

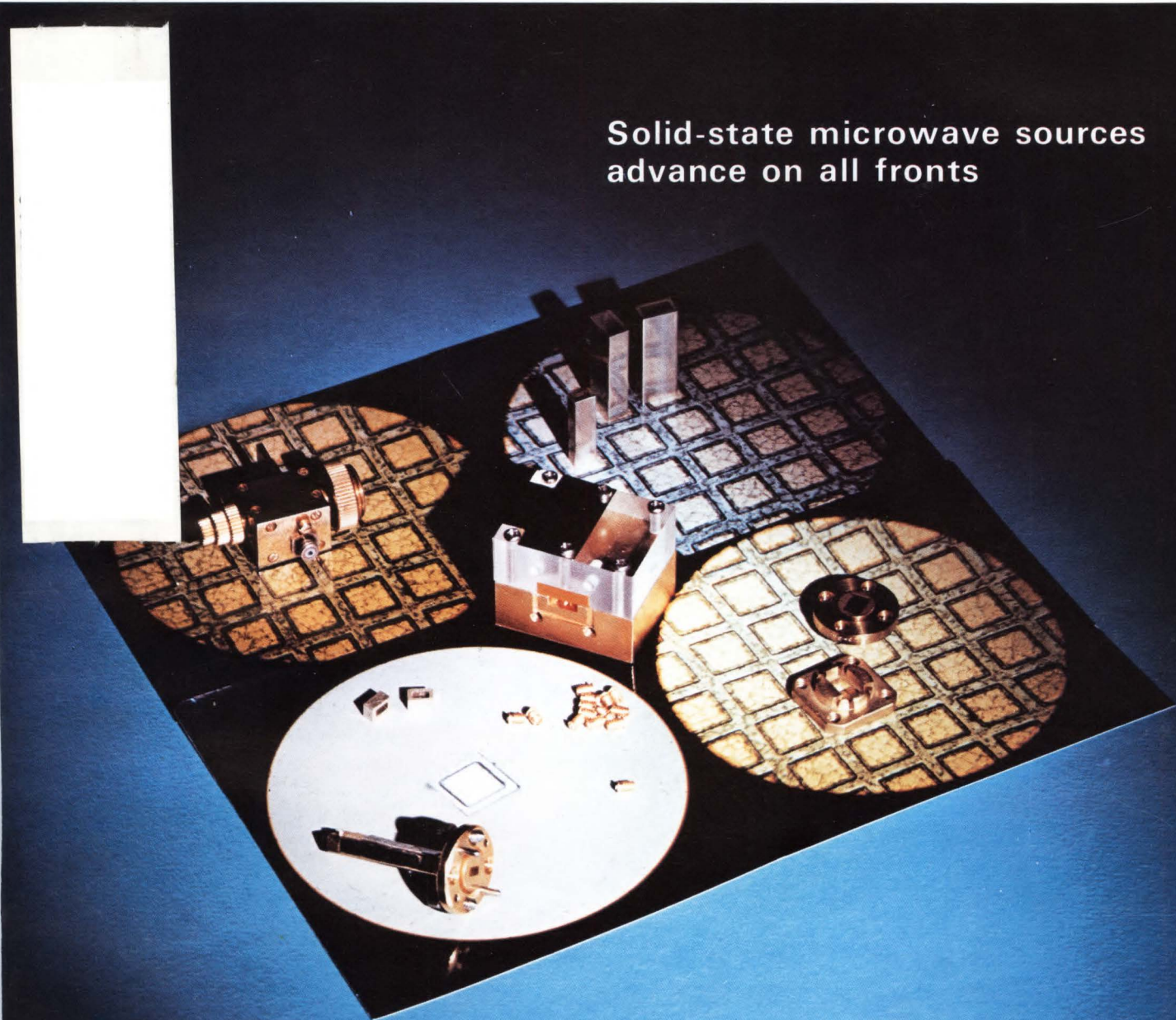
EXCLUSIVELY FOR DESIGNERS AND DESIGN MANAGERS IN ELECTRONICS

# EDN

Avoid obsolescence in  
automated test systems

Simple converters are  
a snap with CMOS

**Solid-state microwave sources  
advance on all fronts**





# Siemens



**No one knows ferrites like a ferrite user.  
We produce and use more quality ferrites than anyone.**

Siemens, a world leader in the design and manufacture of sophisticated telecommunications and computer systems, has also become the world's leading producer of linear, memory and microwave ferrites. Ferrites that are performance and reliability engineered to meet our demanding

system requirements.

Siemens pioneered T38 with permeabilities of 10,000, T9 and T10 high-density ferrites for recording heads, SM6 and M6 filter inductors for high packing densities, N32 linear ferrites with a wide temperature range, and CVB7 microwave material.

Siemens design engineers are ready to assist you in solving your ferrite problems.

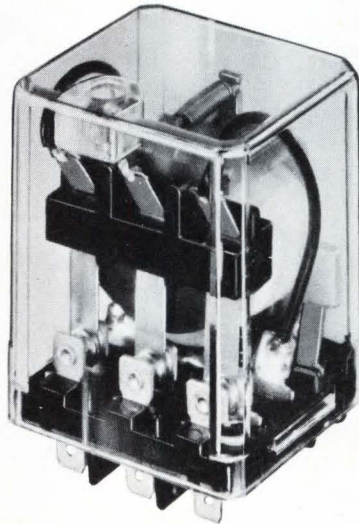
Siemens Corporation, 186 Wood Avenue South, Iselin, N.J., 08830. (201) 494-1000. Siemens. A three billion dollar name in quality products.



**SIEMENS**



# G P



## MAGNECRAFT'S NEW CLASS 388 GENERAL PURPOSE RELAY

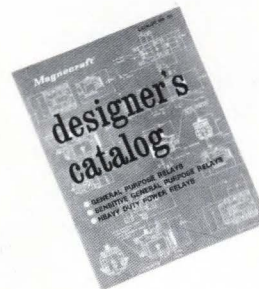
Magnecraft is pleased to introduce the new Class 388 General Purpose Relay. This inexpensive, high performance line of stock relays offers many quality features found only in custom built versions. Available in either a covered plug-in or open style with a wide choice of AC or DC coil voltages and SPDT, DPDT, or 3PDT 10 amp contacts.

All Class 388 relays have 3-way pierced terminals. While spaced for standard plug-in mounting, the flat terminals (0.187" x 0.020") also accept quick-connect receptacles or direct soldering. For plug-in use, three types of chassis mounted sockets are available; quick-connect, solder, or printed circuit terminals. Covered plug-in version has a tough clear polycarbonate plastic cover.

In a highly competitive business, delivery can be a deciding factor. If delivery is important to you, be aware that Magnecraft ships better than 90% of all incoming orders for stock relays, received before noon, THE SAME DAY (substantiated by an independent auditing firm). In addition to our shipping record, most stock items are available off-the-shelf from our local distributor.

# FREE!

## DESIGNER'S CATALOG



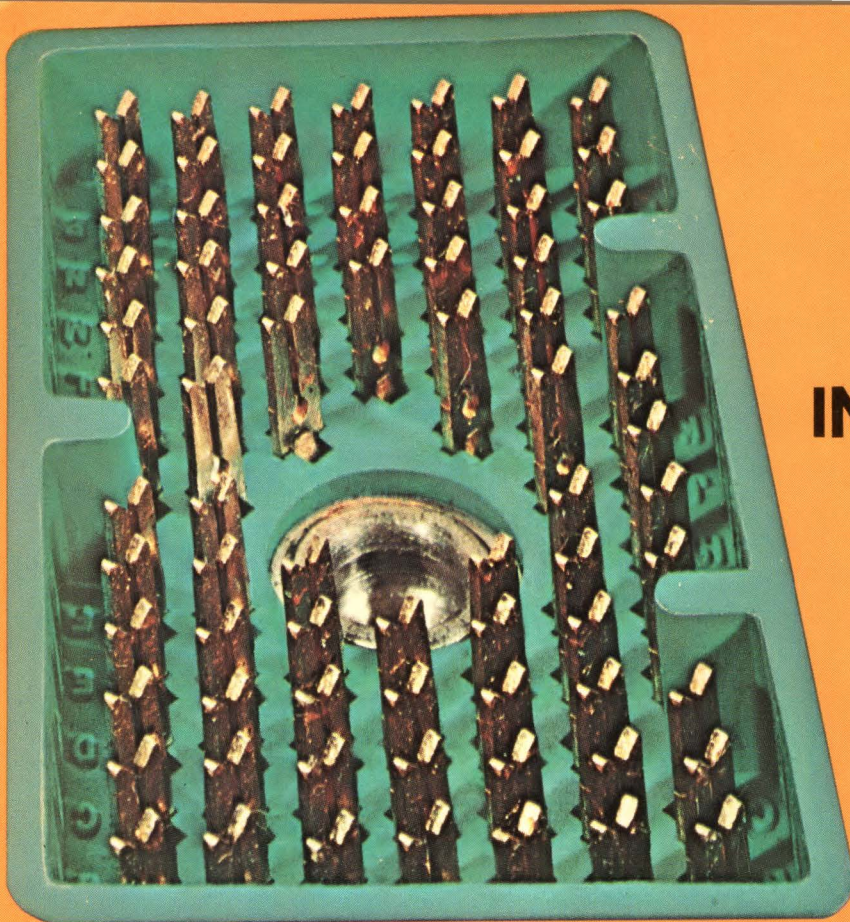
The purpose of this 36-page catalog is to assist the design engineer in specifying the proper relay for a given application. The book completely describes General Purpose, Sensitive General Purpose, and Mechanical Power Relays. New products include the complete line of Class 388 General Purpose Relays.

**Magnecraft<sup>®</sup> ELECTRIC COMPANY**

5575 NORTH LYNCH AVENUE • CHICAGO, ILLINOIS 60630 • 312 • 282-5500 • TWX 910 221 5221

CIRCLE NO. 1





## PACKS TWICE THE CONTACTS IN THE SAME SPACE AT ABOUT HALF THE COST

Elco's solution to the escalating packaging squeeze and packaging costs in electronic circuitry. A line-up of I/O rack and panel and cable-to-cable connectors with contact spacing on .100" and .125" centers.

On a performance/price basis, these high density connectors are your best buy. Quality is equal to or better than, and published prices are much less than those of their pin-and-socket counterparts.

Take the Series 8026 R/P and cable-to-cable connector that's equipped with the Elco high-reliability crimp-and-insert mini Varilok™ contact. Team a Series 8026 117-contact plug with its corresponding receptacle, and you have a 117-contact connector that's in the same envelope as a 56-contact connector on .150" spacing. But packing more than twice the contacts in the same space.

The 75-contact 8026 connector will fit in the same space as a 38-contact connector on .150" spacing. And the 8026 33-contact connector is one of the smallest 33-contact R/P connectors you've ever seen. For back-up, we offer Series 8026 connector with 55 and 79 contacts on .125" square grid.

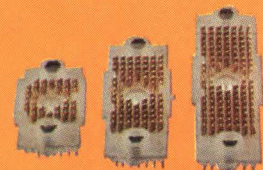
For full details on these new connectors from Elco, contact your local Elco representative or distributor, or: Elco, Willow Grove Division, Willow Grove, Pa. 19090, (215) 659-7000 • Elco, Pacific Division, 2200 Park Place, El Segundo, Calif. 90245, (213) 675-3311.

For your I/O back-panel applications, Elco Series 5540 connectors are available in the same sizes as the 8026, but use the field-proven Varicon™ contact with .025" square wire-wrappable posts. They incorporate—as do the 8026's—a new female turnable jackscrew that eliminates any possibility of damage to plate contacts in difficult or blind mating situations. Both series use standardized polarizing and keying hardware to prevent unmatched plugs and receptacles from being mated.

And by no small coincidence, hardware standardization and using one contact for both sides lets you minimize your in-house and field stocking requirements, and allows you to use the same manufacturing set-up to assemble all sizes.

Besides helping you cope with your close-order circuits, these connectors will help you effect other cost economies. Like using your existing 8016 panel punches. Reducing inventory because they can do duty in R/P and cable-to-cable applications as well as be used as an I/O.

There's one more bonus. Immediate availability. Both series. All sizes. Another service in keeping with CONNECTRONICS, Elco's Total Connector Capability.



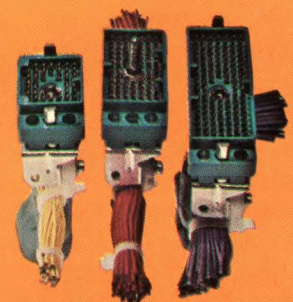
Series 5540 input-output receptacles with or without polarizing hardware. On .100" grid with 33, 75 and 117 contacts. On .125" grid with 55 and 79 contacts.



Polarizing hardware provides 36 polarization combinations per connector pair.



Metal covers for 33, 55, 75, 79 and 117-contact connectors have top and side cable entries.



Cable strain relief clamps are adjustable for small and large cable bundles, can be mounted on plug and/or receptacle.





# If we didn't build a lot more experience into our capacitors, we couldn't get a little more for them



We know you couldn't care less about TRW's experience in making capacitors. Unless it affects your experience—in using them.

It does. Because we come by it two ways. From innovation, which gives us a lead in technology. And from specialization in wound film and tantalum types, giving us the deepest, broadest experience. The kind that makes our capacitors worth more to you.

To see how, consider the metallized kind.

Anyone can make them small. Or reliable. But it takes real design experience to realize their full potential—making them small as possible, without sacrificing performance or full operational reliability. And, plainly, no one has more experience than a company that specializes in them. Us.

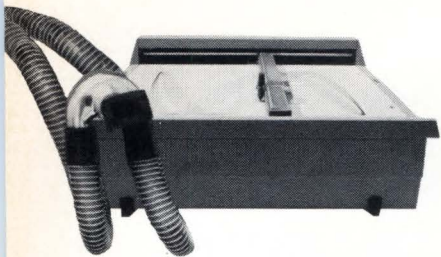
We also have more application experience. We know what metallized capacitors can and can't do. How far they can be pushed. When and how to use them best. We can often solve a customer's size problems by fitting the right design to a specific application where metallized parts hadn't been previously considered.

In manufacturing and handling, our experience means what you see in engineering design is what you get in volume. The same high performance.

Why do so many companies gladly pay the little extra we have to charge for our capacitors? One reason is our experience. Another is theirs.

To share it, write or call TRW Capacitors, an Operation of TRW Electronic Components, Box 1000, Ogallala, Nebraska 69153, (308) 284-3611. TWX 910-620-0321.





# 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.

The 7041A is an OEM machine from the ground up, designed for speeds in excess of 30 in/s. It's the only XY

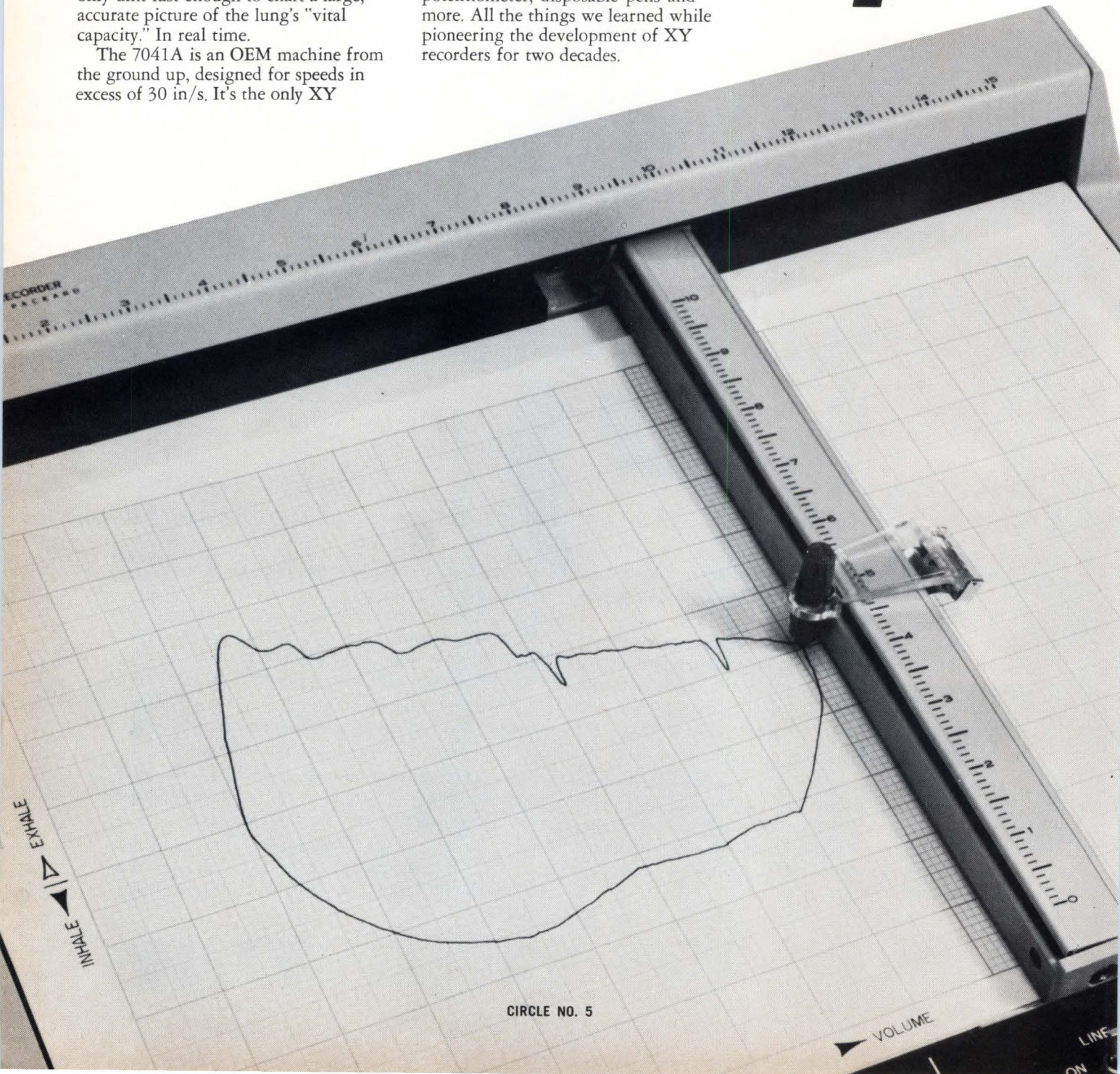
recorder built on a one piece, die-cast aluminum mainframe. And you can choose from nearly 40 independent options to customize the recorder to your special application (standard or high speed). You'll get just what you want... and only what you want.

Our standard features make sense in any OEM system: Autogrip electrostatic holddown, IC circuitry, long-life hybrid potentiometer, disposable pens and more. All the things we learned while pioneering the development of XY recorders for two decades.

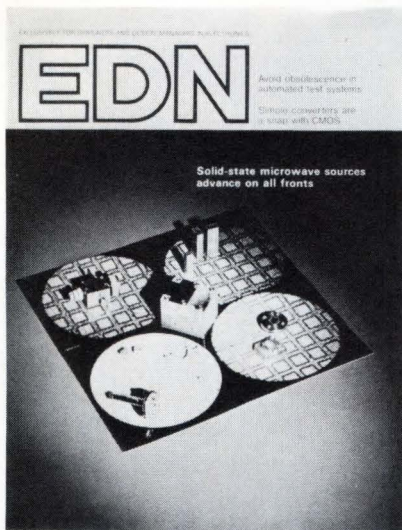
H-P's new cast aluminum XY recorder: high accuracy at breathtaking speed. Make your own diagnosis, get specifications and discount data from Hewlett-Packard, 16399 West Bernardo Drive, San Diego, California 92127. Europe: 1217 Meyrin-Geneva, Switzerland.

112-01

HEWLETT  PACKARD







## COVER

Some of the commercially available state-of-the-art solid-state microwave oscillators and amplifiers are shown in this photo supplied by the Watkins-Johnson Co. For a complete round-up, see the story on page 22.

## DESIGN NEWS

**Computer controlled system speeds up instrument calibration . . . 14**  
. . . Fourth-generation computer techniques are brought to small-system users . . . Inexpensive, portable radiation detector keeps tabs on radio-relay and microwave-oven leaks.

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**Design obsolescence out of automatic test systems . . . . . 30**  
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**Elementary A/D converters efficiently implemented in CMOS . . . 36**  
The special characteristics of CMOS logic allow designers to throw in low-accuracy 1-1/2 to 2-1/2 digit D/A and A/D translations between the analog and digital worlds.

**CIRCUIT DESIGN AWARDS . . . . . 54**  
Three components make stable crystal oscillator . . . Digital pulse repeater . . . Digital error anticipator requires only 4 CMOS gates . . . CMOS one-shot has wide range of output pulses.

## COMPUTER HARDWARE

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**Hovik and Hodge speak out on writable control storage vs ROM . 46**  
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## PROGRESS IN PRODUCTS

**Writable-control store customizes new mini's microprograms . . . 57**  
. . . Multifunction IC serves as building block for communication systems . . . Low-cost 9- $\mu$ sec 14-bit A/D converter available in a plug-in module . . . Sub-modular circuit cuts power supply design time and costs.

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# Everybody wants your components business.

## But we're doing 6 things to earn it.

**1 We build extra reliability into all our components.** Documented reliability from ER through industrial, from precision through general purpose. To let you build extra reliability into all of your systems.

**2 Our pricing is more than just competitive.** If it weren't, why else would our customers have made us the largest supplier of metal film resistors in the country? And that metal film market includes glazed resistors.

**3 We insist on delivery you can count on.** Our "ball parks" are dependable. And our distributors provide off-the-shelf delivery from an inventory in excess of 50,000,000

components. To let you reduce expediting and inventory levels.

**4 Our QC and unique product configurations make your production more efficient.** Many of our customers find they can totally eliminate incoming QC testing of our parts. Others find our parts greatly simplify both hand insertion and automatic insertion operations.

**5 Our new products can give you better alternatives.** Like our FAIL-SAFE™ flame proof resistors. They open — never short — under overload. Plus they're economical replacements for non-inductive and semi-precision power wirewounds.

**6 We back everything with the best support team in the business.** We have the industry's largest technically-trained field force. And a select team of the industry's most service-oriented distributors. Because we know it takes top service to compete for your business.

Like everyone, we want your components business. But we're intent on doing more to earn it. Let us prove how much more on your next project. Write: Corning Glass Works, Electronic Products Division, Corning, New York 14830 or Call: (607) 962-4444, Extension 8381

**CORNING**  
ELECTRONICS

**Resistors & Capacitors**  
for guys who can't stand failures



# NEWS RELEASE

Tektronix, Inc., P.O. Box 500, Beaverton, Oregon 97005

Phone: 503-644-0161



**TEKTRONIX®**

**FOR RELEASE:**

May 8, 1972

**Today's new technology demands new performance.** You need quick, accurate solutions for complex measurement problems. The new 7700 FAMILY, a part of the 7000-Series, is your solution.

You have 250-MHz, 200-MHz and 175-MHz performers to choose from.

**You get:** Maximum measurement flexibility, by using up to four plug-ins. You can choose from twenty vertical and horizontal modes for measurement speed.

**You also get:** Maximum oscilloscope system versatility from a choice of twenty-four plug-ins for amplifier, time base, curve tracer, digital multimeter, digital counter, spectrum analyzer and sampling applications.

Compare the TEKTRONIX MAINFRAME-option-plug-in concept with others. You'll realize immediate cost savings by purchasing only those options and plug-ins you presently require. The 7704A's modular electrical and mechanical design brings you all this plus capacity for future expansion.

Gain performance and save dollars with the 7704A. This is achieved by using proprietary and commercial ICs, a high efficiency power supply, a new fast CRT and a total new design.

You gain even more operator speed and accuracy by using CRT READOUT. It displays all the measurement parameters right on the CRT where you make the measurement.

Look at the entire line of probes, cameras, SCOPE-MOBILE® carts and other accessories, plus the selection of twenty-four plug-ins. This oscilloscope system is an integrated test system that solves virtually any measurement problem.

**Tektronix, Inc. . . .**

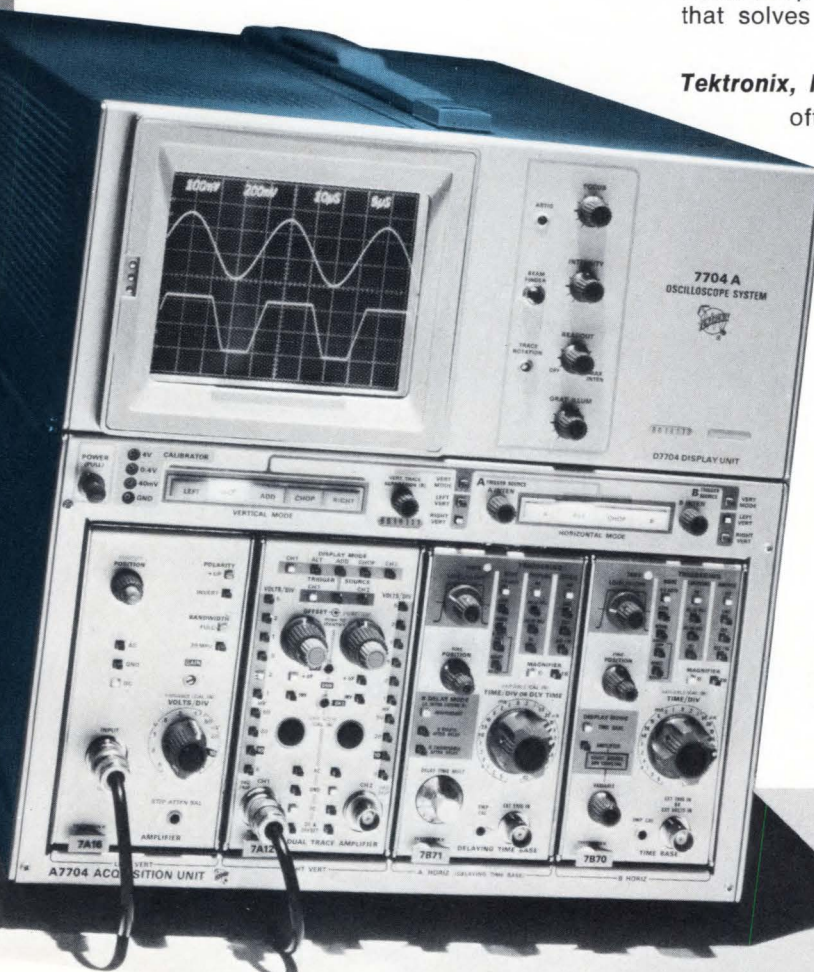
offering sales, after sales support and service . . . world wide.

**250-MHz 7704A Oscilloscope System . . . bandwidth option . . .**  
(less plug-ins) . . . . . **\$2400**

**200-MHz 7704A Oscilloscope System . . . optimum pulse response . . . (less plug-ins) \$2400**

**175-MHz R7704 Oscilloscope . . .**  
(less plug-ins) . . . . . **\$2650**

**7704A Oscilloscope System . . .**  
newest member of the 7700 FAMILY  
and of the GROWING 7000-SERIES







### A salute to the calculator

The next time you push a button on an electronic calculator, pause for a moment and consider what that little box represents. You may think of it as an electronic slide rule or an electronic adding machine. But, symbolically it's much more.

We feel that it represents one of the major achievements realized by the United States' electronics industry in recent years. This is not based on technological accomplishments alone, but on economic and marketing considerations as well. Some great electronics work was done for the Apollo program. But those technological triumphs were accomplished without many of the cost and competitive pressures under which products like calculators were developed.

Today's calculators combine the best of semiconductor, display and packaging technologies, and do so at a cost that would have been thought impossible only a few years ago. The vast potential of the market has acted as a powerful stimulant for component manufacturers to continuously push back the boundaries of technology—not just for better-performance components, but for items that can be mass produced easily and cheaply.

The result is items like MOS circuits and gas-discharge and LED displays that combine the sophistication traditionally associated with aerospace electronics with a cost and mass producibility normally connected with consumer electronics.

All of these accomplishments have made the United States the leading manufacturer of not just calculator components but calculators themselves. And this in spite of the fact that just a year or two ago the Japanese gave every sign of capturing the lion's share of the calculator market, just as they had done with transistorized radios. This time, though, American companies realized that there is a market, created by technological advances, ready to be exploited. And instead of merely being a component supplier, the United States industry went to work with its know-how and capability and showed what it can do when it really wants to.

We'd like to think that the successful marriage between the calculator and the electronics industry will be repeated in other areas. It wouldn't take too many of these almost ideal unions to ensure a healthy and prosperous electronics industry.

*Frank Egan*

Editor



## Another Sprague Breakthrough!

Solid flame-retardant epoxy with precise dimensions for automatic insertion. Completely shock and vibration resistant.

Flat surface permits clear easy-to-read marking.

No rundown to interfere with seating of capacitors on printed wiring board.

Rugged 0.025" dia. tinned leads maintain alignment. 0.100" lead spacing for standard PWB grids.

## PRODUCTION-ORIENTED SOLID TANTALUM CAPACITORS

Top flat for easy identification of positive lead either visually or by touch.

Standoff feet on base to eliminate moisture entrapment and facilitate cleaning of wiring boards.

Formed leads with either 0.200" or 0.250" spacing to permit interchangeability with dipped capacitors.

ACTUAL SIZE

# Type 198D Low-cost Econoline\* Tantalum Capacitors Lead in Performance!

When it comes to low-cost solid tantalum capacitors, the new Sprague Type 198D Econoline Capacitors outperform all other designs. Here are some additional advantages:

- Low d-c leakage
- Low dissipation factor
- Wide voltage range, 4 to 50 VDC
- Capacitance range from 0.1 to 100 $\mu$ F
- Withstand severe temperature cycling and temperature shock over -55 C to +85 C
- Speedier handling for insertion
- Easier-to-read markings

The new Sprague Type 198D epoxy-encased Econoline Capacitor is tooled for mass production and priced competitively with imported dipped units. Investigate this new Sprague breakthrough without delay.

Call your nearest Sprague district office or sales representative, or write for Engineering Bulletin 3546 to: Technical Literature Service, Sprague Electric Co., 491 Marshall Street, North Adams, Mass. 01247.

★Trademark

THE BROAD-LINE PRODUCER OF ELECTRONIC PARTS



CIRCLE NO. 39

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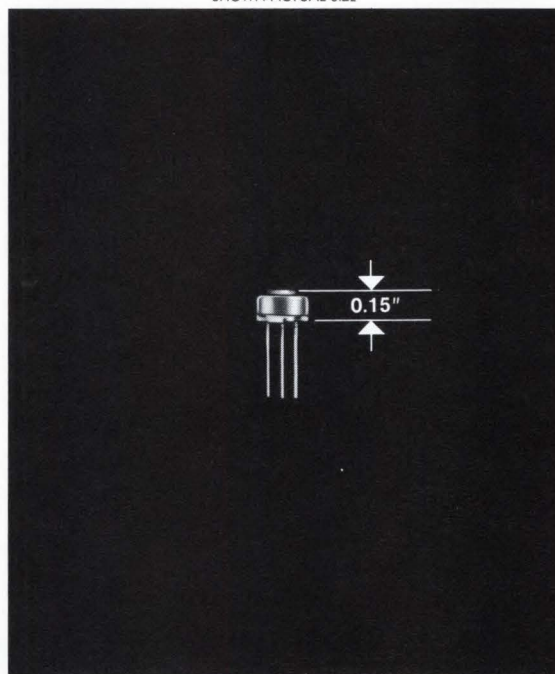
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# New from Helipot: the lowest trimmer profile in the business.

