EXCLUSIVELY FOR DESIGNERS AND DESIGN MANAGERS IN ELECTRONICS

EDN

Avoid obsolescence in automated test systems

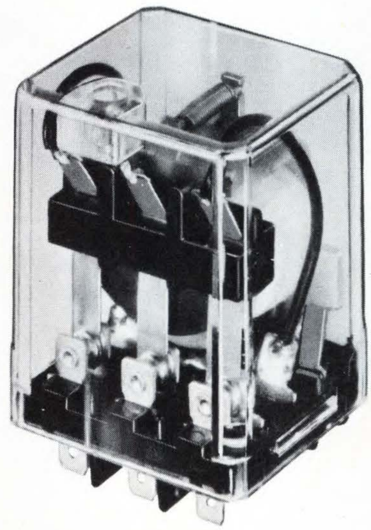
Simple converters are a snap with CMOS

Solid-state microwave sources advance on all fronts

A CAHNERS PUBLICATION

JULY 15, 1972

GP



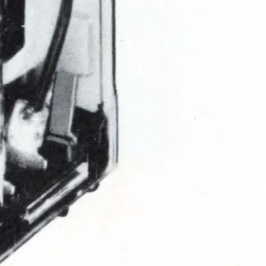
MAGNECRAFT'S NEW CLASS 388
GENERAL PURPOSE RELAY

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!



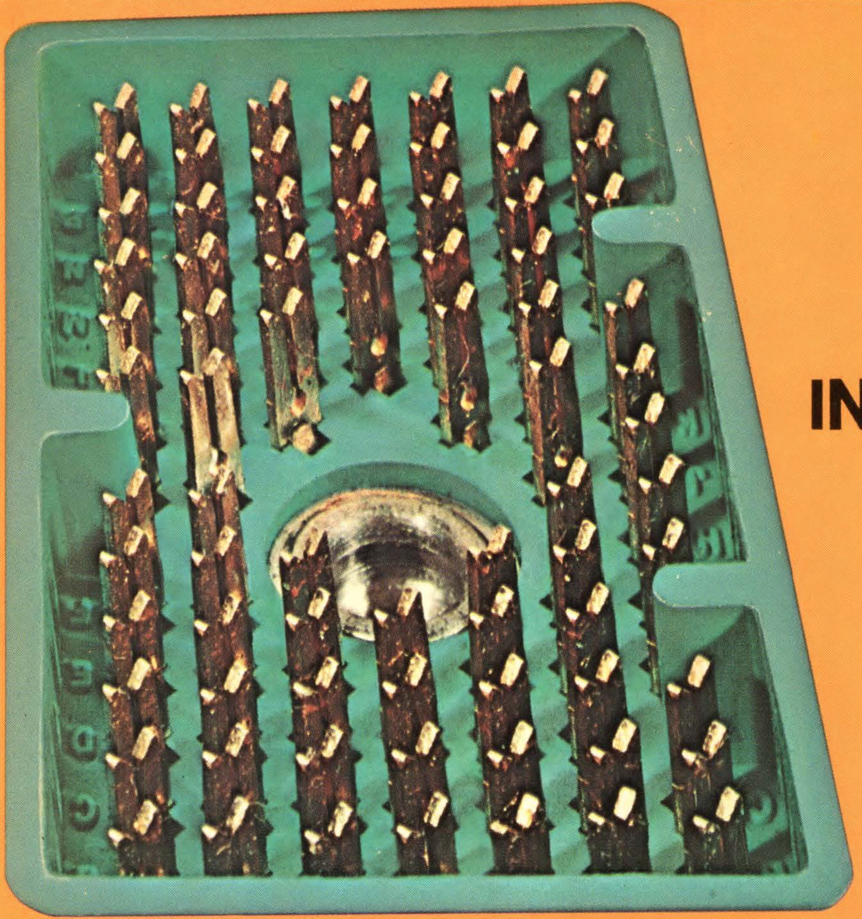
DESIGNER'S CATALOG

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® 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.

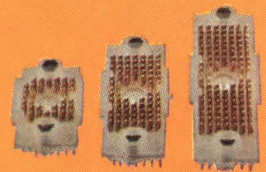
The 75-contact 8026 connector will fit in the same space as a 38-contact connector on .150″ spacing. And the 8026 33-contact connector is one of the smallest 33-contact R/P connectors you've ever seen. For back-up, we offer Series 8026 connector with 55 and 79 contacts on .125″ square grid.

For 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.

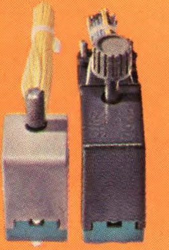
Besides helping you cope with your close-order circuits, these connectors will help you effect other cost economies. Like using your existing 8016 panel punches. Reducing inventory because they can do duty in R/P and cable-to-cable applications as well as be used as an I/O.

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

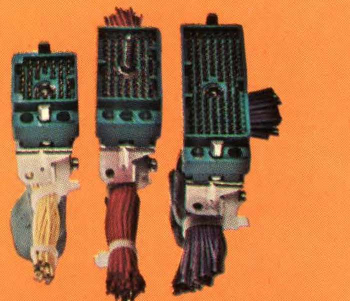


Series 5540 input-output plate receptacles with or without polarizing hardware. On .100″ grid with 33, 75 and 117 contacts. On .125″ grid with 55 and 79 contacts.

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.

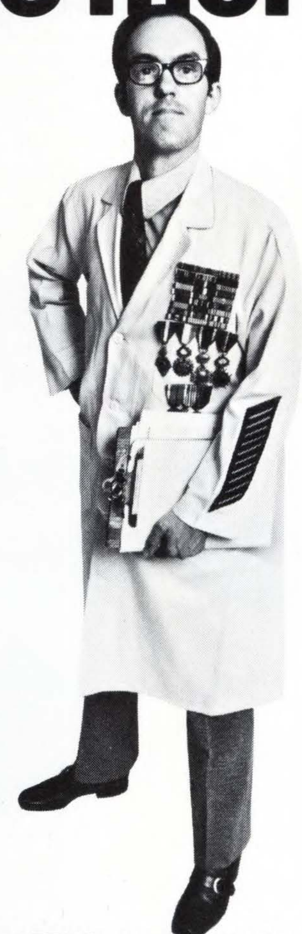
For full details on these new connectors from Elco, contact your local Elco representative or distributor, or: Elco, Willow Grove Division, Willow Grove, Pa. 19090, (215) 659-7000 • Elco, Pacific Division, 2200 Park Place, El Segundo, Calif. 90245, (213) 675-3311.

ELCO TM

Operations and sales offices throughout the world.

CIRCLE NO. 3

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.

CIRCLE NO. 4

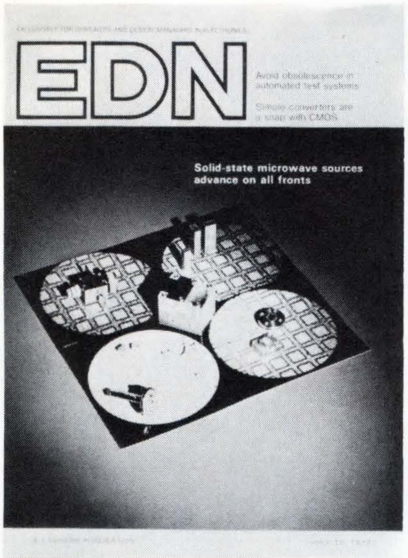
TRW®
CAPACITORS

JULY 15, 1972
VOLUME 17, NUMBER 14

EDN

WITH EEE

EXCLUSIVELY FOR DESIGNERS AND DESIGN MANAGERS IN ELECTRONICS



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.

CP BPA ABP

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

NEWS RELEASE

TEKTRONIX®

Tektronix, Inc., P.O. Box 500, Beaverton, Oregon 97005 **Phone: 503-644-0161**

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.

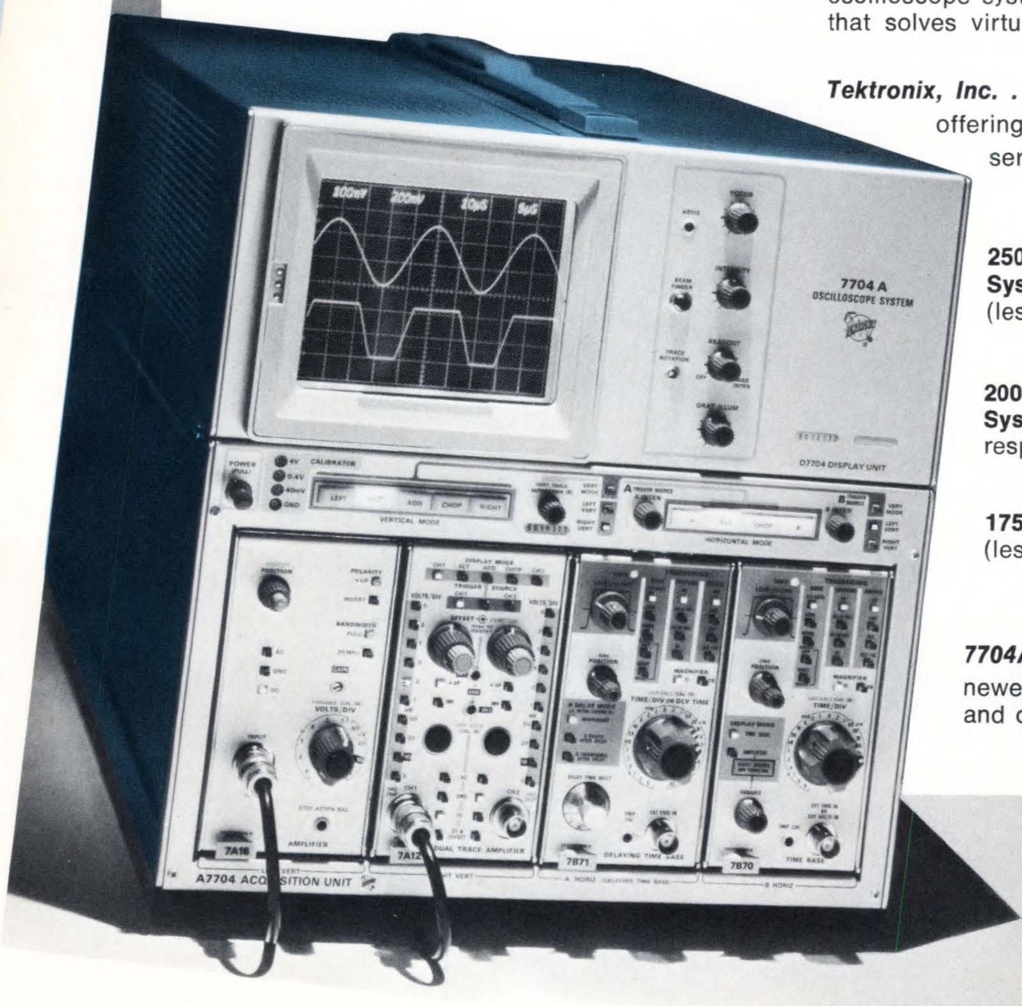
Gain performance and save dollars with the 7704A. This is achieved by using proprietary and commercial ICs, a high efficiency power supply, a new fast CRT and a total new design.

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.



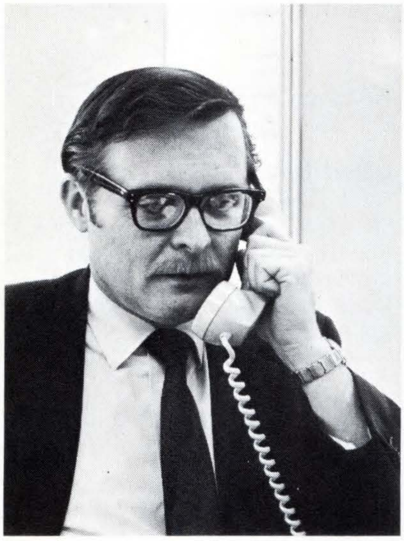
250-MHz 7704A Oscilloscope System . . . bandwidth option . . . (less plug-ins) **$2400**

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

CIRCLE NO. 7



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

STAFF

Publisher
E. Patrick Wiesner

Editorial Staff
Frank Egan, *Editor*
Steven A. Erenburg, *Managing Editor*
Bob Cushman, *New York Editor*
Roy Forsberg, *Boston Editor*
Roger Allan, *Associate Editor*
Bill Furlow, *Associate Editor*
Jerry Moseley, *West Coast Editor*

Art Staff
Dan Kicilinski, *Director*
Roy Nelson, *Illustrator*
Beverly Lembo, *Illustrator*
Patricia Rawlins, *Illustrator*
Elizabeth Garrenton, *Illustrator*

Production Manager
Wayne Hulitzky

Production Assistant
Susan Grober

Circulation Manager
Ron Kinnes

Marketing Services Manager
Ira Siegel

Editorial Consultant
John Peter

Editorial Office Addresses
Executive *(617) 536-7780*
221 Columbus Ave.
Boston, Mass. 02116

New York (212) 689-3250
205 E. 42nd St.
New York, N.Y. 10017

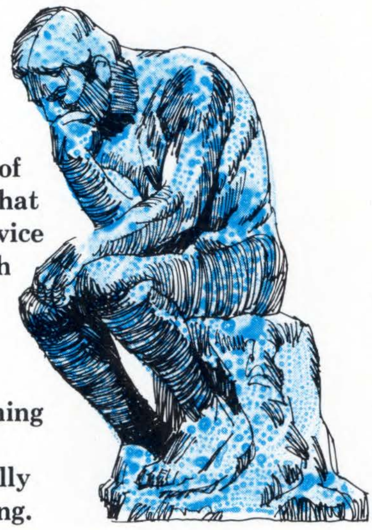
West Coast (415) 383-4220
404 Wellesley Court
Mill Valley, Calif. 94941

Single-Diffused

...better than EpiBase?

