequency counter with ac voltage measurement capability, the Model 3003 becomes ideally suited for measuring center frequency and deviation limits associated with FM tape recorder calibration requirements. The unit has 5 dc and ac voltage ranges with 100 μV resolution, 6Ω ranges, 5 current ranges and 5 ranges of frequency counting. Price is $395. Valhalla Scientific, 7917 Balboa Ave., San Diego, CA 92111. Phone(714) 277-2732. **209**



TRUE-RMS POWER MONITOR Model 165 measures true-rms voltage, current and time-average power for standard line voltages in two voltage ranges, with the capability of alternately monitoring two lines on the lower voltage range. It features accuracy of 1/2 percent of full-scale range for voltage, current and power. Ranges are: power—1500 to 15000W full scale; voltage—150 and 300V single-phase and 150V 3-phase; and current—10, 20 and 50A rms. $3495. Monroe Electronics, Inc., 100 Housel Ave., Lyndonville, NY 14098. Phone(716)765-2254. **210**



PORTABLE $3388 EIGHT-CHANNEL RECORDER FEATURES LIGHT WEIGHT and extra-wide channels. Called the Super 8, the recorder is a complete unit including precision high-speed galvanometers, amplifiers, power supplies and a multi-speed chart drive. It offers full 50-mm-wide channels and is lightweight (only 57 lbs). The instrument will record data from dc to 150 Hz with a true rectilinear presentation at a basic sensitivity of 10 mV/mm. Input impedance is 100 kΩ and the input circuit is single ended and floating. Astro-Med, Division of Atlan-Tol Industries, Inc., Atlan-Tol Industrial Park, W. Warwick, RI 02893. Phone(401)828-7010. **211**

SIX-DIGIT COUNTER WORKS TO 15,000 COUNTS/MINUTE. The Model EC10 counts switch-closure (spdt break-before-make) inputs. The count input is unaffected by contact bounce and minimum contact closure time (either throw) is 2 msec. The counter employs a 7-segment readout and requires 10V ac, 60 Hz, at 10W for operation (power transformer is included for operation at 115V ac). Size is 2-in. high by 5-in. wide by 5-in. deep. $195 each. ENM Co., 5350 Northwest Highway, Chicago, IL 60630. Phone (312) 775-8400. **212**

PORTABLE 10-1b STRIP-CHART RECORDER TR-711 is protected by a cast-aluminum case (finished with scratch-proof epoxy enamel) that will withstand rugged field use. It will record voltages as low as 10mV/div. over dc to 125 Hz. Accuracy is 1% with a drift characteristic of 1/3 mm/8h. Chart speeds ranging from 1 through 50 mm/sec are switch selectable. A heated stylus records on a 40-mm-wide channel using no ink. Gulton Techni-Rite Electronics, Inc., Route #2, E. Greenwich, RI 02818. Phone(401)884-6800. **213**

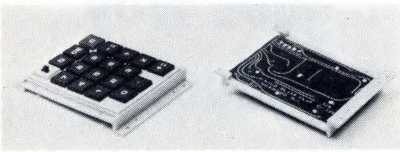
ANALOG TELEMETERING PROVIDES ACCURATE REMOTE MEASUREMENTS. The QATS-20 system permits accurate remote measurement of quantities that can be converted into dc voltages or currents. By means of variable frequency modulation of an FS audio-tone channel, accurate readings of these quantities can then be transmitted any distance. Transmission can be over leased telephone lines, radio or the switched network. This form of telemetering uses a portion of a voice-grade channel bandwidth. Quindar Electronics, Inc., 60 Fadem Rd., Springfield, N J 07081. Phone-(201)379-7400. **214**

THERMOCOUPLE THERMOMETER USES ROM with 512 points of linearization that provides a 0.25°F conformity to NBS curves over an ambient temperature range of 0 to +50°C. The digital ROM linearizer has zero TC which eliminates the error that normally occurs due to ambient temperature change of conventional linearizer circuits. The Model 9500 is available for use with types J and K thermocouples in either Fahrenheit or Centigrade temperatures. Total instrument drift in six months is within 0.1% of full-scale. $425. Electronic Research Co., 10,000 W. 75th St., Overland Park, KS 66204. Phone(816)421-6430. **215**

SELF CONTAINED PULSE GENERATOR FEATURES WIDE FREQUENCY RANGE. The PG610 is a $98, compact (2 × 3.75 × 6.25 in.) digital pulse generator that provides output pulses at repetition rates from 10 Hz to 5 MHz in six overlapping ranges. Output is compatible with TTL, DTL and RTL logic levels. The device has independent adjustments for spacing and pulse width. Computer Products Inc., 1400 N.W. 70th St., Fort Lauderdale, FL 33307. Phone (305) 974-5500. **216**

10-INCH STRIP-CHART RECORDER COSTS $395. The OmniScribe features a multi-speed chart drive independent of line frequency. Four pushbutton selectable speeds range from 1 in. per minute (2.5 to 20 cm/min.). The unit is also available with a divide by 1, 10 and 60. A sprocketless, positive-feed paper drive eliminates sprockets and sprocket holes in the chart paper, which is standard 11 in. × 100 ft. Houston Instrument, 4950 Terminal Ave., Bellaire, TX 77401. **217**

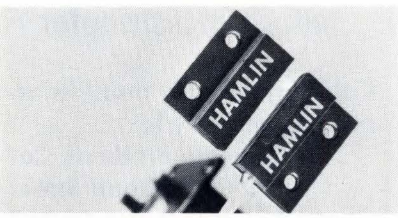
STATIC ELECTRICITY DETECTOR/MONITOR IS BATTERY OPERATED. Model 230 "Stat-Arc" is a new type of hand-held, battery operated electrostatic fieldmeter for use in detecting accumulations of static electricity. Its most significant feature is the small probe which can be removed from the barrel of the instrument and mounted remotely or hand-held. Price is $395. Monroe Electronics, 100 Housel Ave., Lyndonville, NY 14098. Phone(716)765-2254. **218**



MINIATURE KEYBOARDS UNVEILED FOR MINI-CALCULATORS. A 0.33 in. package profile, 1/16 in. key travel and fast switching of low level signals are among the features of the new Microthik miniature keyboard. The contact has a transient noise of less than 1 msec, and requried operating force is 3 ozs. Sample boards are available at $15 each. Wild Rover Corp., 97 Oak St., Norwood, NJ 07648. Phone(201)768-8393. **219**

WELDABLE LEAD RESISTORS ARE SPECIALLY ENCAPSULATED. 1/3W, 5% and 10% copperply-weldable lead carbon film resistors are ideal for neon glow lamp applications. A temperature coefficient beginning at 180 ppm/°C max., a moisture resistance change of ±1.5% max., and shelf life change of 0.15% guarantees parameters superior to carbon composition type resistors. Phier International Corp., 1239 Rand Rd., Des Plaines, IL 60016. Phone (312) 287-1560. **220**

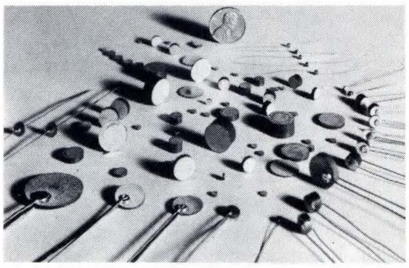
ULTRA-MINIATURE TOROID FITS IN A WATCH. The toroid is approximately 0.100 in. in diameter and 0.150 in. thick, and replaces a much larger cup-core inductor in wristwatch circuits. The maker feels the new ultra-miniature toroid will find wide application in electronic instrumentation and in ultra-miniature high-frequency radio receivers. Vanguard Electronics, 930 Hyde Park Blvd., Inglewood, CA 90302. Phone (213)678-7161. **221**



MAGNETICALLY ACTUATED PROXIMITY SENSORS OFFER VERSATILITY. Actuation is by permanent magnets molded into matching packages. Mode of operation is varied, it can be by head-on, slide or rotary motion, or by shunting. The 5800 Series will switch 1/2A at 10W ac or dc, 100V dc. The 5900 series, incorporating a triac, will switch 1 1/2A at 120/240V ac, 50/60 Hz. Hamlin Inc., Lake and Grove Sts., Lake Mills, WI 53551. Phone (414)648-2361. **222**

MOLDED ABS THERMOPLASTIC CONTAINER AVAILABLE FOR CUSTOM CIRCUITRY. A container molded of high impact ABS thermoplastic has been added to the popular line of "BLACK BOXES." The new box, Model 3850, measures 2.69 in. × 1.81 in. × 1.37 in., supplied with ABS cover and four self-tapping screws. Pomona Electronic Co., Inc., 1500 E. Ninth St., Pomona, CA 91766. Phone(714)623-3463. **223**