SHOWN ACTUAL SIZE



You can't do better than our Series 82 Trimmers for small size and low cost . . . and, of course, Helipot dependability. These  $\frac{1}{4}$ " single-turn, general-purpose cermet models have the lowest profile in the industry with a proven cermet resistance element that can be set to any voltage ratio within 0.05% of full scale. Sealed metal housings, solid stops, and essentially infinite resolution. They'll save you space—they'll save you money. (Our prices start at \$1.40 list.) Two good reasons to write for specs and prices today.

**Beckman®**

INSTRUMENTS, INC.

**HELIPOT DIVISION**

2500 Harbor Blvd., Fullerton, Calif. 92634

HELPING SCIENCE AND INDUSTRY IMPROVE THE QUALITY OF LIFE

CIRCLE NO. 9



# Single-Diffused

## ...better than EpiBase?

We've got both now. Single-diffused, UniBase\* power Darlington. EpiBase\* power Darlington. Plus capability to supply discrete power transistors in both technologies. The first to do this.

Great, you say. "Let me have the latest thing so I can edge my competitor's design."

Wait, though . . . not that easy. Unless you understand the basics of both technologies you won't get what you really want — an optimum device matched to true design needs, with the best trade-offs in device characteristics.

More and more engineers are educating themselves before designing in either process. Questioning and comparing to find out which is really better for their application. Probing. Analyzing. Asking.

"Are they structurally different?"

"Which is better for high-speed switching?"

"Is there an edge in safe operating area?"

"What are tradeoffs in inductive loads?"

"Which is more applicable to complementary designs?"

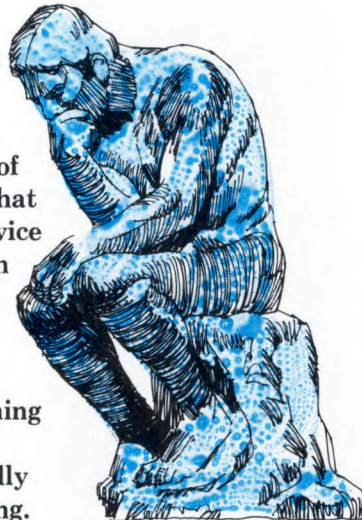
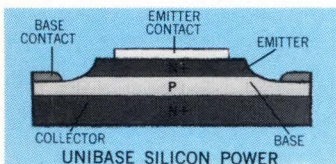
If you're satisfied with your supplier's answers, your education, your design, fine. If not, listen.

### TAKING THE RIGHT SHAPE . . .

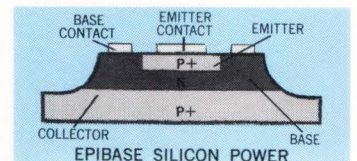
They're different, alright.

Single-diffused, UniBase, is achieved by diffusing collector and emitter into lightly doped P material with the base formed by the undiffused portion of the start material. Emitter and collector are equidistant from opposite chip sides. The deep emitter junction biases off high-current density area and leads to more uniform current distribution throughout the emitter. Result: very good safe operating

area . . . with low frequency response due to distributed resistance and longer RC time constants.



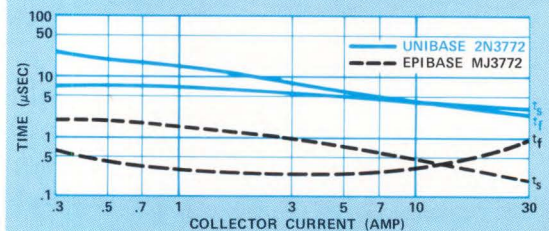
EpiBase offers devices with emitter diffused into an epitaxial base deposited on the collector substrate. The collector voltage depletes into the base region with resulting devices characterized by higher-frequency response and low switching losses with SOA equal to, or better than, UniBase except at or near device  $BV_{CEO}$ .



### THE TRADEOFFS . . .

A couple. If switching efficiency,  $f_T$  or phase shift are your thing, EpiBase wins hands down. Although power-handling and safe area of the two are about equal, UniBase offers an edge in SOA if your design pushes ultimate device break-

Where the action is . . .

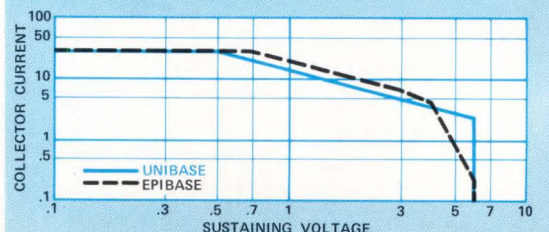


down capability. And, while beta-vs.-current curves are similar for EpiBase and UniBase transistors of given chip size, UniBase will exhibit higher sat voltages and slightly lower high-current beta. Again, a result of higher distributed resistance.

Typically, more gain and gain linearity can be had with EpiBase by sacrificing some ruggedness. With EpiBase, it's near-impossible to achieve high  $f_T$  and high SOA simultaneously . . . something's got to give.

Conversely, single-diffused offers a bit more SOA but slower action; and gain and gain roll-off figures of merit are only about half or less than EpiBase counterparts.

If your motto's "safety first" . . .



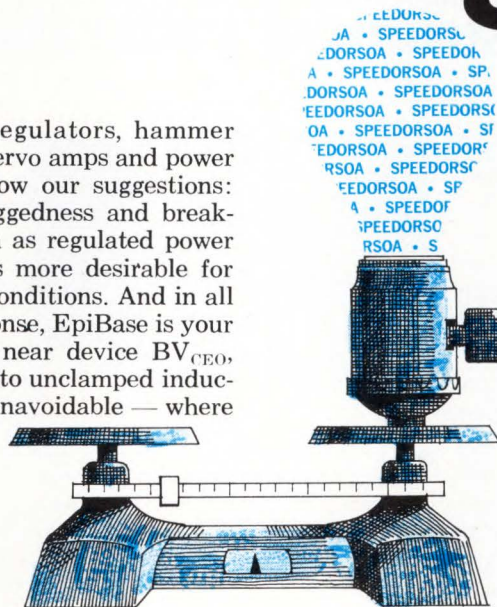


# Power Darlingtontons

## THE APPLICATIONS . . .

Practically everywhere! Commonly, regulators, hammer drivers, inverters, converters, stereo and servo amps and power switching. Which for which? Easy. Follow our suggestions: we've factored in tradeoffs: gain,  $f_T$ , ruggedness and breakdown voltage. In many applications such as regulated power supplies for high-speed logic, EpiBase is more desirable for its better response to fast-changing load conditions. And in all circuits demanding higher frequency response, EpiBase is your best bet. Because of that edge in SOA near device  $BV_{CEO}$ , UniBase is better where you're working into unclamped inductors — not recommended but sometimes unavoidable — where it must absorb stored energy.

Your Design	EpiBase	UniBase
audio	•	
series pass regulator		•
inverter	•	
unclamped inductive load		•
power switch: slow		•
fast	•	



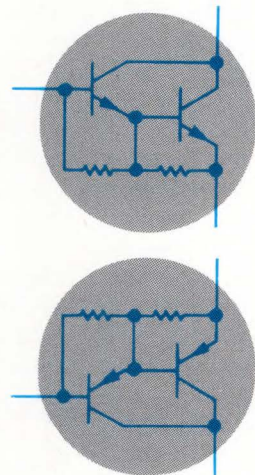
## THE SPECS . . .

## THE DARLINGTONS . . .

Sounds simple: power integrated circuits consisting of driver, output devices and emitter-base resistors on one monolithic chip. But advantages are revolutionary: super-high gain . . . new levels of efficiency, simplicity, cost-savings . . . direct, logic-to-Darlington interfacing . . . with EpiBase available in both NPN and PNP for complementary symmetry designs. Depending on your conclusions and your needs, your choice will be EpiBase or UniBase Darlingtontons.

Draw those conclusions now. Match your design need with an unmatched solid-state power capability. Write us at Box 20912, Phoenix, AZ 85036 — contact your Motorola distributor on prototype or production.

EpiBase or UniBase . . . the choice is yours. But know this. We've got both.



## EPIBASE VS. UNIBASE

### PRIME SPECS ON SOME PRIME

#### . . . NEW DISCRETES

DEVICE	GAIN	FREQUENCY	SAFE OPERATING AREA
EpiBase 2N3055 vs. UniBase 2N3055	20 @ 4A	4 MHz	60V/200 mA
EpiBase MJ3771 vs. UniBase 2N3771	15 @ 15A	4 MHz	40V/200 mA
	15 @ 15A	200 kHz	40V/3.75A
. . . plus a choice between these discrettes			
MJ3772 EpiBase and 2N3772 UniBase	MJ6257 EpiBase and 2N6257 UniBase	MJ3773 EpiBase and 2N3773 UniBase	MJ6302 EpiBase and 2N6302 UniBase
	2N6253 UniBase		2N6254 UniBase

#### . . . NEW DARLINGTONS

DEVICE	GAIN	FREQUENCY	SAFE OPERATING AREA
EpiBase 2N6056 vs. UniBase MJ3521	750 @ 4A	4 MHz	80V/100 mA
EpiBase 2N6283 vs. UniBase 2N6356	500 @ 4A	200 kHz	80V/1.4A
	750 @ 10A	4 MHz	40V/1A
	400 @ 10A	200 kHz	40V/3.75A
. . . plus a choice between these Darlingtontons			
2N6282 EpiBase and 2N6355 UniBase	2N6283 EpiBase and 2N6357 UniBase	MJ3520 UniBase	2N6284 EpiBase and 2N6358 UniBase

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## MOTOROLA POWER

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CIRCLE NO. 10



# Computer controlled test system speeds up instrument calibration

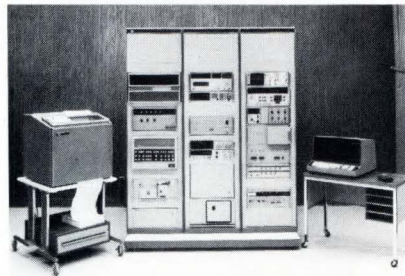
Instrument calibration, traditionally a meticulous and time-consuming procedure, not above human error, has been one area in electronics that has resisted the impact of the computer. But this picture is slowly changing thanks to a new computer-controlled test system from Hewlett-Packard Co., that employs some novel procedures for cost-effective automatic calibration of a wide range of instruments. The HP9550D (Fig. 1) can not only handle voltmeters, oscilloscopes and plug-ins; it can also handle other workloads such as pulse and function generators, electronic counters and oscillators with a slight system expansion.

An example of the system's effectiveness can be shown with a typical dc volt-ohm-ammeter that may have 13 ranges per function. To calibrate such an instrument manually, the operator must redundantly switch through 39 different switch positions and interpret full-scale indications and decide whether the instrument meets its specifications. In addition, he must perform a meter-movement linearity test on one range to make sure that the movement itself is linear. This calibration process can consume upwards of one-half hour. Much of the operator's time is spent visually reading the meter movement.

In contrast, there is the new automatic system (Fig. 2):

1. The system instructs the operator to mechanically zero the meter. With the dc stimulus programmed to 0V, the system DVM measures the actual meter current flowing through the meter movement.

2. The system programs stimulus to provide a nominal 10%-of-fullscale signal and the needle deflects to approximately 10% of fullscale. By means of a hand-held remote-control box with "up/down" buttons, the operator, watching the needle deflection, presses the appropriate button to provide a stimulus adjustment. Thus, he quickly sets the stimulus until the needle deflection is exactly on the 0.1



**Fig. 1—Multitudes of instrument types** can be calibrated easily with this new automatic system from Hewlett-Packard Co. Designated as the HP9550D, it can calibrate analog and digital voltmeters, oscilloscopes, electronic counters and oscillators.

cardinal point. He then presses a "done" button on the remote controller and the system records the actual meter current flowing through the output jack. Meanwhile, the system also records the true dc stimulus.

3. The system next applies a nominal 20%-of-fullscale-signal and the sequence is repeated through each of 10 linearity points as the operator visually adjusts the stimulus and aligns the needle to the exact cardinal points. At each of these points, the system is characterizing the meter movement in terms of the electrical-current output to get a particular mechanical deflection. The entire process takes 30 seconds typically.

4. The system immediately determines whether the meter movement is linear from the recorded stimulus required for the cardinal-point meter deflection.

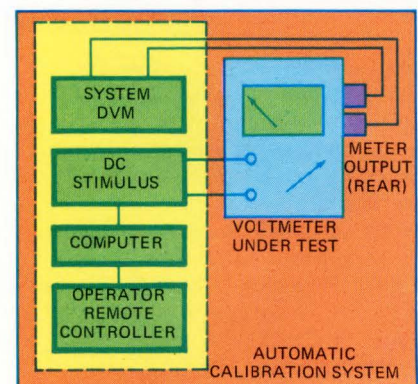
5. The real time-saving impact now occurs as the operator faces the need to test all 3 functions in 13 different range positions. The system instructs the operator to set up, for example, the meter's 1-mV range and with one hand on the range switch he clicks over to the bottom range. In his other hand he presses the "done" button and the system immediately applies 1 mV fullscale. He no longer has to visually read the meter movement because the electrical output and the previously characterized meter data

tells whether the needle is mechanically deflected to precisely fullscale. The system quickly takes its data and then issues the new instruction for the operator to mechanically switch to the next range of 3 mV. The process moves very fast with a range-switch click and a pushbutton depressed waiting only for a short settling time on the meter needle.

6. After the voltage-function calibration is done, the current and resistance functions are run with much the same speed, and again, without any need to watch the meter scale itself.

The overall power of such a fairly simple technique provides a dramatic difference in the calibration procedure itself and primarily in the elapsed time. By restricting the operator to a single visual run of the instrument meter and allowing him to visually hit the meter scale's cardinal points only, his interaction with the test is minimized and the later errors for all 39 range positions are massively reduced.

This basic technique, with minor modifications, can be used to check oscilloscope time bases and vertical-amplifier plug-ins and digital voltmeters. In addition, the new system can be used to make adjustments on out-of-specification instruments. □



**Fig. 2—Rapid dc voltmeter calibration** is achieved with the above configuration. The operator handles a remote controller for a dc stimulus adjustment to the meter's calibration. The controller also allows him to record the actual meter current flowing the meter input once calibration is completed.



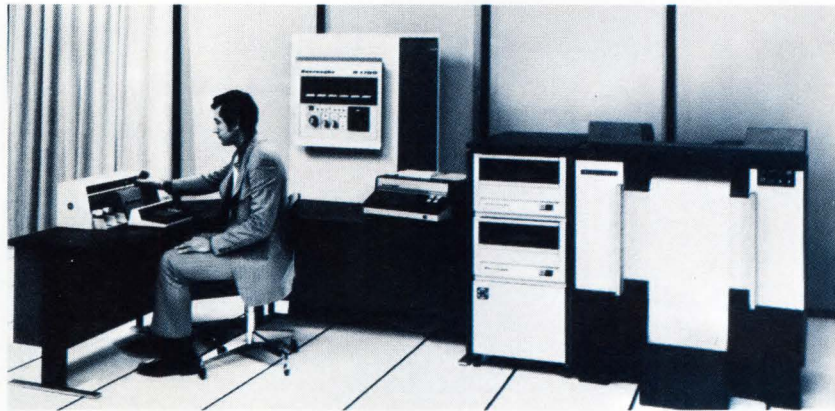
## Fourth-generation computer techniques are brought to small-system users

Interchange Microprogramming, multi-programming & solid-state memory, and virtual memory are now available in a new series of small-scale computer systems announced by Burroughs Corp.

The new B1700 computer systems include microprogramming techniques through use of variable micrologic. Variable micrologic, or more commonly called writable-control store, allows the system's central processor to adapt itself dynamically under program control to a variety of program languages, including FORTRAN, COBOL and BASIC. This means that the system can process any language, including programs written for other systems, at full efficiency. A user can thus select languages that best express the problems he is trying to solve, rather than languages that best suit the computer.

Multiprogramming is introduced to small-scale computer systems with Systems 1700. This feature, as well as virtual memory, is provided by the B1700 master-control program.

The memories are all solid-state.



**Pictured is a typical basic B 1700 system**, one configuration of Burroughs B 1700 Systems, a revolutionary new series of fourth generation, small scale data processing systems introduced by Burroughs Corporation.

The read/write control memory, available in 2k or 4k, 8-bit bytes, has 167 nsec cycle times and 225 nsec write cycle times for a 16-bit (2 byte) word. The main memory has a 666 nsec read cycle time for a 24-bit word and is expandable, 16k bytes to 98k. Having up to eight I/O controls simultaneous reading, writing and computing can be performed. I/O controls

handle all peripherals for the smaller systems, also disk drives and files in the largest system.

Also featured is bit addressability, resulting in highly efficient utilization of memory. This eliminates the need for pre-defined data structures (words-bytes), and permits every unit of memory to be addressed and utilized by the user's data and programs. □

## Inexpensive, portable radiation detector keeps tabs on radio-relay and microwave-oven leaks

With the preponderance of microwave ovens in the consumer field and the increasing use of higher and higher frequency bands for communications in radio-relay installations, an outcry from both the public and the government has arisen over the effects of microwave radiation on human health and safety. Even with a defined U.S. Government occupational guideline of maximum permissible radiation levels of 10 mW/cm<sup>2</sup> for indefinite exposures, little has been available in the way of low-cost and easy-to-operate instruments to measure these radiation levels. Most microwave-measuring instruments are too specialized and costly, working only at specific frequencies and costing from \$400 to \$1000 or more. In addition, they require a thorough understanding of transmission-line theory.

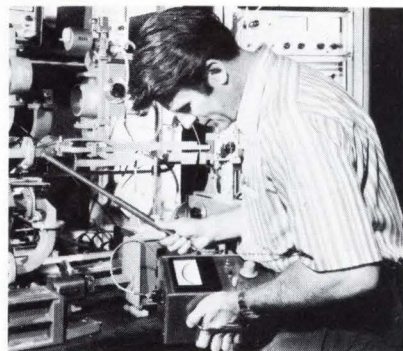
Ronald Petersen, an engineer at Bell

Telephone Laboratories, Murray Hill, N. J., and a member of the environmental and safety department at Bell, has been looking into this problem and has come up with a simple prototype microwave-radiation detector capable of yielding accurate & reproducible results using well under \$100 in components.

The detector covers the 1-to-7-GHz frequency range, which includes the popular 2.45-GHz band for microwave ovens. Most radio-relay installations operate within the instrument's range. Even though the detector is rated down to 1 GHz, it has been used to check microwave ovens that operate at 915 MHz.

Whereas most detectors use thin-film thermocouple junctions, a key factor in their high costs, the new unit uses 4 ordinary metal-barrier diodes (2 in the probe and 2 in the detector).

The cross-dipole probe tip is about 1/10th of a wavelength long at 7 GHz. The probe's design is said to minimize polarization and coupling problems.



**Requiring a minimum of instruction**, this prototype microwave-radiation detector was built for a total-parts outlay of under \$100. It is said to yield accurate and reproducible results, and operates in the 1-to-7-GHz region for checking microwave-oven and radio-relay radiation leaks.







# Think Twice:

## How will you choose your next portable scope ...on faith, or on fact?

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**Scopes Are Changing;  
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082/2

HEWLETT  PACKARD  
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CIRCLE NO. 11

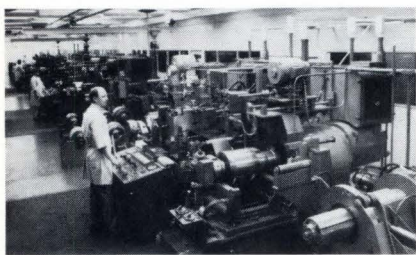


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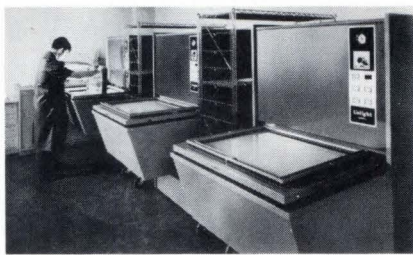
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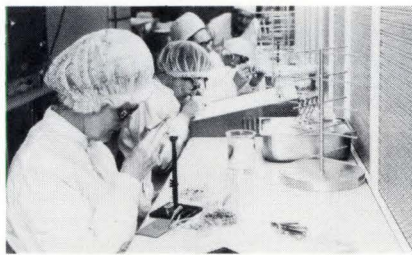
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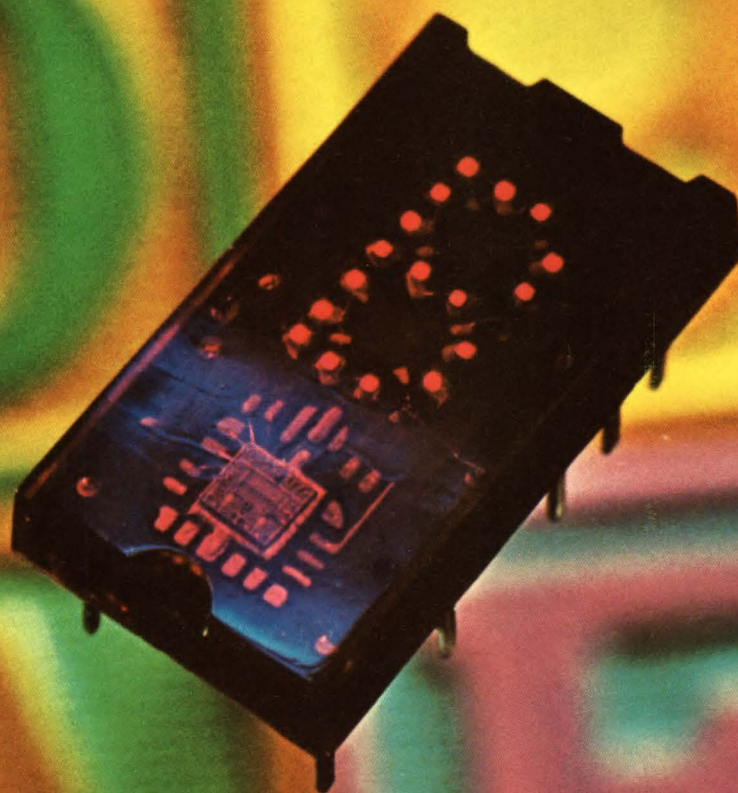
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TIL306	7-segment hybrid with decade counter, latch, decoder, driver	15.50
TIL307	Same as TIL306 but with decimal on right	15.50
TIL308	7-segment hybrid with latch, decoder, driver	12.50
TIL309	Same as TIL308 but with decimal on right	12.50
TIL311	Hexadecimal with latch, decoder, driver	12.50



LED display with an internal TTL/MSI logic chip providing latch, decoder and driver. It accepts 8-4-2-1 data and displays 0 through 9 and A through F with both right and left decimal points.

Other TI displays-with-logic include a 7-segment with latch, decoder and driver and a 7-segment with decade counter, latch, decoder and driver. Both have left and right decimal point versions.

For data sheets on the entire TI hybrid display line, plus applications information, circle 245 on the Reader Service Card. Or for Opto Packet 245 write Texas Instruments Incorporated, M/S 308, P.O. Box 5012, Dallas, Texas 75222.



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\* Reg. Trademark Dupont

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Division of Thomas & Betts Corporation

CIRCLE NO. 14



# Solid-state oscillators tune up at millimeter frequencies

*Here is a round-up of the alternatives available to the system designer looking for solid-state sources and amplifiers of millimeter-wave power.*

**Dr. W. K. Kennedy, Jr. and Dr. J. W. Monroe,** Watkins-Johnson Co.

Solid-state microwave oscillators have gained wide acceptance in both military and commercial systems up to 18 GHz since first becoming commercially available in the mid-1960's. Oscillators using either the transferred-electron (Gunn) effect or the avalanche transit time (IMPATT) effect are just now becoming widely available from 20 to 90 GHz. Oscillators are commercially available with up to 20 milliwatts of cw power at 90 GHz. In the laboratory, 1 watt of cw power has been generated at 50 GHz using a single chip.<sup>1</sup>

This article reviews the different solid-state oscillators and amplifiers available to the systems designer across the 20 to 90 GHz region. Both the advantages and disadvantages of each type of device are covered, with emphasis on the state-of-the-art for commercially-available hardware. This review includes:

- Operating mechanisms
- RF performance
- Availability
- Suppliers

## Device characteristics

Two basic negative-resistance phenomena are used to generate millimeter power. The first type is the transferred-electron or Gunn effect<sup>2</sup>. The Gunn device derives its negative resistance from an inherent property of the semiconductor material from which the device is made. In other words, the material itself exhibits a negative resistance; the device is formed by simply making ohmic contact to the semiconductor.

The most popular material for transferred-electron devices is Gallium Arsenide (GaAs), although Indium Phosphide (InP) has also been used for millimeter devices. The limited space-charge accumulation (LSA) mode is a special circuit-controlled method of operating transferred-electron devices to obtain higher powers and efficiencies. Transferred-electron devices are voltage controlled and are biased to a referenced operating voltage. Application notes on the operation of these devices are available from several companies, including Cayuga Associates, Microwave Associates, Varian, and Watkins-Johnson.

The second negative-resistance phenomenon is the avalanche transit-time (IMPATT) effect. IMPATT diodes derive their negative resistance from an avalanche and drift region within the device. The drift region and the avalanche process cause the rf current to lag more than 90° behind the voltage, producing a negative resistance. The IMPATT diode is the exact opposite of the Gunn device in two important aspects. It has a junction, and it is a current controlled device. Because the diode operates within its breakdown region, the device will fail if the current is not

controlled. Detailed application notes on IMPATT devices are available from Hewlett-Packard Associates, Hughes Aircraft Corporation (Electrodynamics Division), and Raytheon (Microstate Division).

## Transmitters

The IMPATT device is the undisputed high-cw-power champion at millimeter frequencies. IMPATT oscillators at a given frequency typically generate 1 dB to 3 dB more power than transferred-electron devices at the same frequency. Power output as a function of frequency for commercially available IMPATT oscillators is shown in **Fig 1**. Hughes builds a line of fixed-frequency and tunable-IMPATT diodes and oscillators which spans the spectrum from 20 GHz to 95 GHz. Typical minimum output powers for these devices run from 250 milliwatts at 20 GHz to 20 milliwatts at 95 GHz. These oscillators are normally available with less than 90-day delivery.

In addition to higher output powers, IMPATT devices show somewhat better dc-to-rf conversion efficiencies than transferred-electron devices. At 40 GHz, IMPATT's have efficiencies of roughly 4 to 8%, while transferred-electron device efficiencies run about 2%.

High output power, coupled with potential dc-to-rf conversion efficiencies on the order of 10%, have made IMPATTs the choice of the Bell System for repeaters in its "pipe-waveguide" communication system. IMPATTs have the additional advantages of low cost.

The triangular data points in **Fig. 1** provide a glimpse of the future capabilities of IMPATT oscillators. Researchers at Bell Laboratories, using double-drift silicon IMPATT diodes, have experimentally obtained 1 watt of cw power at 50 GHz. Bell scientists have also used IMPATT devices to generate milliwatts of power at 150 GHz. At Hughes, experimental cw IMPATT oscillators have produced 100 milliwatts at 110 GHz. The race to generate higher powers at higher frequencies shows no signs of slowing down, with 200 mW at 200 GHz a realistic research goal for 1975.

Cw Gunn oscillators are now commercially available up through 40 GHz. In contrast to IMPATT's, transferred-electron devices offer the advantages of relatively wide electronic tuning bandwidths and low FM noise for either local oscillator or doppler transmitter applications. **Fig. 2** shows the maximum power-output capabilities of cw Gunn devices as a function of frequency.

Suppliers of hardware in the 18 to 40 GHz range using transferred-electron oscillators include Varian, Microwave Associates, and Watkins-Johnson.

The LSA mode of operation of transferred-electron devices makes watts of pulsed power possible above 20 GHz. However, these devices are still in the early stages of



TABLE 1. COMPARISONS OF BULK MICROWAVE DEVICES		
Device type	Advantage	Disadvantage
Transferred-electron (GaAs bulk effect)	Broadband Low noise Simple power supply (10V dc) Low voltage Linear as amplifier	Low efficiency (5%) Low power (100 mW) GaAs materials
IMPATT	High power (½ watt) High efficiency (10%) Silicon technology	Noisy Narrow band Non-linear as amp. Higher voltage
LSA	Up to 100 watts of pulse power Voltage tunable	GaAs Technology Low average power Tuning-initiated failures

development. Several experimental oscillators have generated more than 100 watts peak at low duty cycles (50 milliwatts average power) at 20 GHz, and greater than 1 watt of peak power at 40 GHz. Cayuga Associates and Watkins-Johnson are currently the only companies developing these devices.

LSA devices offer the promise of up to 50 watts peak power (Fig. 3) by 1975 for beacon applications, such as the Navy's SPN-42 landing system (33 GHz), and phased-array radars in the same frequency region. The higher frequency devices (60 to 90 GHz) offer real advantages in radiometry-type systems, where much of the background clutter and vulnerability to jamming can be overcome. Another advantage of pulsed LSA oscillators at these frequencies is their ability to be "chirped," or frequency-tuned, during an rf pulse. This tunability permits either an increase in the sensitivity of a radiometer or a decrease in the vulnerability of a system to ECM.

Pulsed IMPATT devices are also being developed for millimeter applications. These devices do not have the high peak power potential of LSA devices. However, they offer the systems designer the potential of peak powers approximately an order of magnitude higher than cw powers for IMPATT oscillators. These devices would be extremely useful for commercial applications in the millimeter frequency range, such as small radars for locating planes on airport runways. Many of the automatic braking systems proposed for commercial and private vehicles might also have to move into the millimeter frequency range to reduce spectrum crowding.

### Local oscillator

Transferred-electron devices offer important advantages over IMPATT devices for local-oscillator applications. Gunn devices have very low FM noise and are electronically tunable over a much wider bandwidth than IMPATT devices. IMPATT devices have been developed for local oscillator (L.O.) applications, however, especially by the Hughes Aircraft Corporation. For fixed-frequency L.O.'s, IMPATT diodes operated in high Q cavities can compete with the noise specifications of transferred-electron oscillators. However, the power-output and efficiency advantages of IMPATTs disappear. The relatively simple power-supply requirements of transferred-electron oscillators

make them generally more attractive in L.O. applications.

As mentioned previously, the tuning capabilities of transferred-electron devices are good. Varian makes a 500-MHz bandwidth, varactor tuned oscillator which generates 100 milliwatts of power around any center frequency between 30 and 40 GHz. The bandwidth potential of transferred-electron devices has been demonstrated in experiments in which a single transferred-electron chip has generated power from 4 GHz to 31 GHz<sup>3</sup>.