We've got both now. Single-diffused, UniBase* power Darlingtons. EpiBase* power Darlingtons. 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.

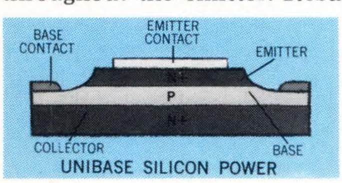
"Are they structurally different?"
"Which is better for high-speed switching?"
"Is there an edge in safe operating area?"
"What are tradeoffs in inductive loads?"
"Which is more applicable to complementary designs?"

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

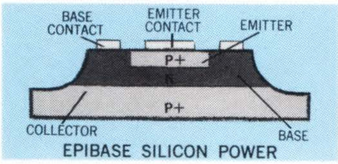
TAKING THE RIGHT SHAPE . . .

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.

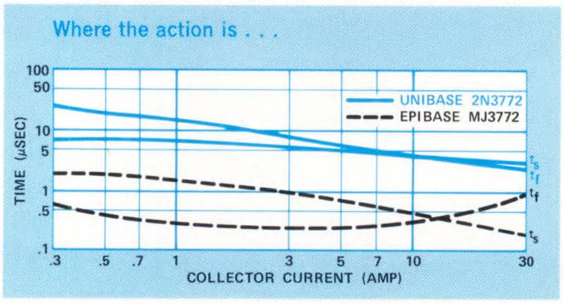


EpiBase offers devices with emitter diffused into an epitaxial base deposited on the collector substrate. The collector voltage depletes into the base region with resulting devices characterized by higher-frequency response and low switching losses with SOA equal to, or better than, UniBase except at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



THE TRADEOFFS . . .

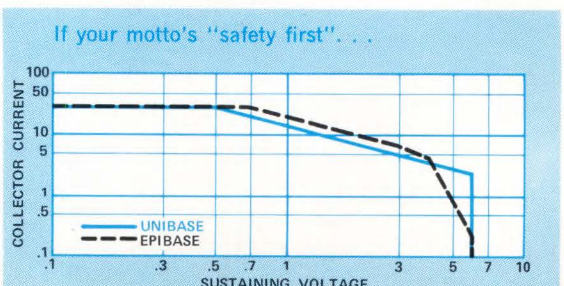
A couple. If switching efficiency, f_T or phase shift are your thing, EpiBase wins hands down. Although power-handling and safe area of the two are about equal, UniBase offers an edge in SOA if your design pushes ultimate device break-



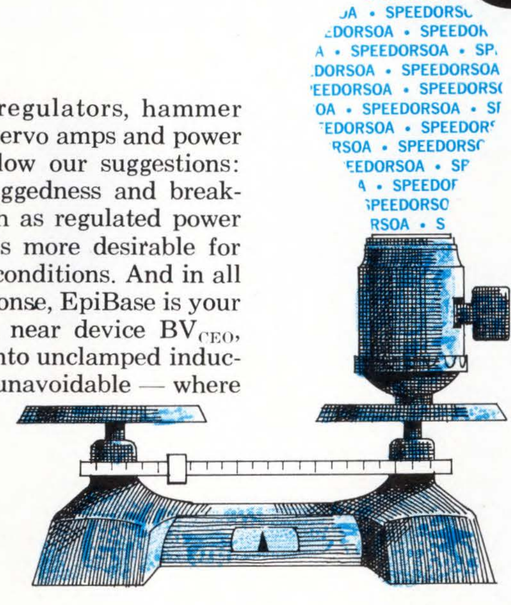
down capability. And, while beta-vs.-current curves are similar for EpiBase and UniBase transistors of given chip size, UniBase will exhibit higher sat voltages and slightly lower high-current beta. Again, a result of higher distributed resistance.

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.



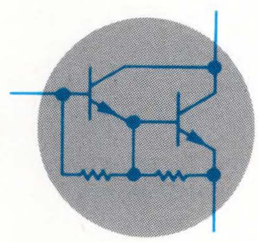
Power Darlingtons

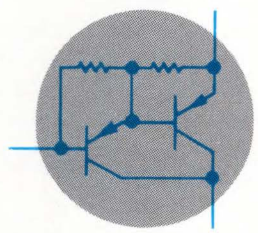


THE APPLICATIONS . . .

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 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 Darlingtons.

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.

THE SPECS . . .

EPIBASE VS. UNIBASE

PRIME SPECS ON SOME PRIME

. . . NEW DISCRETES

DEVICE	GAIN	FREQUENCY	SAFE OPERATING AREA
EpiBase 2N3055	20 @ 4A	4 MHz	60V/200 mA
vs.			
UniBase 2N3055	20 @ 4A	200 kHz	60V/1.5A
EpiBase MJ3771	15 @ 15A	4 MHz	40V/200 mA
vs.			
UniBase 2N3771	15 @ 15A	200 kHz	40V/3.75A

. . . plus a choice between these discretes

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	750 @ 4A	4 MHz	80V/100 mA
vs.			
UniBase MJ3521	500 @ 4A	200 kHz	80V/1.4A
EpiBase 2N6283	750 @ 10A	4 MHz	40V/1A
vs.			
UniBase 2N6356	400 @ 10A	200 kHz	40V/3.75A

. . . plus a choice between these Darlingtons

2N6282 EpiBase and 2N6355 UniBase — 2N6283 EpiBase and 2N6357 UniBase, MJ3520 UniBase — 2N6284 EpiBase and 2N6358 UniBase

*Trademark of Motorola Inc.

MOTOROLA POWER

—Technology By Design, For Design

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.

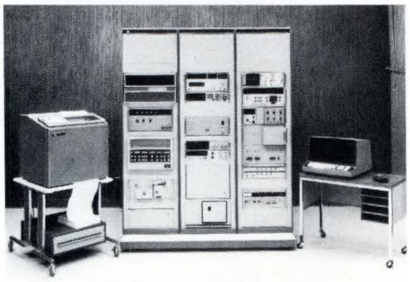


Fig. 1 — Multitudes of instrument types can be calibrated easily with this new automatic system from Hewlett-Packard Co. Designated as the HP9550D, it can calibrate analog and digital voltmeters, oscilloscopes, electronic counters and oscillators.

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 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 paricular 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. □

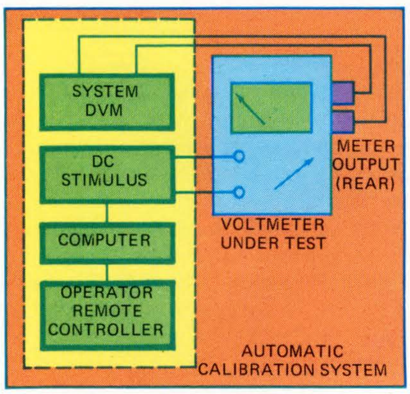


Fig. 2 — Rapid dc voltmeter calibration is achieved with the above configuration. The operator handles a remote controller for a dc stimulus adjustment to the meter's calibration. The controller also allows him to record the actual meter current flowing the meter input once calibration is completed.

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

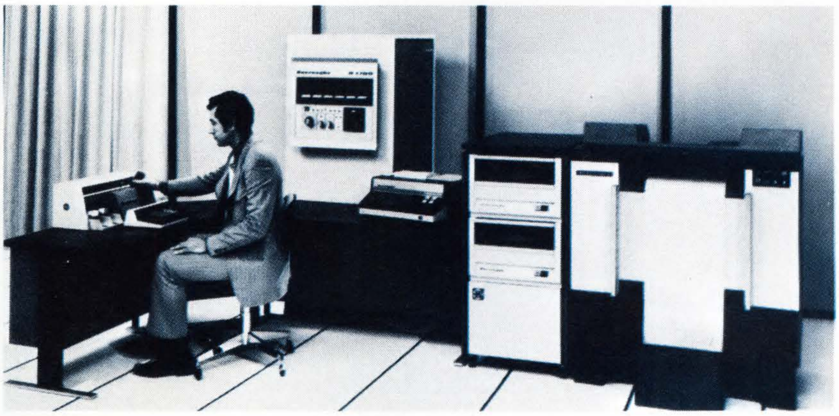
Interchange Microprogramming, multiprograming & solid-state memory, and virtual memory are now available in a new series of small-scale computer systems announced by Burroughs Corp.

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. 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. □



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.

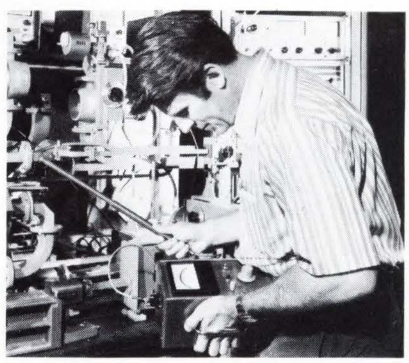
Inexpensive, portable radiation detector keeps tabs on radio-relay and microwave-oven leaks

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/cm² 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.


MEASUREMENT ENGINEERING
MEASUREMENT ENGINEERING
Principles of CHEMISTRY
PERT/CPM

Simplify designs, save space and assembly costs with another new chip on the old block.

Putting the logic in the same package with the display makes a better building block for many of your systems. Designing is simpler, PC boards and chassis get smaller and cheaper. Assembly costs drop.

The net result: your product becomes smaller and more reliable... and costs you less to build.

Since you gain these advantages when logic and display are combined, TI is leading the way in developing a full line. Already you can choose from five parts. (And because the "old" building blocks with display only are still indispensable in some designs, TI maintains a volume production capability on a broad line.)

Newest of the displays-with-logic is the TIL311, a hexadecimal 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.

TI's fast-growing hybrid LED display line.

		100-PIECE PRICE
TIL302	7-segment numeric with decimal	$8.70
TIL303	Same as TIL302 but with decimal on right	8.70
TIL304	Plus or minus overflow	7.80
TIL305	5 x 7 alphanumeric	13.00
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

TEXAS INSTRUMENTS
INCORPORATED

87090

TY-RAP® System Means Lower Harnessing Costs

Here's why this harness costs less than it did last year

SQUEEZE, LOCK, TRIM

This new tool answers the problem of quick and uniform tying even in high-density wiring. The narrow nose and long slim body reaches into confined areas. A squeeze of the trigger cinches the self-locking tie to a preset tension, trims tie evenly. Eliminates rework! Tying uniformity is the responsibility of the tool rather than the installer.

GET A GRIP OF STEEL

One of the most important considerations in plastic ties is the reliability of the tying device. Now, only TY-RAP has a patented non-magnetic, stainless steel locking wedge embedded in the cable tie head. Your customers get a grip of steel every time with TY-RAP ties.

Hundreds of thousands of field-proven applications over 14 years are the credentials for TY-RAP tie reliability. This experience gives you a lower profile tie, a non-slip stippled back, a trademarked, curved tail, a low insertion force head, and the widest range of sizes and configurations. Your customer gets a higher quality job, at a lower installed cost to you.

Retainers that hold and shape the bundle during harness making are one of many aids available for board work.
Cat. Series TC-81

Harness installation and point-to-point wiring are further advanced through use of adhesive mounting bases and hundreds of other devices. Cat. No. TC-342A and TC-353A

How can the TY-RAP System lower your costs? Write for our new guide and catalog.

Sold Only Through T&B Distributors

A PRACTICAL NEW PRODUCTION TOOL

For high volume, we offer a new automatic tool that ties in 8/10 second. It feeds a TY-RAP tie around the bundle, tightens it to a preset tension and trims it evenly. Adjusts itself to bundle diameters from 1/32" to 5/8". Cat. No. TR-300

MARK IT AND TIE IT!

A wide variety of TY-RAP ties have marking surfaces as an integral part of the tie. You get all the advantages of the tie plus the identification area.

BIG ONES, SMALL ONES FAT ONES, THIN ONES

Our new "slim line" tie is the slimmest tie with the smallest head. The new slim cross section gives added flexibility for every operation including "figure eights" and dense or miniature breakouts. Where compactness is a must, a new slim design pays off in both space and weight reductions. This is a practical consideration for applications where "g" loading and vibration are not critical.

You select! There is a standard TY-RAP tie for just about every application . . . including MIL specs. Choose from the little 3-inch for 1/16" bundles, to the 30-inch tie for 9-inch bundles. And, they are molded of Zytel*, a special formulated nylon to give you reliable, long life performance.

* Reg. Trademark Dupont

THE HOLE IN THE HEAD REDUCES YOUR CLAMP INVENTORY

By the simple addition of a mounting hole, the TY-RAP tie has been transformed into a cost reducing strap. Since the tie is infinitely adjustable, a wide diameter range is accommodated. Now, new configurations further reduce your inventory of various sized plastic and metal clamps.

HARNESS BOARDS — A NEW COST SAVER!

Set up costs just about disappear when you adapt the new, fully reusable modular TY-RAP harness board to your wiring operations. Both sides can be used. Metal screening covers the self-healing polyethylene foam. The interlocking borders of each panel snap together for larger work surfaces.
Cat. No. HBF-02-03

The Thomas & Betts Co., Elizabeth, N. J. 07207 • (201) 345-4321
In Canada, Thomas & Betts Ltd., P. Q.

T&B ENGINEERED **THOMAS & BETTS**
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.[1]

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[2]. 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[3].