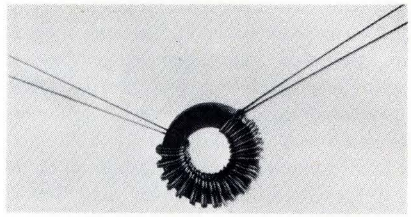
DO IT YOURSELF KIT MAKES INSTANT RESISTORS. "Instant Ohm" is ideal for making resistors, shunts, or multipliers, for repair, production and experimental use—on the spot—for about 2c each. Each kit contains 7 resistance wires ranging from 0.5 to 300Ω/ft., 11 epoxy bobbins, instructions and simple schematics. Kit price is $12.95 each. Chronomite Labs., 21011 S. Figueroa St., Los Angeles, CA 90047. Phone(213) 320-9452. **224**



DISC THERMISTORS OFFER COST SAVINGS. These Disc Thermistors have resistance values extending over the very low ohmic to the extremely high ohmic range. They are ideally suited for use in applications where medium power dissipation is a requirement and space not a problem. The Disc Thermistors are available with standard lead configurations as well as special types engineered to satisfy design requirements. Fenwal Electronics, 63 Fountain St., Framingham, MA 01701. Phone(617)872-8841. **225**

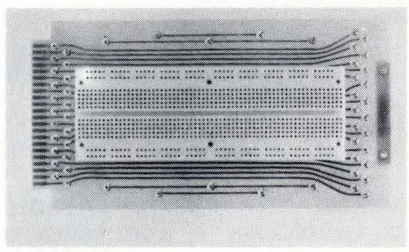
STANDARD DISCRETE RESISTOR NETWORKS IN DIPs. CORDIP dual-in-line resistor networks in four standard configurations for pull-up or in-out functions combine up to 15 resistors in a package. The standard networks provide savings in handling and insertion costs. They also increase component density and enable corresponding board size reductions. CORDIP networks are available in 14 or 16-pin DIP packages that meet EIA and industry standards and are fully compatible with existing automatic insertion equipment. Corning Glass Works, Corning, NY 14830. Phone (607)962-4444. **226**

8-POSITION ROTARY SWITCH COMES IN TO-5 Can. The SP7T (7 live and off-position) or SP8T (8 live positions) low-energy switching devices for printed circuit or panel mount applications are available in knob, or screw driver actuated versions. Price is $1.63 each for basic rotary switch in 1000 lot quantity. Chicago Switch, Inc., 2035 Wabansia Ave., Chicago, IL 60647. Phone(312)489-5500. **227**

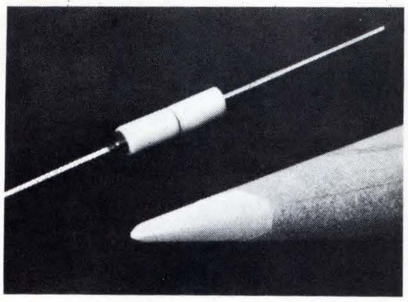


MINIATURE OPEN TRANSFORMERS ARE LOW COST. Miniature open transformers, bifilar wound, with solder pot strippable wire offer versatile applications. You can eliminate core search and winding time by specifying these mini-transformers for your balun, floating switch, inhibit drive and coupling applications. Order 500 and they're 25c each. Pulse Engineering Inc., P.O. Box 12235, San Diego, CA 92112. Phone(714)279-5900. **228**

COATING FOR METALS ABSORBS HEAT and increases light reflection. The newly developed Metal Cold Mirror (MCM) coatings will absorb up to 75% of the focused heat while controlling color and increasing visible light reflectance. Applications of MCM coatings will increase the amount of light reflected from the metal substrate by up to 15%. Steel and nickel reflectors can operate at temperatures up to 950°F and aluminum reflectors can operate up to 550°F. Bausch & Lomb, Rochester, NY 14602. Phone(716)232-6000. **229**

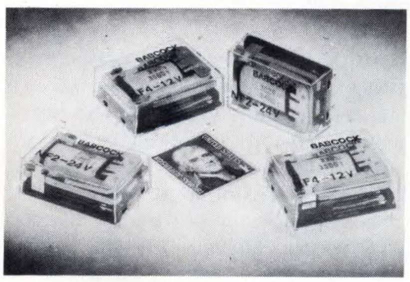


BREADBOARD SYSTEM FEATURES CARD-EDGE CONNECTORS. PL-1 and PL-2, Plug-in Socket Boards, feature one or two patented EL SK-10 component sockets on a 4-1/2 in. × 9 in. glass epoxy G10 pc board. The board includes a 22-pin card edge connector and card extractor handle. There is no soldering required; connections are made with standard 22-24 AWG hook-up wire. EL Instruments Inc., 61 First St., Derby, CT 06418. Phone(203)735-8774. **230**



GLASS RESISTORS ARE RATED FROM 100 TO 100,000 MΩ. Model 104 high MΩ resistor measures 0.250 × 0.070 dia. Operating temperature is −200°C to +150°C. Capacitance is 0.1 pF. The resistive element is semi-conductive glass, fired as a non-spiraled, continuous thick film on a ceramic rod. Price is $2.50 each (1000). Eltec Instruments Inc., Central Industrial Park, Daytona Beach, FL 32014. Phone(904)252-0411. **231**

PC TRANSFORMERS. The "Lady Bug", a new line of commercial-grade audio PC transformers, includes 4 case sizes and 46 electrical configurations with power ratings from 50 mW to 2W. Lady Bug transformers operate to +85°C ambient, withstand storage to −40°C, handle an axial pull of 2 lbs for 5 sec and withstand solder head of 260°C for 5 sec. This new line of audio transformers is designed for sale as a stock item through distributors. ADC Products, Inc., 4900 W. 78th St., Minneapolis, MN 55435 Phone(612)929-7881. **232**



MINIATURE REED RELAY FEATURES 1 BILLION OPERATIONS in both power and dry-circuit applications. The 1A spdt industrial reed relay is offered in both latching and non-latching versions. The new Series R relay has bifurcated rhodium or gold-plated contacts, high sensitivity, and fast response for operation to 500 Hz. Two constructions are offered—plastic-encapsulated and magnetically-shielded. Three modes are available: polar single-side stable, single-coil bistable latching and double-coil bistable latching. Babcock Electronics Corp., 3501 N. Harbor Blvd., Costa Mesa, KA 92626. Phone (714)540-1234. **233**

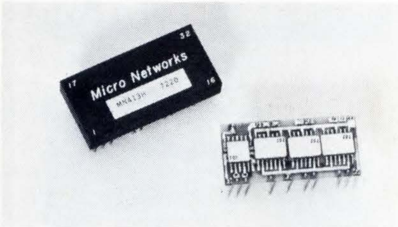
PHOTOMETRIC SENSOR PRECISELY MATCHES HUMAN-EYE SENSITIVITY. Called the Y-BAR-1, this new sensor will be used for the measurement and testing of light intensity. The silicon sensor has a special computer-designed composite glass absorption filter that corrects the specially selected silicon cell to match the photopic luminosity curve as adopted by the International Commission of Illumination. It's resultant spectral response is within 1% linearity over a light-level range of six decades. Photon Products, Box 1230, Cupertino, CA 95014. Phone(408)296-5226. **234**

PRECISION 1/2-IN. POTENTIOMETERS WITH 0.15% LINEARITY. The rotary conductive-plastic potentiometers include absolute standard linearities of 0.35%, with special linearities as close as 0.15%, a resistance range of 250Ω min. to 130 kΩ max., low inertia, low torque (less than 0.1 in.-oz.), a power rating of 1/2W and an ambient temperature range of −65 to +125°C. Overall case length is 1/2 × 1/2 in. New England Instrument Co., 14 Kendall La., Natick, MA 01760. Phone(617)873-9711. **235**

HYBRID THYRISTOR REGULATOR HANDLES 0.5 TO 3 kVA. The new unit offers the facility to change from phase control to burst control by a simple wiring change. The hybrid assembly consists of a power semiconductor chip (thyristor or triac), an IC chip combining firing and control circuits, and ancillary components, all mounted on a 2-×-1-in. substrate. The assembly is resin-encapsulated with a mild steel plate for mounting and heat transfer. The package measures 2 × 1 × 0.6 in. and operates from a 110/220V, 50-Hz power line. Westcode Semiconductors, 282 Belfield Rd., Rexdale, 605, Ontario, Canada. Phone(416) 677-5881. **236**

GOLD V-BAR KEYBOARD SWITCHES feature low-bounce characteristics, 15-million-cycle expectancy and low cost—less than 20c each in production quantities. These mechanical "gold v-bar" switches are so-named because of their switching action which is accomplished by moving a thin gold wire beam spring into the vee formed by the gold terminals. This arrangement combines the best features and proven reliability of wiping and cross-point contact. The spring-on-spring design has the further advantage of providing high hysteresis. Mechanical Enterprises, Inc., 5249 Duke St., Alexandria, VA 22304. Phone(703)751-3030. **237**