IMPATT devices, although theoretically limited to practical bandwidths of about 20%, have been used to make broadband tunable millimeter sources. In the 30-GHz to 40-GHz range, Hughes has built mechanically-tunable oscillators having 50 milliwatts of output power minimum across an 8-GHz bandwidth. Hughes has also developed IMPATT oscillators in the 50-GHz to 90-GHz range which can be tuned over several GHz by varying the IMPATT-diode bias current. This device can be an important competitor of BWO's for microwave test equipment from 50 to 120 GHz, because of the high reliability of IMPATT's relative to BWO's. However, the wideband electronically-tunable IMPATT device is less attractive for L.O. applications, because of the relatively high FM noise levels which accompany the low Q tuning arrangement.

Lower-power IMPATT devices are available from several suppliers, including Varian, Hewlett-Packard, Hughes, and Raytheon. The costs of these devices remain relatively high, however. It is difficult to produce low-cost millimeter solid-state oscillators at this time because of the diversity and small volume of existing applications.

Transferred-electron oscillators constructed from Indium Phosphide (InP) are recent arrivals on the millimeter scene. Recent laboratory results from Great Britain<sup>4</sup> in-

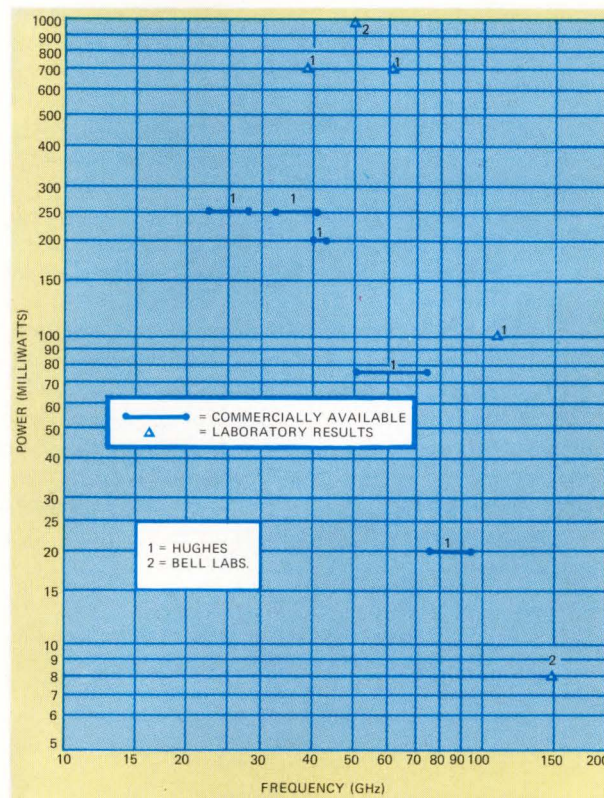


Fig. 1—Comparison of commercially-available and laboratory output powers for cw silicon IMPATT diodes and sources.



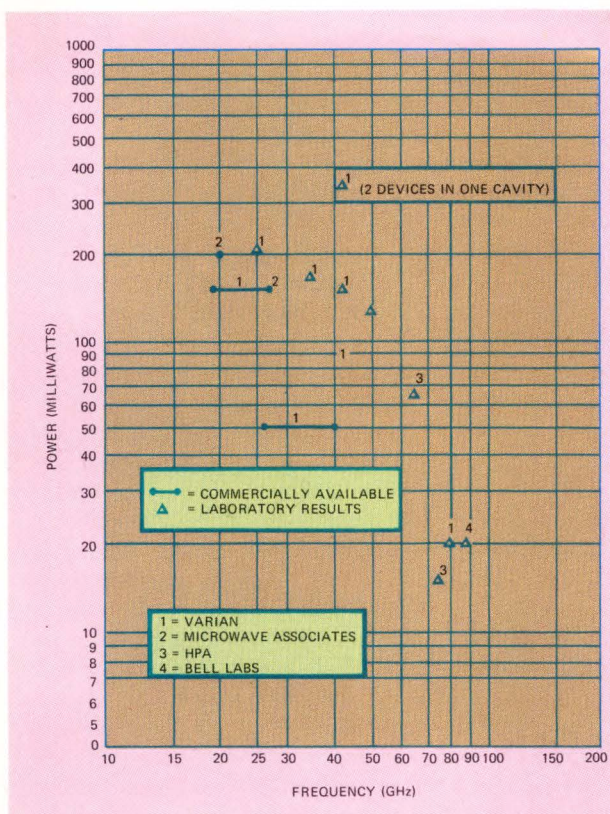


Fig. 2—Comparison of commercially available and experimental cw transferred-electron (Gunn effect) devices.

clude 100 milliwatts of cw power at 35 GHz at 10% efficiency. This result is several years from translation into hardware, however, because of the difficulties associated with production of high-quality InP. Construction from GaAs is listed as a disadvantage in Table 1 because of the "black magic" involved in the epitaxial growth of GaAs.

### Amplifiers

Amplifiers using IMPATT diodes are just becoming available at 35 GHz and above. IMPATT devices are relatively narrowband. They exhibit class-C behavior with output powers similar to those shown in Fig. 1 and noise figures of 35 GHz. Bandwidth limitations on Gunn effect or transferred-electron amplifiers (TEAs) are imposed by available circulators (2 GHz). Other schemes, such as a waveguide structure periodically loaded with transferred-electron devices, may be useful in realizing the waveguide-bandwidth potential of transferred-electron devices.

Noise figures for transferred-electron amplifiers are typically in the 20-dB region at millimeter frequencies. Extremely low noise figures for InP transferred-electron amplifiers have been reported. A noise figure of 7.5 dB at 35 GHz has been observed on a laboratory basis<sup>5</sup>. □

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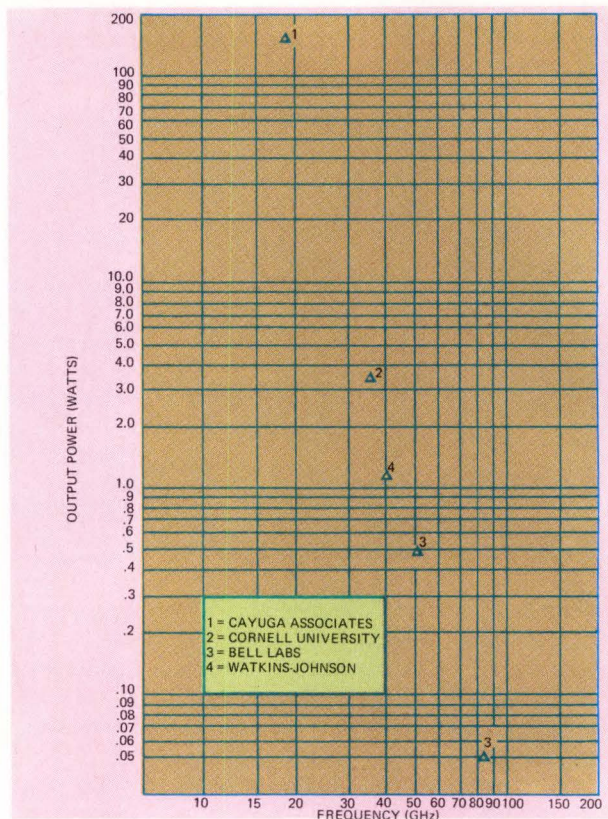


Fig. 3—State of the art pulsed output powers using LSA devices.

### Acknowledgements

The authors would like to thank the following individuals for their time and contributions to this article: Dr. L. F. Eastman of Cayuga Associates and Cornell University, Dr. L. A. MacKenzie of Microwave Associates, Mr. T. Midford of Hughes Aircraft Corporation, and Mr. J. Caldwell of Varian Associates.

### Authors' biographies

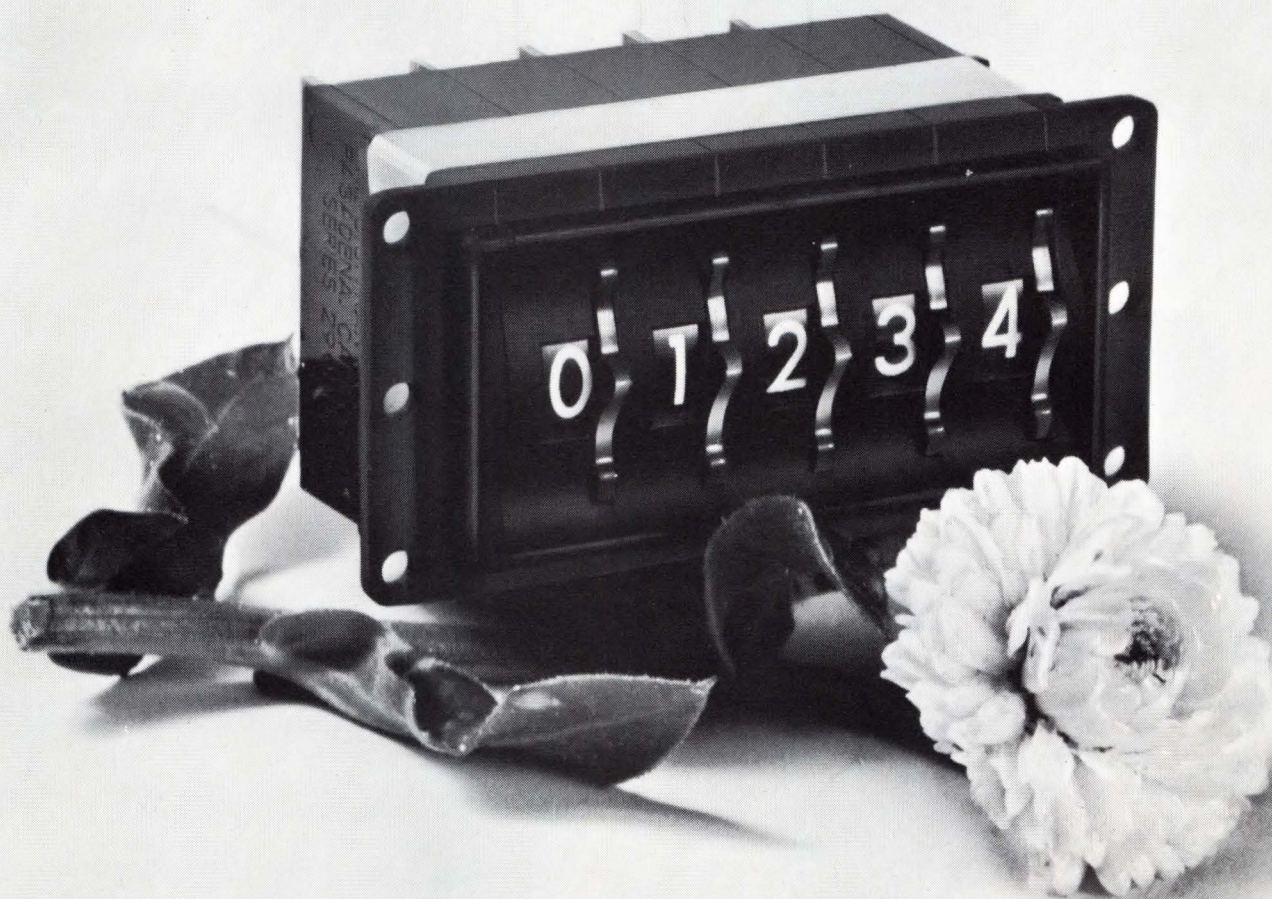
**Dr. W. K. Kennedy, Jr.** is head of the Solid State R & D Section of Watkins-Johnson Co., in Palo Alto, Calif., where he has been employed for the past four years. He is responsible for the development of new microwave millimeter active solid-state components. Dr. Kennedy received his BS, MS, and PhD degrees from Cornell University.



**Dr. J. W. Monroe** is a member of the technical staff of Watkins-Johnson Co. in Palo Alto, Calif., where he has been working for a year and a half. He is responsible for the development of solid-state amplifiers at 7 GHz and above. Dr. Monroe received his BS, MS, and PhD degrees from Cornell University in New York.







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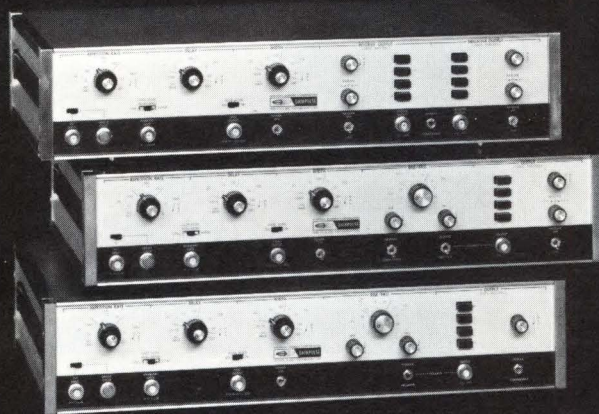
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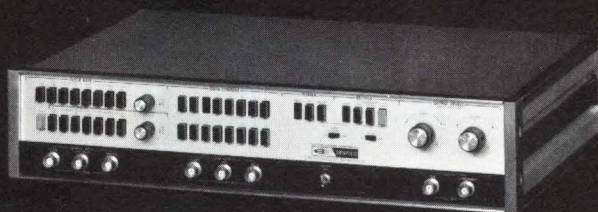
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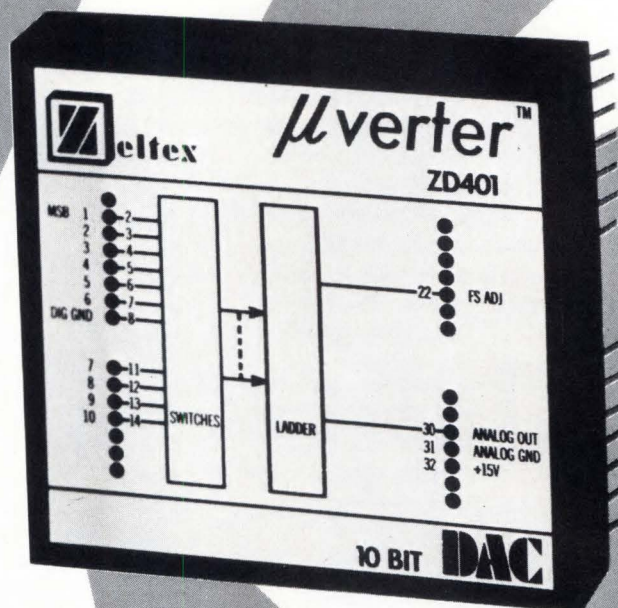
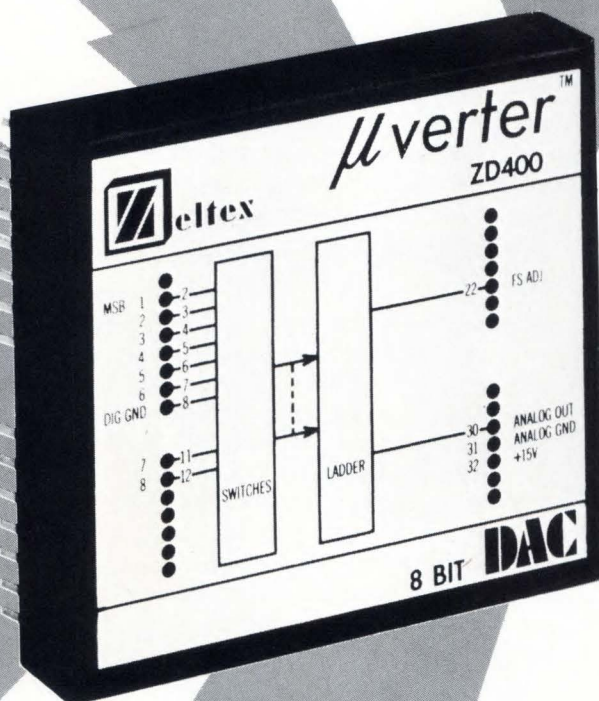
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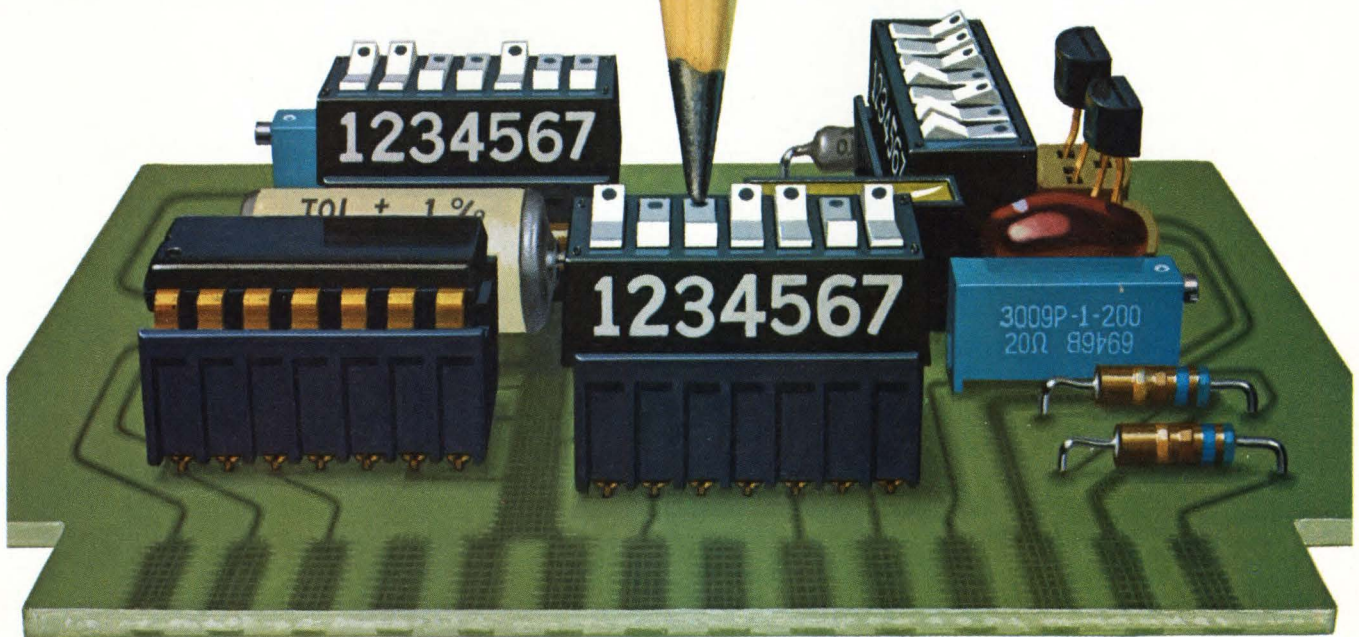
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# Design obsolescence out of automatic test systems

*With the proper software and interfaces, a test system can be designed to handle current and future needs, leaving the user to understand only his unit under test.*

**Phil Jackson**, Instrumentation Engineering, Inc.

Today's designer of complex electronic circuits and systems is faced with a dilemma: How can he best perform a specific series of tests to insure his product's reliability and effectiveness? Should he throw together a homemade benchtester or a group of instruments to do the specific job in question? Or, should he try to win management approval to procure a commercially-available test system?

If his testing problem is very specific, limited and continuous, he may be content with a specialized low-cost homemade tester. However, most testing problems today are complex. If a designer has a variety of concurrent test problems, or knows that he will have many different test requirements not only from week-to-week, but also from year-to-year, then he must either gather up and procure a steadily increasing assortment of new but incompatible test equipment, or try to find a universal test system that will satisfy all his test requirements—now and later. He will find that, from a cost-accounting viewpoint, the latter alternative is the best solution.

## Automatic test systems

The complete realization of automatic multi-purpose test systems depends on the incorporation of the minicomputer, which provides the test engineer with all the inherent advantages of data processing—easy programming, random access, interchangeable peripheral test blocks controlled by the software and non-obsolescence.

Among the many standard test systems available, wide variations in design philosophies are employed. These differences involve interfacing, software, and the building blocks—the peripheral stimuli and measurement devices which can be accommodated by the test system.

To keep the operation of a test system as simple, fast and convenient as possible, pre-designed software should be used to control all hardware, and an interfacing technique should be utilized to facilitate the change of peripheral configurations to meet future test requirements. This philosophy can be realized in a typical test system arranged in the format shown in **Fig. 1**, which for example purposes is Instrumentation Engineering's System 390.

This system is normally controlled by a minicomputer in the same category as the Digital Equipment PDP-8, Interdata 70, or Hewlett-Packard 2115. The device or unit under test (UUT) can be a digital, analog or hybrid component, an IC, a PC board or a subassembly. The test system should be capable of performing functional, static (dc) and/or dynamic (ac) testing on any of these items. It should be available for such purposes as go/no-go production testing, PC-board component-fault isolation, service-facility fault diagnosis, incoming inspection, trend analysis and standard QC/QA procedures.

Such a system can reduce test costs and the manpower for testing, boost production throughput, improve product reliability, reduce capital-equipment and spare-parts inventory and improve customer relations.

## Peripherals

The peripheral devices in this design approach may be standard or non-standard. For maximum usefulness, the test system should be able to accommodate a wide variety of stimuli and measurement devices, such as function and digital-word generators, signal sources, D/A converters, frequency synthesizers, clocks, multimeters, comparators, signal analyzers, etc.

Experience has demonstrated that most of these devices used in automatic test systems are not readily available from the computer manufacturer and therefore must be obtained from a wide array of manufacturers. A key problem in the systems design is how to interface this very diverse mix of peripherals with the input/output bus of the minicomputer.

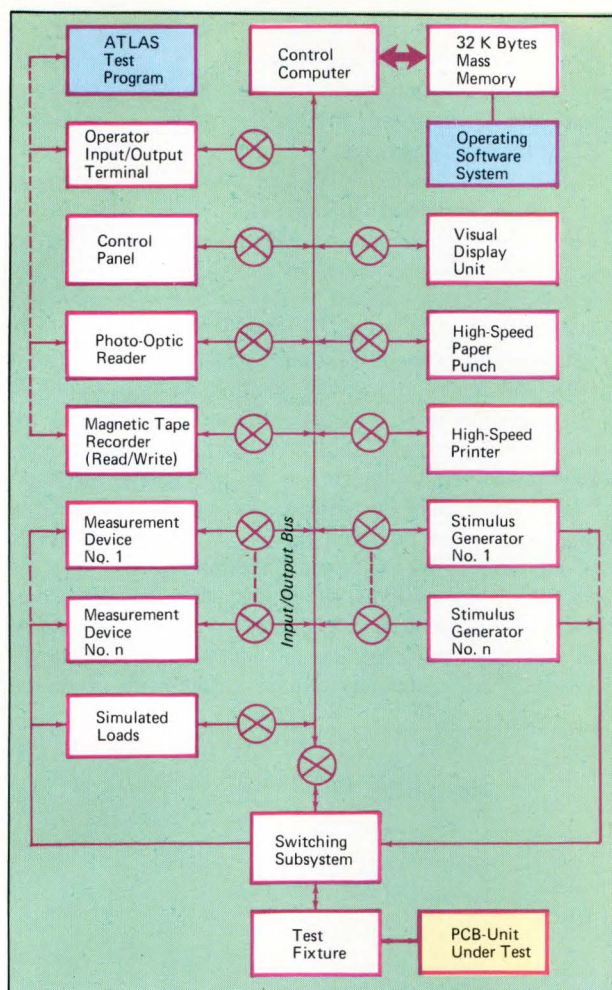
One common approach to the interface problem involves the use of various adapters or controllers along with system-software modification, with resultant tradeoffs. One implementation of this concept, developed at Instrumentation Engineering, relies on an interface called the "device controller" designed so that only five are needed to handle a multitude of peripheral types. Variations within each type of controller do exist, but these differences are minor. The variety of instruments and peripherals that can be accommodated by these five basic types of interfacing controllers is shown in the list of **Fig. 2**.

As an example of the requirements that a controller must meet, the hardware interface may be DTL/TTL, contact closure, discrete levels, etc. The coding may be binary, BCD, etc., and there may be different ways of starting, stopping or reading the device. Even the workings of the device itself must be examined to determine if it can operate under computer control.

It is often desirable to break up the circuitry on device-controller boards into relatively few logic areas. One area is required for control. It contains the necessary logic to identify the board to the computer and to exercise control over incoming and outgoing data, status requests and timing commands. A second area is reserved for buffering data going from the device to the computer (if required). Level shifting and code conversion may or may not be required here.

Still another area concerns status logic to inform the computer if the device is busy or unavailable, and also to generate interrupt signals if the device works on an interrupt basis. And finally, an area is reserved for the timing





**Fig. 1—To keep a test system's operation simple, fast and convenient,** predesigned software should be used to control all hardware, and interfacing should allow easy change of peripheral configurations for future test needs. The above block diagram is the configuration used in Instrumentation Engineering's System 390 which makes use of this philosophy.

logic required to start, strobe, stop or otherwise control the device.

In the past, multiple boards were sometimes necessary to implement device controllers, but with the recent emergence of bipolar MSI ICs, a single board no larger than approximately  $6 \times 8$  in. should be sufficient.

Another important factor in the design of device controllers involves keeping a closed loop between these boards and the control computer. A sync signal should always be available so that communication between the controller and the computer is never open-ended. A constant check in the form of a sync signal should always be employed to verify that information has arrived at the receiving end. The purpose of this signal is not to tell if a bit has been dropped but rather to determine if a gross failure has occurred, or if for some reason a device controller has been disconnected. In the event that a sync signal is not received, an interrupt should occur to provide an error message to the operator of the test system.

With all that can be done via the device controller, some devices must be modified internally to operate properly within the framework of a computer controlled test system. As an example, certain digital multimeters have fixed delays to allow proper accuracy to be reached on

low-level resistance readings. When integrated into a test system, a certain amount of capacitance is added across the meter's terminals by the switching necessary to connect it to the UUT. Due to this added capacitance, the internal delay must be lengthened to allow the lines to be charged up so that maximum accuracy is achieved.

As a second example, some timers can be used very effectively for rise-time measurements if external D/A converters can be used to program trigger levels. This modification greatly extends the use of the device and may sometimes negate the requirement for a separate pulse analyzer in the test system.

## System switching

An automatic test system can achieve peripheral interfacing with the best possible stimulus and measurement devices and still be inadequate if its switching system is not up to par. Many different approaches to switching have evolved, some of them using scanners, matrices, trees, etc. with various relays and solid-state devices used to implement these approaches.

Generally, solid-state switching is employed in digital testing where the largest number of tests are to be performed in a given period of time. Hard-contact or relay systems usually hold sway whenever accurate analog work has to be done, or when high-frequency digital work is performed. This is because hard-contact systems have no inherent offset voltages and slew times to overcome, and if properly designed, present minimum capacitance to the UUT.

A major requirement of any switching system is that it permit the application of the stimulus devices to any pin, or any combination of pins, on the UUT. It is also necessary that all stimulus devices, either similar or dissimilar in nature, and all measurement devices used with the test systems, be capable of simultaneous application to the UUT.

Effective switching depends on the use of a sophisticated software system which should prevent the operator from creating undesirable test situations. As an example, the software should generate error messages to prevent the programmer from placing two stimulus devices on the same pin of the UUT, and to prevent him from applying a measurement device on more than one UUT pin, thereby creating a short circuit. It should keep a record of all actions occurring within the switching system so that the operator need be concerned only with what he wants the test system to do at a specific pin or pins.

## The computer

Selection of a computer for the test system requires careful analysis. If inhouse circumstances do not dictate the selection of the computer, criteria for the final selection should include: (1) high-speed data transfer, (2) as few I/O bus wires as possible, (3) a large number of device locations on the I/O bus, (4) sync pulses to insure closed-loop operation, (5) an efficient interrupt scheme, and (6) an excellent internal structure.

Items (1) and (2) involve a tradeoff. The more parallel bits there are in a word to transfer, the faster it becomes possible to write to and read from the device controller. The smaller the word size, the fewer physical connections needed from one device controller slot to the next.



Item (3) refers not only to the number of devices which can be attached to the computer's I/O bus, but also to the ease with which this can be done. If one device controller after another can be added in parallel on the bus without extension buffering, the best possible test situation results.

Item (4) was already discussed. Item (5) relates to the speed and efficiency with which the operating software can respond to an interrupt from a device which operates on an interrupt basis. And item (6) relates to how well a computer's subsystems are configured to allow for flexibility and efficiency in handling data.

## Software

Generally, the system's software package should enable the test engineer to write his programs rapidly in an easy-to-learn test-oriented language. An engineer using the system should be able to write new programs and operate the system with only minimum training. The objective should be the assurance of rapid generation of programs by low-skill-level personnel on the basis of a massive one-time software effort.

One language that meets these requirements is an adaptation of the ATLAS English test language, a language orig-

inally developed by ARINC for the airlines.

The most competitive test language to ATLAS is BASIC, which is also interactive and designed for writing test programs quickly and easily in English. The source language for both test languages can be stored so that changes can be made easily. However, the compiled ATLAS language can be executed more quickly than BASIC. The latter's source code is converted to another code which must be interpreted each time the program is used. **Fig. 3** shows some examples of specific test programs in a modified ATLAS language.

The designer of the test system knows that there must be a consistent hardware/software tradeoff. As an example, in the programming of a digital multimeter, usually more than one word must be sent from the computer to the interface-device controller via the I/O bus to select a mode properly, and also to provide ranging data. Typically, these words must be assembled in the device controller and strobed into the multimeter simultaneously.

In earlier test systems, this information was often preserved in core memory so that after the multimeter reading was obtained, the digital equivalent of the reading received by the computer from the multimeter could be

<b>Stimulus:</b>	
1. Function generators	10. Signal attenuators
2. Digital word generators	11. Dc signal sources
3. Ac signal generators	12. Ac signal sources
4. Timing generators	13. Dc current sources
5. Pulse generators	14. Square-wave generators
6. Audio oscillators	15. Clock sources
7. Digital-to-analog converters	16. Frequency synthesizers
8. Digital-to-synchro/resolver converters	17. Registers of various bit sizes
9. Logic-level signal sources	18. Multi-phase clocks
<b>Measurement:</b>	
1. Digital multimeters	11. Back-up timers
2. Electronic counters	12. Pulse detectors
3. Analog-to-digital converters	13. Impedance bridges
4. Digital word receivers	14. Digital voltmeters/ammeters
5. Logic-level comparators	15. Phase-angle meters
6. Frequency-response analyzers	16. Distortion analyzers
7. Synchro-to-digital converters	17. Wave-form analyzers
8. Pulse analyzers	18. Network analyzers
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5. Magnetic drum memories	10. Disc storage systems
	11. CRT terminals

**Fig. 2—A multitude of peripheral types** can be handled in an automatic test system using only five device controllers as interface items. This mix of peripherals is listed below under respective categories.



#### Typical ATLAS test program:

```
01  APPLY 200 MILLIVOLTS AC ON PINS 2, 3, 52 $
02  APPLY 5 VOLT, 20 NANOSECOND PULSE ON PIN 7 $
03  VERIFY RISETIME 1 VOLT, 3.5 VOLTS LESS THAN 5 NANOSECONDS ON PIN 22 $
04  MEASURE DCV 10 VOLTS ON PIN 123 $
05  VERIFY RESISTANCE LESS THAN 0.5 OHM ON PIN 150 $
```

**Fig. 3—An example of a test program in a modified ATLAS language.** Such a language best insures the rapid generation of test programs by personnel relatively unskilled in software.

identified as to mode and range. Because the information must be stored at the device controller before being strobed into the meter, there is no need to maintain the information in core memory. When the reading is received by the computer, it only reads the stored mode and range information from the device controller. Relatively minor savings in core memory, as in this example, can result in a more economical and efficient system when repeated many times.