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[4] in-

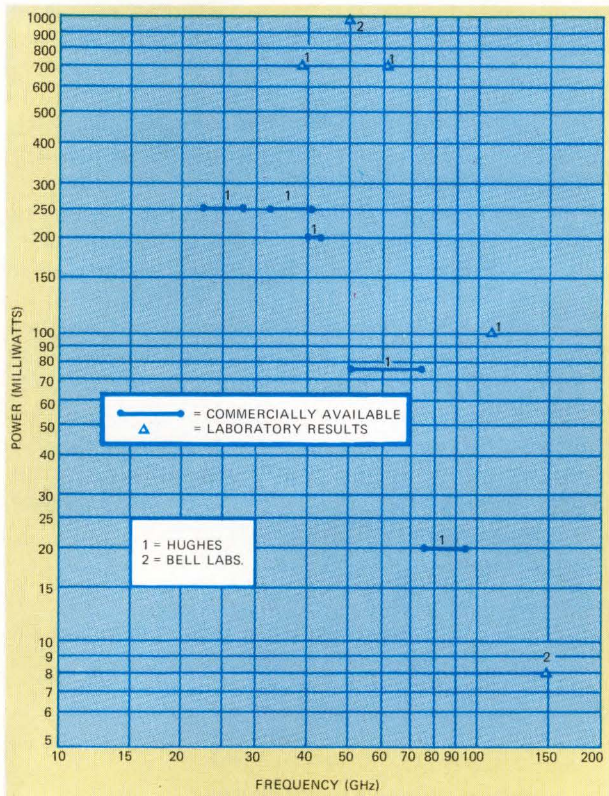


Fig. 1—Comparison of commercially-available and laboratory output powers for cw silicon IMPATT diodes and sources.

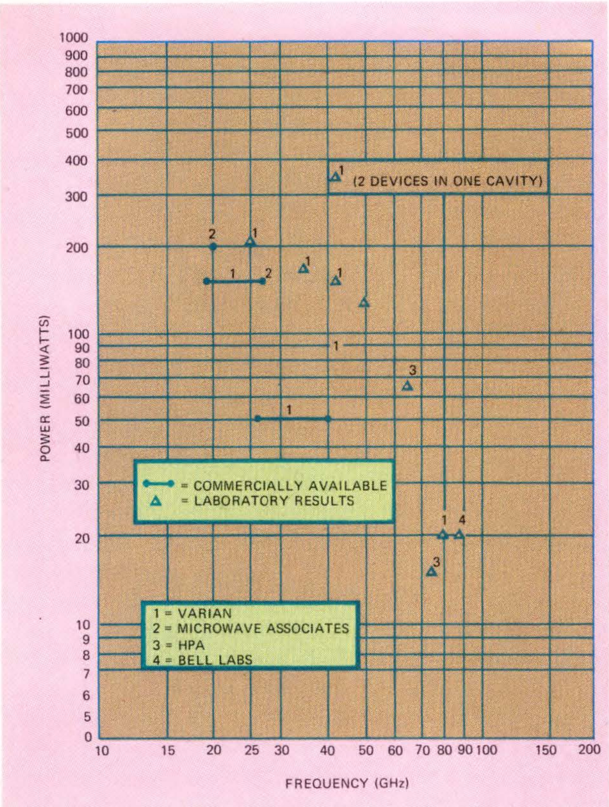


Fig. 2—Comparison of commercially available and experimental cw transferred-electron (Gunn effect) devices.

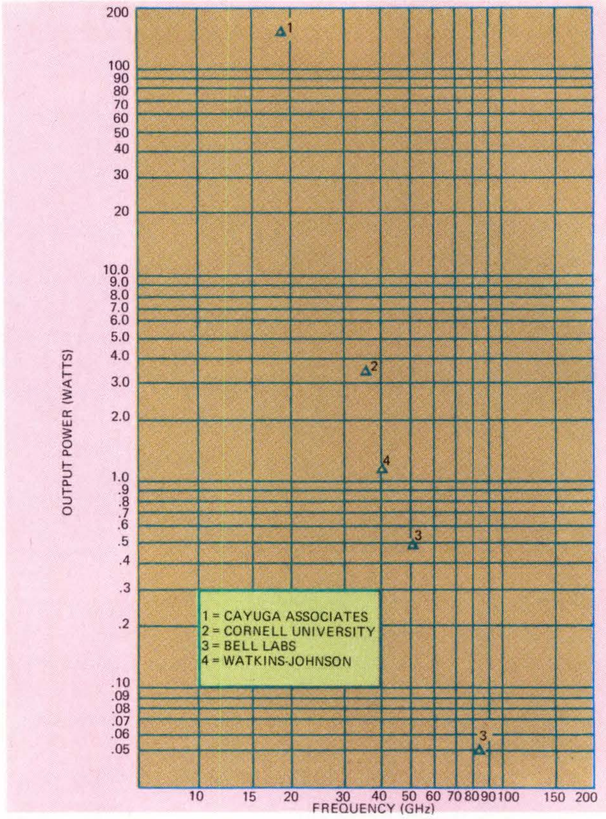


Fig. 3—State of the art pulsed output powers using LSA devices.

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[5]. ▭

References

1. T.E. Seidel, R. E. Davis, and D. E. Iglesias. "Double Drift Region Ion Implanted Millimeter Wave IMPATT Diodes," *Proceedings of the IEEE*, Vol. 59, No. 8, P. 1222.
2. J. B. Gunn. "Instabilities of Current and of Potential Distribution in GaAs and InP," *IBM Journal of Research and Development*, Vol. 8, P. 141.
3. L. A. MacKenzie, private communication
4. D. Colliver, private communication
5. P. N. Robson, to be published in *Electronics Letters*.

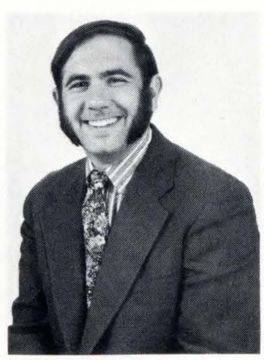
Acknowledgements

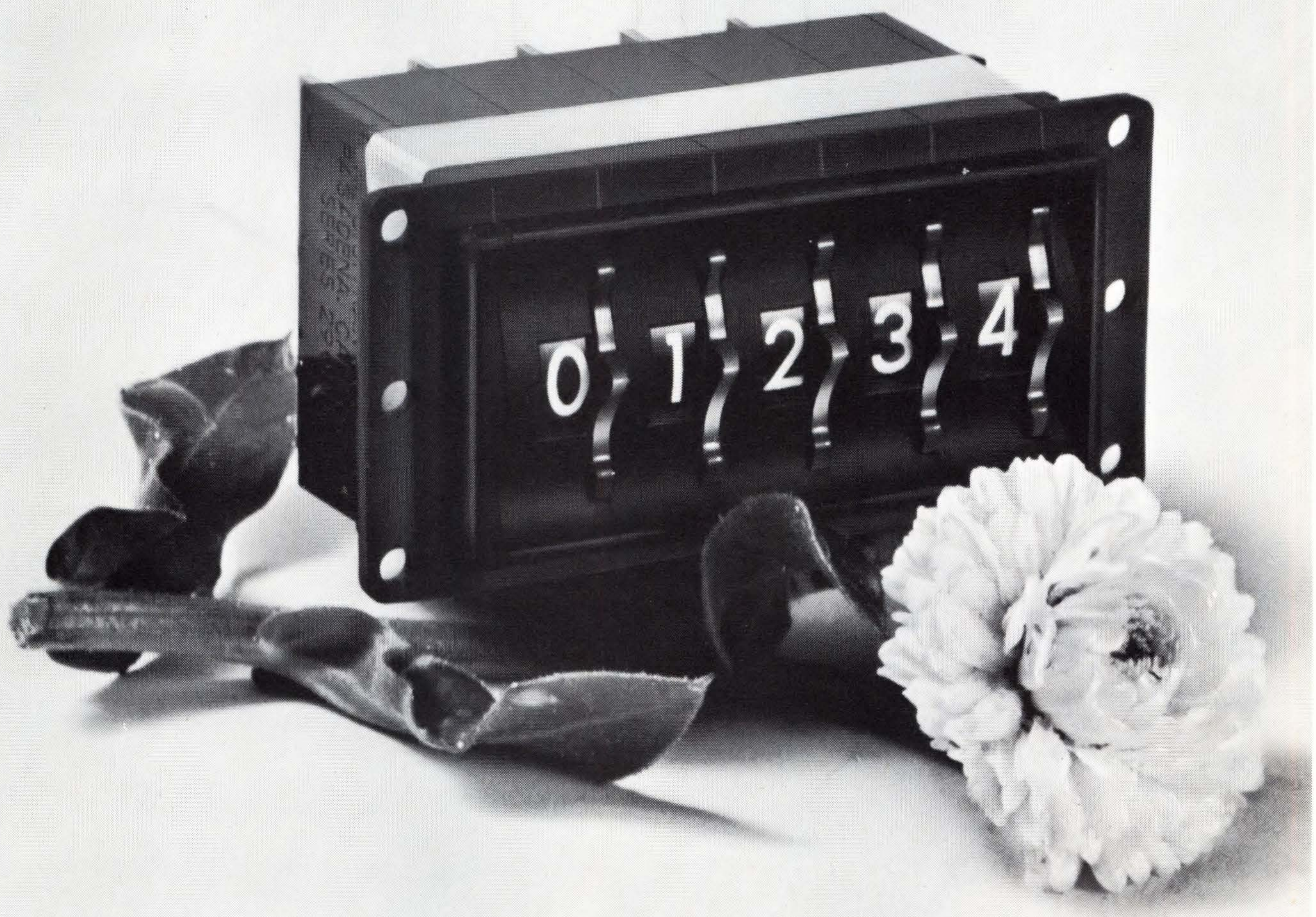
The authors would like to thank the following individuals for their time and contributions to this article: Dr. L. F. Eastman of Cayuga Associates and Cornell University, Dr. L. A. MacKenzie of Microwave Associates, Mr. T. Midford of Hughes Aircraft Corporation, and Mr. J. Caldwell of Varian Associates.

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.





Series 29000. Beauty at a low price.

A new thumbwheel switch. Beautifully made. Beautifully priced.

Each switch module is less than 0.350 inches (9mm) wide and 1.21 inches (31mm) high. And, of course, any number of switch units may be grouped together and quickly assembled by using our stainless steel snap-on strap.

The Series 29000 has the features of more expensive thumbwheel switches. Large (5 mm high) dial characters for an easy-to-read inline display and a new case that protects the contact area from dust and other contaminants. And, you have your choice of two colors; light beige, or black.

Codes available are: BCD. BCO (10 position with stops). BCD plus complement. Single pole decimal. Single pole, double throw, repeating, plus many more.

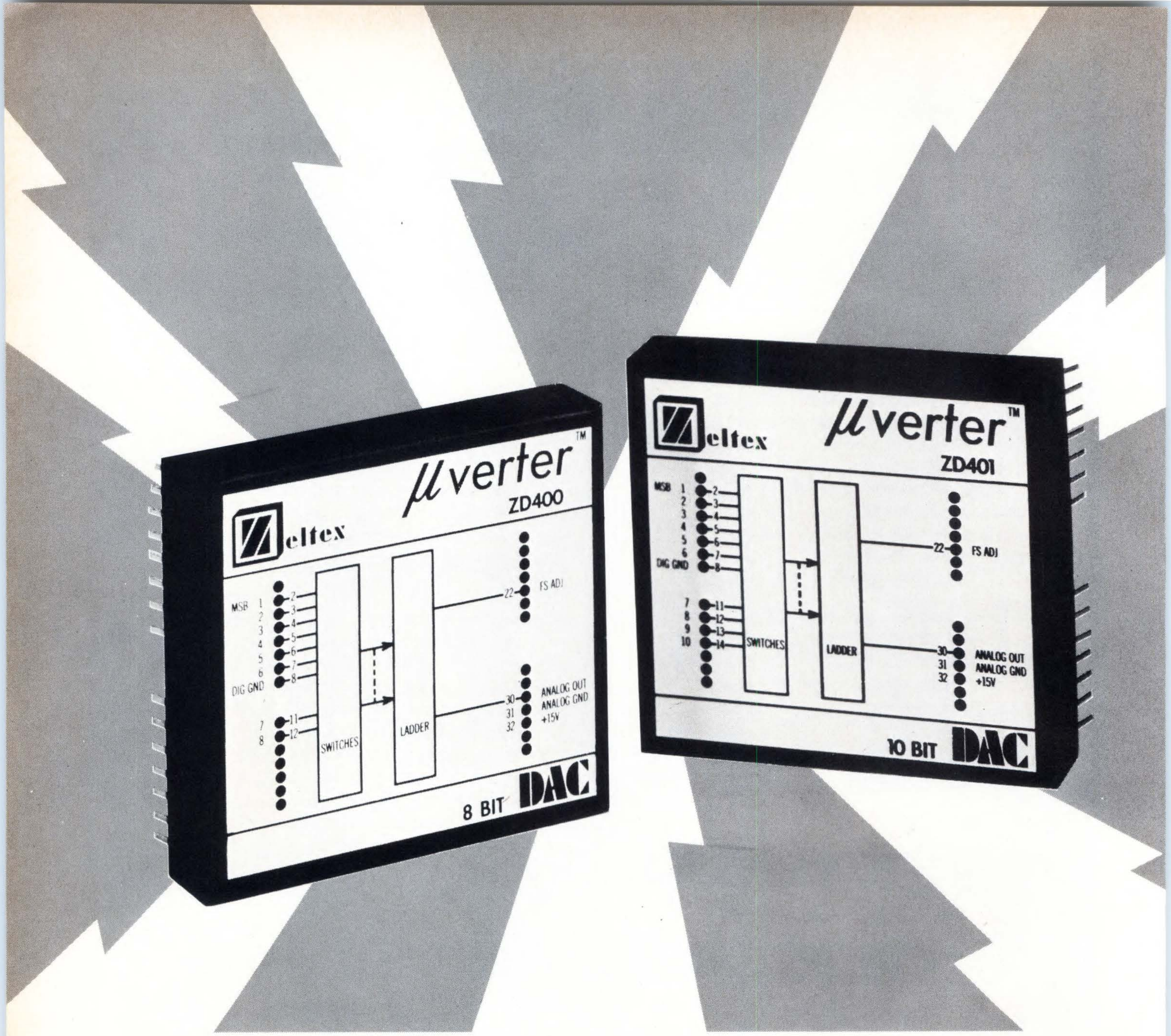
Perhaps you'd like to use a brand new switch. One that is priced low enough to replace those old rotary switches. Go ahead. Add a little beauty to your equipment too. Write for our technical data sheet.