CHECK NO. 24

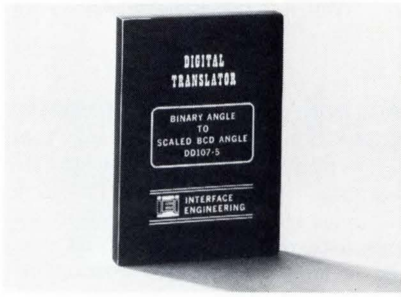


12-BIT D/A CONVERTER MAINTAINS +1/2-LSB ACCURACY FROM −55 to +125°C. The MN413H converter may be user-configured either as a straight 12-bit converter or as an 11-bit-plus-sign multiplying converter. The linearity of ±1/2 LSB and absolute accuracy of ±1 LSB are maintained over the full −55 to +125°C temperature range. Input logic is both TTL and CMOS compatible and power dissipation is 500 mW. Price: 1-24 pieces ($265). The MN413 (0 to +70°C) costs $225. Micro Networks Corp., 5 Barbara Lane, Worcester, MA 01604. Phone (617)756-4635. **170**

HIGH-PRECISION INSTRUMENTATION AMPLIFIER Model 8300XWB-E, features a gain accuracy of ±0.01% and a gain linearity of ±0.01%. The amplification factor of this preset, fixed-gain amplifier can be specified for any value between 1 and 2000X. Bandwidth is also preset, and may be specified for any value between 10 Hz to 100 kHz at the 3-dB point. TC is less than 0.3 μV/°c (referred to input). Preston Scientific Inc., 805 E. Cerritos Ave., Anaheim, CA 92805. Phone (714)776-6400. **171**

SOLID-STATE INDICATING TEMPERATURE CONTROLLERS feature plug-in construction which allows the entire control unit to be removed from its housing without disturbing the customer wiring on the back housing. The controllers are accurate to +0.5% and have a scale length of 5-3/4 in. They are available in "proportioning control" and "on-off limit" types. Omega Engineering, Inc., Box 4047, Stamford, CT 06907. Phone (203)322-1666. **172**

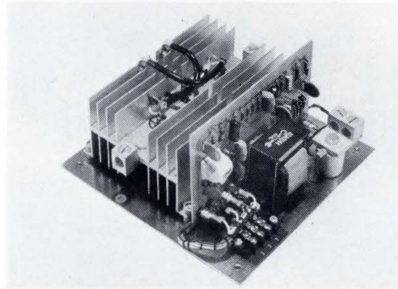
ELECTROMECHANICAL BCD DECODER/DRIVER WITH MEMORY. The improved relay-tree type BCD decoder/driver employs a magnetic latching relay which plugs directly into a PC board without soldering or sockets. The decoder module is packaged on a PC card which measures only 3 × 4 in. This decoder/driver will take any 5, 6, 12 or 24V binary-coded (1248) dc logic and ouput the corresponding decimal. $31.50. Printact Relay Div., Executone, Inc., Box 1430, Long Island City, NY 11101. Phone (212)EX2-4800. **173**



DIGITAL ANGLE TRANSLATOR WITH 500-nSEC SPEED. The DD-107 translator bridges the interface between binary coded shaft-angle data and angle scaled numerical displays, printers and shaft-positioning devices. Input resolution is 15 bits, output resolution is 0.01° and accuracy is ±0.015°. In quantities of 1-9, the 5-digit DD107-5 is priced at $190 and the 4-digit DD107-4 at $160. Interface Engineering, Inc., 386 Lindelof Ave., Stoughton, MA 02072. Phone (617)344-7383. **174**

DIP ATTENUATORS FOR UHF FREQUENCIES. Ultra-high-frequency operation due to short conductor lengths (0.15 in.) highlights this new series of attenuators. Conservatively rated to 500 MHz, they are available in attenuation values of 3,6,10,15, 20 and 30 dB at 50Ω impedance. All are rated at 100 mW of power dissipation. The series features thick-film construction, has a VSWR rating of 1.2:1 and is available from stock to 2 weeks. Morris Enterprises, Inc., Microcircuit Div., 16799 Schoenborn St., Sepulveda, CA 91343. Phone(213)894-9103. **186**

PHASE LOCKED OSCILLATORS COVER 5855 TO 8500 MHz. A new series of phase locked oscillators for both the common-carrier and military-band relay-link systems operate in the frequency ranges of 5855 through 8500 MHz. The Model 4818 Series provides a minimum of 50 mW of power output with ±0.0005% stability over the temperature range of −30 to +70°C. Zeta Laboratories, Inc., 616 National Ave., Mountain View, CA 94040. Phone (415) 961-9050. **187**

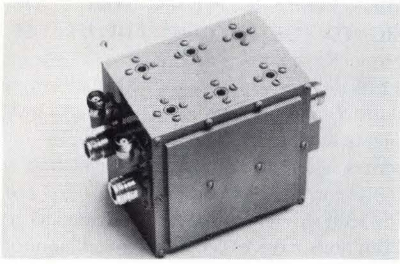


CONDUCTION-ANGLE POWER CONTROLLER LPA-1 is a new single-phase SCR unit designed to control 50/60 Hz of power. It operates into resistive loads and can also operate transformer coupled loads under certain conditions. The output power corresponds to a command signal from a process controller. Models are available for 120, 208/240 and 480V operation. Standard output currents are 30 and 50A in a 50°C ambient. Halmar Electronics, Inc., 1544 W. Mound St., Columbus, OH 43223. Phone (614)276-0131. **175**

ISOLATED POWER MODULES. The CEA1A Series provides integral isolation from 20 dB (standard) up to 100 dB (optional) protecting against destructive and annoying extraneous voltages. This high degree of isolation is obtained by reducing the primary-to-secondary capacitance of the power transformer. The Series offers such standard features as shielded transformers for electrical isolation within the system, 100% testing after a 16h burn-in for guaranteed specification (test data included with shipment) and a three-year guarantee for parts and labor. CEA, Div. of Berkleonics, Inc., 1 Aerovista Park, San Luis Obispo, CA 93401. Phone (805)544-5454. **176**

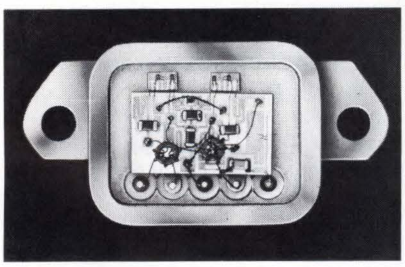
LOW COST AC/DC-TO-DC CONVERTER LINE. Termed the Q4-25 Series, the new line operates from 103 to 127V ac, 45 to 880 Hz and 140 to 180V dc. Outputs are available in 5, 6, 12, 15, 24 and 28V at 25W. Efficiencies of up to 70% are available with regulation of 0.5% for line and 2.0% for load. Ripple is 0.2% rms, operating temperature is −20 to +71°C and size is 4 × 4 × 2 in. Price is $140 each in 1-to-4-piece quantities. Aaron-Davis Co., 1720 22nd St., Santa Monica, CA 90404. Phone (213)829-1834. **177**

POWER AMPLIFIER PROVIDES 300 mW FROM 2 TO 500 MHz. The Model 500 L combines the advantages of thin-film hybrid ICs with an IC power supply to boost the output of any signal source by 27 dB. $295. Electronic Navigation Industries, Inc., 3000 Winston Rd. S., Rochester, NY 14623. Phone (716)473-6900. **178**

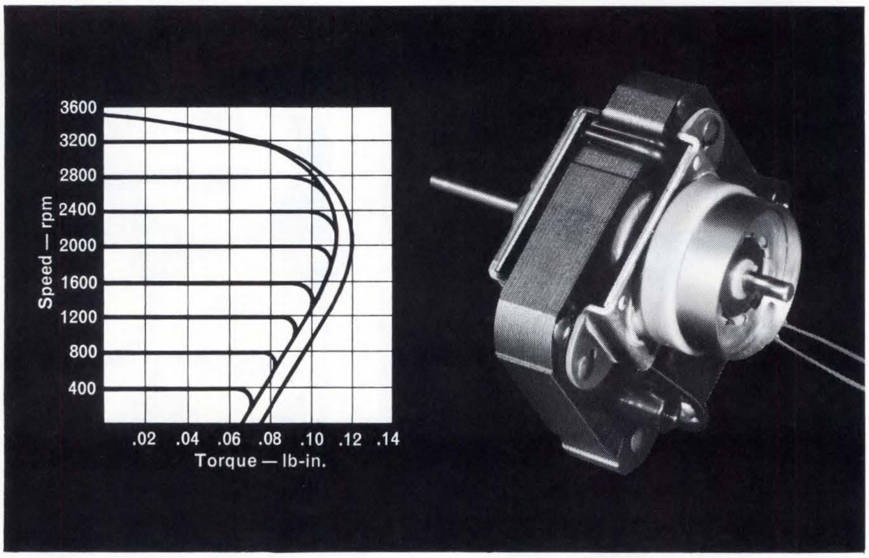


TUNABLE L-BAND DIPLEXER COVERS 962 TO 1213 MHz. Model 2905 diplexer has two channels that are tunable over the frequency range of 962 to 1213 MHz. Channel bandwidth is constant at 13 MHz with a 1-dB loss. Isolation is 66 dB with a 63-MHz channel separation. The connectors are type N and systems mounting holes are provided. Small-quantity price and delivery is $720 and 4 weeks, respectively. Microwave Filter Co., Inc., 135 W. Manlius St., E. Syracuse, NY 13057. Phone (315) 437-4529. **179**