The various software subsystems employed in most automatic test systems include an "executive" for program controlling, a compiler, a utility subsystem, and other elements used for debugging, editing or performing other operational tasks. The executive subsystem also provides man-machine interfacing.

Other portions of the software include a resident generator, an execution subsystem for controlling specific test operations using individual stimulus and/or measurement devices, and a utility support subsystem, which handles debugging, editing, library and other functions not directly related to the actual test functions.

The resident generator is used to translate the source-code terminology, i.e., the test language, into bit patterns (object code) used by the test system. It resides permanently in the core and permits debugging in a manner similar to a software interpreter. Using the resident generator, new test programs devised for a specific UUT can be debugged in real time against the UUT itself. All debugging is accomplished using the test language terms, with the resident generator translating these terms immediately, in order to prove the corrected test procedures.

While having the online debugging capability of the interpreter, the generator does not suffer from the inherent lack of speed which is characteristic of the interpreter. Large source and object-code buffers are created in the core memory of the control computer. Each source-code buffer contains a test program in the higher-order language (ATLAS). The corresponding object-code buffer contains the program as translated by the resident generator. Thus, while the source code is present to facilitate operator/test system communication and the debugging of new programs, the object code can be used to run repetitive programs at computer speed.

If the program is likely to change often, the use of source code is an advantage in effecting modifications. If, however, it is desirable to prevent modifications to the program, the object-code format is very useful. For example, if an operator attempts an unauthorized modification of an object-coded program, he will receive a message informing him of his illegal step. Keeping a program in object code thus assures the avoidance of inadvertent changes. Source and object-coded programs can be interspersed in any combination.

In adopting this approach to software, the user can define his test requirements and insert them into a table resident in the system. Because of this "table-driven" structure, changes or deletions can be made easily and quickly to the software without troublesome or time-consuming reprogramming.

Most large-scale automatic test systems designed for multiple applications employ paper tape, magnetic-tape cassettes or discs. Paper tape can prove to be a serious impediment in instances where a variety of test routines may be needed at any given moment. Magnetic-tape cassettes are generally more reliable, useful and economical as bulk memories in test systems, although discs are rapidly gaining attention in many applications.

#### Test example

A typical test situation will illustrate the ease and speed of adding or deleting peripheral devices and inserting additional programs to underscore the non-obsolescence of this type of computerized test system.

Suppose a user wants to eventually add a programmable ac signal source. First, he finds an empty space in the test system cabinet and physically inserts the signal source. Then, he performs the following steps: First a single circuit board containing the device controller for the signal source is added to an empty slot in the device-controller board file (the I/O bus of the computer is already wired to every slot in the file). Next, a single cable linking the device controller and the ac signal source is added and the two wires of the analog output of the signal source are connected to the switching system. As a final step, the operating software system is informed of the I/O bus address of the device controller and the address of the analog output of the signal source in the switching system, using the operator terminal. No other steps are required, and the updated test system is ready to operate within 2 to 4 hours. □

#### Author's biography

**Phil Jackson** is engineering vice-president at Instrumentation Engineering, Inc., where he is responsible for all product development. He holds patents for his company's System 390 test system and for the 390's switching subsystems. Jackson received a number of degrees from Stevens Institute of Technology, which include a Bachelors in Mechanical Engineering and Masters degrees in both Electrical Engineering and Management Science.





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# Elementary A/D converters can be efficiently implemented in CMOS

*The special characteristics of CMOS logic allow designers to use low-accuracy D/A and A/D translations between the analog and digital worlds much more freely.*

Robert H. Cushman, New York Editor

We hear so much about high-precision 12- and 16-bit A/D converters that we tend to forget that there can be many applications for much lower accuracy in real-world systems. How often do you want to know the outside temperature to greater than two decimal digits? How often do you care to know the wind's speed to greater than two decimal digits? Conversion accuracies of up to 8 bits (about "2-1/4" digits) can be quite useful, especially if they can be achieved at little additional expense.

CMOS logic is superior to any previous integrated-circuit logic when it comes to implementing low-accuracy D/A and A/D conversions. The fact that the logic levels from CMOS gates swing so completely from one power supply polarity to the other allows very direct and simple approaches to D/A conversions. Also, CMOS registers can do their own ladder switching.

## The basic D/A conversion

Fig. 1 shows how simple a D/A conversion can be with CMOS. Here, a three-bit CMOS register is providing the analog voltage levels that feed the weighting resistors of an op amp summer. (For a basic type, see Ref. 1). The outputs of the three CMOS flip-flops are either at the op amp's ground (because the CMOS's negative supply has been tied to ground) or at the positive supply voltage. The CMOS gates will, if not loaded, swing within millivolts of these two supply voltages. The regenerative push-pull action of the CMOS's P and N devices ensure this complete switching. (See Ref. 2, CMOS Finally Gets It All Together,"

for a brief discussion of CMOS gate characteristics).

Thus, if the CMOS power supply is well regulated and the CMOS outputs are not unduly loaded, the CMOS digital logic levels can also be considered to be precision analog voltages and a point of common reference between the digital and analog worlds. In practice these conditions can be met for accuracies up to 8 bits, or 0.5%. Power supplies with accuracies of 0.1 to 0.01% are easily provided for the CMOS because CMOS draws so little power that even the smallest IC regulator (like the 723) can do the job with reserve. Actually, inexpensive small Zeners will often suffice.

Load resistors of 100 k $\Omega$  to 1M $\Omega$  and over will prevent the CMOS gates from showing loading effects. The standard CMOS outputs (as found in the 4000 family of CMOS) typically have ON resistances of 1 k $\Omega$  or less. Special large-area driver outputs can have ON resistances as low as 100 $\Omega$  and can accordingly drive lower value resistors. However, it is desirable for the CMOS outputs to have symmetrical ON resistances. This means that certain "lop-sided" buffers, such as those with oversized N devices for sinking TTL loads, should be avoided. Fortunately, CMOS logic inputs do not load CMOS gates (statically at least), so there is effectively no restrictions on the amount of CMOS logic that can also be driven off these outputs. For example, the flip-flop outputs can still drive the decoding logic for visual readouts or other functions.

There are two limitations to this type of CMOS D/A conversion. First, is that the offsets, which will be in the

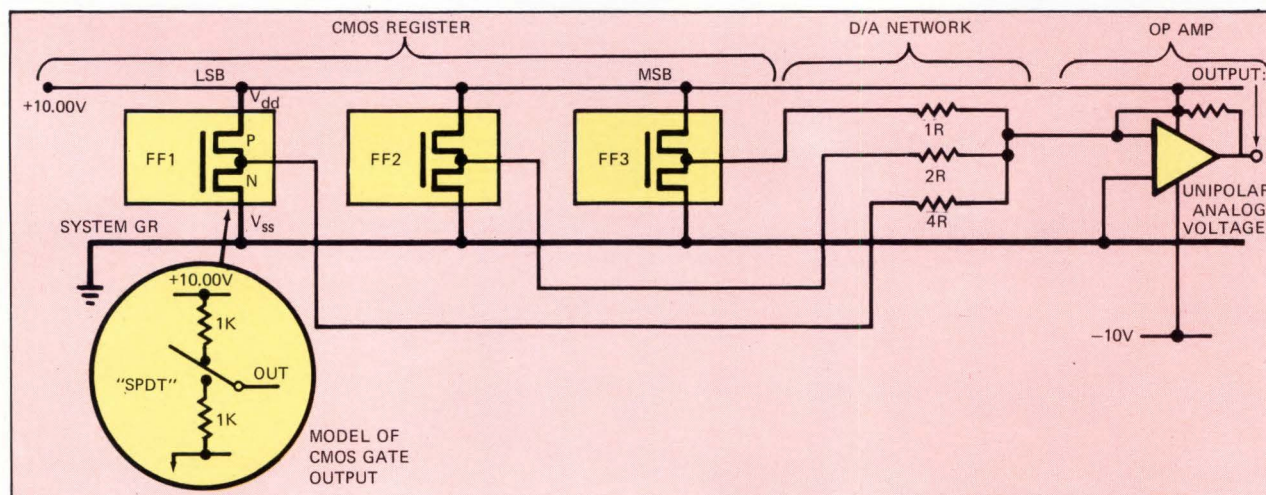
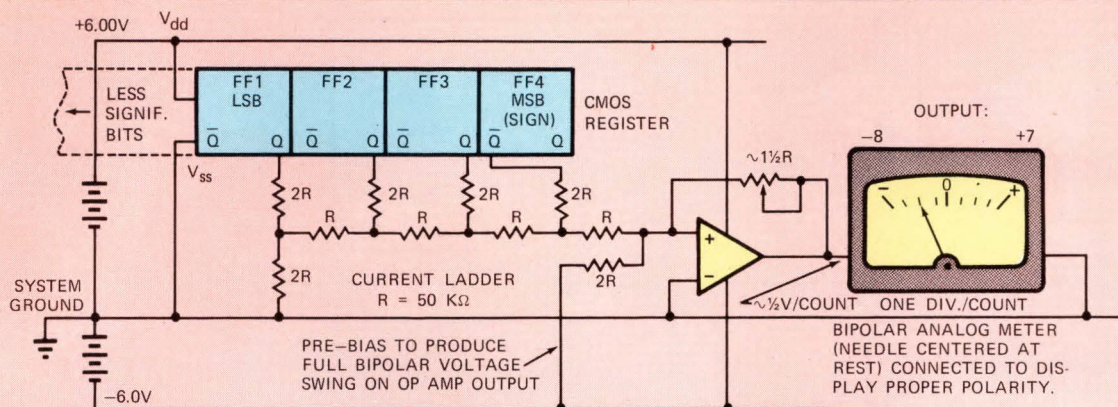


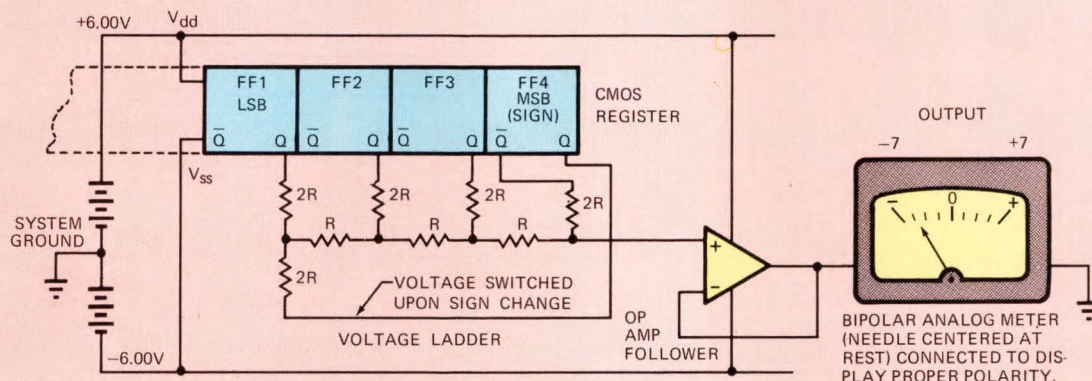
Fig. 1—Outputs from CMOS flip-flops provide the precision analog voltages for the weighed resistors of this D/A converter. The op amp sums the currents from the weighted resistors and provides the analog output. As the model shows, a CMOS inverter

gate is like a SPDT switch operating between the positive and negative voltage supplies. The ON resistances of the P and N devices are less than 1k $\Omega$ , so the resistances going into the op amp must be 100 k $\Omega$  or greater if the CMOS outputs are not to be loaded.

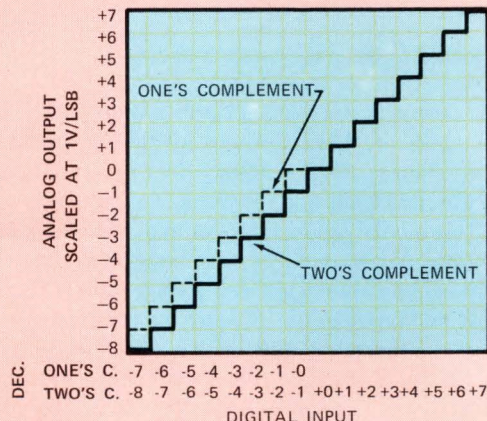




(a) BIPOLAR ANALOG READOUT WITH TWO'S COMPLEMENT NOTATION IN DIGITAL REG.



(b) BIPOLAR ANALOG READOUT WITH ONE'S COMPLEMENT NOTATION IN DIGITAL REG.



(c) D/A TRANSFER FUNCTION

DEC. BINARY	MSB	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	
		0	0	0	0	1	1	1	1	0	0	0	0	1	1	1	
		0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	
	LSB	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	
	ONE'S C.	-7	-6	-5	-4	-3	-2	-1	0								
	TWO'S C.	-8	-7	-6	-5	-4	-3	-2	-1	+0	+1	+2	+3	+4	+5	+6	+7

DIGITAL INPUT  
(STATE OF REGISTER)

DIGITAL INPUT  
(STATE OF REGISTER)

Fig. 2—Quick-look analog meter displays of contents of digital registers are examples of elementary D/A converters. Analog displays are easier for humans to evaluate at a glance and are particularly useful when an operator must make rapid coarse adjustments. Both circuits (a) and (b) will handle positive and negative words.

order of 10 mV, make accuracies of over 8 bits difficult to reach. Second, is that the high resistances needed for the weighting resistors make the converter's operation slow. Just assuming normal circuit capacitances in the order of 10-20 pF per output, it can be seen that the operating bandwidth will be under 100 kHz, and it will be impossible to make 8-bit conversions much faster than 1 kHz. If wirewound resistors are used, the series inductance may be significant. Another drawback stemming from the need to use high resistances is that it won't be as easy to use the existing resistance ladders developed for bipolar converters, as they have resistances down in the 10 kΩ region.<sup>3</sup>

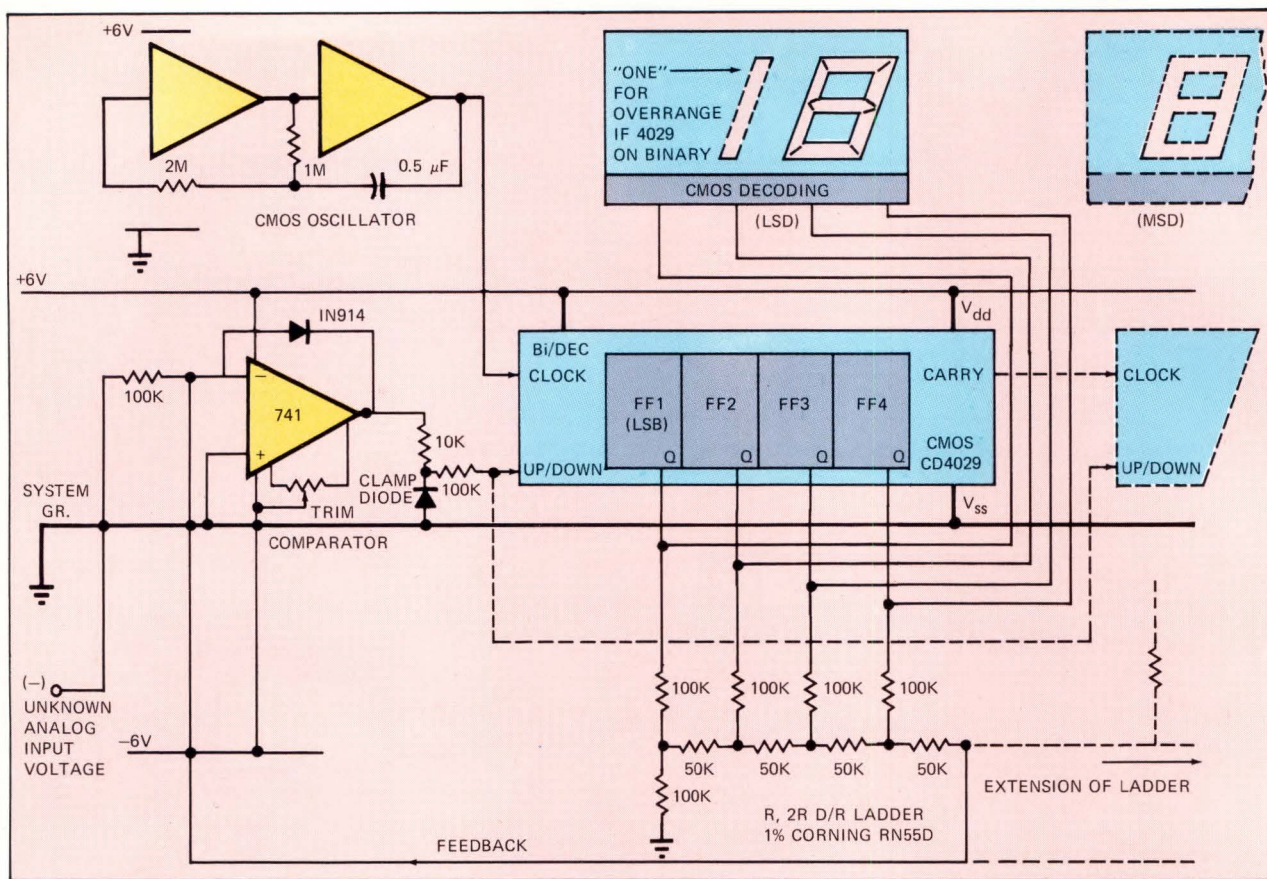
### A quick-look analog display

Fig. 2 shows how the conversion technique of Fig. 1 can be used to implement an easy-to-interpret analog display

for a digital register. This could be useful in industrial process-control systems where the operators have traditionally worked with moving analog indicators. Only the four most significant digits are shown being converted, as the resulting 16:1 resolution is about as much as an operator could comprehend on a quick-look basis. One might go to five bits for the equivalent of a 1-1/2 decimal digit display, but not much further. Reasonably-priced analog meters can't achieve much better accuracy, and if more accuracy were needed it would be better to have a full digital readout below the quick-look analog readout.

Both of the circuits shown in Fig. 2 will handle positive and negative digital words. The MSB (most significant bit) shown in Fig. 2 at the right-hand position in the register is the sign bit. Following common practice, this is assumed to indicate a positive digital word when it is ZERO and a





**Fig. 3—This elementary CMOS A/D converter operates as an oscillating servo.** The 4029 up/down counter counts up one beyond the unknown input value, and the 741 comparator reverses the 4029 to count down. Then the 4029 counts one below the

unknown value and the 741 reverses the 4029 to count up again. And so on. Only one 4-bit 4029 is shown but another could be added (dashed outline) to extend the conversion to 8 bits. Note the clamping diode on the output of the 741.

negative digital word when it is ONE.

The circuit arrangement of **Fig. 2a** uses a current-summing ladder, as was used in **Fig. 1**. However, an R, 2R ladder is used instead of the binary-weighted resistor ladder of **Fig. 1**. There are two other changes from **Fig. 1**. The false output of the MSB rather than the true output is applied to the ladder. This is necessary to agree with the sign bit convention. Second, there is another 2R input to the op amp's summing point that is connected to the opposite voltage polarity. This provides the offset bias that places the op amp's output at analog zero for digital 0000 in the register; otherwise the op amp's output would be at mid-scale for 0000. This bias also allows the op amp output to swing in both directions. (The polarities shown happen to make the op amp's output go minus for positive numbers and positive for negative numbers, but it is a simple matter just to reverse the meter connections to make the meter needle deflect in the correct sense).

The op amp's feedback resistor and meter sensitivity are scaled to produce deflections within the op amp's voltage-swing capability, say  $\pm 4V$  for the  $\pm 6V$  supplies. The feedback resistor can be adjusted to make the needle deflections line up with the meter scale marks. Actually, many of the moving-ribbon-type meters might be better than the moving-needle-type meter shown, as they would enhance the quick-look readability of the display.

The circuit configuration of **Fig. 2b** puts the system ground at the midpoint of the CMOS supplies so that the resistive ladder puts out both polarities of analog voltages.

In this case it is necessary to also switch the 2R resistor that anchors the lower left end of the ladder when the sign bit changes. This switching is easily accomplished in CMOS by just tying this resistor to the true output of the MSB. This bipolar ladder operates in the voltage mode and a high-impedance amplifier must be used to sense its output. An op amp connected as a voltage follower serves the purpose and provides the drive for the analog meter.

There is a functional difference between the two circuits of **Fig. 2**. The first circuit (**2a**) is intended to convert bipolar digital words expressed in the TWO's-complement form, while the second circuit (**2b**) is intended to convert words expressed in the ONE's-complement form. As shown in **Fig. 2c**, the difference between the two notations as far as the conversion is concerned is that the TWO's complement analog output rises steadily with up counts into the register, but the ONE's complement analog output remains at ZERO V for two counts at digital zero. As shown graphically in **Fig. 2c**, the first circuit produces a steady staircase, while the second circuit has one double-width step in the middle. Which notation is used will probably be a matter that is decided by the logical design of the digital system.

### An oscillating servo

**Fig. 3** shows a complete low-accuracy A/D converter. An RCA CD4029A four-bit up/down counter (also second sourced by others) is used as the register. Corning type RN55D 1% resistors are used for the R, 2R type resistive



ladder and a Fairchild 741 op amp is used for the comparator. Additional CMOS gates are used for the clock oscillator and control gates, and small flashlight batteries are used for the power supplies.

The unknown analog input to the converter must be a negative voltage because the CMOS is placed between the op amp ground and positive voltage. But the CMOS can just as well be put between ground and the minus voltage so that the circuit will handle positive unknown inputs.

When presented with a negative unknown voltage, the output of the 741 comparator will go positive. This will cause the up/down control input to the 4029 to command the 4029 to count up. Clock pulses will enter the 4029 and cause the 4029's outputs to go positive in the usual binary fashion. As each 4029 output goes positive, it causes a current to flow in the resistive ladder that is proportional to the ladder's weight at that point. As soon as the currents from the 4029 outputs overbalance the opposite current from the unknown input, the output of the 741 will switch negative. This will reverse the command to the up/down control and cause the 4029 to "uncount" itself.

Thus, the 4029 counter will oscillate between counting up and counting down. The system will act as a servo limit-cycling between two digital numbers that bracket the unknown input. If the input is somewhere between 7 and 8, for example, the 4029 will oscillate between these numbers. With the clock adjusted to about 2 Hz, a cycling of the least significant digit results that is not difficult to read. To some users this cycling might prove irritating, but to others it might give a confidence that the system was functioning. The 2 Hz rate would of course mean that the "DVM" could only follow slowly-varying inputs.

Another variation that would be easy enough to implement with CMOS is to use an up-counter like the 7-bit CD402A register and have a 1-kHz or so clock continuously count up until stopped by the comparator. It could then hold the display at the value for a second or so (using a CMOS one-shot), then reset the 4024 to start another measurement cycle. If the readout were only turned on for the hold period, the user would not be annoyed with the blurr of rapidly changing display digits upon each conversion. (See Ref. 4 for a description of this type of converter.)

Several features of the Fig. 3 circuit bear comment. Note that there is a clamping diode at the output of the op amp comparator. CMOS specifications say that the inputs to CMOS gates should not go more than 1/2V below the negative CMOS supply. This diode clamps the negative swing of the 741 to a safe level. As a further precaution, a current-limiting resistor was added in series with the up/down control input to the 4029. The CMOS gates have such high input impedance that a 100 k $\Omega$  resistor should have no effect. The positive swing of the op amp should not go beyond the CMOS supply. In this circuit, this is automatically taken care of by having the op amp's positive supply the same +6V that powers the CMOS.

Only one four-bit 4029 is shown, which limits the digital resolution to just one decade (though 15 counts can be provided for "overrange" by putting the proper command on the 4029's BCD/binary control input). Another 4029 and more resistive ladder stages can be added for up to 8-bit conversion, but then all the circuit adjustments may have to be tightened up several notches. And it might be desirable to use an op amp with lower input leakage cur-

rents than the 741, since, with the high ladder resistance values necessary to prevent loading, the currents would begin to become smaller than the 741 leakages.

The output of this A/D conversion is, of course, the contents of the 4029 register. This could either be handled as a digital word and sent to some other part of a larger system or it could be converted into a visual readout for a human observer. We have found that almost any of the commercially-available readouts can be used with CMOS—LED's, vacuum fluorescent tubes, incandescent tubes, gaseous discharge panels, etc. But most of them either draw relatively large currents or demand higher voltages. Therefore, it would be advisable to provide a separate power supply for them, so as not to interfere with the accuracy of the positive voltage feeding the CMOS.<sup>5</sup>

There are two possible readouts that could be driven from the same supply. One is the vacuum fluorescent tube and the other is the new liquid crystals. Both of these draw very little current. However, they both need voltages at the high end of the CMOS 4000 family rating, which is about +15V, if they are to have reasonable visibility. CMOS logic should be used to decode the register outputs in the displays to ensure that there is no loading.<sup>6,7</sup>

An application where the circuit of Fig. 3 might prove useful is for remote reading of temperatures in warehouses. Small battery-powered units (or even telephone powered!) could convert the analog outputs from temperature transducers (thermister bridges) to 7-bit words for transmission over phone lines. Equipment in a central station could automatically poll and record these temperatures. The 7-bit accuracy would be sufficient to indicate if the warehouse temperatures were either getting dangerously low indicating the pipes might freeze or dangerously high indicating that a fire might be breaking out. To save power, the op amp could be turned off between readings. One of the newer op amps (like the RCA 3080) that can be shut off by turning off the differential amplifier's constant current source could be used. There would be little point in turning off the CMOS circuitry since it operates at micro-power levels anyhow, but it would be a good idea to reset the CMOS register to zero to prevent wasteful currents from flowing in the D/A ladder. □

## Acknowledgements

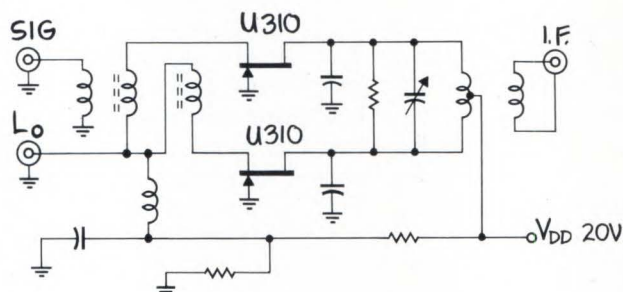
*Private conversations with Russ Knapp, Dick Funk, Merle Hoover and Andy Bosso of RCA, Somerville, N. J., were of great value in developing the circuits described.*

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<sup>†</sup> Estimated    \* Conservative minimum

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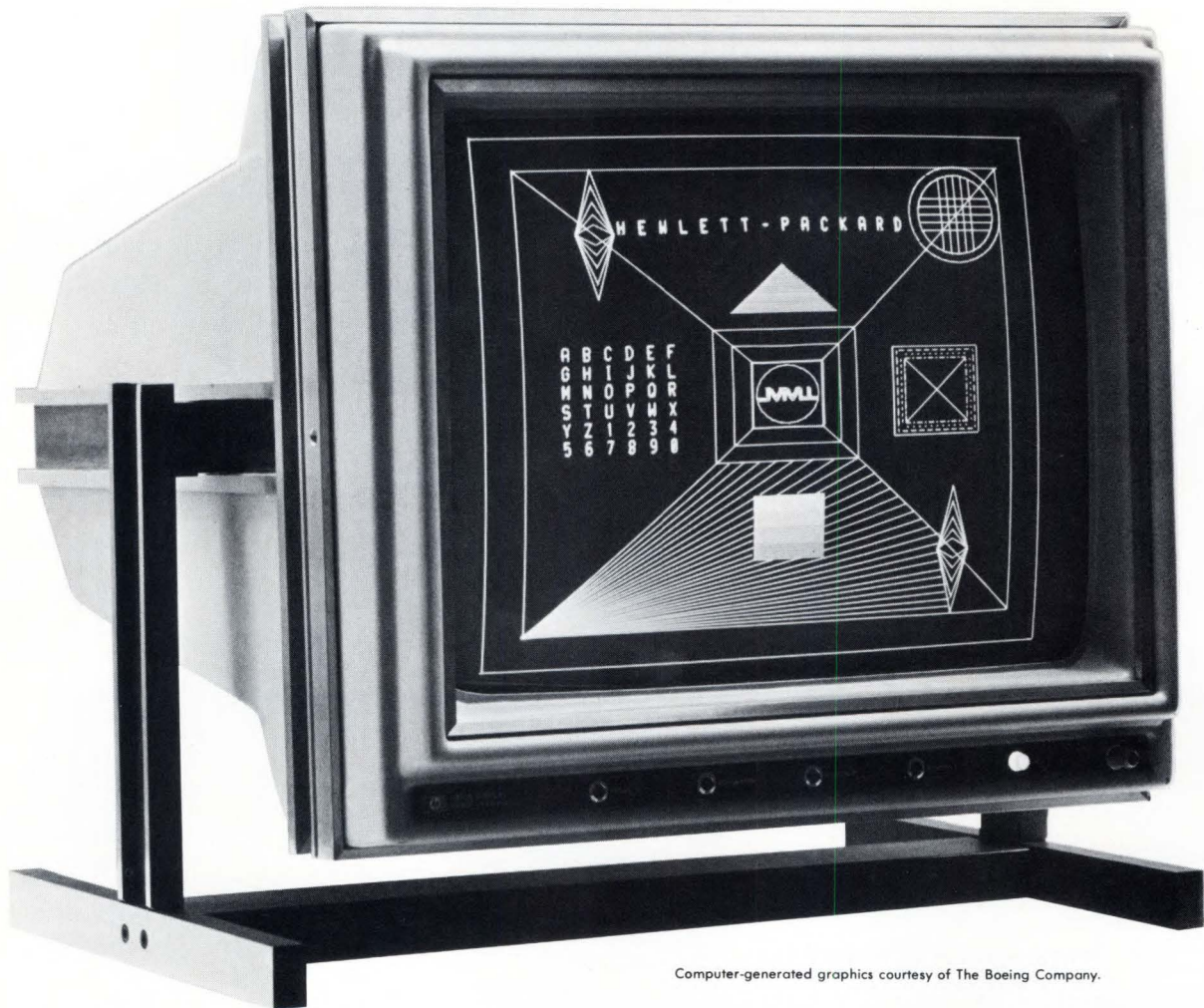
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081/14A

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CIRCLE NO. 24



# Binary weighting after switching boosts D/A converter performance

*High speed and accuracy are attained in current-mode digital-to-analog converters by switching equal currents and by balancing thermal effects.*

**Eric Burwen**, Harvard University

The conventional current-mode digital-to-analog converter (IDAC) (**Fig. 1**) suffers from three major problems as a result of the binary weighting of the currents switched by the common base transistors. These problems have limited speeds of such devices to about 25 nsec, and accuracy to 8 bits.

The first problem is one of dynamics. The ability to switch the common-base transistors is limited by parasitic capacitances, because current flowing through the least significant bit will limit the attainable speed due to  $1/Cf$  idt effects. If stray capacitance alone was the only limit on speed, then in an eight-bit digital-to-analog converter, the least significant bit would only be  $1/128$  as fast as the most significant bit. But stray capacitance is not the only factor.