THE DIGITRAN COMPANY

A Division of Becton, Dickinson and Co. B-D

855 South Arroyo Parkway, Pasadena, California 91105
Phone: (213) 449-3110, TWX 910-588-3794

CIRCLE NO. 15



ZELTEX DACability!

Meet the two newest current DAC's to join our μverter™ line: The ZD400 and ZD401... 8- and 10-Bit Models that sell for only \$8.00 and \$12.65 (in OEM quantities).

The ZD400 settles to ½ LSB in less than 1 μsec; the ZD401 is accurate to $\pm 0.05\%$ $\pm ½$ LSB. Output current for both converters is rated at 0 to +2.6 mA with a compliance voltage of +1.2V.

Plus higher reliability: Our thick-film DAC's are subject to 16 hours "stabilization bake" at 85°C reducing infant mortality to virtually zero; active resistor trimming guarantees accuracy; DIP leads provide compatibility with most DIP printed circuit boards, and high quality packaging meets most shock, stress, and environmental conditions.

Use them for CRT ramp generators, special function generators, and for building custom ADC's.

Ask about our other 17 versions of DAC's—from 2-Digit BCD to 12-Bit Binary, from modules to systems—μverters™ mean DACability!

Call or write today for a complete Zeltex Data Pak.

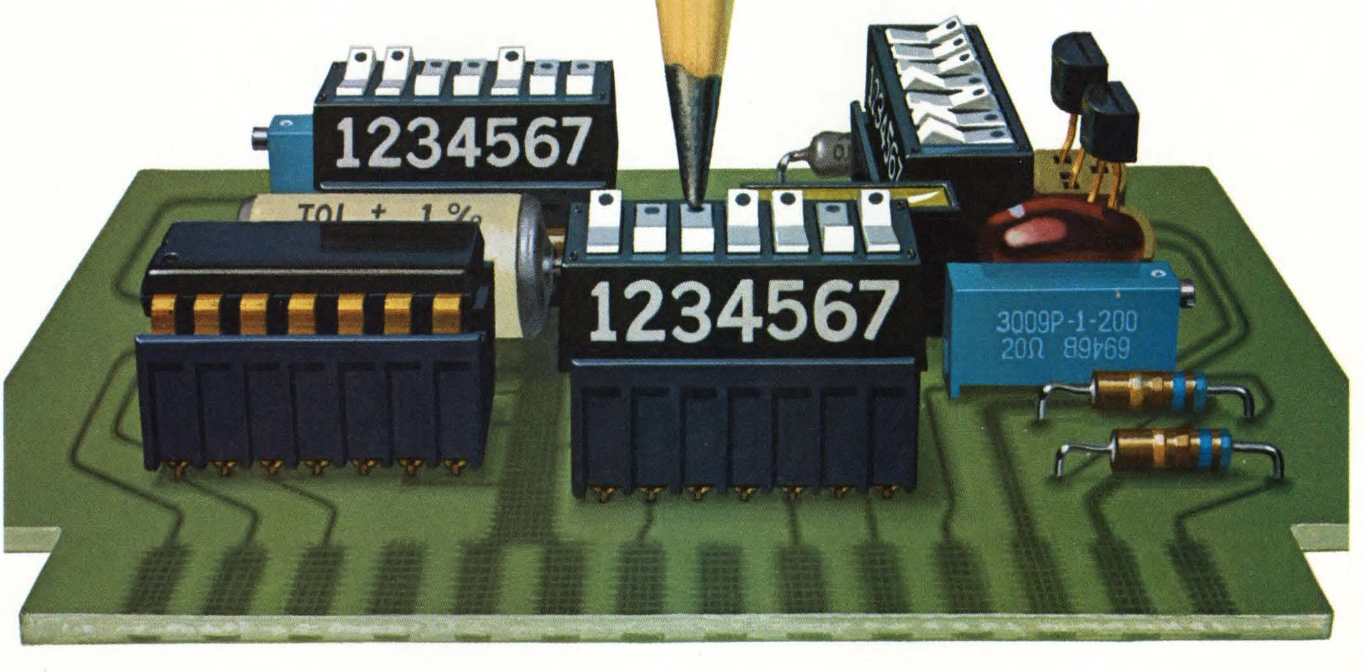
Conversion Products Specialists

(415) 686-6660
TWX (910) 481-9477
1000 Chalomar Road
Concord, Ca. 94520

Zeltex INC.

CIRCLE NO. 18

Economical on-board programming. Quite a switch.



Our DIP switch, in fact. A brand-new device that lets you program your IC's right on their boards. Without the labor costs, nuisance and excessive space required by jumper wires or bracket-mounted toggle switches.

Now all you need for fast, reliable programming is a pencil and a logic diagram. Rocker buttons operate positively but easily with the touch of a pencil. And they're legibly marked to show "on" and "off" positions.

New, low-profile DIP switches take up no more room on the board than a standard DIP. And can be reflowed into plated through-holes or plugged into our DIP headers. Gold-over-nickel plating on phosphor-bronze contacts assures reliable operation in the milliamp "dry-circuit" range.

These DIP switches are available with any number of poles you want, from 4 to 10. Most popular to date are the 7-pole and 8-pole versions which correspond, respectively, to 14-lead and 16-lead standard DIP's.

For more information on really economical on-board programming with DIP switches, write to:
AMP Incorporated, Industrial Division, Harrisburg, Pa. 17105.

AMP
INCORPORATED

Manufacturing and direct sales facilities worldwide: Barcelona, Brussels, Buenos Aires, Frankfurt, London, Mexico City, Paris, Puerto Rico, Sao Paulo, s'Hertogenbosch (Holland), Sydney, Stockholm, Tokyo, Toronto, Turin, Vienna.

CIRCLE NO. 19

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 it if 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

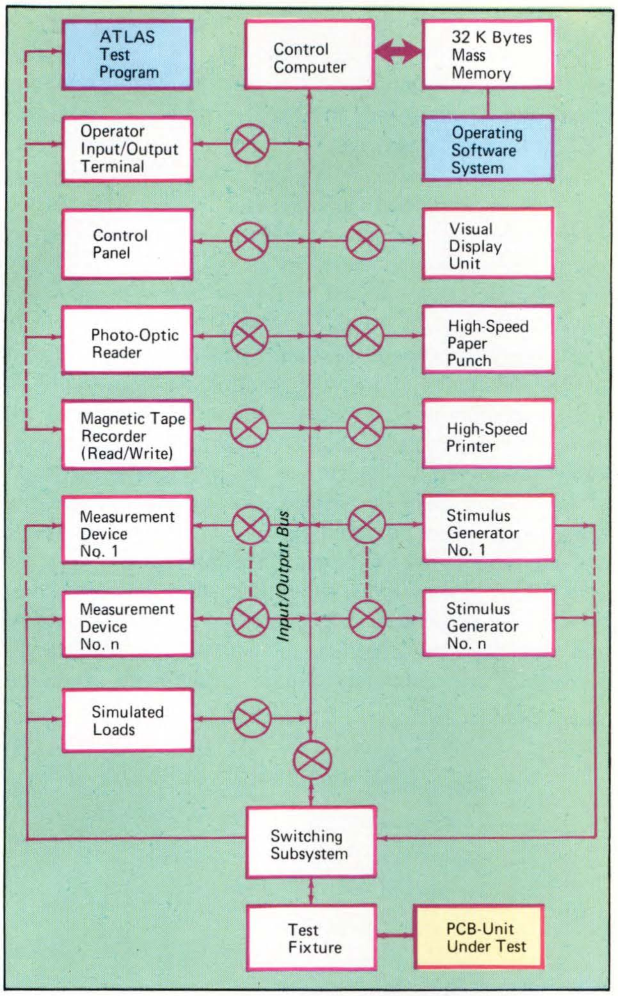


Fig. 1—To keep a test system's operation simple, fast and convenient, predesigned software should be used to control all hardware, and interfacing should allow easy change of peripheral configurations for future test needs. The above block diagram is the configuration used in Instrumentation Engineering's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

Stimulus:

1. Function generators
2. Digital word generators
3. Ac signal generators
4. Timing generators
5. Pulse generators
6. Audio oscillators
7. Digital-to-analog converters
8. Digital-to-synchro/resolver converters
9. Logic-level signal sources
10. Signal attenuators
11. Dc signal sources
12. Ac signal sources
13. Dc current sources
14. Square-wave generators
15. Clock sources
16. Frequency synthesizers
17. Registers of various bit sizes
18. Multi-phase clocks

Measurement:

1. Digital multimeters
2. Electronic counters
3. Analog-to-digital converters
4. Digital word receivers
5. Logic-level comparators
6. Frequency-response analyzers
7. Synchro-to-digital converters
8. Pulse analyzers
9. Time-interval meters
10. Dynamic test measurement devices
11. Back-up timers
12. Pulse detectors
13. Impedance bridges
14. Digital voltmeters/ammeters
15. Phase-angle meters
16. Distortion analyzers
17. Wave-form analyzers
18. Network analyzers
19. Sampling oscilloscopes
20. Logic-level converters
21. Resistance and impedance banks

Control:

1. Control and display panels
2. ASR-33, ASR-35, KSR-33, KSR-35 teletypewriters
3. Dual-channel magnetic cassette recorders
4. High-speed photo-optic readers
5. Magnetic drum memories
6. IBM-compatible magnetic-tape units
7. Line printers
8. High-speed strip printers
9. High-speed paper-tape punches
10. Disc storage systems
11. CRT terminals

Fig. 2—A multide 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 desirous 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 Engieering and Masters degrees in both Electrical Engineering and Management Science.

These amplifiers make your test equipment–and your budget–look good.

Hewlett-Packard's new wideband RF amplifiers improve the sensitivity of your scopes, spectrum analyzers, counters, network analyzers – anywhere you need low-noise, high-gain amplification.

As a result of HP's hybrid thin-film microcircuit technology, these amplifiers bring you superior performance and high reliability at low cost.

The table below gives frequency ranges, prices and performance of the six basic configurations. Dual channel versions of the preamps can also be supplied to improve the performance of 2-channel instrumentation.

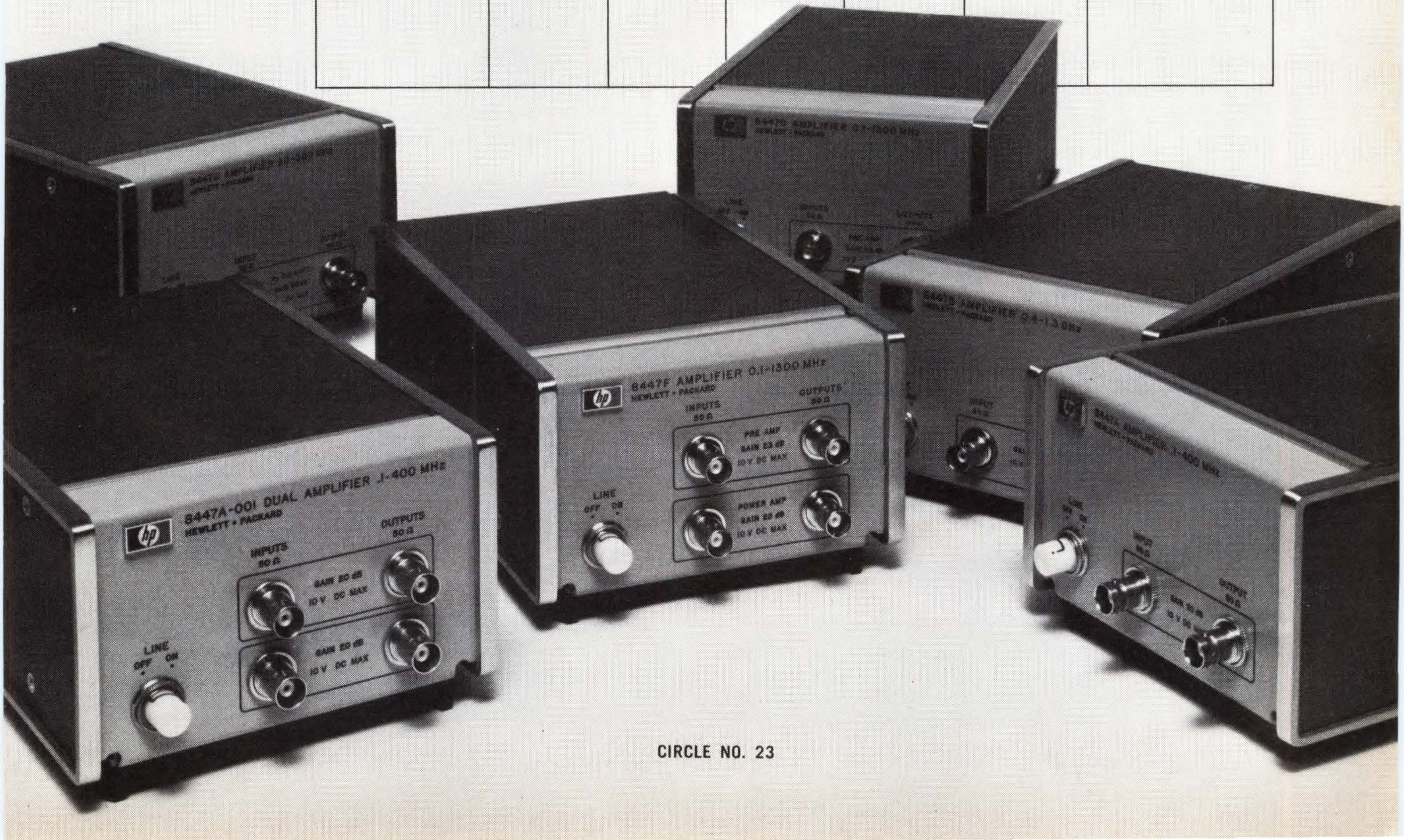
They're ready for delivery now. A call to your HP field engineer will bring you the details of how these amplifiers can help enhance the test equipment you're using now. Or write to Hewlett-Packard, Palo Alto, California 94304; Europe: 1217 Meyrin-Geneva, Switzerland.