UNIVERSAL 3-PHASE RFI POWER-LINE FILTERS. New 3-phase 5-section T Series RFI power-line filters feature the smallest high-current types available (4 × 4 × 4 in.) and come in 20A (20T48), 30A (30T48) and 60A (60T48) models for operation at 115 to 440V ac, 50 to 60 Hz. The T Series RFI filters have 1.5 mA of maximum leakage current and will withstand a 2100V dc high-pot test. Price ranges from $29.50 to $90. Corcom, Inc., 2857 N. Halsted St., Chicago, IL 60657. Phone (312)327-6566. **180**

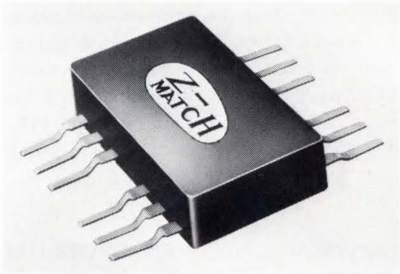


THREE NEW HYBRID CATV AMPLIFIER MODULES: Type MHW560 provides 16-dB power gain, 8.5-dB noise figure and a bandwidth of 40 to 300 MHz (within ±0.3 dB). The MHW561 provides an additional 15-dB gain and is intended as the output function in a line extender. Cross-modulation distortion is −57 dB at 47 dB mV output (21 channels). Type MHW562 offers 15-dB gain which is provided with cross-modulation distortion of −60 dB (+50 dB mV output and 21 channels). Prices for 25 to 99 quantities are MHW560 ($39), MHW561 ($44.50) and MHW562 ($50.50). Motorola Semiconductor Products, Inc., Box 20924, Phoenix, AZ 85036. Phone (602)273-3466. **181**



CIRCUITS

HIGH-VOLTAGE POWER SUPPLY DESIGNED FOR PHOTOMULTIPLIER USE. Model RMX308 has an output voltage from 1250 to 2500V and Model RMX309 from 2300 to 4000V. Each can deliver 200 mW output at all voltages in its range. Input current is less than 60 mA. Load regulation is 0.5% for the RMX308 and 2% for the RMX309, for no-load to full-load regulation. Both units have ±0.05% line regulation for 28V dc, ±10% input variations. Ripple is 0.01% rms. Each encapsulated supply measures 2 × 2 × 2 in. Spellman High Voltage Electronics Corp., 1930 Adee Ave., Bronx, NY 10469. Phone(212)671-0300. **182**



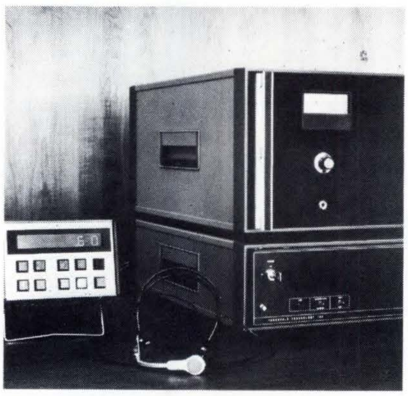
LOW COST DOUBLY BALANCED MIXER OPERATES TO 500 MHz. Model DBM-166 mixer, is for general purpose use in CATV translators, low-cost receivers, modulators and other commercial communication equipment. Conversion loss is typically 6 dB, and Interport Isolations of 40 dB are typical up to 100 MHz. Price (1-24, $15.00) (100-999, $6.95). The Vari-L Co., 3883 Monaco Pkwy, Denver, CO 80207. Phone (303)321-1511. **183**

WIDEBAND TUNABLE COAXIAL MAGNETRON OKH1663 DELIVERS 75 kW PEAK POWER OVER 32 to 35 GHz. Pulse width is 0.1 to 1.0 μsec with a duty cycle of up to 0.001. Peak voltage is 16.5 kV with peak current of 16.25A. The magnetron can be supplied with either a knob-type tuner drive or a shaft extension to accommodate a motor drive. The 12-lb tube is air cooled and has an integral magnet package. Raytheon Co., Microwave and Power Tube Div., Foundry Ave., Waltham, MA 02173. Phone (617) 899-8400. **184**

MINIATURE THERMOCOUPLE AMPLIFIER IS SELF-POWERED. The OMNI-AMP I is a completely portable microvolt amplifier that will boost thermocouple signals up to 100 times. A choice of seven fixed gains plus a variable gain are provided. The frequency response is from dc to 10 kc. Priced at only $85 complete with batteries, jacks and adaptors. Omega Engineering, Inc., P.O. Box 4047, Stamford, CT 06907. Phone (203)322-1666. **185**

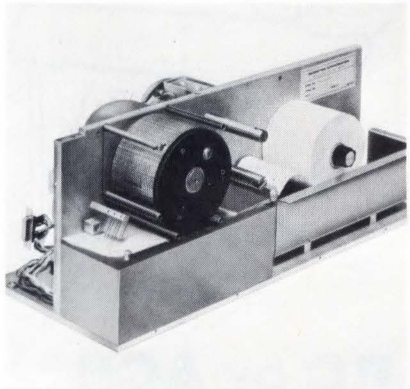
COMPUTER PRODUCTS

DISC PACK SYSTEM FOR MINIS STORES UP TO 44M BITS and is composed of a disc controller and one to eight disc drives. The controller is an automatic transfer, block oriented device. Read, write, and select routines provide the software required to put this system on-line, while a diagnostic program verifies correct operation, or notifies the user of malfunction. Per Data's disc system is available for any of the computers in use today—mini or maxi. Per Data, 102 New South Rd., Hicksville, NY 11801. Phone(516)938-2851. **244**

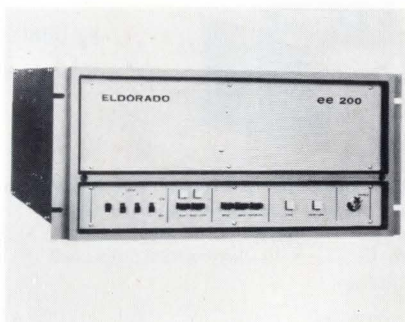


DATA ENTRY SYSTEM IS ACTIVIATED BY VOICE. The VIP-100 can be used by any speaker regardless of language, vocabulary or accent for machine control and computer data entry systems. Expansion for multi-speaker operation is available. A number of options are available on the system including vocabulary expansion to 100 words, telephone interface, voice response, hard copy and special visual display. The basic system, including teletypewriter, minicomputer and display, costs $17,500. Threshold Technology Inc., Cinnaminson, N J 08077. Phone(609)829-8900. **245**

READ/WRITE CORE MEMORY HAS 330 NSEC ACCESS TIME. This 3D-3 wire memory is available as 4k × 18 or 8k × 8 bits with a 900 nsec cycle time. It is field alterable to 32k × 18 or 64k × 9 bits, with operating temperature range 0-50°C and features a power protect circuit. The board size is 15 × 10 × 0.6 inches and uses two 72 pin edge connectors with 0.125 in. centers. Prices start at $1199. Unicom International, 1275 Bloomfield Ave., Fairfield, N J 07006. **246**



DIGITAL PRINTER COMES IN KIT FORM. The Model 722k main frame provides for 10, 20, 30, 40, or 60 lps with a line width of 22 numeric or A/N characters. A/N characters follow the ASCII format but without lower case. Accessories of all kinds are available . . . from slide tracks to complete cabinets, as well as power supplies, circuit boards, switches and similar electronic items. Price of the basic unit is under $500. Datadyne Corp., 37A Valley Forge Ctr., King of Prussia, PA 19406. Phone(215)265-1793. **247**



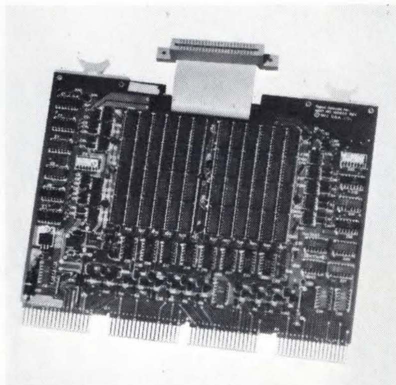
NEW MINICOMPUTER BOASTS EASE OF USE. The ee 200 features: a universal bus with space for 12 memory and/or peripheral devices in the basic unit, DMA, priority interrupts, bipolar or core memory, 69 basic instructions which are both 8-bit byte and 16-bit word oriented, 4k bytes of core memory standard, 16 levels of 16 GP registers, a bootstrap loader and serial teletype interface, and a stack pointer for fully recursive programming. $1915 w/4k bytes of core, $2600 w/8k bytes. Eldorado Electrodata Corp., 601 Chalomar Rd., Concord, CA 94518. Phone(415)686-4200. **248**