The second problem deals with temperature stabilization. Each switching transistor dissipates a different amount of power, due, once again, to the binary weighted currents they switch. As a result, base-to-emitter voltages of the transistors will not track, and this is reflected as a change in current flow for each bit.

Lastly, the resistors must be selected with other than simple 1, 2, 4, 8 . . . etc. ratios in order to compensate for the different base-to-emitter voltages associated with the weighted emitter currents. In addition, the base-to-emitter voltages will not track the current changes manifested by a change in reference voltage. This effect limits use in high-accuracy multiplying digital-to-analog converters.

## Equal switching currents improve performance

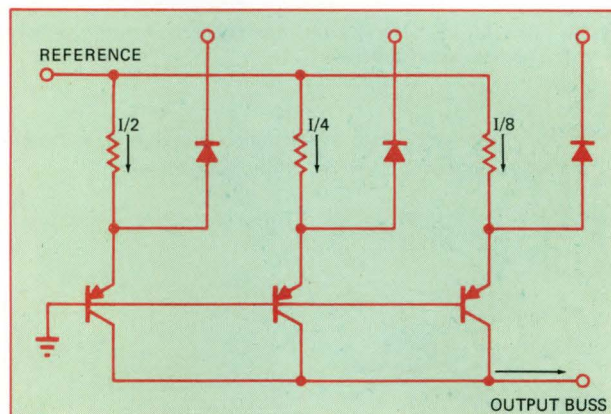
If equal currents are passed through the common-base transistors, and binary weighting is performed after switching, the above problems can be eliminated. Schematically, this technique appears in **Fig. 2**. It is evident that in this configuration all bits switch in the same time, and that the base to emitter voltages track with changes in temperature and current level. However, these significant advantages are gained at the expense of increased power dissipation and the need for additional weighting resistors.

The Thevenin equivalent of a single bit is readily derived in **Fig. 3a**, which then allows the entire converter to be modeled as the Thevenin equivalents of each bit tied to a common buss, as shown in **Fig. 3b**.

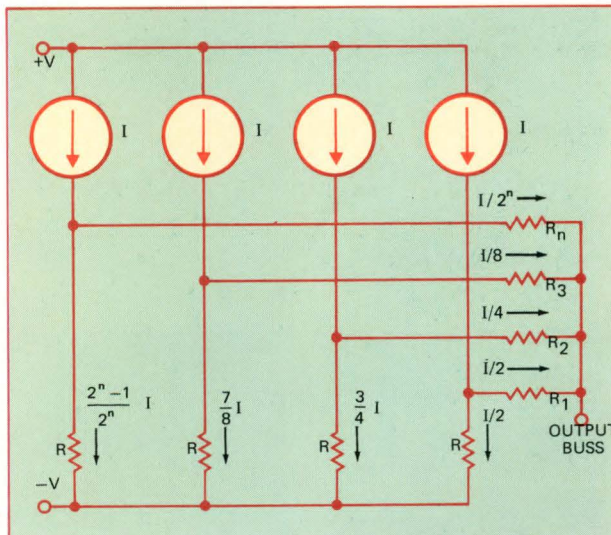
Therefore:

$$e_{out} = \frac{e_a Y_a + e_b Y_b + e_c Y_c + \dots e_n Y_n}{Y_a + Y_b + Y_c + \dots Y_n}$$

Substituting the Thevenin equivalents into the bussed model we have:



**Fig. 1**—Conventional current-mode D/A converters switch unequal currents, which limit speed and accuracy.



**Fig. 2**—Common-base transistors switch equal currents when binary weighting takes place after switching.

$$e_{out} = \frac{\frac{IR}{R + R_1} + \frac{IR}{R + R_2} + \frac{IR}{R + R_3} + \frac{IR}{R + R_n}}{\sum_a^n Y}$$

$$\therefore e_{out} = \left( \frac{1}{\sum_a^n Y} \right) \underbrace{\left( \frac{R}{R + R_1} + \frac{R}{R + R_2} + \frac{R}{R + R_3} + \dots \frac{R}{R + R_n} \right)}_{\text{binary weighting factors}}$$

scale factor



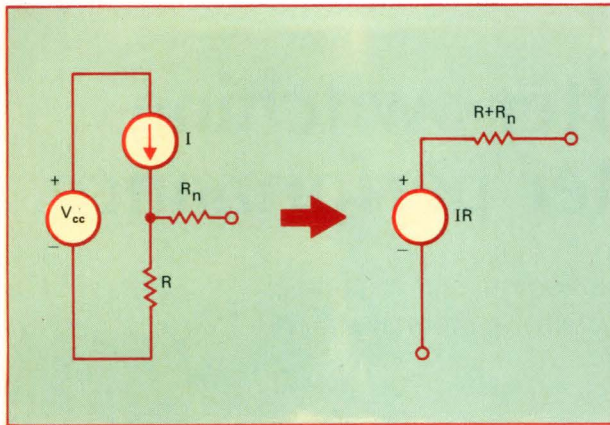


Fig. 3a—One bit of the converter from Fig. 2 is shown together with its Thevenin equivalent.

To design an IDAC with a full scale voltage of  $E$ , with an output resistance of  $R_x$ , and of 'n' bits we proceed:

$$E = \left( \frac{I}{\sum_a^n Y} \right) \left( \frac{2^n - 1}{2^n} \right) \text{ but } \frac{1}{\sum_a^n Y} = R_x$$

$$\therefore I = \left( \frac{2^n}{2^n - 1} \right) \left( \frac{E}{R_x} \right) \quad \text{eq. 1}$$

$$\frac{R}{R + R_n} = \frac{1}{2^n}$$

$$\therefore R_n = R(2^n - 1) \quad \text{eq. 2}$$

$$\sum_a^n Y = \sum_a^n \frac{1}{R + R_n} = \sum_a^n \frac{1}{2^n(R)} \text{ since } R_n = R(2^n - 1)$$

$$\therefore R = \left( \frac{2^n - 1}{2^n} \right) \left( \frac{I}{\sum_a^n Y} \right) \text{ but } \frac{1}{\sum_a^n Y} = R_x$$

$$\therefore R = \left( \frac{2^n - 1}{2^n} \right) (R_x) \quad \text{eq. 3}$$

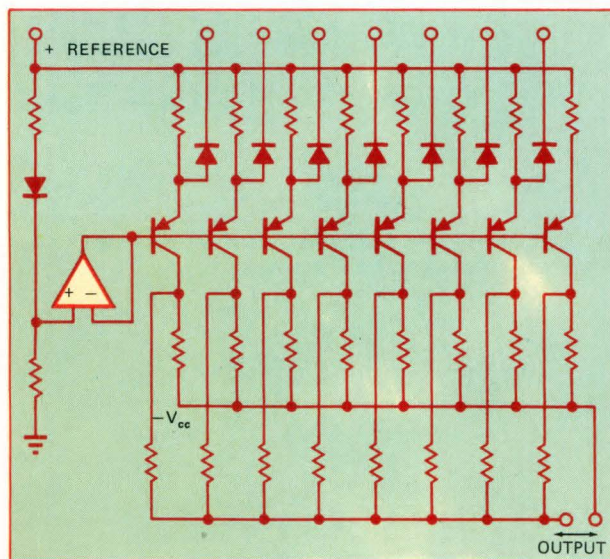


Fig. 4—An 8-bit current-mode D/A converter with temperature compensation of  $V_{BE}$ .

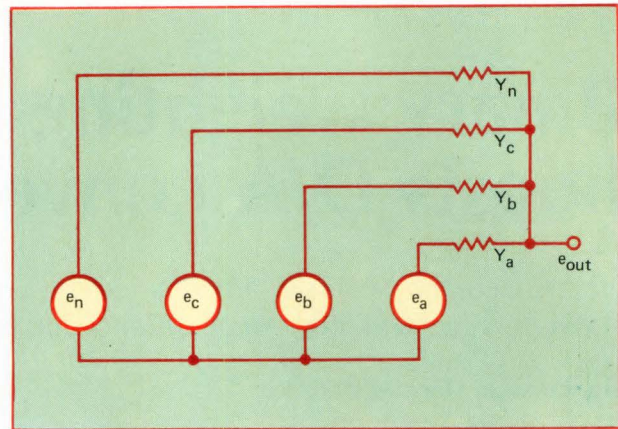


Fig. 3b—The entire converter is modeled as the Thevenin equivalents in order to derive design equations.

The three equations derived provide the necessary relationships for designing an IDAC. To design an eight-bit converter with a five-volt full-scale output and an output impedance of  $500\Omega$  (Fig. 4) the equations are used as follows:

$$\text{Eq. 3 } R = \left( \frac{2^n - 1}{2^n} \right) (R_x)$$

$$\therefore = \left( \frac{2^8 - 1}{2^8} \right) 500 = \left( \frac{255}{256} \right) 500 \approx 498.05\Omega$$

$$\text{Eq. 2 } R_n = R(2^n - 1)$$

$$\therefore R_1 = 1(R) \approx 498.05\Omega$$

$$R_2 = 3(R) \approx 1494.15\Omega$$

$$R_3 = 7(R) \approx 3486.35\Omega$$

$$R_4 = 15(R) \approx 7470.75\Omega$$

$$R_5 = 31(R) \approx 15445.55\Omega$$

$$R_6 = 63(R) \approx 31383.15\Omega$$

$$R_7 = 127(R) \approx 63261.35\Omega$$

$$R_8 = 255(R) \approx 126522.75\Omega$$

$$\text{Eq. 1 } I = \left( \frac{2^n}{2^n - 1} \right) \left( \frac{E}{R_x} \right)$$

$$\therefore I = \left( \frac{2^8}{2^8 - 1} \right) \left( \frac{5}{500} \right) = \left( \frac{256}{255} \right) 10 \approx 10.0392 \text{ mA}$$

□

### Author's biography

**Eric Burwen** is a Junior at Harvard University and is also enrolled at MIT under a cross-registration program. He has been active in electronics for a number of years having worked for Analogic, Microwave Magnetics, Meditech, and Veeder-Root. Mr. Burwen is presently a consulting engineer for Beams Productions, Inc., Allston, Mass.





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# Kjell Hovik and Win Hodge of IPC speak out on writable-control storage vs ROM

*Both types of storage are finding their way into third-generation computers.  
If the computer is microprogrammed, writable-control store is more efficient.*

Third-generation computer architectures are defined as being the most generalized architectures possible, whereby the control storage word controls all processor data flow. Microprogramming is a sequence of instructions in the processor's control storage unit which provides the programming for the machine. Significant cost incentives for using third-generation architectures emerge when the processor contains 20 or more basic machine instructions. As the complexity of the machine increases, a microprogram machine costs less than its sequential-logic second-generation brother. With this in mind let's determine which will be most efficient in such computers, Writable Control Storage or ROM?

ROM is not readily alterable, even though there are field-alterable ROMs which can be altered. A word can be altered in some ROMs in a period of 10 to 15 minutes, and several words can possibly be changed in a period of 20 minutes. But essentially they are not alterable, at least not under program control. Therefore, the term ROM reflects a read-only memory which is not electrically alterable. Electrically alterable ROMs, which have a reasonable write time, are considered writable-control-storage units.

In microprogramming, overlays of different subroutines sharing the same address assignments are very valuable cost wise, as well as for the general ease of microprogramming. However, overlays are not possible with microcode existing in read-only memory. Since microprogramming in ROM requires one physical address location to be dedicated to each actual instruction of the microprogram, significant microprogramming activities cannot be efficiently accommodated with ROM.

---

**In the case of writable-control store, subroutines frequently used, but not used together, can be overlaid one upon another in the same physical locations of the writable-control store unit.**

---

Writing microprograms in binary is very tedious, and inhibits the microprogrammer's visibility. In other words, it's very awkward for him to look from his current microinstruction back to some previous instruction, because it must be decoded completely by hand. Therefore, binary microcoding is difficult and exceedingly inefficient, and thus very error prone. For efficient microprogram generation, it becomes mandatory that the user have such tools as a microprogram compiler complete with syntax generators, microprogram-diagnostic simulators, microcode linkage editors, and a microprogram-macro library from which to call commonly used microcoded subroutines.

With these required tools, we are in a position where we can develop microprograms for third-generation com-

puter systems possessing either writable-control storage or read-only control storage.

---

**Writable-control store affords the microprogrammer the same ability to have alterable programs via microprogramming as do other programmers using software.**

---

However, microprogramming is significantly more efficient than software programming.

Writable-control store affords the user the ability to overlay the microprogram subroutines one on top of the other. Assume, for example, that an area of 256 locations is reserved for half to a dozen subroutines. Any subroutine that will fit in that space can be positioned in the control store, and moved out whenever another section is required. Therefore, a microprogram which totally requires perhaps 10,000 words of control store, can fit into a machine possessing 2000 to 4000 control-storage words. This clearly indicates the economy achievable with writable-control storage vs ROM.

Effective use of overlays is brought about by paging. Writable-control store makes it possible to set up the microprogramming tasks so that the most frequently used routines are paged in and out of the writable-control store.

Dynamic microprogramming is the ability to dynamically alter a control-storage word while a microprogram is running. It gives the microprogrammer the ability to generate, with micro-instruction, additional instructions which later can be actually implemented by the microprogram on a dynamic basis. Other advantages of dynamic programming are that it allows the development of machine language sets to aid in the compiling of programs, and the development of different instruction sets for the implementation of those programs. In this way, programming efficiency for software can be optimized.

Numerous examples of dynamic microprogramming exist, and essentially stagger the imagination of anyone who has had the opportunity and enjoyment of developing dynamic microprogramming. This technique is best implemented with writable-control storage.

A third significant advantage of writable-control store is the ability to provide the user with access to a writable store. The user can then prepare his own microprograms to supplement the processor instruction set, or entirely change the instruction subset that exists within the set he is using. In many cases, special-machine op codes would be very beneficial in increasing the efficiency of certain types of programs. Thus, giving the user access to the control store opens a new world of programming opportunities. By preparing his own microprograms, the programmer can achieve many significant new types of functions.



In CPU operations, where the CPU has a writable-control store, it may be very desirable to microprogram into the machine one instruction set for compiling, and another instruction set for running, in order to provide optimized through-put on the machine for particular types of programs. Other areas could include such user applications as special error correction and checking (ECC). These are particular types of programs that have certain data peculiarities in them where the standard manufacturer provided error-determination and correction techniques are not satisfactory. Giving the user access to the microcode allows him to develop his own error-checking and correction algorithms, which are optimized to the particular type of data sets he is using.

Other types of applications for user access to the writable-control store include data compaction and data formatting. With the former, a user who is writing programs in BCD may find it extravagant to reserve one byte of data for each BCD digit. Therefore, subroutines which pack and unpack used data may be very desirable.

Sometime, a user may want to do special data formatting to make his data completely transparent to his software; or he may want to generate some microcoded subroutines which encode his data on disc files or tapes to provide a degree of security, but which is completely transparent to the software. These and other data-encoding techniques which are completely software transparent are possible by the availability of user microcode preparation.

Let's now examine the requirements for supporting writable-control store. Since writable-control store is just beginning to make its appearance, we might ask ourselves the question, "Why has it taken so long?" The answer is obvious! It has to do with the price of the writable-control storage elements.

Random-access memories are the primary ingredients for writable-control storage units. It has only been recently that reasonable high-speed random-access memories have dropped below the 1¢ per bit price. An inexpensive microprogram loader is also required since the aggregate cost of the control storage unit per bit is basically determined by the cost of the microprogram loader and the control-storage elements themselves. Recently, four manufacturers have announced that they will be building writable-control-storage-microprogram loaders which are compatible with IBM, and are sufficiently inexpensive to make this utilization of writable-control store desirable.

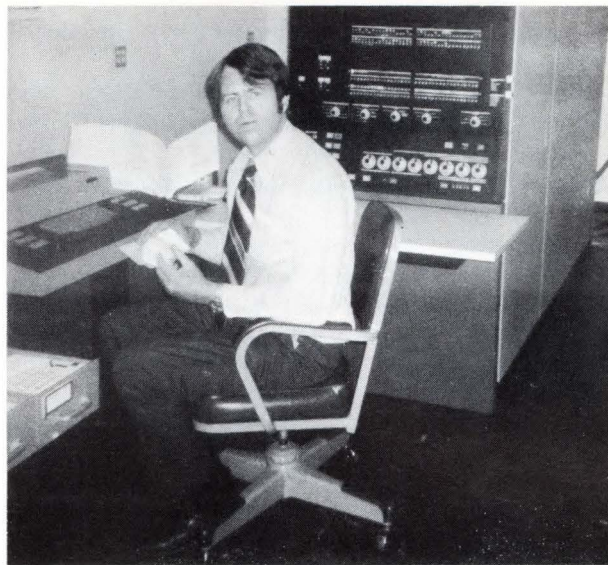
Another requirement for successful writable-control storage implementation is that the tools for microprogramming be available. It is possible to link and prepare microprograms for read-only memories, but efficient use of writable-control storage implies that significantly large volumes of microcode exist, and significantly large volumes of microcode cannot be generated in binary by hand. The last requirement for successful implementation is to have competent personnel in the area of machine architectural development, logic design, and probably most important, the area of microprogramming.

---

**Writable-control storage is not always as glamorous as it first appears. In actuality, it provides the capability for an inexperienced microprogrammer to "bomb" a system.**

---

If the system is in a multiprogramming environment, he has the ability to bring down the whole system. Inexperi-



enced individuals can do severe damage to the operating system by making improper or unauthorized changes to the system's microcode. Complete system compatibility between the operating system and the machine-language-instruction set can be made totally incompatible by inappropriate microcoding.

Proper combinations of software and microprogramming to inhibit the use of writable-control store by inexperienced personnel can minimize these problems. The writable-control store must then be protected from misuse. The way to achieve this is by having control-storage-protect keys for the control storage unit, software keys to prevent unauthorized uses of "load microcode" instructions, and the software verifying that the appropriate linkage of new microcode into the existing microprogram has been achieved prior to the loading of the microcode into the writable-control storage unit. This, of course, requires that the software tools for microprogram generation, as described previously, be part of a software system.

---

**One of the important future concepts that is beginning to evolve, is the concept of total virtual systems, including the concept of virtual peripherals.**

---





A total virtual system possesses the virtual peripheral concept.

What then is virtual peripheral in a virtual system? The total virtual system possesses the ability to transfer control of a peripheral from the computer to the controller, or transfer the process capability of the computer to the controller, or transfer the controller capability to the CPU. For example, should a failure occur in either the supervisor or any of the worker peripherals, microcode transfers can be transferred from the defective unit to one of the other good units, and processing can continue in a satisfactory manner, with only a slight amount of overall degradation in terms of time required for processing programs.

Complete transparency to software is possible with a total virtual system in microprogrammed systems. Should the supervisor processor, namely the CPU, become deficient due to a failure in one more of its parts, its microcode can be transferred to one of the workers, and that worker can provide the supervisory functions to the other worker units.

A large programmed-switching matrix allows any combination of interconnections between workers and supervisor, therefore allowing the worker peripherals to evaluate the performances of the supervisor in their spare time. Should the supervisor not be working up to par, any three workers or more, or the majority of the workers, can impeach the supervisor and assign the supervisory functions to any of the other workers. This concept can be expanded to envision many other similar areas. With this type of system concept, evolutionary systems operations are possible. Writable-control storage, associated with an efficient microprogram-loading mechanization, provides for low-cost system enhancement. □

#### Author's biography

**J. Kjell Hovik**, president of International Peripherals and Computer, Newport Beach, CA, received his BSEE and MSEE from the Norwegian Institute of Technology. His previous experience includes president of Datapac, Inc., and manager of memory development at Varian Data Machines.

**Winston W. Hodge**, vice president and director of engineering at IPC, received his BSEE from Chapman College and is currently doing graduate work at UCLA and California State College. Mr. Hodge was previously director, Systems Division at Datapac, Inc., and holds three patents.

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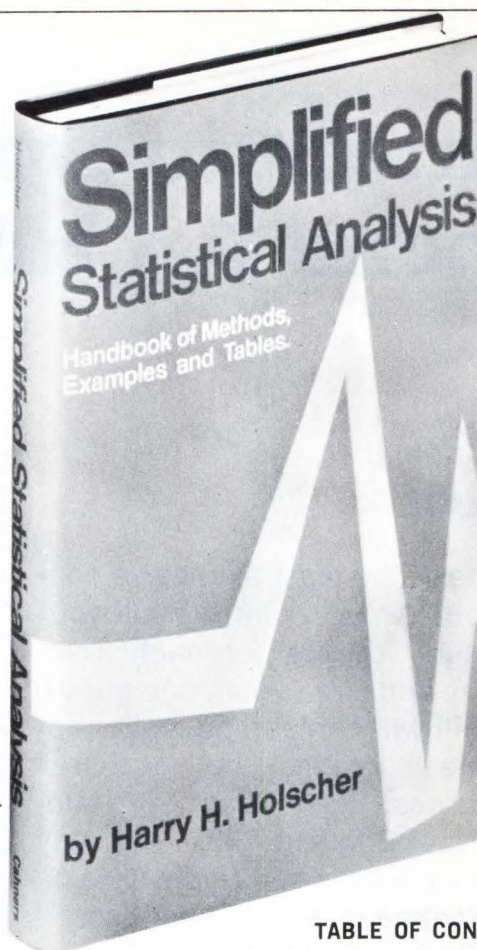
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# CIRCUIT DESIGN AWARDS

### 3 components make stable crystal oscillator

---

**Mark Trueblood,**

Wesleyan University Middletown, Conn.

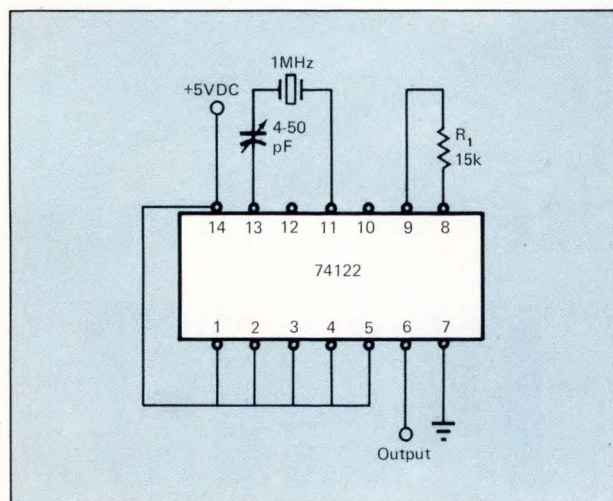
A 74122 one-shot, a resistor, and a crystal can be used to make a small, simple, stable square-wave oscillator for any crystal frequency from 200 kHz to 25 MHz.

In the low-to-medium frequency version of the circuit, shown in **Fig. 1**, the one-shot is made to oscillate by feeding the positive (Q) output at pin 8 back to the  $R_{int}$  input at pin 9. With nothing connected to pins 11 and 13 (the  $C_{ext}$  pins), the oscillator free-runs at a frequency determined by the internal and external R and C values. With a wire (zero  $\Omega$ ) between pins 8 and 9 this frequency will be about 8 MHz and can be lowered to about 5 MHz with the addition of the 15 k $\Omega$  resistor.

The circuit works as follows: Q begins in a LOW state, but flips to a HIGH state after the internal and external capacitors charge up. Being in a HIGH state is unstable, and the one-shot discharges the Q output through the resistor, returning Q to a LOW state, and the cycle repeats.

When only a capacitor is placed between pins 11 and 13, the frequency depends in part on the value of this capacitor, being 250 kHz and 300 pF, and 1.6 MHz with 30 pF, both values with the 15 k $\Omega$  resistor between pins 8 and 9. This means the circuit can be used as a VFO, a Theremin (high frequency only), or a liquid level sensor (the author's application) using an external capacitor.

A crystal placed between pins 11 and 13 will force the one-shot to oscillate at the crystal frequency, provided that the crystal frequency is less than the free-running frequen-



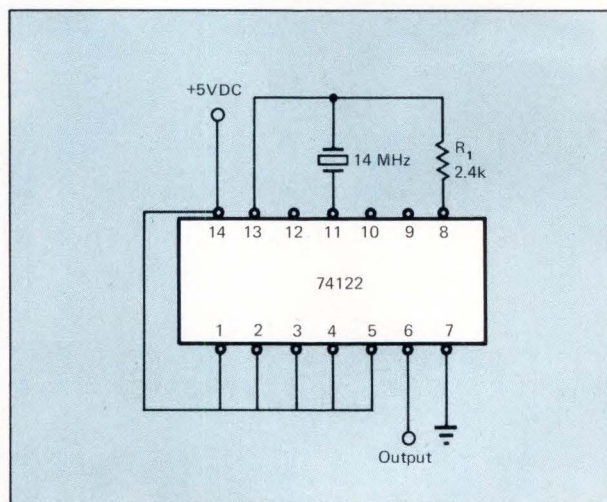
**Fig. 1—Low speed oscillator circuit** can be tuned from 5 to 8 MHz by varying  $R_1$  from 15 k $\Omega$  to 0 $\Omega$ . Frequencies as low as 200 kHz are achieved by variation of the external capacitor.

cy. Using the circuit in **Fig. 1**, the author has achieved a clean square-wave at 1 MHz with the 15 k $\Omega$  resistor, and a usable but slightly distorted square-wave at 6 MHz with a wire between pins 8 and 9. The crystal frequency can be raised by adding a trimmer capacitor in series with it, and lowered with the trimmer in parallel.

A faster circuit is shown in **Fig. 2**. Instead of using the internal timing resistor at pin 9, this resistor is by-passed and the Q output is fed back into the one-shot via the  $R_{ext}/C_{ext}$  input at pin 13. With no crystal connected at pin 11 and with only a wire between pins 8 and 13, the one-shot free-runs at roughly 30 MHz. The frequency is lowered to 22 MHz by the addition of a 1 k $\Omega$  resistor between pins 8 and 13, to 19 MHz with 2.4 k $\Omega$  resistor, and to 15 MHz with a 3.9 k $\Omega$  resistor. A pulsed output was obtained using a 14 MHz crystal and the **Fig. 2** circuit.

The author left the inputs at pins 1 through 5 floating with no ill affects, but these inputs should be tied high, as shown in both figures, for good noise immunity.

When placed in an oven and heated to 70°C from room temperature a **Fig. 1** circuit with a 1-MHz crystal drifted a few hundred hertz, a drift characteristic to be expected from the crystal used. Thus, the temperature stability of the crystal-oscillator circuit is limited only by the temperature stability of the crystal used.  $\square$



**Fig. 2—High speed circuit** can provide outputs up to 25 MHz by bypassing the internal timing resistor. Without the crystal, and with pins 8 and 13 wired together, this circuit free-runs at approximately 30 MHz.

**To Vote For This Circuit  
Circle 150.**



# Digital pulse repeater makes programmable multivibrator

L.D. Young, Jr.

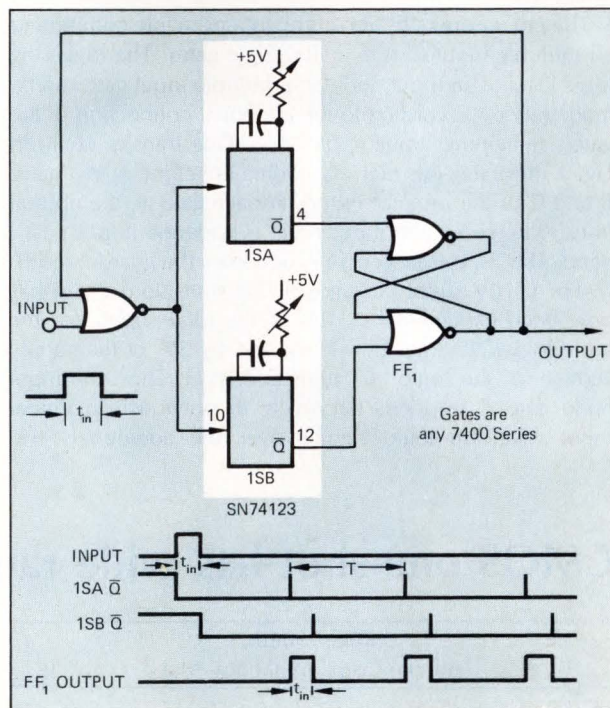
Western Electric Co., Greensboro, North Carolina

The circuit shown here can be used to repeatedly regenerate a single input pulse width at an adjustable rate. Possible uses are: a repeater for isolated pulses to enable scope presentation, or a multivibrator with easily programmable duty cycle. Only two IC packages are required.

The two one-shot (1SA, 1SB) periods are carefully adjusted (using 10-turn pots) to be equal in duration (T). The periods determine the repetition rate of the pulses and should be longer than the period of the longest anticipated input.

Initially, 1SA and 1SB are clear, giving high inputs to both inputs of FF1. On the leading edge of the input, 1SA triggers and releases the set input to FF1. On the fall of the input pulse, 1SB triggers leaving FF1 cleared. At the end of 1SA's period, T, FF1 sets from the  $\bar{Q}$  output of 1SA and remains set until cleared by the  $\bar{Q}$  output of 1SB at the end of 1SB's period. Since the two one-shots have equal periods and since 1SB was triggered one input pulse width later than 1SA, FF1 will remain set for a period equal to the input pulse width. The output of FF1 is then fed back to the one-shot inputs to repeat the sequence. □

To Vote For This Circuit  
Circle 151



**Pulse repeater circuit** will duplicate the width of a single input pulse in a continuous string of output pulses until reset by the next input pulse.

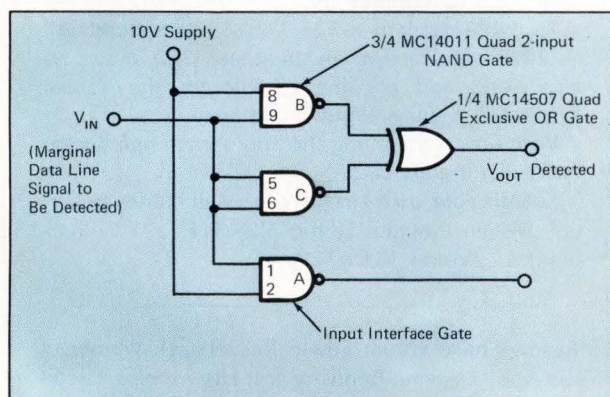
## Digital error anticipator requires only 4 CMOS gates

Bernie Schmidt,

Motorola, Phoenix, Ariz.

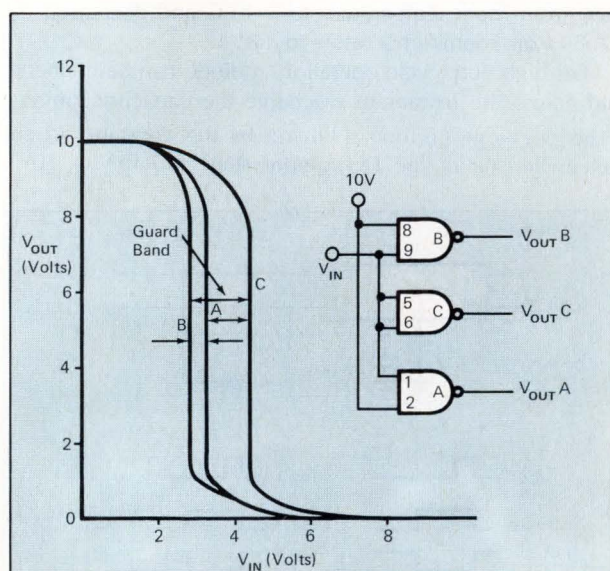
A simple, low-cost logic circuit that detects marginal input-waveform logic levels can be built using low-power CMOS devices. This circuit, shown in Fig. 1, is useful in system interface applications where failures due to input signal degradation must be anticipated. It can replace presently used, but more expensive, voltage comparators.