HEWLETT hp PACKARD

04021A

HEWLETT-PACKARD 8447 SERIES LAB AMPLIFIERS

	HP 8447A Preamp	HP 8447B Preamp	HP 8447C Pwr. Amp.	HP 8447D Preamp	HP 8447E Pwr. Amp.	HP 8447F Preamp/Pwr. Amp.
Frequency Range	0.1-400 MHz	0.4-1.3 GHz	30-300 MHz	0.1-1300 MHz	0.1-1300 MHz	0.1-1300 MHz
Nominal Gain	20 dB	22 dB	30 dB	26 dB	22 dB	48 dB
Gain Flatness	±0.5 dB	±1 dB	±1 dB	±1.5 dB	±1.5 dB	±3 dB
Noise Figure	<5 dB	<5 dB to 1.0 GHz <6 dB, 1.0-1.3 GHz	<11 dB	<8 dB	<11 dB	<8 dB
Output Power @ 1 dB Gain Compression	>+7 dBm	>−3 dBm	>+17 dBm	>+7 dBm	>+14 dBm	>+14 dBm
Price	$550	$600	$450	$650	$700	$1175



CIRCLE NO. 23

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 kΩ to 1MΩ 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 kΩ or less. Special large-area driver outputs can have ON resistances as low as 100Ω 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

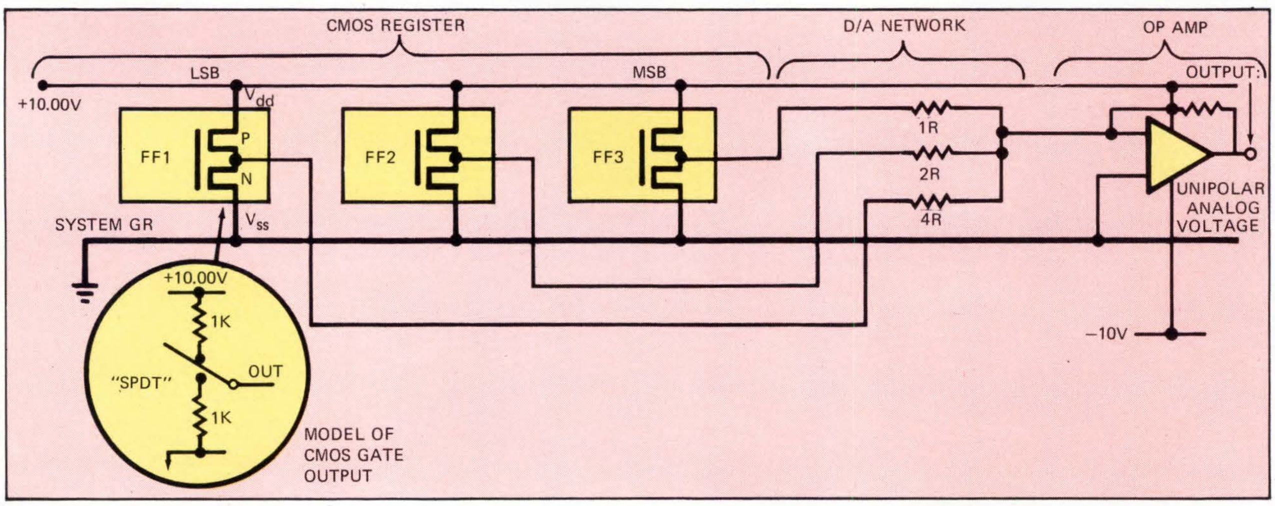


Fig. 1—Outputs from CMOS flip-flops provide the precision analog voltages for the weighed resistors of this D/A converter. The op amp sums the currents from the weighted resistors and provides the analog output. As the model shows, a CMOS inverter gate is like a SPDT switch operating between the positive and negative voltage supplies. The ON resistances of the P and N devices are less than 1kΩ, so the resistances going into the op amp must be 100 kΩ or greater if the CMOS outputs are not to be loaded.

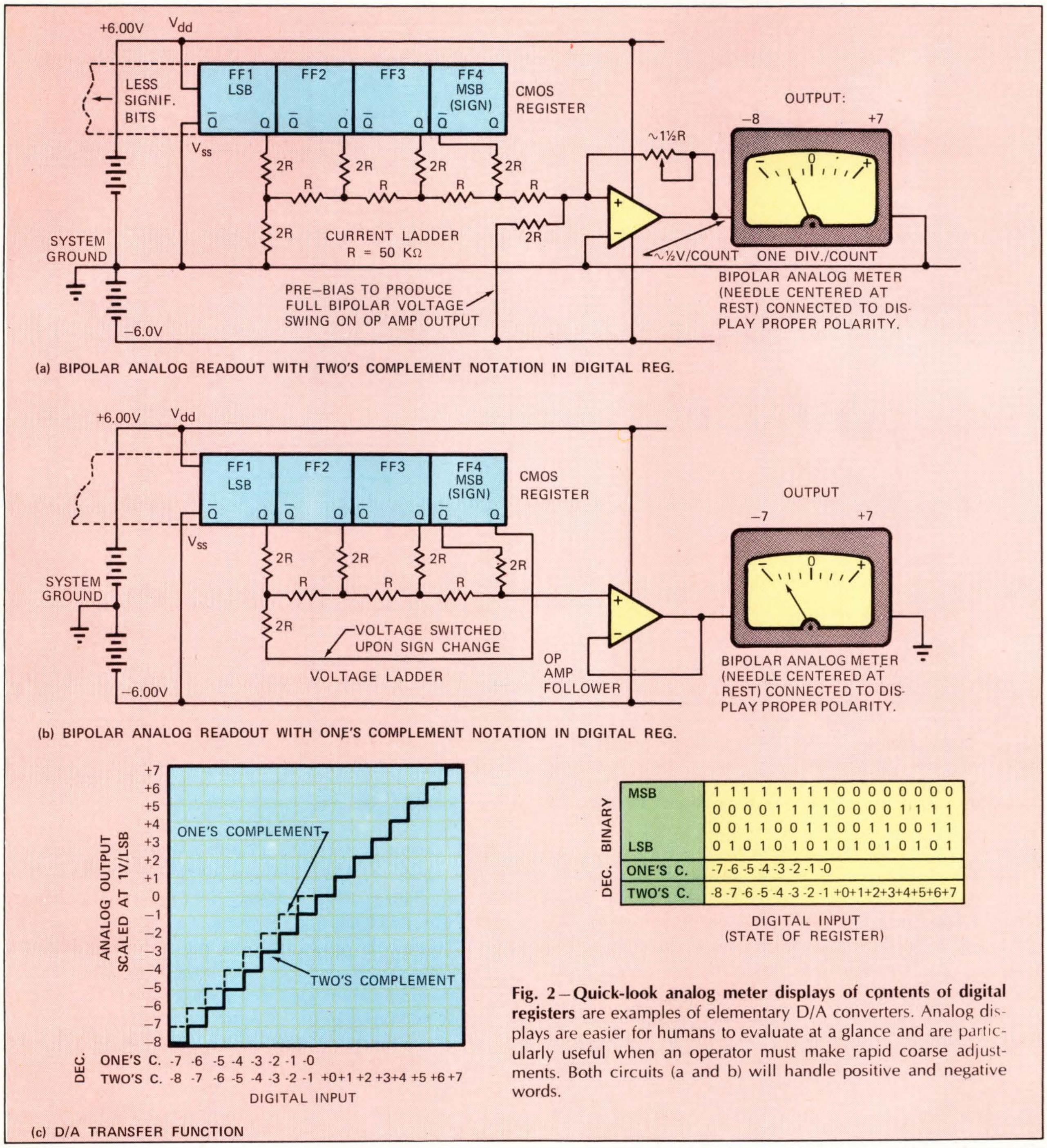


Fig. 2—Quick-look analog meter displays of contents of digital registers are examples of elementary D/A converters. Analog displays are easier for humans to evaluate at a glance and are particularly useful when an operator must make rapid coarse adjustments. Both circuits (a and b) will handle positive 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.[3]

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

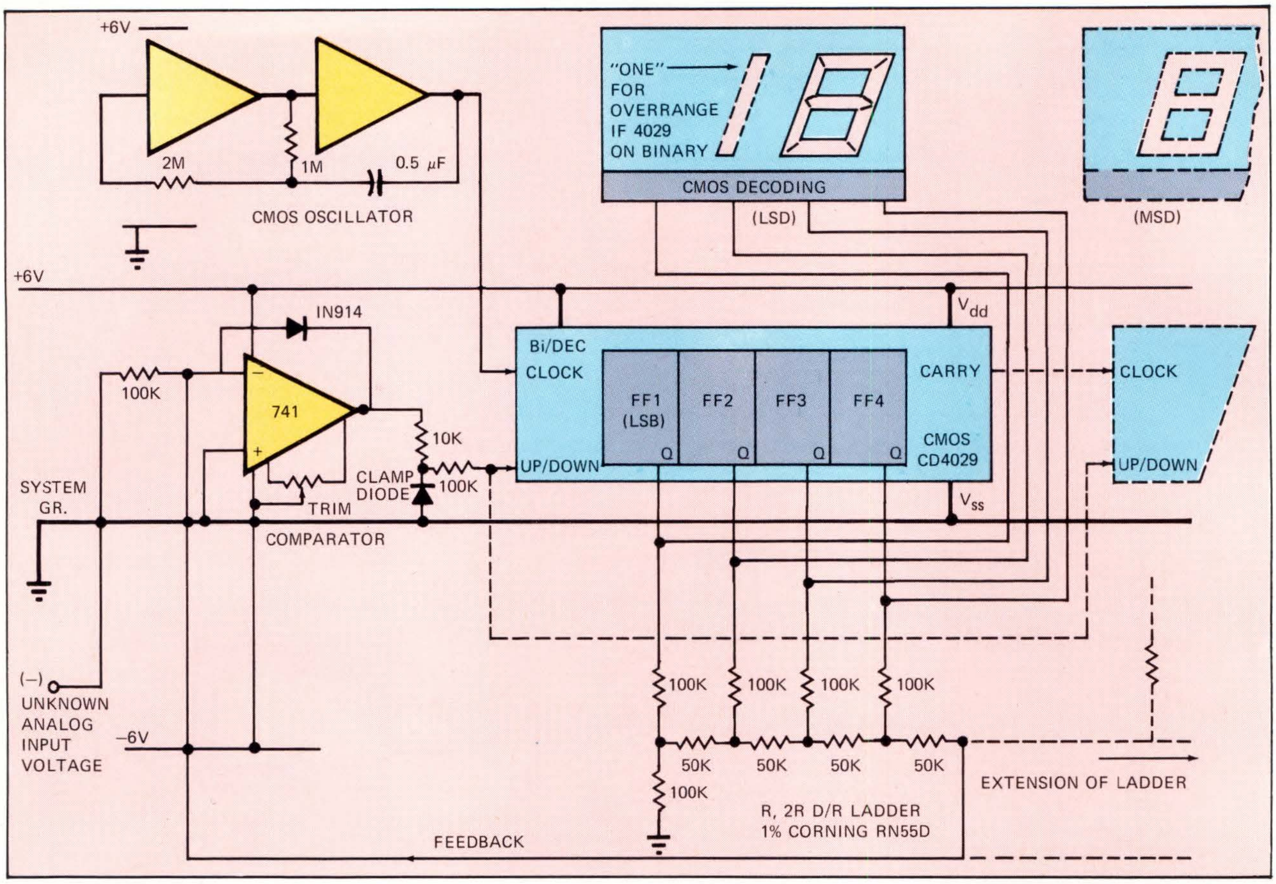


Fig. 3—This elementary CMOS A/D converter operates as an oscillating servo. The 4029 up/down counter counts up one beyond the unknown input value, and the 741 comparator reverses the 4029 to count down. Then the 4029 counts one below the unknown value and the 741 reverses the 4029 to count up again. 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 midscale 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 ±4V for the ±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 kΩ 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 currents 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.[5]

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.[6,7]

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 micropower 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