CARD READERS READ BOTH MARK-SENSE AND PUNCH CARDS. Models 6028 and 6029 are compact units designed to read punched and hand-marked data simultaneously or separately to a computer or magnetic tape. Model 6028 reads cards in the IBM format—80 punched columns and 27 marked columns—and Model 6029 reads cards with a pre-printed timing track—80 columns for punched or marked data. The units can read the cards face-down or face-up, at a rate of 225 or 400 cards/min. $2780 and $2900. Mohawk Data Sciences Corp., 781 Third Ave., King of Prussia, PA 19406. Phone(215)337-1910. **249**

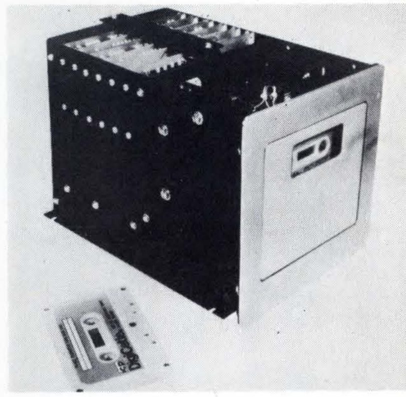
READ/WRITE MEMORY ADDED TO PDP-14 PROGRAMMABLE CONTROLLER. Digital's new read/write memory option is a single 4k word package priced at $2750. It is specially protected for harsh industrial environments and it allows the user to make quick on-line changes in the controlled machinery, without dedicating a computer to the application. It is implemented with standard relay symbology or Boolean equations. Digital Equipment Corp., McCormick Place, Maynard, MA 01754. Phone (617)897-5111. **250**

GIVE YOUR MINICOMPUTER A VOICE. The S-11 is a new peripheral for PDP-11s which plugs directly into the UNIBUS. Output is through a speaker or headset. Also, a TOUCH-TONE input decode option provides remote two-way communications. Standard software consists of an output routine for generating speech from a stored vocabulary table and a composer for use in adding words or modifying inflections. Interfaces and software for most other minicomputers are also available. Interface Systems, Inc., 5 Research Dr., Ann Arbor, MI 48103. Phone(313)769-5900. **251**

ADD-ON CORE MEMORY QUADRUPLES MEMORY OF HP 2114 A/B MINIS. The DSS system is available in seven sizes, 4k, 8k, 12k, 16k, 20k, 24k, and 28k, thus allowing for combinations of HP and DSS memory totaling 32k words. The DSS extension memory is completely hardware and software transparent to the HP 2114 A/B computers. The controller and memory module(s) are housed in a standard 5-1/2 in. RETMA rack unit. Digital Systems Services, P.O. Box 1239, Mountain View, CA 94040. Phone (415)968-4257. **252**



SEMICONDUCTOR MEMORY REPLACES CORE IN PDP-12. The RAM, which plugs directly into the PDP-12 chassis, is both electrically and physically compatible with the DEC core memory. It provides up to twice the storage capacity in the same space, requires less power drain and has wider operating margins. 4k of expansion memory costs $2850 while 8k is priced at $4050. The add-on memory is expandable in 4k increments to a total of 28k. Signal Galaxies, Inc., 6955 Hayvenhurst Ave., Van Nuys, CA 91406. Phone(213)988-1570. **253**



INCREMENTAL CASSETTE RECORDER OFFERS HIGH SPEED. The PI-72 permits bidirectional character by character operation during both record and playback on a completely asynchronous basis at any rate from 0 to 300 cps. The PI-72 is free of all code, format, and record length restrictions and it provides a ninth bit for control or for use with extended code sets. Thus full 8-bit binary data can be recorded without restriction. Single unit price is $1015. International Computer Products, Inc., P.O. Box 34484, Dallas, TX 75234. Phone (214)239-5381. **254**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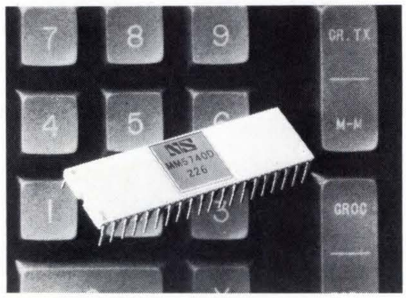
SEMICONDUCTORS



90-KEY ENCODER FEATURES TRI-STATE^{TM} DATA OUTPUTS. The new MOS/LSI keyboard encoder is a complete interface system capable of encoding 90 single pole, single throw switches to a usable 9-bit code. It is organized as a bit-paired system capable of either N-key or two-key rollover. Pricing in 100-up: Ceramic DIP is $18.16; Epoxy-B DIP is $15. National Semiconductor Corp., 2900 Semiconductor Dr., Santa Clara, CA 95051. Phone(408)732-5000. **188**

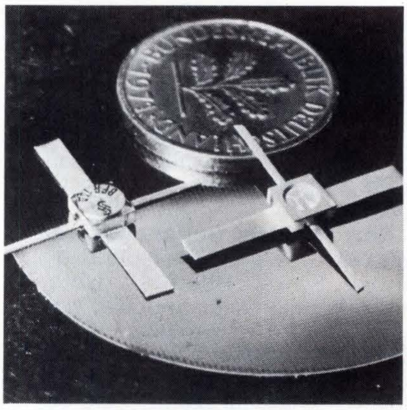
HIGH SPEED 741 OP AMP IS 4 TIMES FASTER. Input offset (I_{OS}) and input bias (I_b) currents are also improved. The 741HS, available in MIL and commercial temperature ranges, is a pin-for-pin equivalent to the standard 741. 100-piece price for the commercial-temp version, packaged in a plastic 8-pin MINIDIP or TO-5 can, is $0.95. Intersil, 10900 N. Tantau Ave., Cupertino, CA 95014. Phone (408)257-5450. **189**

DUAL AUDIO AMP IC IS RATED AT 2W PER CHANNEL. The LM377 has a high input impedance ($>10m\Omega$) which is ideal for the ceramic phone cartridges found in most home stereo sets. Gain is 100 dB and distortion is only 0.5% at 1 kHz. Power bandwidth for the LM377 is 65 kHz. Supply voltage is 18V dc. It is priced at $3.95 in quantities of 100. National Semiconductor Corp., 2900 Semiconductor Dr., Santa Clara, CA 95051. Phone (408)732-5000. **190**

LINE DRIVER FACILITATES PARTY-LINE OPERATION. The MC75113 was designed to be used in data transmission systems where numerous drivers and receivers share a common twisted-pair line. It features a TTL compatible four input OR gate and output currents of nominally ± 20 mA. Output current mismatch is a max. of 3 mA. Propagation delay time is 25 nsec. The device sells for $3.10 in 100-up quantities. Motorola Semiconductor Products Inc., P.O. Box 20912, Phoenix, AZ 85036. Phone (602)273-6900. **191**

PHOTOTRANSISTORS PROVIDE HIGH GAIN AT LOW LIGHT LEVELS. Designated the SD 3442 and SD 5442 Series, they offer the stable performance associated with regular phototransistors along with the ability to function at very low light levels—typically 1 mW per CM^2 compared with the 20 mW per CM^2 generally required. Prices are $4 each at the 1000-piece level. Spectronics, Inc., 541 Sterling Dr., Richardson, TX 75080. Phone (214)231-9381. **192**

HIGH SPEED MOS UNIVERSAL SYNCHRONOUS RECEIVER TRANSMITTER (U-SRT) subsystem achieves input strobe widths of 200 nsec, output propagation delays of 250 nsec, and receiver/transmitter rates of 250 kilobaud. TRI-state output levels are also provided for those output signals which are busstructured. Available in a 40-lead dual inline cermaic package, the price is $30 in small quantities. Standard Microsystems, Corp., 1230 Bordeaux Dr., Sunnyvale, CA 94086. Phone(408)734-8444. **193**

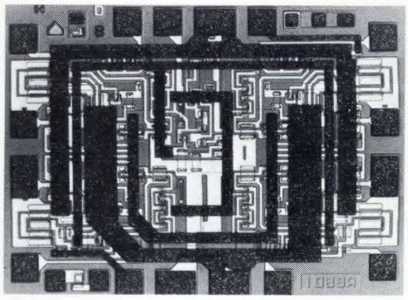


SI-PLANAR TRANSISTOR OPERATES AT FREQUENCIES UP TO 5 GHz. The low-power epitaxial NPN Silicon microwave planar transistor is characterized by a low noise figure, high gain and low distortion. The ceramic strip-line metal casing (approx. 3.5 mm $\times$ 3.5 mm) has been designed for use in microwave integrated circuits. Siemens Corp., 186 Wood Ave., Iselin, N J 08830. Phone (201)494-1000. **194**