Such conditions as power-supply ripple, component degradation, battery voltage "droop," or external noise



**Fig. 1—Digital error anticipator** provides warning of power supply or data degradation that may provide incorrect performance of systems. Loading to system is negligible due to CMOS input impedance of  $10^8\Omega$ .

can all affect logic levels and can prevent an input gate from triggering properly. The anticipator circuit is highly flexible because it can operate from any existing power supply over the range of 3V dc to 18V dc. Further, it requires no calibration and produces negligible loading to



**Fig. 2—Triggering levels** of multiple input CMOS gates can be changed by varying the connections of the remaining inputs, as shown in these voltage transfer curves of an MC14001 when wired as shown in Fig. 1.



the data line being monitored (input impedance greater than 100 M $\Omega$ , 15 pF with a quiescent power requirement of less than 50 nW).

The circuit operates according to a principle common to all multiple-input CMOS digital logic gates. The triggering logic level of an input node of a multiple input gate can be made to vary according to the electrical connection of the gate's remaining inputs. The dc voltage transfer curve in Fig. 2 illustrates this fact. By adding envelope-detect gates B and C to the original input interface gate A, the normal transfer curve for the input node is widened into a guard band. That is, transfer curve A becomes the guard band B-C. For a 10V supply as shown, the transition region has now been expanded by 10% of the total supply for the input logic "1" transition level, and by 3% of the supply voltage for the logic "0" transition level. Thus, the input node gate A responds decisively to previously marginal input-waveform logic signals over the additional 13%

guard band. Note, however, that despite these substantial variations in triggering levels, an excellent overall noise margin of at least 30% of supply noise margin still exists.

The Exclusive OR connection of gates B and C, as shown in Fig. 1, enables any input level within the guard envelope to be logically detected, but, to ensure good matching of dc transfer curves of the gates, all three gates, A, B, and C, should be in the same IC package. Any triple-3 or quad-2 CMOS-gate package can be used.

It is important to note that only input signals that remain within the guard band for periods greater than 2 CMOS gate delays ( $\geq 50$  nsec) will be detected. Adding external capacitive loading to the detect circuit's output (gates B and C in Fig. 1) would further desensitize the circuit.  $\square$

To Vote For This Article  
Circle 152

## CMOS one-shot has wide range of output pulses

Roger Smith,  
Adcole Corp., Waltham, Mass.

This one-shot circuit uses a CMOS D-type flip-flop with RC feedback to the reset input. The flip-flop triggers on the positive edge of the input pulse and resets when the capacitor at the reset input charges to approximately 1/2 the peak output amplitude. The normal output pulse width is:  $\tau = 0.69 RC$ . Since the typical load current of a CMOS input is 10 pA, long time constants are possible using high valued resistors. A pulse width of 3.48 hours was measured using a  $1.6 \times 10^{10} \Omega$  resistor and a  $1 \mu F$  capacitor.

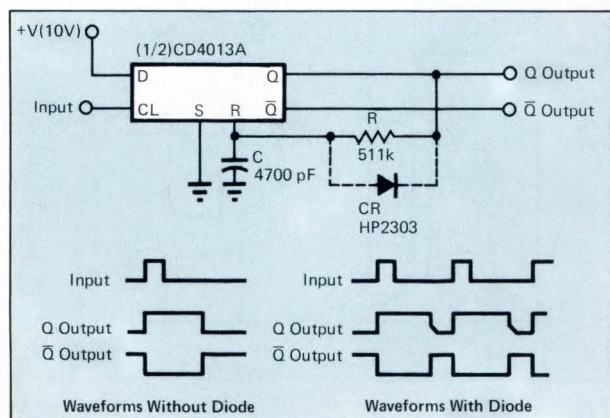
The output pulse width measures 1.91 nsec with the values of the components listed in the diagram. The pulse width increased by 1.5% when the supply voltage was changed from 10 to 15V. The pulse width increased by 6% from room temperature to  $-40^\circ C$  and decreased by 2.3% from room temperature to  $+85^\circ C$ .

For high-duty-cycle operation, a diode can be connected across the resistor to discharge the capacitor rapidly. The discharge current is limited by the constant current characteristic of the FET output stage (10 mA at 10V),

which results in a sloped trailing edge of the Q output pulse. However, since the flip-flop features buffered outputs, the  $\bar{Q}$  output is not affected. For maximum pulse width stability at high duty cycles, a Schottky diode and a high supply voltage (15V) should be used. With the duty cycle of 97%, a 3% decrease in pulse width, compared to the pulse width at low duty cycles, was observed with a supply voltage of 15V.

If a negative pulse is used for the trigger input, the one-shot can be made retriggerable by connecting the diode between the reset input and the trigger input instead of the Q output. An input pulse occurring coincident with an output pulse will discharge the capacitor and restart the timing cycle without otherwise affecting the output pulse.  $\square$

To Vote For This Article  
Circle 153



CMOS one-shot provides output pulses from 2  $\mu$ sec to 3-1/2 hours. The diode is only required for high-duty-cycle operation.

**Your vote determines this issue's winner.** All circuits published win a \$25 U.S. Savings Bond. All issue winners receive an additional \$50 U.S. Savings Bond and become eligible for the annual \$1000 U.S. Savings Bond Grand Prize.

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**Submit your own circuit**, too. Mail entries to Circuit Design Program Editor, EDN/EEE, 221 Columbus Ave., Boston, MA 02116.

**Readers have voted:** Edwin R. DeLoach winner of the April 1 Saving Bond Award. His winning circuit is "SCRs form electronic combination lock." Mr. DeLoach is with Astro-Dynamics Electronics, New Orleans, La.



# Writable-control store customizes new mini's microprograms

## PROGRESS IN COMPUTERS

The VARIAN 73 is a 16-bit, asynchronous minicomputer combining user-accessible microinstructions, multiple bussing, and data transfer rates over 3 million words per second on each bus. It utilizes the entire 620 series software base, thereby drastically slashing the largest single cost of computer operations. It also allows vast escalations of performance via low cost increments as needed.

"The VARIAN 73 introduces three economies in performance unmatched by any other available minicomputer system," claims Varian Data Machines president George Vosatka. It provides user-accessible microprogramming by means of an inexpensive writable-control store, and comes with abundant, fully-tested software, including the VORTEX real-time, multi-task, background-foreground operating system.

The Varian 73 (Fig. 1) is a microprogrammed machine, with flexible data pathing controlled by hundreds of microinstructions stored in a read-only control memory. Execution time per microinstruction is 165 nsec. The standard minicomputer configuration can process all previous Varian 620 series programs and offers the 620 instruction set as a standard feature. By adding the writable-control store option, this microprogramming can be extended by the user to create special-purpose instructions and macro-algorithms. Additionally, the user can create plug-in control store emulators of other machines.

Programming efficiency is increased

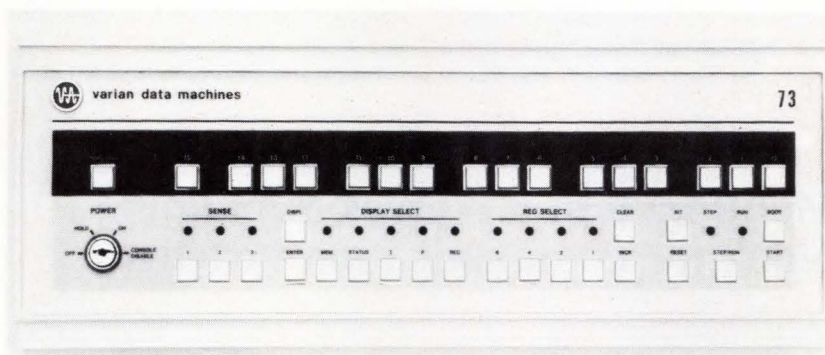


Fig. 1—New minicomputer provides user-accessible microprogramming and a fast, flexible dual-port memory system.

by a wide (64-bit) control word and 16 general-purpose registers. A single control word provides fields for specifying diverse machine functions, such as source and destination register, arithmetic or logical operation, shift, jump, address of next microinstruction, memory-register operation and I/O bus-register operation. Register reference instructions are completed in 330 nsec, and memory reference instruction in 660 nsec. In addition,

the many registers save main memory space and time.

### Take your pick of memories

The basic VARIAN 73 offers three high-performance memories, with cycle times of 190 nsec, 330 nsec, and 660 nsec. For main memory, the user may select MOS semiconductor for speed (330 nsec), core (660 nsec) for economy, or any combination of the two. Memories of both types may be

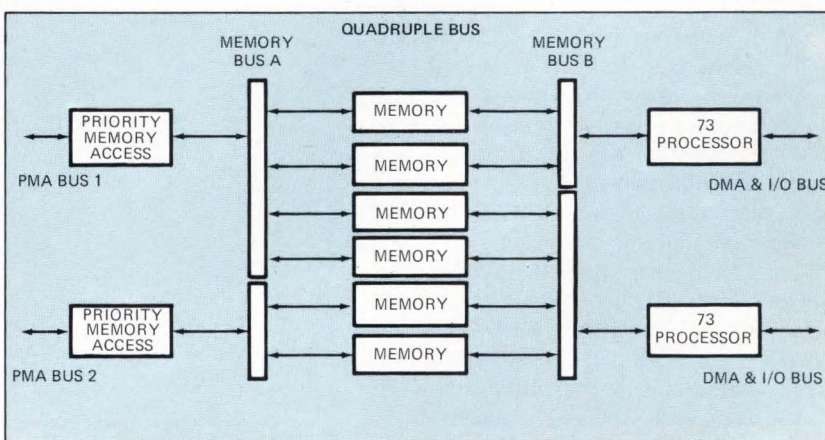


Fig. 2—Quadruple-bus structure features completely overlapped operation between two processors and two PMA channels. Additional processors can share the busses.



mixed in any combination without loss in continuous memory sequencing. Main memory may be expanded up to 262k words. Cores are available in 4k and 8k modules, and MOS in 1k, 2k, 4k and 8k modules.

All memories are dual port for fast interleaving of I/O and processor functions. Multiple processors may also share in common memory. In multiple-memory systems, one memory may be communicating with a processor, while another is exchanging data with an I/O device or another processor. Direct I/O to memory data transfer can take place at rates up to 3.03 million words per second on a single bus.

Multiple buses interconnect the processors, memories, and I/O for efficient data pathing. For example, in the quadruple bus structure in Fig. 2, ad-

ditional processors can interface with bus A and/or bus B, and share the available memory cycles. Common bus structure allows both fast data transfer and ease of expansion. The VARIAN 73 connects to a wide range of peripherals and other data sources. Four means of I/O communication allow connecting to peripherals of various speeds with minimum loss in processor time. Included are programmed I/O, to 500 kHz, direct memory access (DMA) I/O to 333 kHz, high-speed DMA to 1 MHz, and priority memory access to 3 MHz. Thus all speeds of I/O devices can be accommodated, from teletypes and other low-speed devices, to ultra high-speed peripherals which transfer data at full memory-cycle rates.

Hardware priority interrupt structure

is expandable at low cost up to 64 levels. Each level of interrupt is assigned a unique memory location.

The most advanced MSI/LSI technology is used in the new computer. The entire central processor, with control ROM, is contained on a single circuit board. Similar boards encompass up to 8k of semiconductor or core memory. All boards plug into universal slots connecting to a printed circuit bus structure in either a 7-inch or 14-inch chassis.

Price of the standard VARIAN 73 system ranges from \$15,000 to \$100,000 with deliveries planned for September.

Varian Data Machines  
2722 Michelson Dr.  
Irvine, Ca. 92664  
(213) 387 5346

281

## Multifunction IC serves as building block for communication systems

### PROGRESS IN MICROELECTRONICS

Industrial communications is a rapidly expanding area of electronics, yet, the influx of integrated circuits into this field has been relatively slow. One reason for this is that the IC needs of most communication systems are highly specialized, requiring custom designs for particular applications. This segment of the market has not been efficiently served by standard, off-the-shelf ICs designed for general applications. The XR-S200 from Exar Integrated Systems represents a novel approach towards a solution to this problem by the development of a "partially committed" integrated system.

If one examines the needs of the communications industry closely, it becomes apparent that even though the applications are highly specialized, most of the circuits used can be categorized into the following three circuit functions: Multipliers (also known as modulators, phase-comparators or synchronous detectors); Gain blocks (operational amplifiers, sense amplifiers, comparators); Oscillators (both fixed and variable frequency, voltage controlled or crystal controlled types).

These three basic circuit functions

are suitable for monolithic integration, and several commercial designs of each type are available. But the XR-S200 shown in the block diagram, is the only IC available which performs all three functions.

Each of the three functional circuits incorporate a large number of design options, and they can be used either independently or in conjunction with each other. They can be externally interconnected in any respective order without requiring either external biasing or interface circuitry.

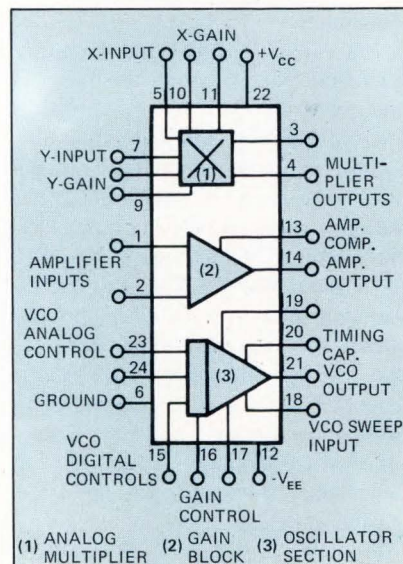
In many communication systems,

both analog and digital signals may be present simultaneously. Consequently, the circuit was designed to accommodate both types of signals and to also be capable of interfacing with either conventional bipolar or MOS-logic families. A high degree of flexibility has been built into the monolithic design to allow it to handle input signals ranging from 0.1 mV to 5V and operate over a frequency range extending from 0.1 Hz to 40 MHz with a wide choice of power supply voltages from  $\pm 5V$  to  $\pm 18V$ .

The three functional blocks can be

#### TYPICAL APPLICATIONS OF THE XR-S200

- Phase-locked loops
- FM demodulation
  - Commercial FM-IF
  - Narrow and wideband FM
  - TV sound and SCA detection
- FSK detection (MODEM)
- PSK demodulation
- Signal conditioning
- Tracking filters
- Frequency synthesis
- Telemetry coding/decoding
- AM detection
  - Quadrature detectors
  - Synchronous detectors
- Linear sweep & FM generation
  - Crystal controlled
  - Double sideband
  - Suppressed carrier
- Tone generation/detection
- Waveform generation
  - Sine/square/triangle/sawtooth
- Analog multiplication





directly interconnected to perform a large number of complex circuit functions, from phase locked loops to the generation of complex waveforms. The accompanying table contains a listing of some typical applications of the XR-S200 system.

By eliminating the unnecessary

components and internally connecting the required functions, the total pin count can usually be reduced from the standard 24-pin DIP so that production circuits that correspond to unique system requirements can be supplied in a 14-pin or 16-pin package.

To assist designers interested in the

XR-S200 a 42-page specifications and application note booklet discussing in detail most of the applications listed in the accompanying table is available from Exar. Exar Integrated Systems, Inc., 733 N. Pastoria Ave., Sunnyvale, CA 94066. Phone (408) 732-7970. **282**

## Low-cost 9- $\mu$ sec 14-bit A/D converter available in a plug-in module

### PROGRESS IN INSTRUMENTATION

Designers looking for high-speed (100-kHz and up) high-resolution A/D converters usually had to settle for large and cumbersome rack-mount units containing not only the converter, but a mating sample-hold amplifier, buffer amplifiers and possibly a multiplexer, all at a cost of several thousand dollars. High-frequency interference problems necessitated purchasing an entire data-acquisition system whose components were designed for optimum matching.

Analogic Corp. has now introduced a pair of low-cost, high-speed and high-resolution A/D converters avail-

able in plug-in modules. The firm's MP2913A and MP2914A 13 and 14-bit converters come in  $2 \times 4 \times 0.39$ -in. Modupac modules and are rated for total conversion times of 8 and 9  $\mu$ sec yet cost only \$715 and \$765, respectively. These speeds are achieved without any sacrifice of accuracy and linearity. The absolute accuracy (at 25°C) is  $\pm 0.015\%$  refer to NBS. This includes a relative accuracy of 0.006% of full scale and a reference accuracy. Stability is enhanced with a gain TC of  $\pm 7$  ppm/°C and an offset TC of  $\pm 12$  ppm/°C.

According to Analogic, the use of high-speed monolithic current switches, and MSI programmer, a newly designed comparator and careful layout

of the converter's ground plane made the modular design possible.

As for matching systems components, Analogic's MP270 1- $\mu$ sec sample-hold unit and the MP215 buffer amplifier are available.

Additional specifications for these new A/D converters include full scale input voltage ranges of 0 to +10V,  $\pm 5$ V,  $\pm 10$ V or 0 to +5V. Input impedance is  $125\Omega/V$  of full scale. The converters are guaranteed to be monotonic and are recommended for recalibration intervals of 6 months. They operate from +15V at 60 mA, -15V at 60 mA and +5V at 500 mA.

Analogic Corp., Audubon Road, Wakefield, Mass 01880. (617) 246-0300. **283**

## Sub-modular circuit cuts power supply design time and costs

### PROGRESS IN POWER SUPPLIES

The new "CM" Series sub-modular power supply from Powertec provides the user with a simple, cost-effective building-block concept for multiple or single-output supply units.

The basic building block is a sub-modular power supply which includes the rectifying, filtering, regulating and protective functions. The circuit features adjustable fold-back current-limiting, fusing, adjustable-threshold-overvoltage protection, and output-voltage trimming. No addition of external components is needed to provide these functions. The other building blocks include an ac transformer, wiring harness, heat-sink for the sub-module (s) and a case.

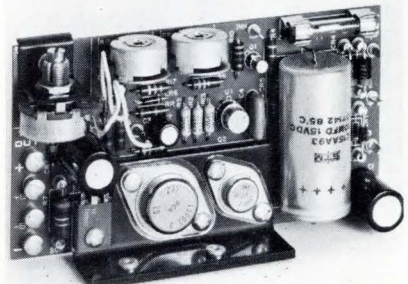
After the design engineer has the power requirements specified, he need only select a proper heat sink, transformer, and "CM" Series model (from the 25 standard stock models available), and then:

- Bolt a power supply circuit to heat sink through the bracket.
- Add one transformer, connected to the ac power cord.
- Connect a circuit board to the transformer and the power busses of the equipment.

Labor costs for assembly of such a power supply are minimal. Twenty-five standard models provide voltages to 30V and currents to 18A (without external bypass components). Prices range from \$14 to \$38 in 100-piece quantities. Typically, a 5V/6A model with adjustable overvoltage protection costs \$22.

A unique feature of the sub-module is the low-level logic-control input for shutdown of the output voltage. The unit is unconditionally guaranteed for one year.

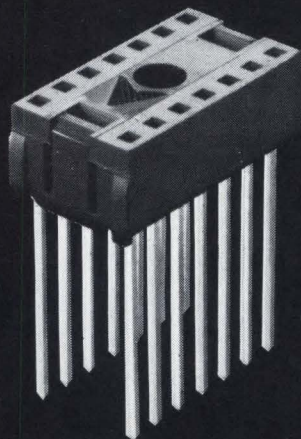
Powertec, 9168 De Soto Ave., Chatsworth, CA 91311. (213) 882-0004. **284**



The "CM" Series sub-modular power supply includes rectifying, filtering, regulating and protective functions.



# ME-2

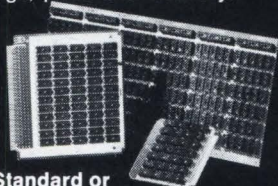


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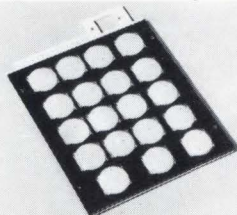
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## COMPUTER PRODUCTS



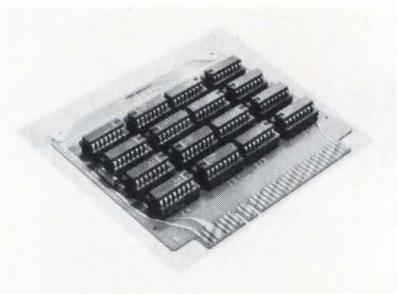
**CALCULATOR KEYBOARD PROVIDES TACTILE FEEDBACK.** A new keyboard system provides snap action feel and sound feedback. The 1KS KLIXON series has a profile of 0.150 in. and is offered in complete arrays up to 20 switches. All contact surfaces are gold, providing low impedance for MOS interfacing. Switch life is in excess of 10 million cycles. The entire switch area is sealed with mylar, so contacts are lint-proof and coffee-spill proof. Texas Instruments Inc., Control Products Div., Atteboro, MA 02703. Phone (617) 222-2800. **170**

**MINICOMPUTER DISC SYSTEM STORES UP TO 2.4 MILLION WORDS.** A new family of data-storage systems provides direct interfacing of Diablo disk drives with the Varian 620 Series minicomputers. The Diablo Systems Model 33 dual-platter disk drive is used in the high-density storage system which has a storage capacity of 2.4 million words. Price is \$12,550, including controller, power supply, and interface hardware. System Industries, 535 Del Rey Ave., Sunnyvale, CA 94086. **171**

**CONTACTLESS KEYBOARD USES CAPACITIVE SWITCHING.** Full keyboard encoding can use either discrete ICs or MOS, depending upon design requirements. The CAPSCAN keyboard features 2-key or n-key rollover, contactless switch operation, individually illuminated switches where desired, choice of mechanical or electrical shift lock, 2-shot molded keycaps, and a liquid-proof design. The keyboards are offered in a standard design at less than \$90.00 each in quantity-Raytheon Industrial Components, 465 Centre St., Quincy, MA 02169. Phone (617) 479-5300. **172**

**CASSETTE ADDS 6000 DATA REGISTERS TO CALCULATOR MEMORY.** Model 9865A cassette memory adds the ability to store very long programs or large amounts of data to models 9810A and 9820A H-P desktop calculators. Search speed is 130 fpm in either direction from anywhere on the tape. Transfer rate is 50 registers or 400 program steps/sec. Up to nine cassette memory units can be operated with one

calculator, each with a capacity of 6000 data registers or 48,000 program steps. \$1750. Hewlett-Packard Co., 1601 California Ave., Palo Alto, CA 94304. Phone (415) 493-1501 **173**



**RAM CARDS HOLD P-CHANNEL DEVICES.** Designated part number 784-2004-01, these static memory devices require +5V and -9V for operation. The 4.5-in. square cards interconnect through a 70 finger-edge connector and directly interface with CAMBION's standard DTL and TTL family of logic cards. The memory card has a capacity of 4k words × 1 bit and contains 16 ICs. Cambridge Thermionic Corp., 445 Concord Ave., Cambridge, MA 02138. Phone (617) 491-5400. **174**

**AUTOMATIC MULTI-LINE CALLING AND ANSWERING UNIT** is an alternative to dedicated communications systems. Model 1200 ACAU is modularly constructed in units of 5, 10, 15 or 20 lines. It interfaces with computers in accordance with EIA RS-366 and RS-232C standards and is compatible with Bell 202C modems. Normal speed is up to 1200 bps. The Model 1200 ACAU allows computers to make and answer calls automatically over the Bell System DDD network. Teleprocessing Industries, Inc., 82 McKee Dr., Mahwah, N J 07430. Phone (201) 529-4600. **175**

**MEMORY OFFERS MULTIPLE CHOICES.** The CC-150 is sold in four product configurations—as a core array with 65k words, as a 65k submodule with core array and all drive and sense electronics, as a module with up to 8 submodules and a single additional board containing all required timing and control electronics, and as a complete auxiliary or mainframe memory system in a stand-alone cabinet with up to 6 modules (525k words) power supply, power controller, system self-test and a customer-specified processor interface. Costs are as low as 0.6¢/bit. Lockheed Electronics Co., Inc., Data Products Div., 6201 E. Randolph St., Los Angeles, CA 90040. Phone (213) 722-6810. **176**



**"STUNT BOX" CONTROLS UP TO 100 DEVICES USING FOUR-CHARACTER COMMANDS.** Each such command causes the box to activate a contact closure, momentary or latching, to turn on or off any electric or electronic device. It may be interfaced with a communications terminal between the computer and the terminal without affecting normal data transmission, or may be driven by paper tapes off-line. It may also be driven remotely from a terminal without going through the computer. Time Share Peripherals Corp., Miry Brook Rd., Danbury, CT 06810. Phone (203) 743-7624. **177**

**TWO CONTROLLERS EXPAND MINI-COMPUTER COMMUNICATIONS CAPABILITY.** Models 2612 and 2612-1 asynchronous controllers enable Micro 1600 minicomputers to communicate with local and remote asynchronous devices and service eight and four, full-duplex channels respectively. Every channel is double-buffered and has seven switch-selectable baud rates ranging from 75 to 9600 bps. \$200/channel for the 2612 and \$250/channel for the 2612-1. Microdata Corp., 644 E. Young St., Santa Ana, CA 92705. Phone (714) 540-6730. **178**

**TAPE CONTROLLER FOR PDP-11.** The *data path* Series 1X15 is available as a complete tape memory subsystem or as controller interface. It provides complete control of data flow between the PDP-11 and up to four transports (7- or 9-track compatible) and controls generation of tape format. I/C driver subroutines and diagnostics are supplied. \$3040. Information Products, Inc., 4202 Directors Row, Houston, TX 77018. **179**



**KEYBOARD HAS JAPANESE LEGENDS** Katakana (Japanese character) keyboards for those OEMs supplying interactive data systems to the Japanese end user feature N-key rollover, selective-repeat functions, and selective-inhibit functions. Over 150 Katakana keytop legends and lighted keytops for special function keys are offered. Key Tronic Corp., Bldg. 14, Spokane Industrial Park, Spokane, WA 99216. Phone (509) 924-9151. **180**

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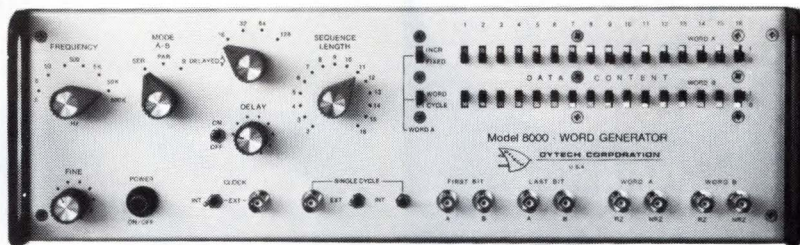
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**Heat Sinks**

CIRCLE NO. 53

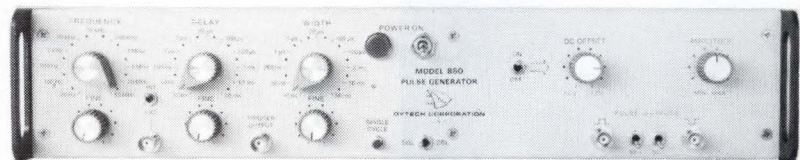
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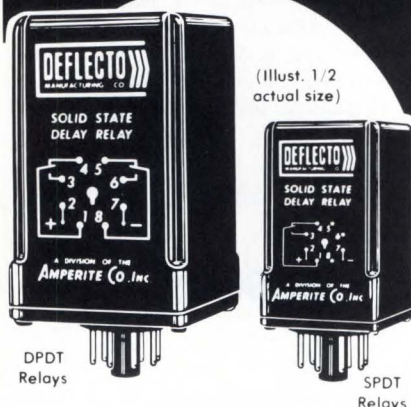
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DPDT Relays: \$13.65 in 100 lots; wt. 6 ozs.

Write for Bulletin No. DSR-1

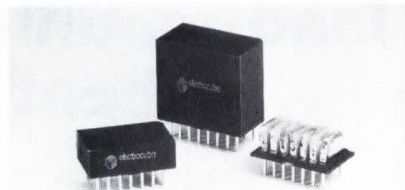
**DEFLECTO Mfg. Co.**

Div. of Amperite Co., Inc.