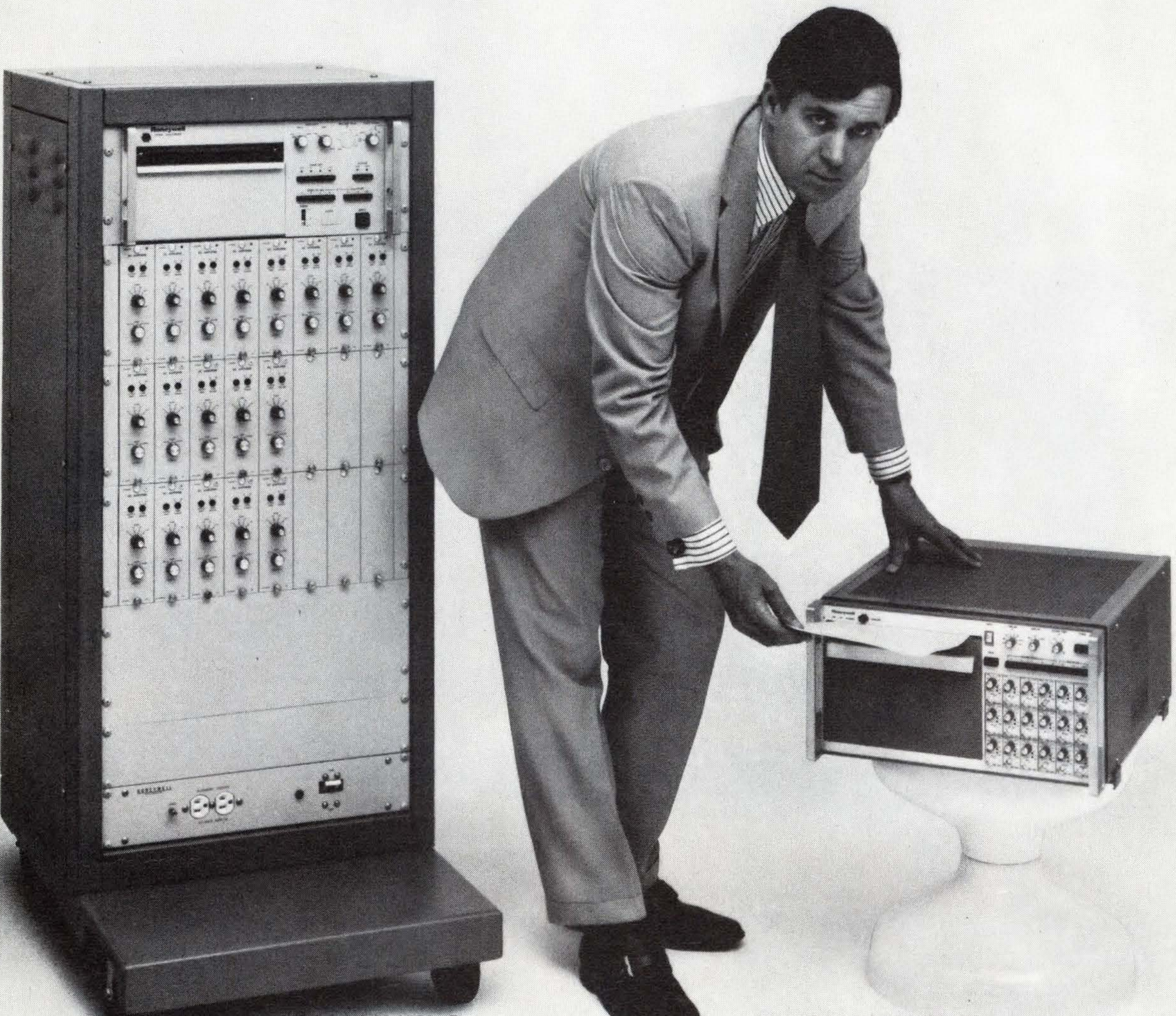
Private conversations with Russ Knapp, Dick Funk, Merle Hoover and Andy Bosso of RCA, Somerville, N. J., were of great value in developing the circuits described.

References

1. **"Operational Amplifiers, Design and Applications,"** J. Graeme, G. Tobey, L. Hueselman, McGraw-Hill Book Co., 1971. On pages 341-346 and on page 358 basics of D/A and A/D circuits are described.
2. **"CMOS Report,"** EDN, June 15, 1972.
3. **"Ladder Networks,"** EDN, Feb. 1 and Mar. 1, 1969.
4. **RCA Application Note ICAN-6166.** See Fig. 7 for A/D application.
5. **RCA Application Note ICAN-6733.** Covers CMOS driving various readouts.
6. **"Lower-Voltage Readout Tubes Can be Driven by MOS,"** EDN, Jan. 15, 1969, page 33.
7. **RCA COS/MOS Seminar Notes,** Mar. 1972, New York, N.Y. Includes circuit using EXCLUSIVE-OR gates to produce ac waveform across liquid-crystal displays.

NEW FROM HONEYWELL

A complete graphic data acquisition system, with its own built-in signal conditioning, in a package just 8¾" high!



18 CHANNELS
THEN

18 CHANNELS
NOW

Our new one-piece data acquisition system offers benefits that other graphic systems can't, such as:

Completely self-contained. Signal conditioning circuitry is built right into the 1858! All you do is select and plug your choice of modules into the front panel.

Most readable and accurate record available. Our 1858 allows any trace to be positioned at any point on the record with full record width deflection, plus digital trace identification. In addition, it offers high-frequency response and a super-fast rise time—without trace overshoot—and without high-frequency trace wipe-out . . . for the easiest-reading record, the best resolution ever.

As easy to use as an oscilloscope. With the all-electronic, fiber-optic CRT 1858, there are no galvanometers or pens to fuss with. No mathematics or matching networks to fool with. There's simple front panel set-up for calibration, trace position and sensitivity. Just plug in your signal inputs and you're ready to record.

18-channel recording capability. This new system records up to 18 channels, each with DC to 5,000 Hz response. You also get a choice of 42 discrete paper speeds up to 120" per second!

True portability. Just because our 1858 gives you an 80% reduction in rack space and weight isn't the only reason it's called portable. It's also because *everything* you need is self-contained within that package, including signal conditioning and paper take-up! You can stick it in a rack, set it on a table, or carry it away.

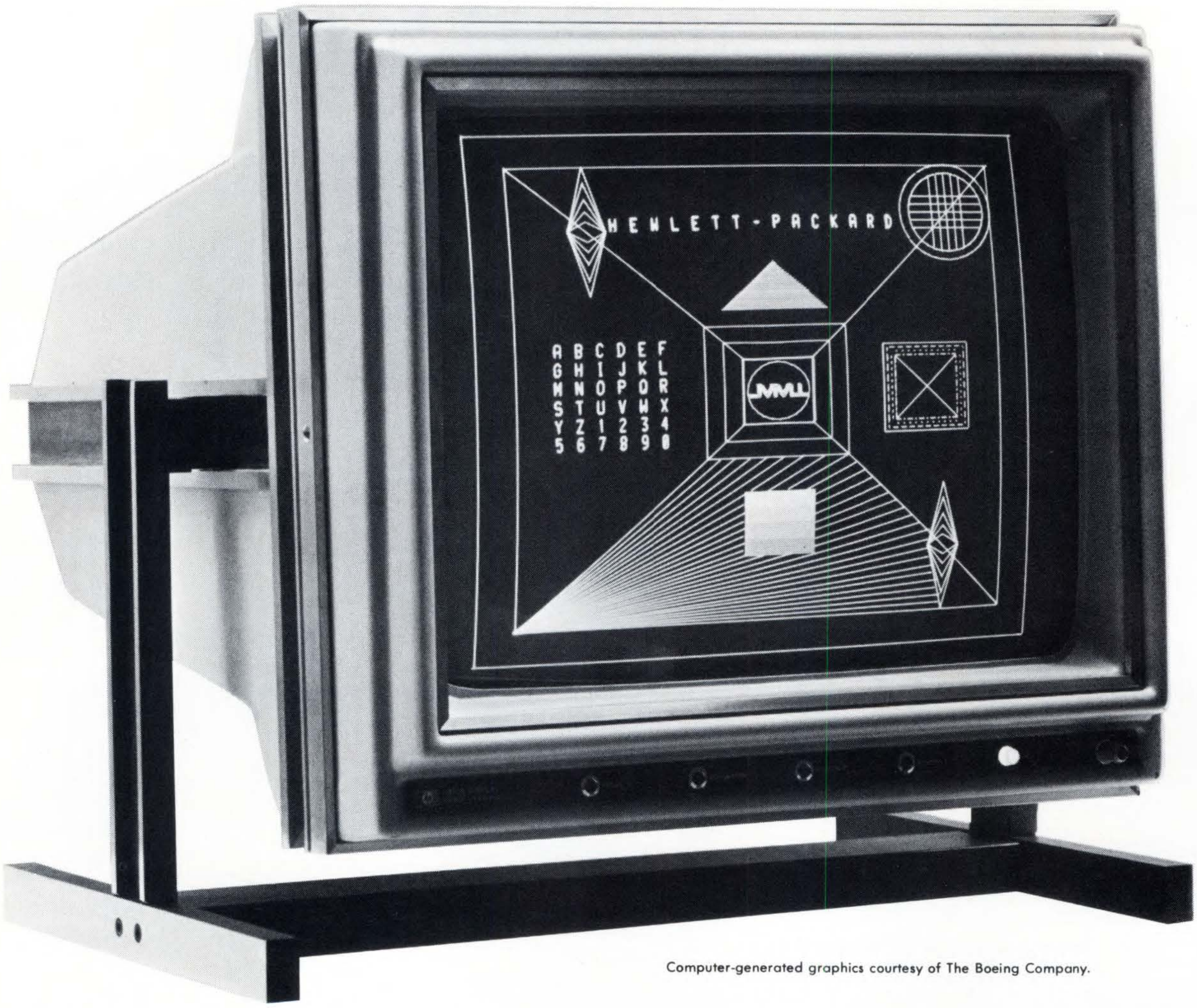
A variety of signal conditioning modules. Your choice includes a high-gain differential amplifier, a low-gain differential amplifier, a medium-gain differential amplifier, an impedance interface module, a strain gage control unit and a thermocouple control unit.

And this is only part of the story. For more information, call 303-771-4700. Write Lloyd Moyer, MS 218, Honeywell, Test Instruments Division, P. O. Box 5227, Denver, Colorado 80217.

Honeywell
The Automation Company

CIRCLE NO. 21

This display writes as fast as your computer can talk.



Computer-generated graphics courtesy of The Boeing Company.

HP's new 1310A 19-inch-diagonal X-Y display is the answer to many an OEM's prayer . . . because it's the **first display ever that can keep up with the graphic information output of today's high-speed computers.**

The 1310A has a **writing speed of 10 inches per microsecond** – 10 times faster than any other display's. Its slew rate is 100 inches per microsecond. And its large-step jump and settle time is 1 microsecond. Thus, the 1310A gives you the ability to display information as fast as your computer puts it out – in any desired sequence of locations, without "smearing." No longer must you program outputs in a manner imposed by display limitations.

The key to the 1310A's outstanding performance is its **unique, advanced cathode ray tube** which uses electrostatic deflection to control its electron beam.

Also as a result of using electrostatic deflection, the 1310A is smaller, lighter, and **requires less power** than any competitive graphic display – only 100 watts. Because it uses the latest, highly rectangular CRT face glass, its display area is equal to that of many 21-inch units. And its **0.020-inch spot size** gives you a crisp, clear image over that entire area.

And performance is only the beginning! With the 1310A, you also get plug-in-board construction for fast, easy servicing. Replacement boards are available from any of HP's service centers around the world, on an exchange basis, within 48 hours. And it takes only minutes to remove or insert any board.

Yet, despite all these advantages, the **1310A costs only $3000**—far less than competitive displays (covers and stand, $100 extra). Or, for $2875, you can get all the features of the 1310A, in the new 14-inch-diagonal 1311A. **OEM price schedules are available on both the 1310A and 1311A.**

For further information on both of these new displays, contact your local HP field engineer. Or write Hewlett-Packard, Palo Alto, California, 94304. In Europe: 1217 Meyrin-Geneva, Switzerland.

081/14A

HEWLETT *hp* *PACKARD*

OSCILLOSCOPE SYSTEMS

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 $1/C\int idt$ 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.

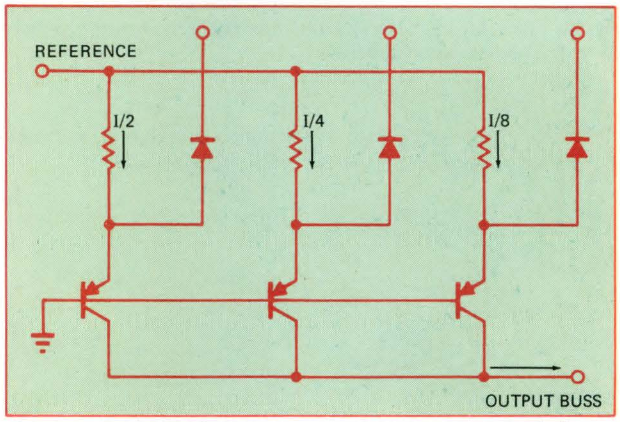


Fig. 1 — Conventional current-mode D/A converters switch unequal currents, which limit speed and accuracy.

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.

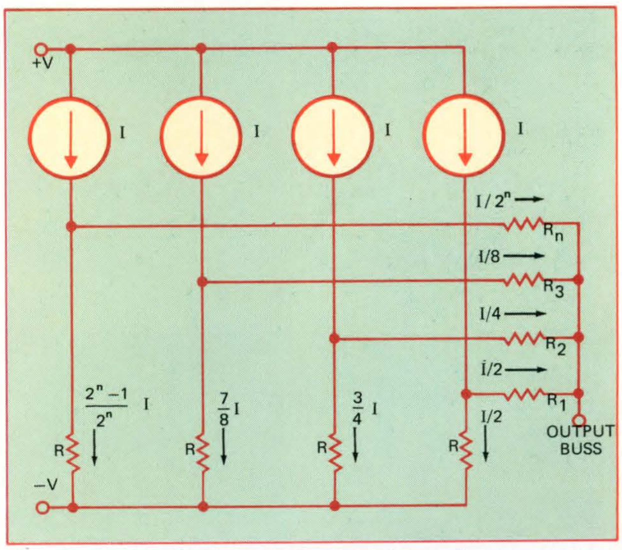


Fig. 2 — Common-base transistors switch equal currents when binary weighting takes place after switching.