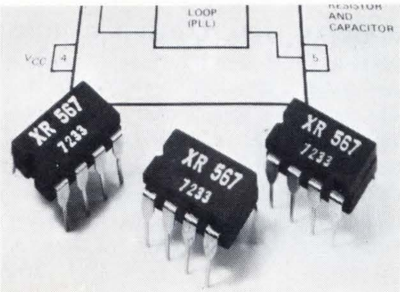
DUAL LINE RECEIVER FEATURES ± 100 mV INPUT SENSITIVITY. The device requires input current of less than 100 μA allowing it to be used in bus organized systems. As many as 100 receivers may be used per line. The SN75140P features externally adjustable threshold from 1.5 to 3.5V. Price in 100-piece quantities is $2.52. Texas Instruments Inc., 13500 N. Central Expressway, Dallas, TX 75222. Phone(214)238-2011. **195**

SEMICONDUCTORS

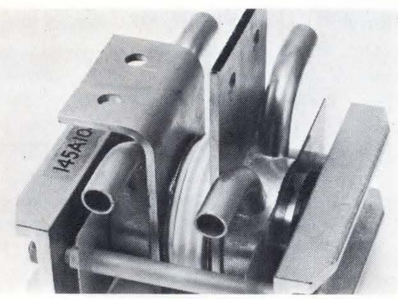
SEVEN MORE FUNCTIONS JOIN 54/7400 TTL SERIES. 54/74124, universal pulse generator features clock and delayed pulse generation, and positive Schmitt trigger input. 130, 131, quad 2 input, open collector AND power drivers, features 100 mA 1_{sink}, 15 and 30V ratings. 138, 139, quad 2 input, open collector OR power drivers are pin compatible with 54/7432. 135 and 137, quad/hex nand Schmitt triggers features high input impedance—compatible with 54/74L, MOS, HLL and high voltage transducers. ITT Semiconductors, 3301 Electronics Way, West Palm Beach, FL 33407. Phone(305)842-2411. **196**



ECL DRIVER AND RECEIVER INTERFACE WITH TTL AND MOS. The "10124" quad differential line driver can also function as a TTL-to-ECL translator. Inputs are diode-clamped and compatible with standard Schottky TTL levels, and the outputs operate at standard "ECL 10,000" levels. In plastic, they sell for $4 each when purchased in 100-piece lots. Signetics, 811 E. Arques Ave., Sunnyvale, CA 94086. Phone(408)-739-7700. **199**



MONOLITHIC PHASE LOCKED LOOP OPERATES TO 500 kHz. The XR-567 operates over a 0.01 Hz to 500 kHz frequency band and has a logic compatible output which sinks up to 100 mA of load current. The center frequency stability rated at 25°C case temperature is 35 ppm/°C. Bandwidth is adjustable from 0 to 14% and the PLL circuit is designed to reject out-of-band signals and noise. Exar Integrated Systems, Inc., 750 Palomar, Sunnyvale, CA 94086. Phone(408)732-7970. **197**



HIGH-POWER SCRs ARE MOUNTED IN WATER COOLED PACKAGES. A new family of high-power SCRs and diodes incorporating a 2-1/2 in. diameter silicon slice, designated type D1200, is offered in a capsule package or in a flat-base package for single sided cooling. The SCRs have current ratings of up to 1500A and handle transient voltages to 3.5 kV. Surges of up 16,000A can be accomodated. Diodes have current ratings up to 1500A. Westcode Semiconductors, 282 Belfield Rd., Rexdale 605 Ontario, Canada. **198**

TRIMMERS/POTS/SWITCHES/RESISTOR NETWORKS. A new 8-page distributor short-form catalog describes the operating characteristics of 56 types of cermet, carbon and wirewound trimmers, potentiometers, cermet DIP resistor networks, and rotary selector switches. CTS Corp., 905 North West Blvd., Elkhart, IN 46514. **255**

FRACTION/DECIMAL/MILLIMETER EQUIVALENTS CHART. A free fraction/decimal/millimeter equivalents chart on 8-1/2-×11-in. card stock includes millimeter equivalents to the third decimal conforming to the adopted standards as published by the National Bureau of Standards. A 15-month calendar on the reverse side shows the year 1973 and the first 3 months of 1974. Boker's, Inc., 3104 Snelling Ave., Minneapolis, MN 55406. **258**

HIGH-TORQUE AC TIMING MOTOR is featured in a new bulletin. The two-page bulletin describes the S9100 Series industrial timing motor. This unit offers high torque in the 720-to-20-RPM timing range. Dimensional drawings, a wiring diagram and general electrical and torque specifications are included. North American Philips Controls Corp., Cheshire Industrial Park, Cheshire, CT 06410. **269**

'TECH TIPS' EXPLAINS RIGHT AND WRONG WAYS TO FIRE THYRISTORS. "Tech Tips 4-2," explains the one correct way and the two incorrect ways of causing a thyristor to turn on. Illustrations help give a better understanding of how firing occurs. Westinghouse Electric Corp., Box 2278, Pittsburgh, PA 15230. **265**

LIQUID-CRYSTAL INFORMATION. "Liquid Crystals," Kodak Publication No. JJ-14, describes liquid-crystal compounds and their classifications—nematic, smectic and cholesteric. For application in the measurement of surface temperature variations, the publication lists more than 100 liquid-crystal mixtures available from Eastman Organic Chemicals.
Eastman Kodak Co., 343 State St., Rochester, NY 14650. **268**

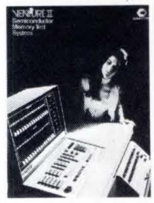
DATUM SHORT-FORM CATALOG. This 12-page catalog covers the general product areas of each of the company's four divisions. It contains a brief description of the company, specifications on typical magnetic tape input/output systems, digital cassette drives and mass memory devices, all with software and interfaces to a wide range of minicomputers. DATUM, Inc., 170 E. Liberty Ave., Anaheim, CA 92801. **256**

DIRECTORY OF ELECTRONIC DATA PROCESSING FIRMS. The Directory contains a listing of nearly 600 organizations in the computer services industry who offer data processing, software and timesharing services. ADAPSO's membership represents more than 40% of the total industry as reported in the directory. $10. ADAPSO, 551 Fifth Ave., New York, NY 10017. **260**

DIGITAL TRANSMISSION SYSTEMS. This short form catalog includes information on systems capability, and products such as D1, D2 subscriber-carrier, wideband data and SM-T terminals. Also detailed are VICOM's multiplex-microwave capability, outside line equipment, test equipment, and span terminating equipment. Vicom, 77 Ortega Ave., Mountain View, CA 94040. **263**

SOLID-STATE CONTROL DEVICES. A full line of solid-state control devices—timers, photoelectric controls, resistance-sensing and multi-pole relays—is described in a condensed catalog sheet. Regent Controls, Inc., Harvard Ave., Stamford, CT 06902. **267**

PROXIMITY-FOCUSED IMAGE INTENSIFIER. An 11-page booklet entitled "The Proximity-Focused Image Intensifier" explains the basic operation of the proximity-focused image intensifier and compares it to other types of image intensifiers. It also contains a section on the Channeltron electron multiplier array and how it is used in conjunction with proximity-focused image intensifiers. Bendix Corp., Teterboro, N J 07608. **261**



SEMICONDUCTOR MEMORY TEST SYSTEM. A new page brochure illustrates the Venture II Semiconductor memory test system, a dedicated system that provides 10 MHz real-time functional testing of MOS, TTL, and ECL RAMs, ROMs and shift registers. Computest Corp., 3 Computer Dr., Cherry Hill, N J 08002. **257**

MODULAR DATA COMMUNICATIONS SYSTEM. An 8-page brochure describes a new modular approach to adding low-cost IBM-compatible data communications capabilities to either an existing or future system. The brochure contains a functional description and suggested design configurations for the data communications modules. Pertec, 10880 Wilshire Blvd., Los Angeles, CA 90024. **262**

VIDEO DELAY LINE. Product bulletin MCA-5.04 entitled "Video Delay Line" describes how the device is used to store analog signals for TV vertical enhancement and other image-processing functions. The data sheet provides a photo of the device showing its glass ultrasonic delay line and associated circuitry, a block diagram and electrical and mechanical specifications. Corning Glass Works, Raleigh, NC 27602. **264**

IBM REPLACEMENT MEMORY. A new brochure describes operation and specifications of the Ampex Model ARM-22 mainframe core memory, which replaces and expands IBM 360/22 mainframe memory economically. Request brochure C-165/5-72. Ampex Corp., Marketing Communications, 13031 W. Jefferson Blvd., Marina del Rey, CA 90291. **259**