600 Palisade Ave., Union City, N.J. 07087  
(201) 865-5648

CIRCLE NO. 29

## COMPONENTS/MATERIALS

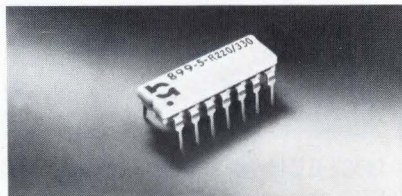


### PLUG-IN CAPACITOR PACKAGES SAVE ASSEMBLY TIME AND PACKAGE SPACE.

Each of the 14 or 16 lead packages will accommodate seven or eight capacitors. Combinations including other components such as resistors or filter components can be packaged to customer requirements. Three heights from 0.375 to 0.750 are available for each package length. Both round solder-in leads and flat plug-in leads are available. Electrocube, 1710 South Del Mar Ave., San Gabriel, CA 91776. Phone (213) 283-0511. **185**

### LOW-PROFILE IC SOCKETS INCREASE PACKAGING DENSITY.

These 14-, 16-, and 18-pin dual-in-line sockets also reduce the overall height of socket mounted components. Only 0.150 in. high, the 3100 Series sockets may be end-to-end mounted on 0.1000 in. centers and side-by-side mounted on 0.4000 in. centers. The entry way is chamfered for automatic or manual insertion. Stanford Applied Engineering, Advanced Packaging Products, 2165 S. Grand Ave., Santa Ana, CA 92705. Phone (714) 540-9256. **186**



**RESISTOR PACKAGES, CONSISTING OF 24 OR 28 THICK FILM RESISTORS**, are designed primarily for pulse squaring networks or logic terminators. The resistors are placed in groups of two hooked together in series having a common line for power and a common line for ground. The center point of each pair is brought out to a separate terminal. Helipot Div., Beckman Instruments, Inc., 2500 Harbor Blvd., Fullerton, CA 92634. Phone (714) 871-4848. **187**

### PUSH-TUBULAR SOLENOID LINE OFFERED.

The design provides direct push force from 1.25 up to 8 lbs. Features include electroless nickel plated plunger and brass bushing for extended solenoid life and positive alignment. A plunger stop and impact

cushion protect the pole faces. Available in coil ratings from 3.3 to over 200V, prices range from \$4.85 to \$7.75 in small quantities. Ledex Inc., 123 Webster St., Dayton, OH 45401. Phone (513) 224-9891. **188**

### MANUAL-RESET CIRCUIT BREAKER DESIGNED TO INDUSTRY'S NEW SAFETY REQUIREMENTS.

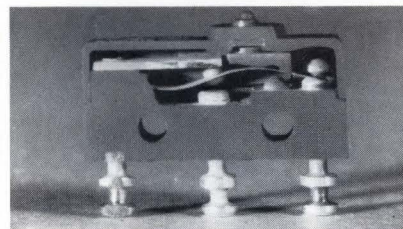
A newly-designed circuit breaker that uses a fire retardant, self-extinguishing SE-O rated insulating base material and is 180 second arc resistant with current capacities up to 4.14A at 125V ac, has been developed. Littelfuse, Inc., 800 East North-west Hwy., Des Plaines, IL 60016. Phone (312) 824-1188. **189**

### TRIGGER TRANSFORMERS ARE DESIGNED FOR USE IN SCR POWER-CONTROL CIRCUITS.

Designated the 505 Series, this new line is available in 3 basic case styles: open or encased for lower-cost applications, or encapsulated construction for special humidity or military applications. Both standard and custom versions are available. BH Electronics, 245 E. 6th St., St. Paul, MN 55101. Phone (612) 228-6463. **190**

### WIREWOUND POTENTIOMETER OFFERS 1W, 18-TURN CAPABILITY IN DIP PACKAGE.

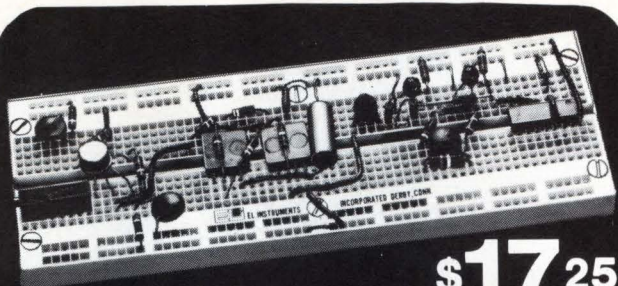
Sealed against humidity, liquids, potting and soldering compounds, this device also features SILVERWELD termination which alloys with multiple-resistance wires, thus eliminating vulnerable, single-wire termination. Price is \$2.25 in 1000-1999 quantities. Bourns Inc., 1200 Columbia Ave., Riverside, CA 92507. Phone (714) 684-1700. **191**



### SUBMINIATURE SWITCH INCORPORATES A "SINUOUS" MOVING ELEMENT

that creates a snap-action as well as a contact wipe. Designed to meet the requirements of MIL-S-8805/2F and MS25085, these switches accommodate both resistive and inductive loads. Available with either solder lugs or single-double turrets. Prices range from \$2.09 to \$1.21. Airpax Electronics, 6801 W. Sunrise Blvd., Ft. Lauderdale, FL 33313. Phone (305) 587-1100. **192**





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CIRCLE NO. 30

## NEW LED LOGIC CHECKER



Displays logic state of most  
 14 or 16 pin IC's with no external  
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**ALCO**

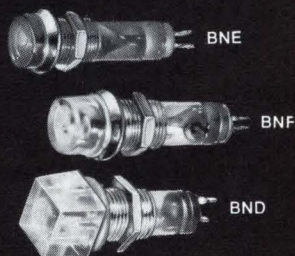
ELECTRONIC PRODUCTS, NORTH ANDOVER, MASS.

CIRCLE NO. 52

## ALCO LITE OFFERS MORE

Ideal for space limitations. BNE's lens appears slightly above panel. BNF lens is higher for greater illumination. BND square lens projects from panel for max. light intensity. With and without internal resistor.

### MODERN NEON PILOTS

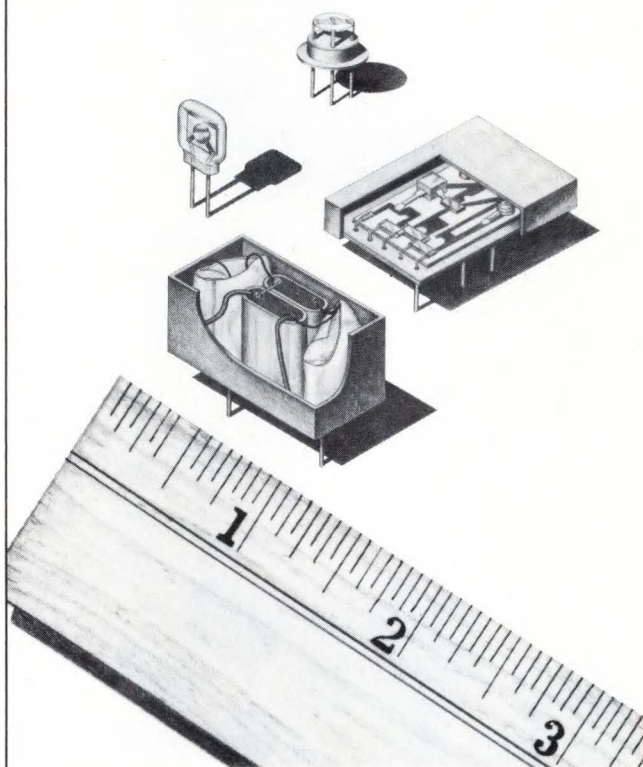


**ALCO**

ELECTRONIC PRODUCTS, LAWRENCE, MASS.

CIRCLE NO. 31

## three cheers for the little guy!



The "little guy"—a miniaturized crystal, filter or oscillator—is an integral part of McCoy's product line. This tiny fellow is pressed into service in space programs, where light weight and compact designs prevail in portable miniature transceivers for commercial and industrial applications, in mini computers and modems, in small wildlife tracking systems, in headgear communications systems where reliability is paramount...in fact we're sure that one of our "little guys" can find a home in equipment of your manufacture, adding value while reducing space and weight.

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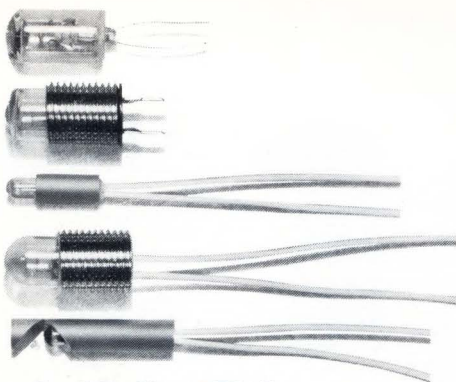
**McCoy** ELECTRONICS COMPANY

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CIRCLE NO. 32





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CIRCLE NO. 33



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**FREE...** new industrial control products summary catalog — listing Babcock's line of industrial timers and sensors, and dry reed, mercury-wetted and general purpose relays.

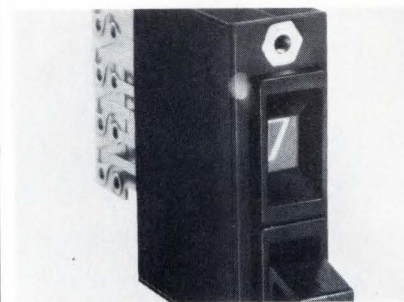


**BABCOCK**

A UNIT OF ESTERLINE CORPORATION

CIRCLE NO. 34

## COMPONENTS/MATERIALS



**BI-DIRECTIONAL TOGGLE SWITCH IS FRONT-PANEL SEALED AGAINST HARSH ENVIRONMENTS.** The dial numbers of the switch are completely visible during switch operation, and the fingertip-detent action and short arc between positions makes precise setting more rapid than standard thumbwheel switches. Available as a ten-position switch, the Series 24000 has a rated life of one million detent operations at load of 28V dc at 125 mA (resistive). The Digitran Co., 855 So. Arroyo Parkway, Pasadena, CA 91105. **193**

**MINIATURE ROTARY SWITCH FOR CIRCUIT BOARD MOUNTING ANNOUNCED.** Called the 5-2500 Rotary Pin Switch, it is available with continuous rotation or with stops. Single pole construction, in a package size of 0.240 in. x 0.350 in. Switch is actuated by a screwdriver slot, and pin location is for 0.100 in. grid center layout. Contact rating is 0.25A at 28V dc, and a life of 10,000 cycles at rated current. Janco Corp., 3111 Winona Ave., Burbank, CA 91504. Phone (213) 845-7473. **194**

**MINIATURE TWO-PIECE CONNECTOR BOASTS A BROAD RANGE OF ADAPTABILITY.** The new series, called 8229, is available in five discrete sizes; 6, 9, 10, 12 and 15 single-row contact positions, all on standard 0.100 in. centers. The connector features wire-crimp/removeable mini-Varilok™ contacts in a flame resistant, glass filled insulator, with special mounting brackets for recessed, flush, or upright mounting. Elco Corp., Willow Grove, PA 19090. Phone (215) 659-7000. **195**

**SELF-ADHESIVE FASTENER OFFERS SECURE RETENTION OF WIRE BUNDLES.** Backed by a 1/32 in. thick pressure-sensitive tape, the fastener has a tensile holding power of 30 lbs. No special tools are required for application. Especially useful on thin, fragile metal sections or delicate components. Leg can be easily unlocked for addition or removal of wires. Eaton Corp., Engineered Fasteners Div., Dept. 14., Cleveland, OH 44101. Phone ? (216) 523-5000 **196**



MIL-R-6106



MIL-R-5757



TIMERS/SENSORS



MERCURY WETTED

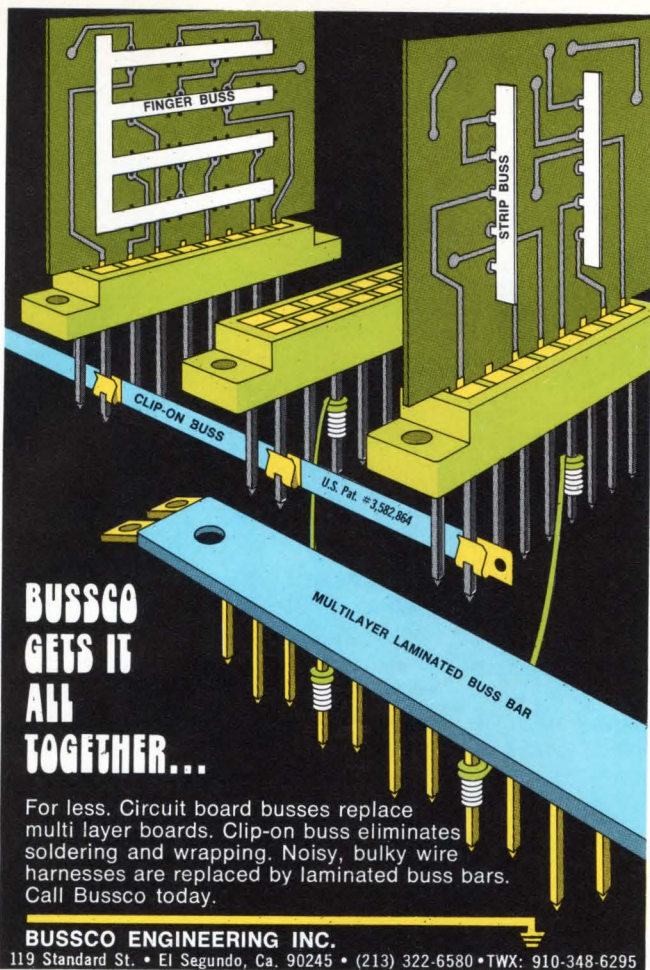


20A INDUSTRIAL



2A INDUSTRIAL



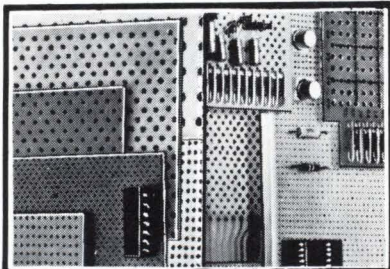


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CIRCLE NO. 36

# Your old counter and \$365\* gets you to 600 MHz



The new Heath/Schlumberger SM-114A Scaler extends the useful range of any counter with more than 100 kHz capability. Three pushbutton-selected ranges allow division of input frequency by 1, 10 and 100. The ÷ 1 range provides for direct transmission of frequencies from 10 MHz to 100 MHz with a gain of 17 dB; ÷ 10 and ÷ 100 ranges will scale frequencies between 40 MHz and 600 MHz.

**Output voltage and impedance matches all counters.** The new SM-114A features a 50 ohm output impedance with 50 mV rms sensitivity and an output of 1 V P-P into a 50 ohm load. The input is protected to 5 V rms and has a VSWR of 2:1 up to 2 V rms. The 1 V P-P output will drive virtually every counter on the market, and with only 50 mV required from the signal source.

**Simple to use.** Unlike many other frequency scalars, the Heath/Schlumberger SM-114A has no sensitivity adjustment or input attenuator. Just connect the input and output signals with standard BNC-type cables and select the dividing range. Scale frequency into the UHF region at low cost.

Order the SM-114A now.

**Assembled SM-114A, 8 lbs. . . . . \$365.00\***

**SM-114A SPECIFICATIONS — INPUT — Frequency Range:** ÷ 1 — Sine or square wave: 10 MHz to 100 MHz. ÷ 10 — Sine wave: 40 MHz to 600 MHz (typical 15 MHz to 600 MHz). Square wave: 10 MHz — 600 MHz. ÷ 100 — Sine wave: 40 MHz to 600 MHz (typical 15 MHz to 600 MHz). Square wave: 10 MHz — 600 MHz. **Amplitude:** Minimum — 50 mV RMS. Maximum — 2.0 V RMS (to maintain 2:1 VSWR) protected to 5 V RMS. **Impedance:** 50 Ω with less than 2:1 VSWR from 10 MHz to 600 MHz and less than 2 V RMS input voltage, AC coupled. **OUTPUT — Amplitude:** 1 V P-P. **Impedance:** 50 Ω, AC coupled. **POWER REQUIREMENTS** — 120 V, 50/60 Hz, 7 watts. May be changed to 240 V with internal switch and change of fuse. **DIMENSIONS** — 9 1/4" deep, 6 3/4" wide, 2 1/4" high.

## Count Frequency To 80 MHz For As Little As \$350.\*



For counting capability into the high frequency region at modest cost, check out the Heath/Schlumberger 80 MHz frequency counters:

Our SM-105A provides 10 Hz to over 80 MHz range, 5-digit LED readout, 100 mV rms input sensitivity and time base stability of ±10 ppm . . . for just \$350.\*

Our SM-104A counter provides the same range and readout as the SM-105A, but has a research-grade TCXO time base guaranteed stable to 1 part in 10<sup>6</sup> per year and 5 digits of TTL-compatible BCD output . . . for only \$500.\*

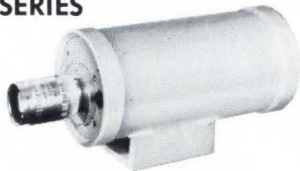
<b>HEATH/SCHLUMBERGER SCIENTIFIC INSTRUMENTS</b> Dept. 531-233 Benton Harbor, Michigan 49022		<b>HEATH</b> <b>Schlumberger</b>
<input type="checkbox"/> Please send additional information on the SM-114A Scaler. <input type="checkbox"/> Please send latest Scientific Instruments catalog, which includes SM-104A & SM-105A information.		
Name _____		
Title _____		
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CIRCLE NO. 37



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- General Purpose • Low Cost
- 800 Line Horizontal Resolution
- Environmental Proofed • Rugged
- Remote Control

## 1400 SERIES



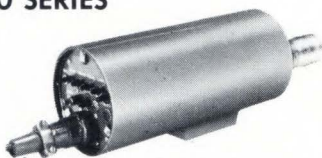
- Miniature Size • Low Cost
- 800 Line Horizontal Resolution
- Low Power Requirement

## 1500 SERIES



- Subminiature Size • Extra Rugged
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- Battery or Line Operated

## 2800 SERIES



- Self-Contained • General Purpose
- 800 Line Horizontal Resolution
- RS 170 Synch Generator
- Power Line Operation

## MODEL V1000



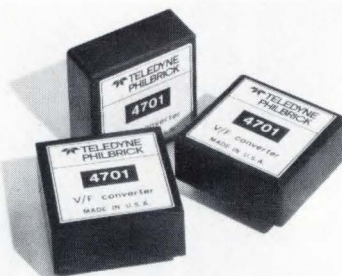
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CIRCLE NO. 38

## CIRCUITS



**VOLTAGE-TO-FREQUENCY CONVERTER PERMITS 2-WIRE DIGITAL DATA TRANSMISSION AT 12-BIT ACCURACY AND COSTS ONLY \$59.** The model 4701 features 0.01% linearity and 27-ppm stability from 0 to +70°C in converting 0 to +10V input to a corresponding 0 Hz to 10-kHz output. Output waveform is a train of DTL/TTL-compatible 30-μsec pulses with a repetition rate proportional to the analog input value. Teledyne Philbrick, Allied Dr. at Rte 128, Dedham, MA 02026. Phone (617) 329-1600. **275**

**8-BIT 15-MHz A/D CONVERTER HAS 0.2% ACCURACY.** The IAD-7108 integrates two converters—a 100 MHz, 4-bit a/d encoder and a 50-MHz, 5-bit encoder—and arranges them together in a sub-ranging configuration. They also function on an either/or basis. The modular approach provides flexibility required in data-acquisition. Cost of the IAD-7108 is \$12,000. Inter-Computer Electronic Laboratories, Inc., Box 507, Lansdale, PA 19446. Phone (215) 822-2929. **276**

**TWO NEW LOW-COST CURRENT D/A CONVERTERS** are Models ZD400 and ZD401 which offer 8- and 10-bit resolution and 1 and 2-μsec settling times (to 1/2 LSB), respectively, at costs of only \$8 (ZD400) and \$14.25 (ZD401). Each converter features ±0.2% accuracy, 100 ppm/°C TC, 0 to 2 mA of output current and standard binary input data coding. Operating temperature range is 0 to +70°C and operating voltage is +15V. Zeltex, Inc., 1000 Chalomar Rd., Concord, CA 94520. Phone (415) 686-6660. **277**

**NEW VOLTAGE-TUNED OSCILLATORS COVER OCTAVE BANDWIDTHS OVER 0.1 TO 12 GHz.** Series SSDV-0100 devices span an output-power range of 10 to 500 mW, feature 20-dB harmonics and tuning rate of 10 MHz. FM noise is low—only 50 Hz rms/kHz/10 kHz. Each unit in the Series measures just 1 by 1.25 by 1.5 in. and weighs a mere 2.5 oz. Cost per unit ranges from \$400 to \$2300 and delivery is 90 days. Solid State Technology, Inc., 1190 Norman Ave., Santa Clara, CA 95050. Phone (408) 243-1800. **278**

**2-QUADRANT MULTIPLYING D/A CONVERTERS**, Series DAC-MI, feature 150-nsec output settling time and a dc-to-2-MHz bandwidth. Spanning 8-, 10- and 12-bit resolutions, they exhibit accuracies of 0.01% of fullscale and TCs of ±0.002%/°C. The converters have a unipolar variable-reference input which when multiplied with the digital input produces an analog output. Cost ranges from \$100 to \$139, depending on resolution. Datel Systems, Inc., 1020 Turnpike St., Canton, MA 02021. Phone (617) 828-6395. **279**

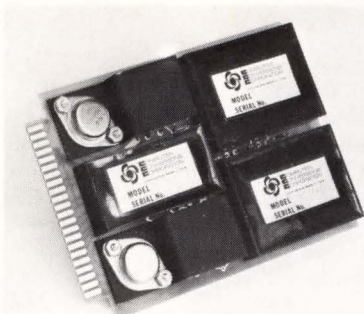
**1.5-TO-20-MHz 2-kW TRANSMITTER HARMONIC SUPPRESSOR.** Model FLD-500 switchable low-pass filter suppresses all second and higher-order harmonics by 30 dB minimum over the entire frequency range of 1.5 to 20 MHz. Five low-pass filters make up the FLD-500. These are arrayed in five bands and are remotely switched by vacuum relays. American Electronic Laboratories, Inc., Box 552, Lansdale, PA 19446. Phone (215) 822-2929. **280**

**NEW RF SWITCHING ARRAYS FEATURE PLUG-IN MODULAR DESIGN.** Series 1500 1-GHz array modules are available in configurations of 1 × 2 to 1 × 5. The plug-in method of rf interconnection allows arrays of up to 1 × 25 to be constructed without the need for any coaxial cable. Typical VSWR for a 1 × 4 module at 250 MHz is 1.07:1 with isolation greater than 46 dB between unswitched ports. Fifth Dimension, Inc., Box 483, Princeton, NJ 08540. Phone (609) 924-5990. **206**



**DUAL-LINE OPTICAL ENCODER FEATURES ENGLISH AND METRIC OUTPUTS.** The Optecon encoder has standard 500-line (English) resolution and 635-line (Metric) resolution. In application, resolutions are switched between the two systems by an electronic signal. Other outputs are available on special order. Four basic physical configurations are offered with prices starting from \$320 and delivery from 4 to 6 weeks. Data Technology, Inc., 65 Grove St., Watertown, MA 02172. Phone (617) 924-1773. **207**





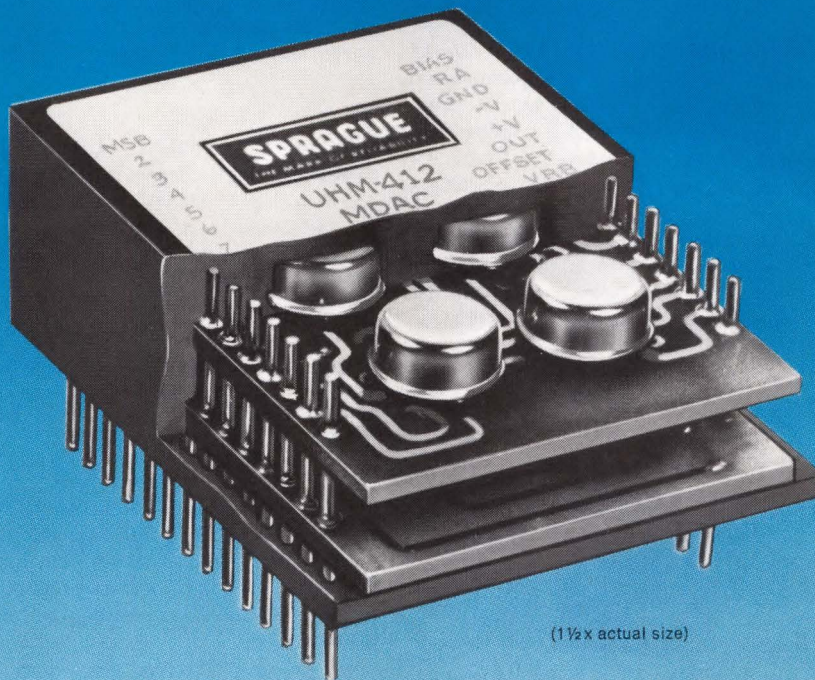
**LOW-COST DC-TO-SYNCHRO CONVERTERS CAN BE REPAIRED.** The converters offer up to  $\pm 6$  minutes of accuracy and output over-current and short-circuit protection. They convert any two dc inputs from  $-10$  to  $+10$ V representing sine and cosine into three-wire synchro outputs. The converters are available with either 11.8V or 90V line-to-line at 400 or 60-Hz outputs. Pricing for production quantities start at \$295 each. Computer Conversions Corp., 6 Dunton Ct., E. Northport, NY 11731. Phone (516) 261-3300. **208**

**ANALOG DIVIDER OPTIMIZED FOR DIVISION AND SQUARE ROOTING.** Model 4290 has 0.5% accuracy over a 100:1 denominator range with no external adjustments needed. External trimming may be used to bring accuracy down to 0.25%. Small-signal ac bandwidth ( $D = 0.1$ V) is 20 kHz and large-signal bandwidth ( $D = 10$ V) is 60 kHz. The Model 4290 operates over  $-25$  to  $+85^\circ\text{C}$  and costs \$75. Burr-Brown Research Corp., International Airport Industrial Park, Tucson, AR 85706. Phone (602) 294-1431. **209**

**PERMANENT-MAGNET AND VARIABLE-RELUCTANCE STEPPING MOTORS,** Series WK, are available in die-cast housings and equipped with permanently lubricated, precision ball bearings. The permanent-magnet units convert stator winding excitations into precise rotor positions. The rotors will magnetically lock at the last command position when de-energized. Electric Indicator Co., Inc., 195 Danbury Rd., Wilton, CT 06897. Phone (203) 762-8655. **210**

**COMPACT PUSHBUTTON FIXED-INTERVAL TIMER** is available in a wide variety of fixed time intervals ranging from 1/30th of a second to 1 month. The timer contains a synchronous hysteresis timing motor and an enclosed snap-action 10A switch, linked together by a plastic cam to create a controller. The timer can turn power off to any device or circuit for fixed intervals of time. Various operating voltages and frequencies may be specified. The Bristol Saybrook, Co., 97 Coulter Ave., Old Saybrook, CT 06475. Phone (203) 388-3414. **211**

# It's what's inside that counts!



(1½x actual size)

## A-C REFERENCE 12-BIT D-TO-A CONVERTERS ... TOP QUALITY FOR ONLY \$5.00/BIT!

The Sprague UHM-412 A-C or D-C Reference ... one of a new generation of digital-to-analog converters that give you economy *plus* performance.

All internal devices are hermetically-sealed and are designed to meet or exceed MIL-STD-883. Monolithic IC ladder switches and buffer amplifiers feature input voltage offsets of less than 5mV and saturation resistances of less than  $0.1\Omega$ . Nickel-chromium precision resistor networks assure the stability inherent in thin-film; resistors are laser adjusted to achieve typically  $\pm 0.1\%$  resistance tolerance and matching to within 0.01%. A monolithic output op amp supplies 5mA peak into a  $2000\Omega$  load. Also available are 8- and 10-bit A-C or D-C reference modules at \$5.00/bit!

Operating temperatures are  $-55^\circ\text{C}$  to  $+125^\circ\text{C}$  for  $\pm 1$  LSB accuracy, or  $-25^\circ\text{C}$  to  $+100^\circ\text{C}$  for  $\pm \frac{1}{2}$  LSB accuracy. Finished units are packaged as DIP-compatible plastic modules.

• For complete information, call or write Ron Beck, Semiconductor Division, Sprague Electric Co., 115 Northeast Cutoff, Worcester, Mass. 01606. Tel. 617/853-5000.

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for Signal Processing**

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## EQUIPMENT



**NEW 5-DIGIT DMM TESTS ITSELF.** Model 3490A has a built-in microprogrammed subroutine that lets the user quickly check calibration or isolate trouble from the front panel. It measures ac from 1 to 1000V in 4 ranges, dc from 0.1 to 1000V in 5 ranges and resistance from 100 $\Omega$  to 10 M $\Omega$  in 6 ranges. Among the DMM's self tests are a series of logic tests, measurement of ratio-amplifier offset and measurement of the reference voltage. Basic cost is \$1650. Hewlett-Packard Co., 1501 Page Mill Rd., Palo Alto, CA 94304. Phone (415) 493-1501. **215**



**\$1295 5-1/2-DIGIT DMM FEATURES 1- $\mu$ V AC/DC RESOLUTION.** Model 2540/A1 with 18 ranges measures ac and dc from 100 mV to 100V fullscale (+20% over-range), resistance from 100 $\Omega$  to 10 M $\Omega$  fullscale and dc ratio from 1000:1 to  $\pm$ 100.000:1. Accuracies and stabilities are said to be equal to or better than those offered in competitive designs at 2 to 3 times the price. Other models in this new series range down to \$1095, with the same high resolution but fewer parametric ranges. Data Precision Co., Audubon Rd., Wakefield, MA 01880. Phone (617) 246-1600. **216**

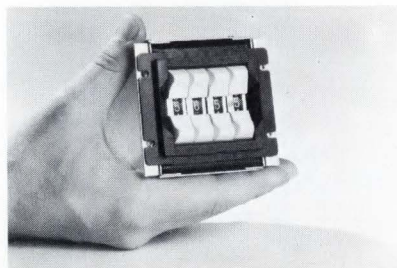
**WIDEBAND SCOPE FEATURES A DC-TO-250 MHz BANDWIDTH OPTION** for frequency-domain measurements, a dc-to-200 MHz optimum-pulse response for pulse measurements, an 8 x 10-cm CRT and 7-cm/nsec writing speed. The 7704A has four-plug-in flexibility (24 plug-ins are available), CRT readout, vertical and horizontal-mode switching, versatile trigger-source selection, pushbutton switching (with lighted indications) and color-keyed panels. Basic price is \$2400. Tektronix, Inc., Box 500, Beaverton, OR 97005. Phone (503) 644-0161. **217**

**A PULSE GENERATOR/POWER SUPPLY COMBINATION FOR \$395.** Repetition rates of Model 88 are from 2 Hz to 20 MHz

with 5-nsec rise and fall times. The unit also doubles as a 5V, 1A supply regulated to 1% and includes voltage and current protection. The generator portion has variable pulse widths from 20 nsec to 200 msec with a variable output from 1 to 5V into 50 $\Omega$ . Systron-Donner Corp., Datapulse Div., 10150 W. Jefferson Blvd., Culver City, CA 90230. Phone (213) 836-6100. **218**

**NEW POTENTIOMETRIC FLATBED RECORDERS,** single-channel Model 2741A and dual-channel Model 2742A, are available as linear, linear with integrator, linear/log and linear/log with integrator recorders. As single range instruments, they offer a selection of 16 current sensitivities from 50 nA to 5 mA or 17 voltage sensitivities from 500  $\mu$ V to 100V fullscale. Simpson Electric Co., 5200 W. Kinzie St., Chicago, IL 60644. Phone (312) 379-1121. **219**

**SYSTEM 1000A/1100A DIGITAL COMMUNICATIONS TEST SET** extends Tau-Tron's bit-rate testing capability from dc up through the uhf band. The test set transmits, receives, synchronizes, measures and displays error rates under pseudo-noise conditions. The transmitter and receiver are in separate packages to facilitate remote operation. Base price is \$14,000 depending upon option. Tau-Tron, Inc., 685 Lawrence St., Lowell, MA 01852. Phone (617) 458-6871. **220**



**RESISTANCE DECADES SPAN 0.01 $\Omega$  TO 10 M $\Omega$ .** Designated Series DA-X, the 0.01%-accurate decades are available in 23 models in 3, 4, 5, 6 and 7-decade units. Total resistance values range from 999 $\Omega$  to 9.999999 M $\Omega$ . Precision wirewound resistors are used throughout with TCs of +3 ppm/ $^{\circ}$ C. Allowable power dissipation is 1/4W per resistor. General Resistance Inc., 500 Nuber Ave., Mount Vernon, NY 10550. Phone (914) 699-8010. **221**

**3-1/2-DIGIT DPM USES A REMOTE LED DISPLAY.** Model 3330/32 (unipolar/bipolar) with the new remote readout shrinks behind-the-panel-depth to less than

3/4 in. The remote-readout cable is a flexible extender whose width is about 1-1/2 in. and length varies from 18 in. to 4 feet. The DPM has an accuracy of 0.1% of reading  $\pm$ 1 digit. Remote-display units are available for \$45 more than the standard meter price of \$245. Digilin, Inc., 1007 Air Way, Glendale, CA 91201. Phone (213) 240-1200. **222**