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:

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

Substituting the Thevenin equivalents into the bussed model we have:

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

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

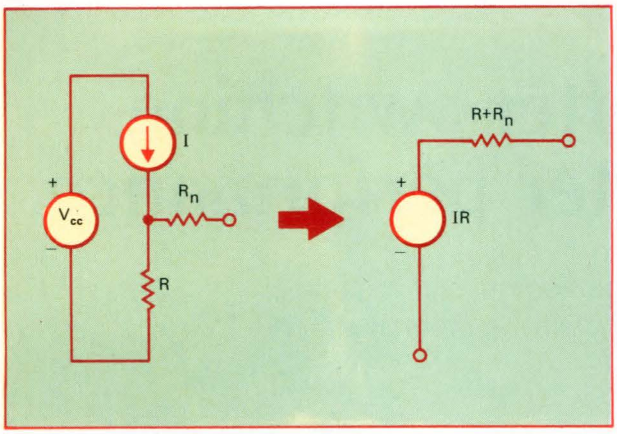


Fig. 3a—One bit of the converter from **Fig. 2** is shown together with its Thevenin equivalent.

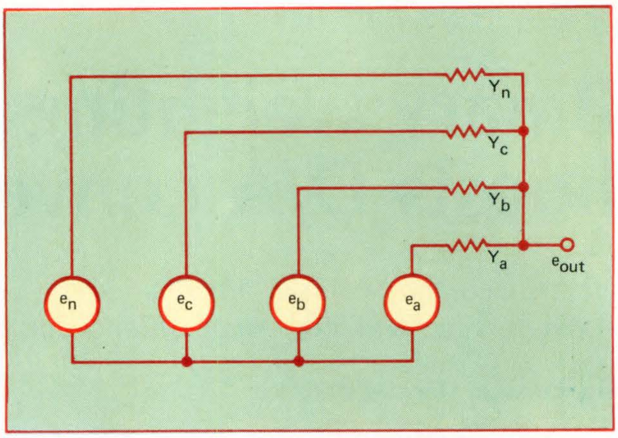


Fig. 3b—The entire converter is modeled as the Thevenin equivalents in order to derive design equations.

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

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

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

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

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

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

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

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

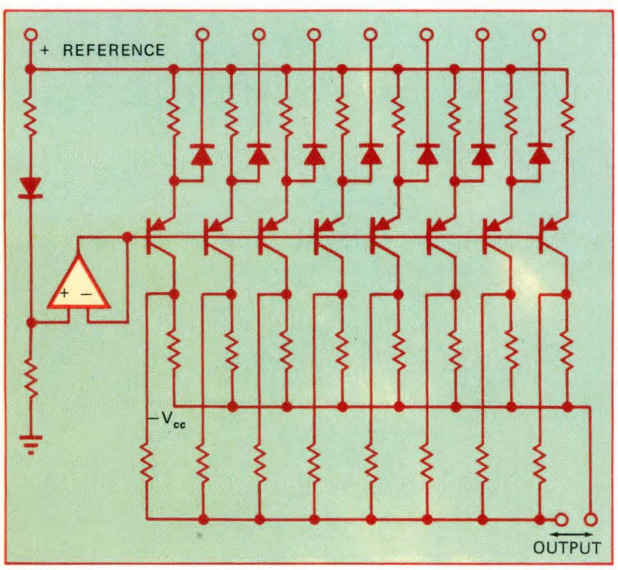


Fig. 4—An 8-bit current-mode D/A converter with temperature compensation of V_{BE}.

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 500Ω (**Fig. 4**) the equations are used as follows:

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

$$\therefore = \left(\frac{2^8 - 1}{2^8}\right) 500 = \left(\frac{255}{256}\right) 500 \approx 478.5\Omega$$

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

$$\begin{aligned}
\therefore R_1 &= 1(R) \approx 478.5\Omega \\
R_2 &= 3(R) \approx 3(478.5)\Omega \\
R_3 &= 7(R) \approx 7(478.5)\Omega \\
R_4 &= 15(R) \approx 15(478.5)\Omega \\
R_5 &= 31(R) \approx 31(478.5)\Omega \\
R_6 &= 63(R) \approx 63(478.5)\Omega \\
R_7 &= 127(R) \approx 127(478.5)\Omega \\
R_8 &= 255(R) \approx 255(478.5)\Omega
\end{aligned}$$

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

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

Author's biography

Eric Burwen in 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.

SILICON FUSE CUTS COST OF NEW PROM

Lowest priced 1024-bit PROM ships immediately and programs easily.

Intel has developed a 1024-bit bipolar PROM that's programmed by breaking fusible links of silicon —a new, superior programming technique.

In 100-piece quantities, the Intel 3601 PROM costs only $39, which is less than any other 1024-bit PROM on the market.

It's economical to produce because it combines two well-known, high-volume production techniques: the Schottky process and polycrystalline silicon deposition as used in our silicon-gate MOS devices. That's why we've been able to produce it reliably, have already stocked our distributors for immediate delivery, and can meet your production requirements with ease.

You'll find that the silicon-fuse PROM is much easier to program than the blown-junction type. Pulse width and pulse rise time are not critical. Typical programming time by automatic means is only one second. The silicon fuse separates cleanly and cannot cure or re-link. We'll sell you an automatic programmer, Model 7600C, or tell you how to build one yourself.

The 3601 PROM has a maximum access time of 70 ns from 0° to +75°C ambient over power supply variations of ±5%. It's pin-compatible with Intel's mask-programmed Type 3301A, so you can switch easily whenever you have high-volume requirements.

For immediate delivery of our 3601 phone your local Intel distributor: Cramer Electronics, Hamilton Electro Sales, Industrial Components or Sheridan Associates. In Europe Intel is at Avenue Louise 216, B 1050 Bruxelles. Phone 492003. Intel Japan, Inc. is at Hanei 2nd Bldg., No. 1-1, Shinjuku, Shinjuku-ku, Tokyo 160. Phone 03-354-8251.

Intel Corporation now produces memory devices, memory systems and micro computers at 3065 Bowers Avenue, Santa Clara, Calif. 95051. Phone (408) 246-7501.

intel® delivers.

CIRCLE NO. 25

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 overlayed 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 computer 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 degreee 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.

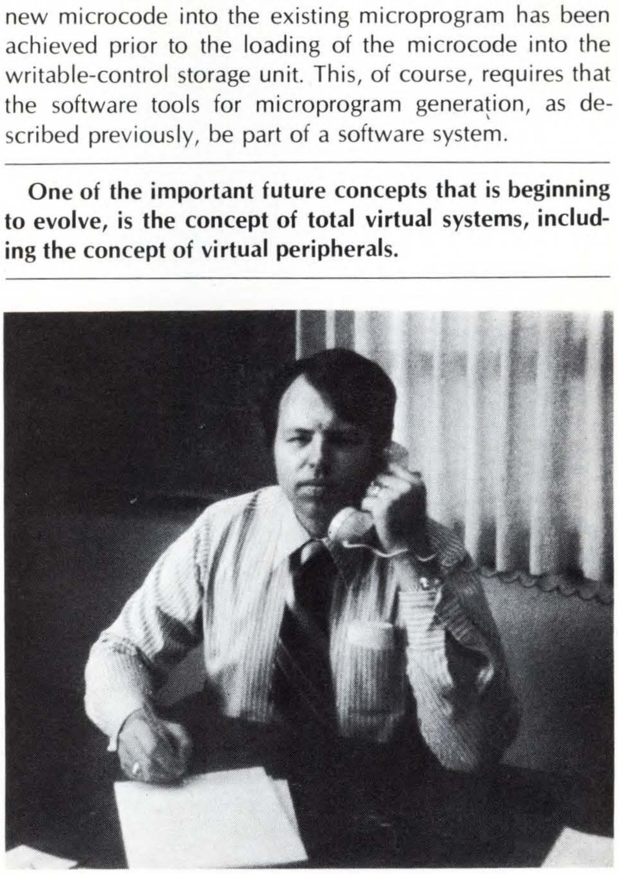
Writable-control storage is not always as glamorous as it first appears. In actuality, it provides the capability for an inexperienced microprogrammer to "bomb" a system.

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.

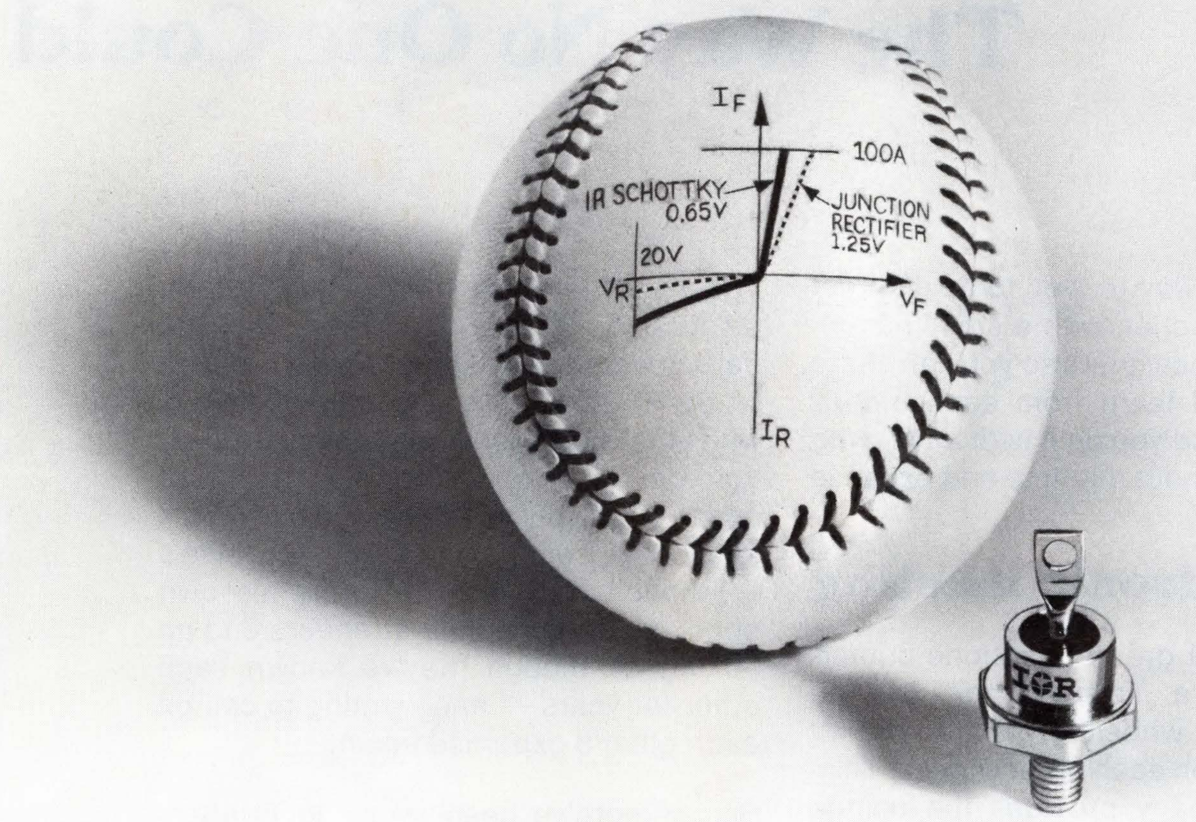
Complete transparency to software is possible with a total virtual system in microprogrammed systems. Should the supervisor processor, namely the CPU, become deficient due to a failure in one more of its parts, its microcode can be transferred to one of the workers, and that worker can provide the supervisory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



The IR/Schottky Power Curve. A new twist that cuts power loss 50%.

Schottky had a good idea. His hot-carrier principle brought unique advantages to users of signal level diodes. So we teamed up to bring the same advantages to the high power league: designers of I/C power supplies and switching regulators in the 50 Amp/20 Volt range. Now it's a whole new ball game.

Check our curve. The dotted line shows the voltage-current characteristics of junction rectifiers. The solid line is the basis for our new pitch. There's quite a difference.

Half The Forward Voltage Drop. Note the forward voltage drop of 0.65 Volt vs. 1.25 Volts for typical rectifiers. At low voltage-low frequency, it means 50% less power loss, for a marked increase in efficiency. Like 10% at 5 Volts/100 Amps. Now you can use fewer rectifiers, smaller transformers, and cut heat-sinks in half. If you design high-frequency circuits, you'll do even better.

More Efficient at High Frequencies. The higher the operating frequency, the greater advantage the Schottky has over junction rectifiers. For example, at 20 KHz, the IR/Schottky gives you 25% more system efficiency. And you can operate at even higher frequencies.

No Reverse Recovery Losses. Unlike junction rectifiers, the IR/Schottky barrier doesn't store minority carrier charges. There are none to be swept out as it is switched to the reverse mode. So time-lag and electrical loss are virtually zero, which accounts for its increased efficiency in high and ultra-high frequency systems.

Reliability/Stability. You can forget about conservative derating. IR proprietary passivation and metallization technology assure long-term stability, extremely low leakage and low sensitivity to temperature. You can count on reliability and optimum life at full ratings.

Try our new curve. Call your IR sales office or distributor today and ask for details on IR/Schottky Power Rectifiers — in either forward or reverse polarities. You'll get everything you need for a whole new ball game.