COMPUTER BROCHURE—A new 12-page brochure on the 24-bit DC 6024/5 computer includes details on how the new computer can be useful to end users and original equipment manufacturers, with details on input/output, I/O transfer, operator's display and control console, and the CPU. Other information includes a description of the DC 6024/5 system configuration, software, and technical specifications. Datacraft, 1200 Northwest 70th St., Ft. Lauderdale, FL 33307. **266**

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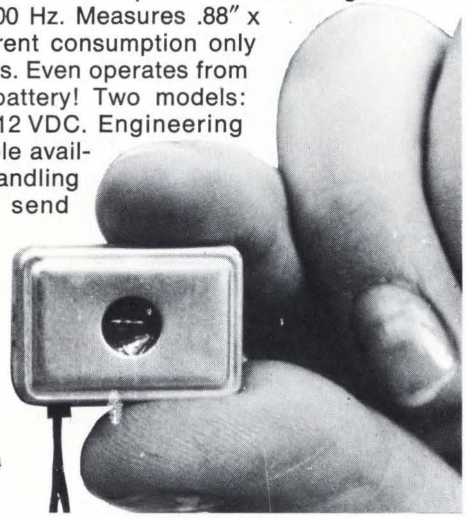
Compact size and high sound output give this unique buzzer wide applicability . . . intercom sets, timers, test apparatus, automotive warning signals, alarm clocks, sensors and other portable or battery-powered products. Solid state . . . no moving contacts, no arcing, no sparking, no electrical interference or RF noise. Easy to install with or without our versatile panel mounts. Weight: ¼ oz. Sound output 400 Hz. Measures .88″ x .61″ x .39″. Current consumption only mA at 1.5 volts. Even operates from a hearing aid battery! Two models: 1.5-3 VDC and 12 VDC. Engineering evaluation sample available for $4.50 handling charge. Please send check or money order; $5.95 each if invoiced against purchase order.



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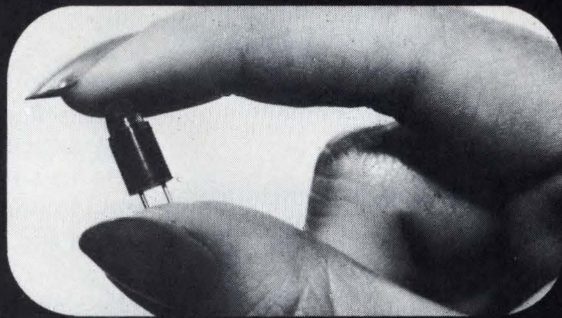
CHECK NO. 31

T-1¾ Bi-Pin LED Replacements



Remember how you only get 500 hours, at the most 10,000 hours, from the use of an incandescent bulb? Well, Unique Devices has a replacement bulb with a gallium arsenide phosphide light source that will deliver a million hours. This highly reliable Bi-Pin LED has a built-in current limiting resistor. Polarity marking on the black molded case. Fully guaranteed. Stocked for immediate delivery. Specify series resistor wanted.

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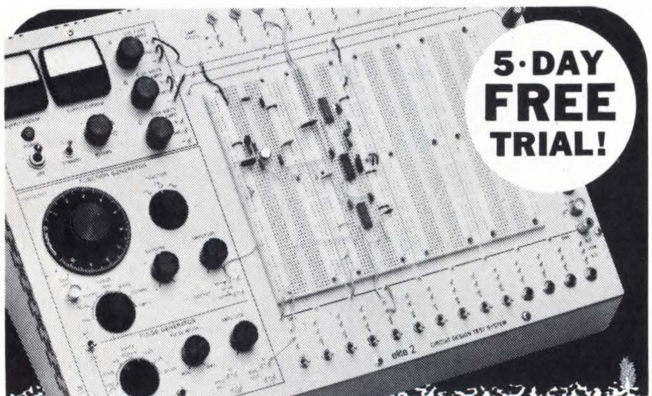

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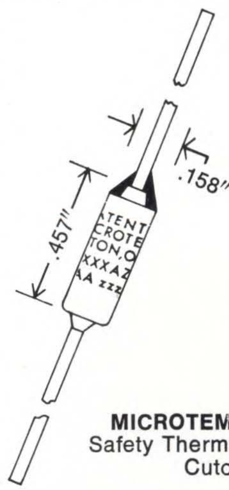

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CHECK NO. 34

signals and noise

The White House responds

After reading a draft of EDN's news story concerning S.32 (October 1, 1972, page 14), the President's Office of Science and Technology responds:

Thank you for the opportunity to read over your proposed article on S.32, the Kennedy Bill, and letting us check the accuracy of our viewpoints as expressed in the piece.

The major comment is that the section which supposedly states the administration's position is not accurate. As you are aware, we have worked on the very problems this bill addresses for a long time. . . . Based on our experience in dealing with these problems, we have concluded:

S.32 is inadequate to meet the needs. It could not make a significant impact in the foreseeable future. It fails to bring to bear the technical capabilities of the departments and agencies best equipped to work on civil problems. The scheme outlined in S.32 would, therefore, create expectations that would not be fulfilled. . . .

Furthermore, the administration feels that a much more effective and immediate way to put engineers to work on civilian problems is to expand the R&D going on in existing federal agencies such as NASA, AEC, HEW, DOT, etc., rather than trying to push the narrowly science oriented NSF into these engineering-type programs.

As for employment, the administration wants the nation's unemployed and underemployed scientists and engineers working at real jobs, not temporary make-work projects. These people are a vital national resource and our goal is to get them into jobs where they can do themselves and the country the most good. That means the creation of jobs. That's our goal. We see new jobs in expanding agency programs and industrial R&D as far more immediate than developing potential jobs under an expanded bureaucracy. As far as retraining is concerned, we in the administration agree with those representatives of the unemployed who testified at the original S.32 hearings. They said then, that retraining and retreading is a waste of time and money if there are no jobs. . . . Many thanks for your courtesy. *Office of Science and Technology, Executive Office of the President Washington, DC 20506*

"Well naturally if you look for mistakes you're bound to find some."

It won't work that way!

Dear Sir:

There were some serious errors in my CDA article, "Sine Wave Synthesizer" on page 52 in Aug. 15 EDN. These errors will cause the reader to seriously doubt the credibility of my article. The errors are as follows:

1. Both inputs to the 741 op amp (through the 100k resistors) are connected to the same point. One of the resistors should have been connected to the other summing node.

2. The label SQUARE WAVE INPUT is misleading. It should have been labeled INPUT CLOCK =16X DESIRED FREQUENCY. The square wave input to the transversal filter is actually derived by the SN74L93 and exists at pin 12 of that chip.

3. Capacitors C_1 and C_2 should have had values given along with the appropriate comment. For example 0.033 μF gives -50 dB harmonic distortion at 2400 Hz. Also, the feedback resistor on the op amp should be 100 kΩ.

Sincerely,

Lee J. Mandell
Communications
Data Systems Div.
Litton Systems, Inc.
Van Nuys, CA 91409

The truth shall win out . . .

Dear Mr. Egan:

We wish to take this opportunity to thank you for your coverage on our new product release outlining polypropylene-foil capacitors. You may be interested to know that to date, this release has generated over 300 inquiries from your magazine alone.

There is some speculation on our part regarding the validity of these inquiries. By this we mean, whether or not a certain percentage of inquirers believe what they read or are seeking to determine whether, in fact, we can make a 150°C polypropylene capacitor which, of course, is impossible. In our release to you, the maximum temperature specified was 105°C. You will note your magazine carried it as "150°C".

Is there some way in which you can acknowledge this error? It would be appreciated as I am sure there will be many people who will classify our release as misleading, when comparing the information to our data sheet.

Very truly yours,

James R. De Santy
Marketing Manager
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A compact, solid-state multimeter with digital readout — at a fantastic kit-form price. The new Heathkit IM-1202 has four overlapping ranges to measure voltages from 10 mV to 1000 V on DC (either polarity), 10 mV to 700 V rms on AC, 10 uA to 2.5A on AC or DC current. Five resistance ranges measure from 1 ohm to 2.5 megohms. Front panel polarity switch reverses inputs without changing leads. 6 lbs.