**INSTRUMENTATION AMPLIFIER OFFERS EXTREMELY HIGH ACCURACY.** Model 8300XWB-A has 0.01% gain accuracy, 0.005% gain linearity, variable gain to 2500X, bandwidth selection between 10 Hz and 100 kHz and high common-mode rejection at peak levels up to 350V. The amplifier has a slewing rate of 3V/ $\mu$ sec and the output settles to within 30  $\mu$ sec to  $\pm$ 0.01% of final value. Temperature coefficient is less than 0.1  $\mu$ V/ $^{\circ}$ C (referred to input). The 8300XWB-A is priced at \$645. Preston Scientific, Inc., 805 E. Cerritos Ave., Anaheim, CA 92805. Phone (714) 776-6900. **223**

**NEW DIGITAL-CONTROL METERS** provide both digital display and on-off control in a small package (2-1/8 x 4 x 4-1/2 in.). Model 4350-K (0 to 199 readout) displays and controls voltage and current to an accuracy and resolution of 1/2%. Model 4354-K (0 to 499 readout) displays and controls voltage, current, resistance, and temperature with an accuracy and resolution of 0.2%. LFE Corp., Process Control Div., Waltham, MA 02154. Phone (617) 890-2000. **224**



**DIGITAL COMPARATORS** Series 2500 are available in single and dual-limit configurations. All models are directly compatible with most panel meters and provide a Form C output-relay closure for each limit set point. This enables them to serve as an alarm condition monitor and perform an on/off controller function simultaneously. Each unit is supplied with its own power supply and control relay(s). Prices start at \$126 each for Model 2503 (single-limit, 3-digit unit). Electronic Research Co., 10,000 W. 75th St., Overland Park, KS 66204. Phone (913) 631-6700. **225**



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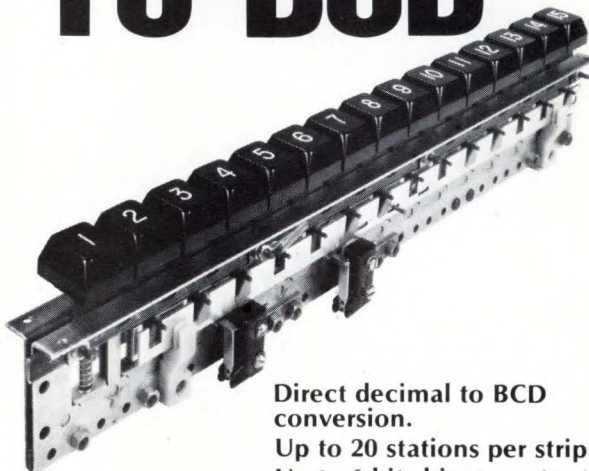
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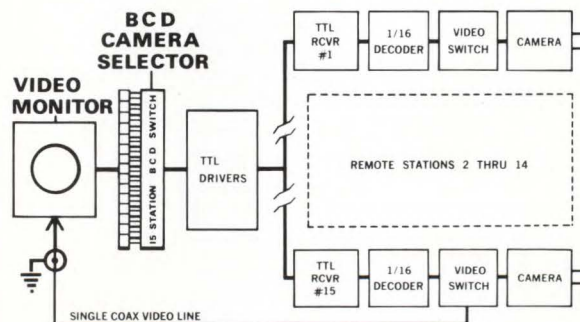
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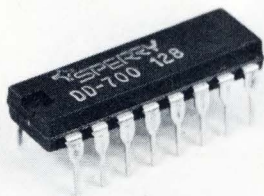


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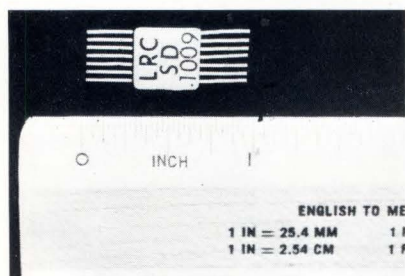
## SEMICONDUCTORS



**DISPLAY DECODER/DRIVER FOR HIGH VOLTAGE SEVEN-SEGMENT DISPLAYS.** Model DD-700, will accept BCD information, and decode it to provide seven outputs for driving each segment. The decoder has a hexadecimal output which provides a numerical readout from "0" to "9" and letters A through F. Available in a standard 16-pin dual-in-line package. Sperry Information Displays Div., P.O. Box 3579, Scottsdale, AZ 85257. Phone (602) 947-8371. **230**

**CMOS MEMORIES, THE CD4036A FOR BINARY ADDRESSING,** and the CD4039A for direct word-line addressing, are 4-word x 8-bit RAMs with non-destructive readout. The CD4036A and CD4039A are currently available on a limited sampling basis in the 24-lead dual-in-line ceramic package. Price: \$25 (1-99 unit level). RCA Solid State Div., Box 3200, Somerville, N J 08876. Phone (201) 722-3200. **231**

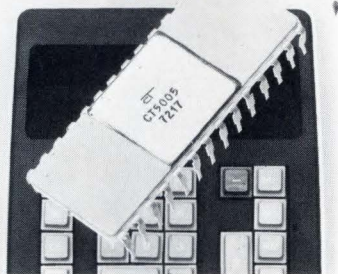
**CMOS 3-1/2-DIGIT COUNTER AND DISPLAY DEVICE HAS BCD OUTPUTS.** The CM4102 is a very low-power complementary MOS/LSI universal 3-1/2-decade counter with BCD-output decoders and drivers. The device features low operating power, 2 mV typically. It is battery compatible,  $V_{DD} = +5.0V \pm 20\%$ , and inputs are fully protected. Pricing for the CM4102 in quantities of 1 to 99 is \$9.90. Solitron Devices, Inc., 8808 Balboa Ave., San Diego, CA 92123. Phone (714) 278-8780. **232**



**INVERTING PIN SWITCH DRIVER IS TTL COMPATIBLE.** It complements the non-inverting SC 1000 Series. The SD 1009 drives shunt, series and series/shunt microwave PIN diode switches with less than 10 nsec total switching time. To provide high-

speed diode switching, current spikes are provided to inject and remove carriers from the switching diode junction. Typical power dissipation is 850 mW. LRC, Inc., 11 Hazelwood Rd., Hudson, NH 03051. Phone (603) 883-8001. **233**

**MONOLITHIC-TIMING CIRCUIT** is capable of producing accurate time delays, or oscillation. In the time-delay mode of operation, the time is precisely controlled by one external resistor and capacitor. For stable operation as an oscillator, the free-running frequency and the duty cycle are controlled with two external resistors and one capacitor. Signetics, 811 E. Arques Ave., Sunnyvale, CA 94086. Phone (408) 739-7700. **234**

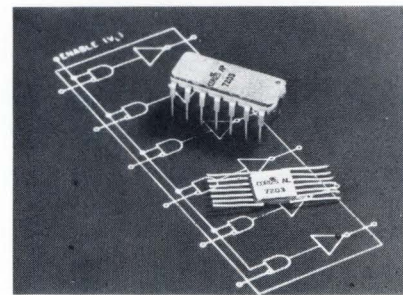


**CALCULATOR CIRCUIT FEATURES FOUR FUNCTIONS AND MEMORY ON A SINGLE CHIP.** The CT5005 contains over 400 gates and 230 shift-register bits. It has automatic keyboard debounce, leading-zero suppression, and automatic lockout on a P-channel MOS chip with two operation registers as well as the memory. Packaging is a 28-pin DIP. Price is \$23 in large quantities. Cal-Tex, 3090 Alfred St., Santa Clara, CA 95006. Phone (408) 247-7660. **235**

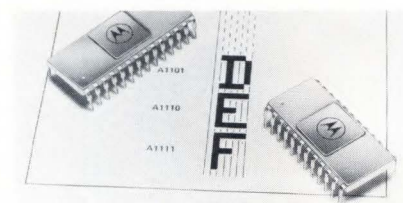
**LINE DRIVER AND RECEIVER GROUP CONVERT DTL OR TTL LOGIC** to levels that interface with data communications terminal equipment in conformance with standard RS232C. Prices for the new circuits in 100-up quantity are: Am1488, hermetic DIP—\$5.50 ea., Am1489, hermetic DIP—\$4.00 ea., Am1489A, hermetic DIP—\$4.05 ea. Advanced Micro Devices Inc., 901 Thompson Place, Sunnyvale, CA 94086. Phone (408) 732-2400. **236**

**CMOS DECADE COUNTER/DIVIDER,** the CM4017A, features medium-speed operation, 5 MHz at 10V, fully static operation and MSI complexity on a single-chip decade counter plus 10 decoded outputs. It consists of a 5-stage Johnson decade coun-

ter and an output decoder. The single operating supply voltage is 3 to 15V. Solitron Devices, Inc., 8808 Balboa Ave., San Diego, CA 92123. Phone (714) 278-8780. **237**



**MONOLITHIC ICs DRIVE FET ANALOG SWITCHES** CDR125 series of 6-channel FET-switch drivers, perform the amplification and dc level-shifting required between low-level logic and MOS or JFET switches. Four types of drivers are available—CDR125AL, CDR125AP, CDR125BL, and CDR125BK. The AL and AP models are MIL types, packaged in flat packs, while the AP and BK models are in ceramic DIP packages. Unit prices range from \$10.30 to \$30.20. Teledyne Crystalonics, 147 Sherman St., Cambridge, MA 02140. Phone (617) 491-1670. **238**



**CUSTOM ROMS PROVIDE WIDE RANGE OF MEMORY CAPABILITY.** The MCM1100 series of custom-programmable read-only-memories (ROMs) offer memory capability ranges from 2048 to 4069 bits in a variety of word-length configurations. Each of these PMOS, metal gate ROMs is offered as a custom, mask-programmable memory with additional devices available pre-programmed. Motorola Semiconductor Products, Inc., P.O. Box 20924, Phoenix, AZ 85036. Phone (602) 273-6900. **239**

**MAGNETICALLY-ACTIVATED ICs FOR SWITCHING APPLICATIONS** have been added to a series of Hall-effect ICs. Type ULN-3004 is a dual-output device designed for sensing a magnetic field and converting it into two 20  $\mu$ sec to 100  $\mu$ sec digital-output pulses. Type ULN-3006 consists of a silicon Hall-generator, amplifier, trigger, and output stage. Sprague Electric Co., North Adams, MA 01247. Phone (413) 664-4411. **240**



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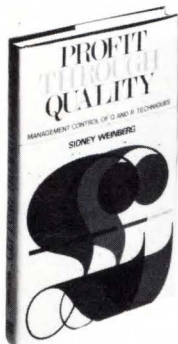
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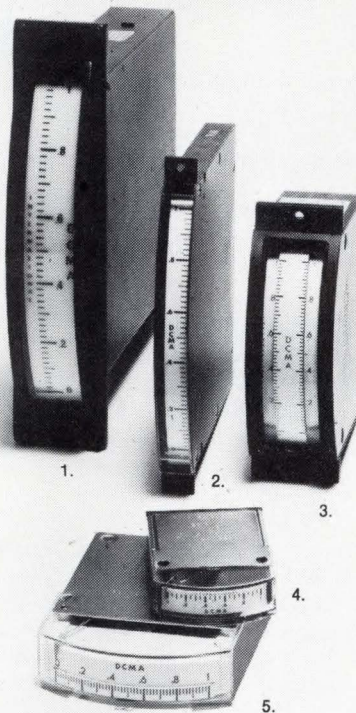
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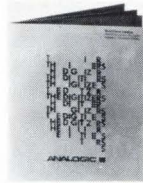
## LITERATURE



**ULTRA-HIGH-SPEED D/A CONVERTER** modules offering state-of-the-art output settling times are described in a new four-page brochure. Electrical and mechanical specifications, operating and application data are listed. Datel Systems, Inc., 1020 Turnpike St., Canton, MA 02021. **285**

**MINICOMPUTER MANUAL.** User's manual for Comstar Star System 4 includes descriptions, features, applications, instruction repertoire and programming examples. Comstar Corp., 7413 Washington Ave. S., Edina, MN 55435. **246**

**TEKTRONIX 7700 SCOPE SERIES.** The series is described in a brochure which includes the 7704A with a dc-to-200-MHz optimum pulse response, a dc-to-250-MHz bandwidth option, an 8-X-10-cm display, 7-cm/ns writing speed and four-plug-in flexibility. Tektronix, Inc., Box 500, Beaverton, OR 97005. **247**



**A/D/A CONVERTERS AND DPMs** are described in the "Digitizers," an 8-page short-form catalog. A complete line of high-performance DPMs, data-conversion systems are described. Analogic, Audubon Rd., Wakefield, MA 01880. **248**

**CASSETTE-TAPE OPERATING SYSTEMS.** An eight-page illustrated brochure describes the various Canberra Model 2020 cassette-tape operating systems as well as interface and software for the Model 2020/PDP-8, Model 2020/PDP-11, and Model 2020/NOVA. Canberra Industries, Inc., 45 Gracey Ave., Meriden, CT 06450. **249**

**POWER CENTER SYSTEMS.** A new 8-page bulletin describes a building-block system of dc power sources and remote regulators. The system permits the user to create his own regulated supplies by combining a few basic elements. ERA Transpac Corp., 67 Sand Park Rd., Cedar Grove, NJ 07009. **250**



**COMBINED X-Y AND STRIP-CHART RECORDER BROCHURE.** The Omnigraphic 2000 X-Y and 3000 one- and two-pen strip-chart recorders from Houston Instrument are described in a 16-page brochure. Described are signal-handling characteristics and time-base and point-plotting modules. Houston Instrument, 4950 Terminal Ave., Bellaire, TX 77401. **251**

**PROGRAMMABLE DATA SYSTEMS.** A new 6-page brochure describes new 100 and 200-channel digital data acquisition systems, which convert analog data signals to printed digital and to computer compatible forms. The systems, which can be manually set for a wide range of functions such as print rates, also offer optional high- and low-limit alarm channels. Esterline Angus, Div. of the Esterline Corp., Box 24000, Indianapolis, IN 46224. **252**

**IMPEDANCE, PHASE, TRANSFER-FUNCTION AND POWER INSTRUMENTS** are described in a new 12-page comprehensive catalog. It illustrates high-speed precision instruments and test systems for measuring impedance, phase angle, voltage and current, transfer function, and real and imaginary power. Dranetz Laboratories, Inc., 2385 Clinton Ave., S. Plainfield, NJ 07080. **253**

**A DUAL-SPEED SYNCHRO-TO-DIGITAL CONVERTER** designed to NAFI requirements is described in a data file. The unit consists of two transformer card modules and 17 circuit card modules designed for mounting in a simplified rack. The data file contains photographs, specifications, features and outline drawings. Astrosystems, Inc., 6 Nevada Dr., Lake Success, NY 11040. **254**

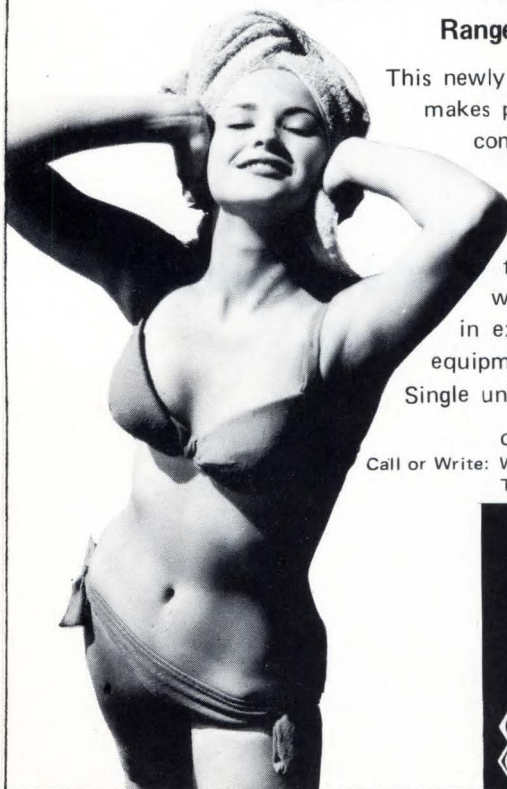
**DATA-CONVERSION PRODUCTS AND SYSTEMS** specifications and prices are shown in a new brochure. The line consists of computer-compatible data-converter instruments assembled from Xincom's standard modules and a broad range of modular packaged a/d and d/a converters, as well as a sample-and-hold module. Xincom Corp., 20931 Nordhoff St., Box 648, Chatsworth, CA 91311. **255**

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**STEPPING MOTORS** of advanced design and high speed are described in a catalog. Useful formulas and sample selection calculations are given as well as complete engineering data and specifications. The Superior Electric Co., 383 Middle St., Bristol, CT 06010. **256**

**CAMERA-TUBE PRODUCT GUIDE** for broadcast, commercial, industrial and educational TV applications. The 8-page guide and its companion broadside provide capsule data to aid customers in their selection of RCA's camera tubes and accessories. Included are a layout and indexing approach that makes it easy for the user to look up type numbers by specified categories. RCA Electronic Components, 415 South 5th St., Harrison, NJ 07029. **257**

**A LINE OF RESISTOR AND TRIMMER PRODUCTS** with low TCs is described in a new 6-page short-form catalog. Performance tables, circuit diagrams and illustrations are used to describe lines of low-cost bulk-metal film resistors ultra-precise resistors, rectangular and 1/4-in.-square trimmers, networks, voltage dividers, BCD modules, attenuators and pin-for-pin replacement-ladder networks. Vishay Resistor Products, 63 Lincoln Highway, Malvern, PA 19355. **258**

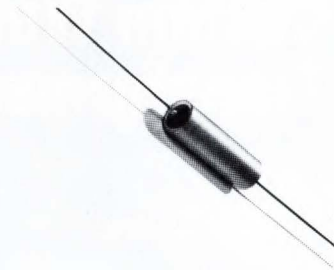
**PRINTER INTERFACE.** New supporting literature is now available on the printer interface circuit which is designed to interface the new Printec-100 line printer with Data General and Digital Computer Controls minicomputers. The Series 160 interface provides electrical interface as well as supporting software, at a cost of less than \$600. Mini-Systems, Inc., 4935 Boone Ave. N., Minneapolis, MN 55428. **259**

**MULTI-PURPOSE BYTE I/O CONTROLLER** interfaces several input and output devices with the Micro 800 and Micro 1600 mini-computers. The 4-page bulletin contains general information, application information, standard features, a functional description, an instruction list, physical characteristics and specifications. Block and connection diagrams are also included. Microdata Corp., 644 E. Young St., Santa Ana, CA 92705. **260**

**EMI/FIELD-INTENSITY METER** Model NM-35/57 is described in an eight-page brochure. The instrument performs programmable emi measurements from 30 MHz to 1 GHz and meets MIL-STD-461A/826A for all automatic and semi-automatic testing. The brochure gives background information on the development of interference test methods, military specifications and interference meters. Singer Instrumentation, Los Angeles Operation, 3211 S. La Cienega Blvd., Los Angeles, CA 90016. **261**



**EMI FILTERS** are shown in a new 4-page brochure. Broadband and lowpass, they are said to offer the low dc resistance and excellent temperature stability. Republic Electronic Corp., 176 E. 7th St., Paterson, NJ 07524. **262**



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## LITERATURE

### CASSETTE RECORDERS AND MEMORIES.

A new 4-page brochure describes the TERMI SERIES of digital cassette recorders and memories for point-of-sale equipment, data capture, peripheral storage, data communications, keyboard-to-tape and other modern applications. Telex Communications Div., 9600 Aldrich Ave. S., Minneapolis, MN 55420. **268**

**INDUSTRIAL DIGITIZING SYSTEMS** are described in a new 24-page brochure. The

brochure gives application information and system configurations. Analogic, Audubon Rd., Wakefield, MA 01880. **272**

### OCTAVE-BAND VOLTAGE CONTROLLED OSCILLATORS

in the 500-to-4000-MHz frequency range are described in a bulletin. Complete rf and mechanical details on the 34849 Series are included. Micromega Div. of Bunker Ramo Corp., 12575 Beatrice Ave., Los Angeles, CA 90066. **271**



**DISC FORMATTER BROCHURE** provides technical specifications and a functional description of the recently introduced disc formatter. The brochure describes the internal formatter organization with a complete description of operation. System designers will also be interested in the complete interface description. Pertec Peripheral Equipment, 9600 Irondale Ave., Chatsworth, CA 91311. **269**

**POINT-OF-LOAD REGULATOR SYSTEMS** are detailed in a six-page catalog. The described systems are specifically designed for computer power and related applications and permit the user to assemble an almost limitless variety of power-supply systems to best meet his requirements. ERA Transpac Corp., 67 Sand Park Rd., Cedar Grove, NJ 07009. **270**

**VOLTSSENSOR VOLTAGE-COMPARATOR MODULES** in over 70 different models are described in a selection chart. The solid-state meter-relay substitutes are available in single and dual set-point models with options of controller action, time delay, latching, adjustable hysteresis and reversed polarity. Calnex, Box 555, Alamo, CA 94507. **274**

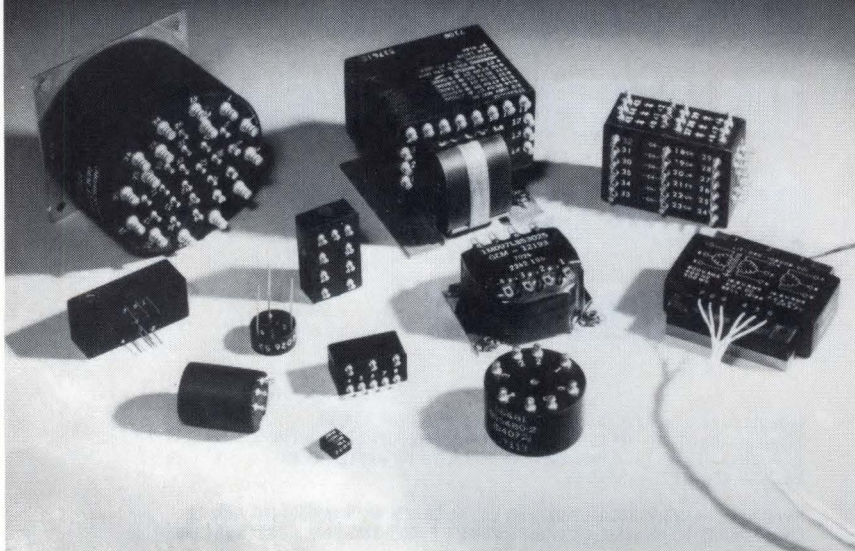
**VOLTAGE-TUNED OCTAVE-BANDWIDTH OSCILLATORS** spanning 50 to 13 MHz are described in a catalog. The units feature high harmonic rejection, low FM noise and state-of-the-art frequency and bandwidth performance. Solid State Technology, Inc., 1190 Norman Ave., Santa Clara, CA 95050. **266**

**AN RF LEAK-DETECTION SYSTEM** which includes a hand-held battery operated detector and a portable rf generator is described in a bulletin. The detector can be used independently to detect spurious rf emission over 10 kHz to 10 GHz. Singer Instrumentation, Los Angeles Operation, 3211 LaCienega Blvd., Los Angeles, CA 90016. **273**

**DIGITAL SIGNAL SOURCES** for general-purpose, semiconductor and digital communication testing are outlined in a new catalog. Single and multi-channel units are described in detail as well as semiconductor-memory test systems that operate up to 100 MHz. Tau-Tron, Inc., 685 Lawrence St., Lowell, MA 01852. **264**

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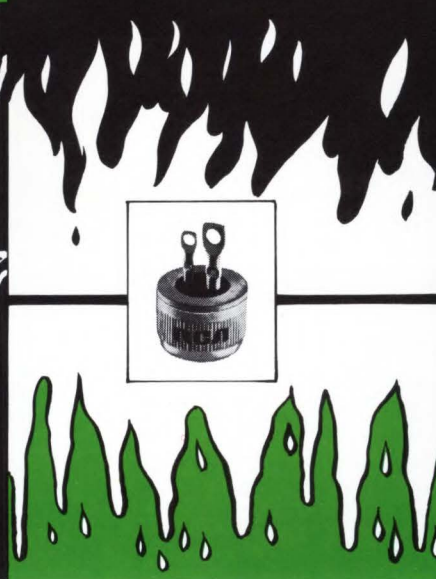
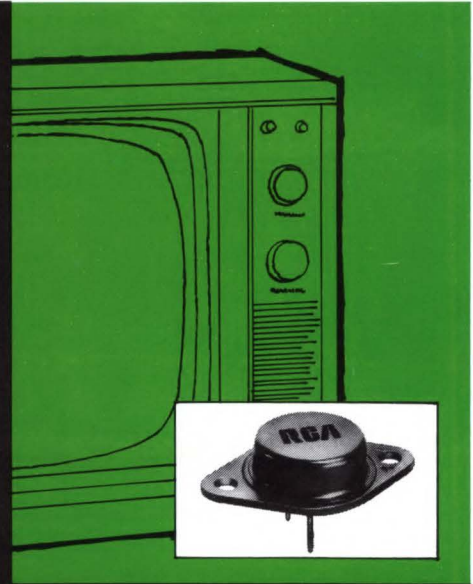
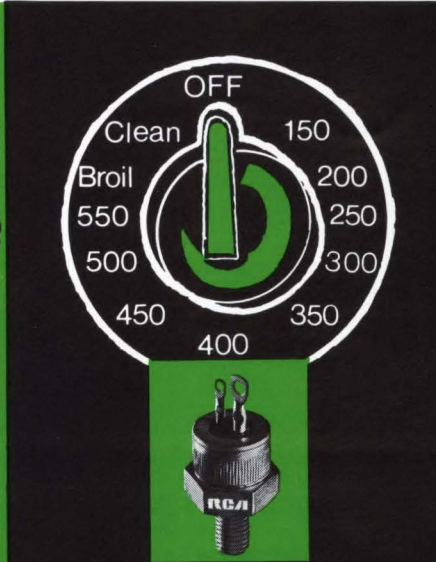
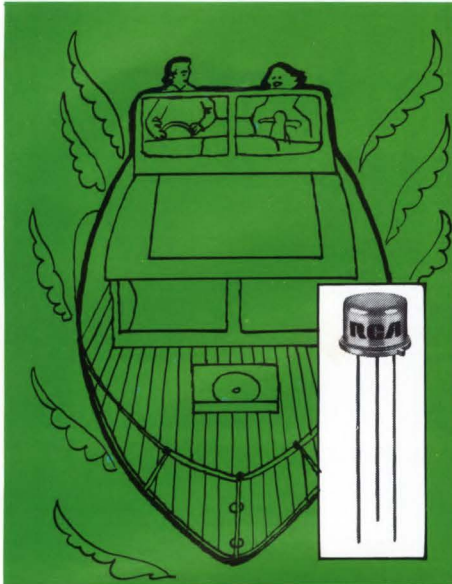


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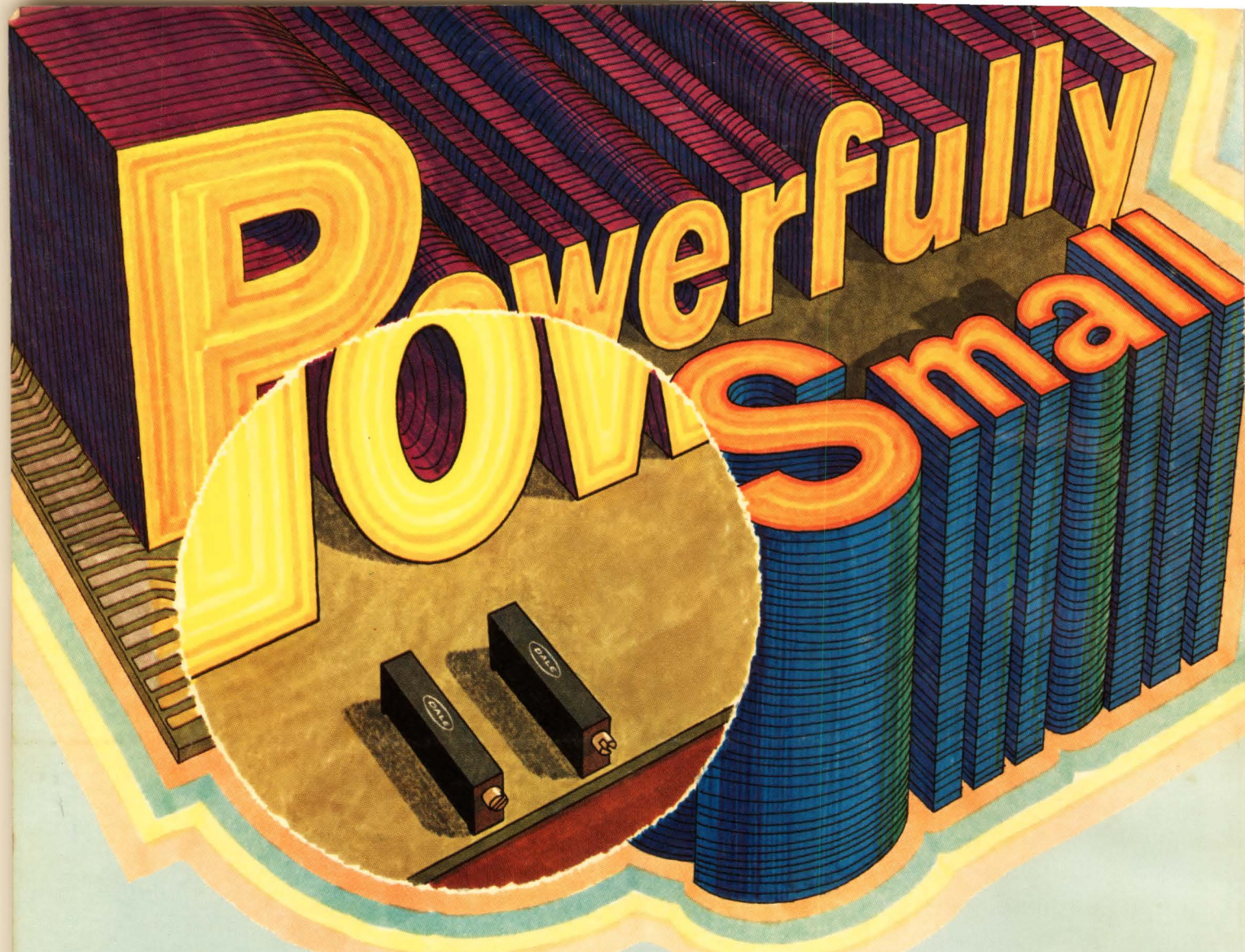
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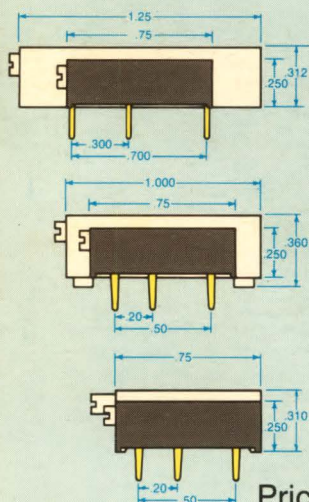
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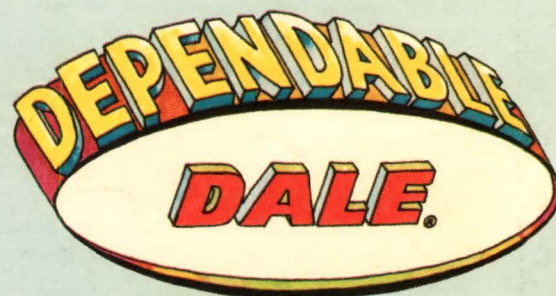
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