NEW Heathkit 30 MHz Counter

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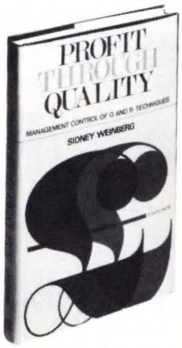

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ADVERTISERS INDEX

Application Notes

TWO ENGINEERING BULLETINS, giving application information on Koolmeter electro-chemical timing cells and operating considerations for these miniature timers, are now available. The brochures are intended to help circuit designers looking for methods of using solid state devices to replace many forms of electromechanical integrators and timers. Sprague Electric Co., 551 Marshall, N. Adams, MA 01247. **238**

MAGNETIC DIODES DESCRIBED IN 4-PAGE APP. NOTE. Magnetic diodes are magnetic-sensitive semiconductor devices, which (like indium-antimony devices) change their internal resistance as a function of an external magnetic field. By altering the magnetic field, signals may be obtained which allow the conversion of non-electrical quantities into electrical quantities. European Electronic Products Corp., 10150 W. Jefferson Blvd., Culver City, CA 90230. **239**

GETTING HIGH-SPEED DATA IN THE 1-TO-10-MHz REGION INTO DIGITAL FORM for on-line storage or processing is a problem which is becoming increasingly prevalent. "How to Make a Thousand Words as Good as a Picture" discusses the types of error which can degrade a signal in the A/D process and even turn an 8-bit converter into a 4-bit one. Computer Labs, 1109 S. Chapman St., Greensboro, NC 27403. **240**

BULLETIN DESCRIBES APPLICATIONS OF FOUR-QUADRANT IC MULTIPLIER. Called Bulletin AO11, it discusses in detail the uses of the 8013, a ±0.5% accuracy general-purpose monolithic analog multiplier. Block diagrams depict use in multiplication, division, squaring and square-root applications. Intersil, 10900 N. Tantau Ave., Cupertino, CA 95014. **241**

APPLICATION NOTE ON USE OF SOLID-STATE PHOTODETECTORS in small-signal detection systems available free. "The Use Of RCA Solid-State Photodetectors In Small-Signal Detection Systems", RCA AN-4849, develops the basic equation for noise equivalent power (NEP) and provides two nomographs that will be useful to all users of solid-state photodetectors. RCA, Electronic Components, 415 S. Fifth St., Harrison, N J 07029. **242**

RESISTOR ENGINEERING HANDBOOK. A newly expanded and revised version of RCL's "Resistor Engineering Handbook" updates technical specifications on a large selection of precision and power wire-wound and high-reliability resistors. Also included is information on chip resistors for use in computer and peripheral equipment applications, plus 100 and 250W aluminum-housed resistors. Millimeter conversions, as well as a Mil-Spec reference guide, are also included. RCL Electronics, Inc., 700 S. 21st St., Irvington, N J 07111. **243**

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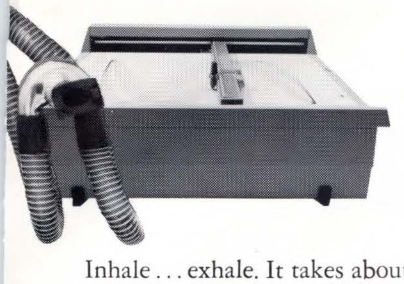

One OEM xy recorder works at breathtaking speed.

Inhale . . . exhale. It takes about 4.5 seconds. Just about any XY recorder could chart the volume of air in a human breath—if doctors were willing to settle for a flow loop the size of a half dollar. But they won't. In a breath analyzer, a small flow loop means imprecise, hard-to-read measurements. And Hewlett-Packard's new Model 7041A High Speed XY Recorder is the only unit fast enough to chart a large, accurate picture of the lung's "vital capacity." In real time.

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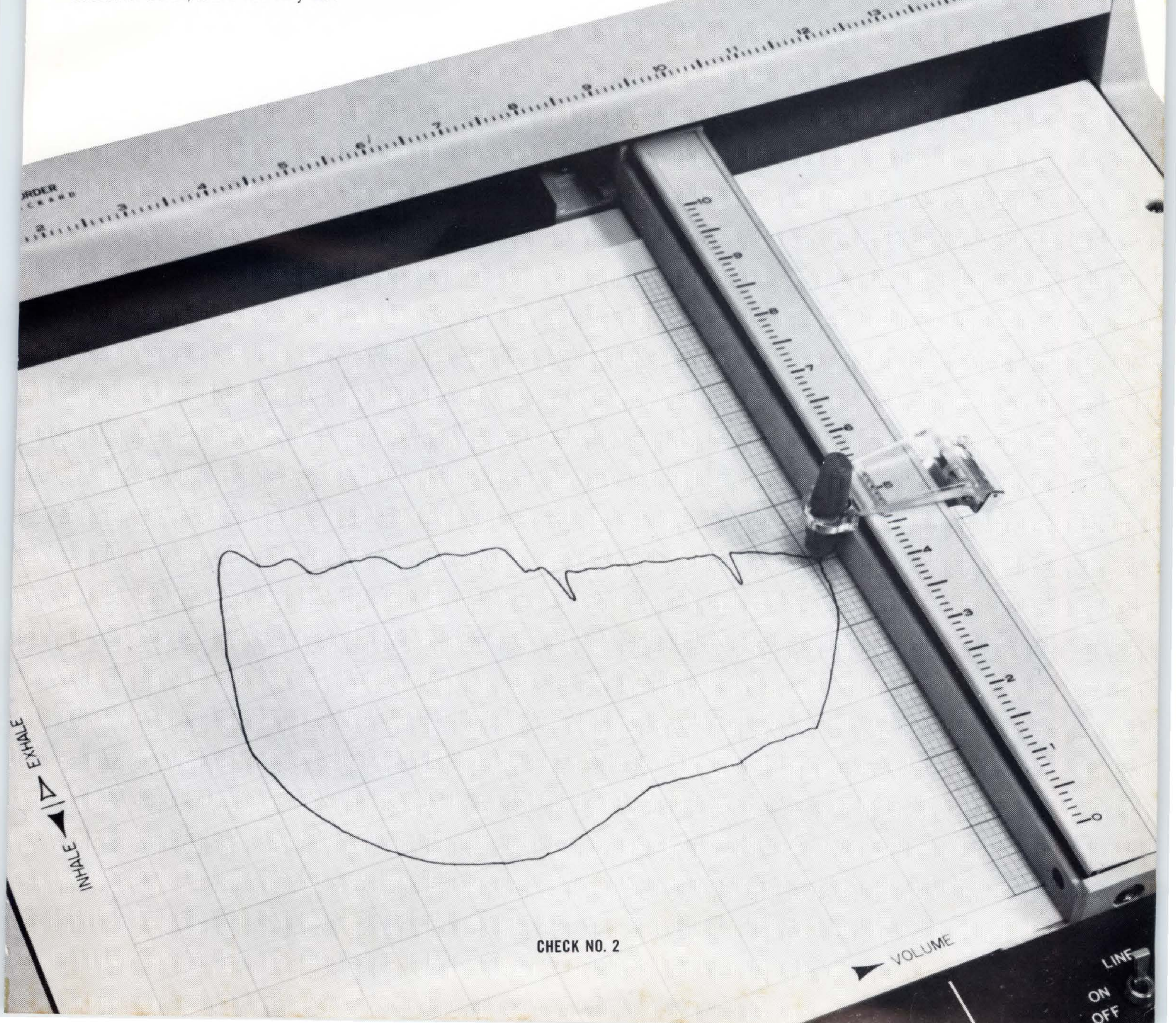

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16/18 Character Position Panel, 5 x 7 Dot Matrix, Characters 0.4" High. Available as numeric only or alphanumeric panel with 64-character format.

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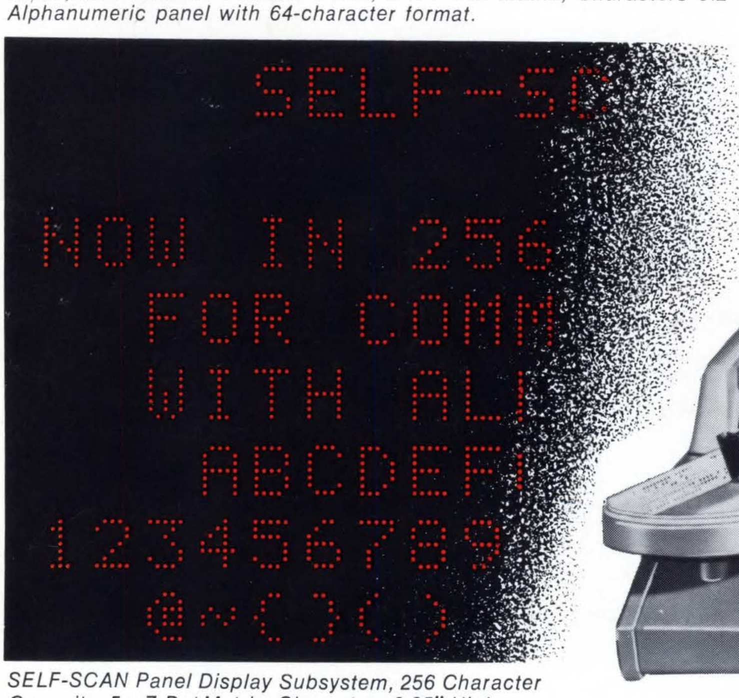

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