New from IR...

the innovative power people

IOR INTERNATIONAL RECTIFIER

SEMICONDUCTOR DIVISION • 233 KANSAS STREET, EL SEGUNDO, CALIFORNIA 90245 • (213) 678-6281

CIRCLE NO. 51

Do You Have Enough
The Way No One Could

We've found a way for you to be in direct personal interaction with a small nationwide group of designers so you can share know-how and learn from each other's experience. And you do it *without leaving your desk.* Without the time and expense of travel either.

The electronic meeting

You dial into a group telephone conference, called a TeleSession.* It's an hour-long free wheeling discussion that lets you build on each other's ideas. TeleSession Company provides the unique telephone conference system that repeals geography, and our editors pick the agenda topics for each small group.

A surprising experience

You'll find this specially engineered conference system and the group dynamics different from any "conference call" you may have experienced. At the session time you dial into the discussion from wherever you are that day. Our moderator greets you, introduces everyone, and gets things started. Then he makes sure all the agenda points are covered.

Everyone on the line can ask questions, explore ideas or just listen. You'll find it more informal than a face-to-face discussion — you simply chime in whenever you have a comment — yet there are surprisingly few interruptions.

*TeleSession is a service mark of TeleSession Company, 475 Fifth Avenue, New York, N.Y. 10017

The result is a stimulating and orderly discussion. We've discovered that the participants are willing to reveal the best of their knowledge and ask questions when they don't know something. So what you get is a chain reaction of ideas and high-payoff solutions. One person's knowledge complements everyone else's — though each person forms his own conclusions. Complete strangers end up talking as though they've known each other for years — and wanting to call on each other's expertise again.

So far there've been over 700 TeleSessions. It works.

Your Group

When you circle one of the reader service numbers shown here we want to make sure you're invited to a TeleSession with those most involved and knowledgeable in the problems you're grappling with right now. So for each topic we schedule *many* small groups, taking into consideration such criteria as industry, job function and company size. You'll be on the line with people who speak your language — enough like you to share your problems and different enough to offer a storehouse of surprising insights and new ideas.

Our editors or other industry experts also dial into your TeleSession whenever appropriate.

Imagination to Spend An Hour
Ever Spend An Hour Before?

The Cost

It will be one of the least expensive conferences you were ever in: We bill your company thirty dollars for each TeleSession. In addition your company's telephone bill will contain the station-to-station phone charge that "got you there" (typical charges: West Coast $27, Midwest $19, New England $13). You may cancel up to five days before the session or have someone else take your "seat."

How to reserve your TeleSession "seat"

Check the reader service card number and you will get by return mail:

- ☐ The date and time of your TeleSession
- ☐ Your group's specific Agenda
- ☐ List of Other Participants
- ☐ Details on How to dial into the discussion
- ☐ Tips on how to get the most out of it

TOPICS AVAILABLE

	Reader Service #
• High Speed Logic Families	200
• A/D & D/A Converters	201
• Semiconductor Memories	202
• Plated Wire Memories	203
• Keyboards	204
• Terminals & Displays	205

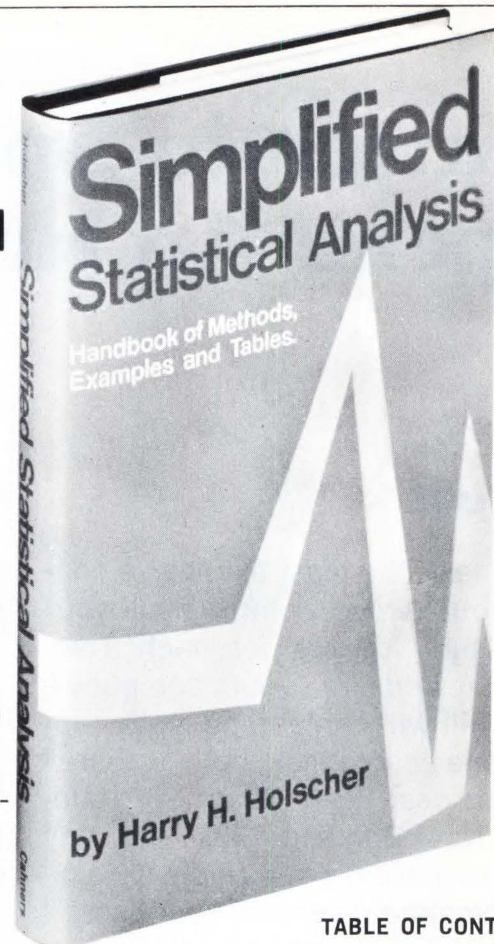
EDN/TeleSession®

THE DISCUSSIONS YOU DIAL INTO

Now...

Solve that tough statistical problem fast... without a computer!

Get yourself a copy of this book.



Just one word precisely describes this book... NECESSARY. Here are quick, accurate short-cuts for solving statistical problems without a computer, and without complicated mathematical computations. Precise and complete, a real "desk-top" tool for the practical engineer, research experimenter, marketing manager, financial executive or laboratory scientist.

235 pages.

TABLE OF CONTENTS

15-day Free examination... Satisfaction guaranteed...

Cahners Books Dept. EDN
89 Franklin St., Boston, Mass. 02110

Please send me _____ copy(ies) of SIMPLIFIED STATISTICAL ANALYSIS @ $13.50. If I am not satisfied, I may return the book(s) within fifteen days and owe nothing.

Send check and we pay all postage and handling

Name_____

Company_____

Address_____

City/State/Zip_____

☐ Payment Enclosed ☐ Bill Me ☐ Bill Company

Please add any applicable sales tax.


give...so more will live
HEART FUND

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 Ω) 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 kΩ 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 kΩ 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 frequency. Using the circuit in **Fig. 1**, the author has achieved a clean square-wave at 1 MHz with the 15 kΩ 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 kΩ resistor between pins 8 and 13, to 19 MHz with 2.4 kΩ resistor, and to 15 MHz with a 3.9 kΩ 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. □

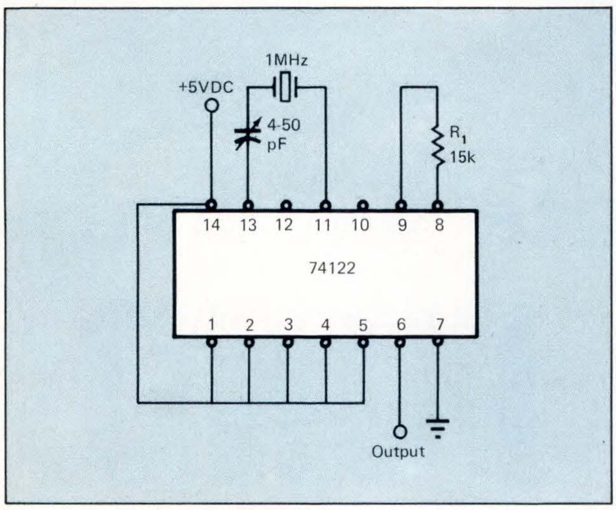


Fig. 1—Low speed oscillator circuit can be tuned from 5 to 8 MHz by varying R_1 from 15 kΩ to 0Ω. Frequencies as low as 200 kHz are achieved by variation of the external capacitor.

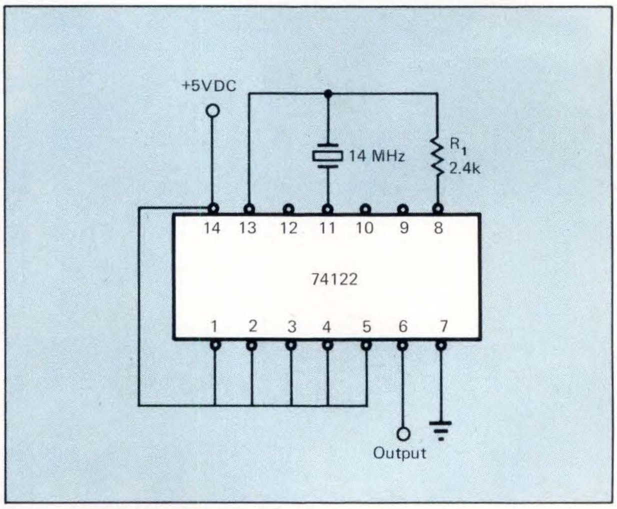


Fig. 2—High speed circuit can provide outputs up to 25 MHz by bypassing the internal timing resistor. Without the crystal, and with pins 8 and 13 wired together, this circuit free-runs at approximately 30 MHz.

To Vote For This Circuit Circle 150.

Digital pulse repeater makes programmable multivibrator

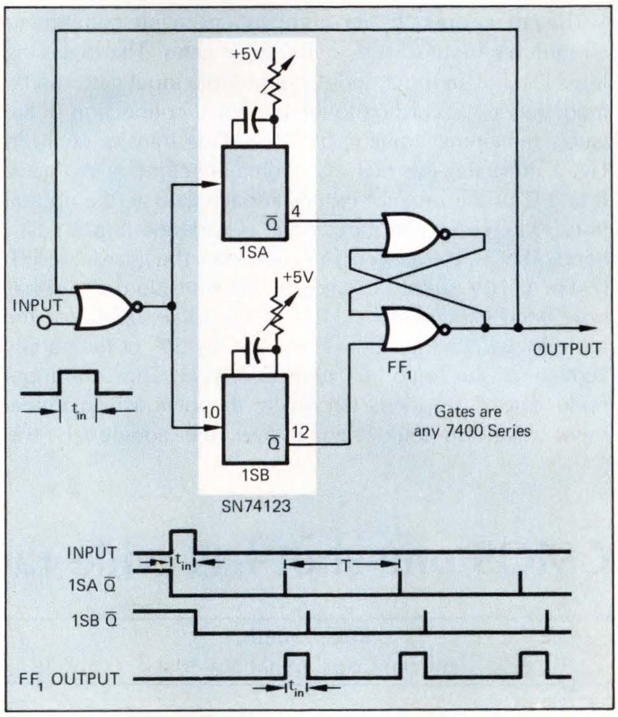
L.D. Young, Jr.
Western Electric Co., Greensboro, North Carolina

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 pluses 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 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

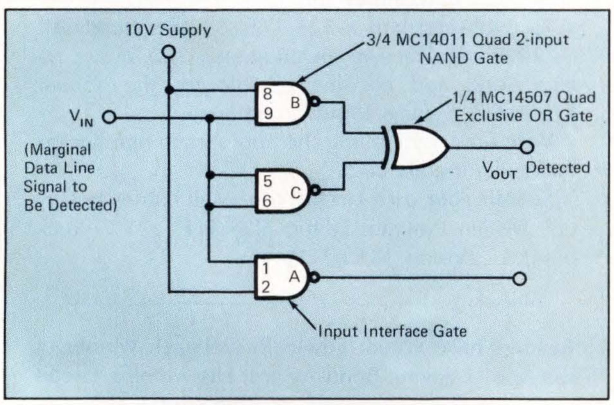


Fig. 1—Digital error anticipator provides warning of power supply or data degradation that may provide incorrect performance of systems. Loading to system is negligible due to CMOS input impedance of $10^8\Omega$.

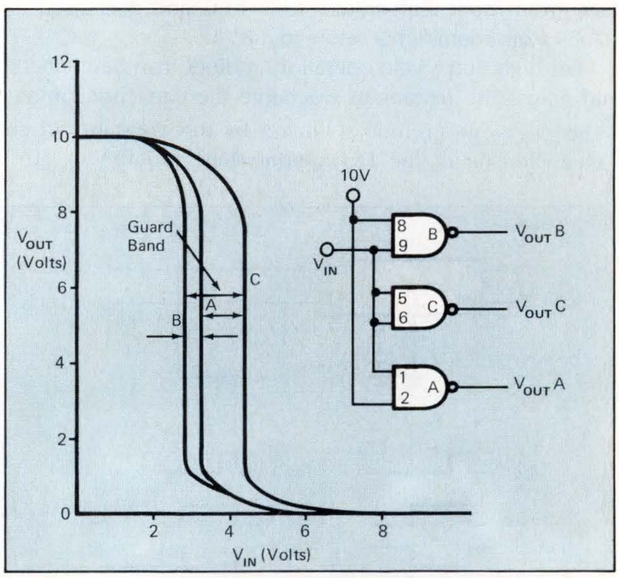


Fig. 2—Triggering levels of multiple input CMOS gates can be changed by varying the connections of the remaining inputs, as shown in these voltage transfer curves of an MC14001 when wired as shown in **Fig. 1**.

the data line being monitored (input impedance greater than 100 MΩ, 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 (≥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. □

To Vote For This Article
Circle 152

CMOS one-shot has wide range of output pulses

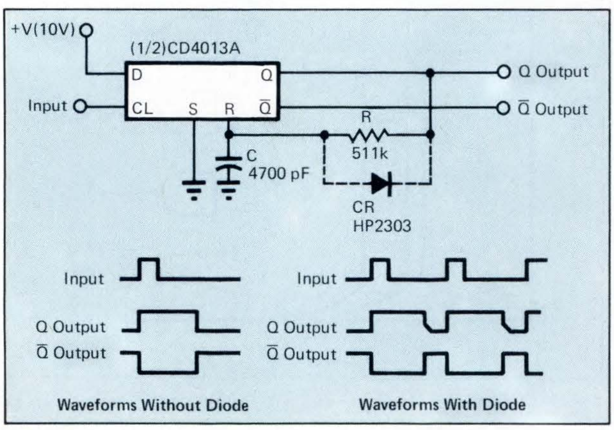
Roger Smith,
Adcole Corp., Waltham, Mass.

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 μF 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°C and decreased by 2.3% from room temperature to +85°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. □



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

To Vote For This Article
Circle 153

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.

Vote now, by circling the appropriate number on the reader inquiry card.

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, multitask, 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 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.

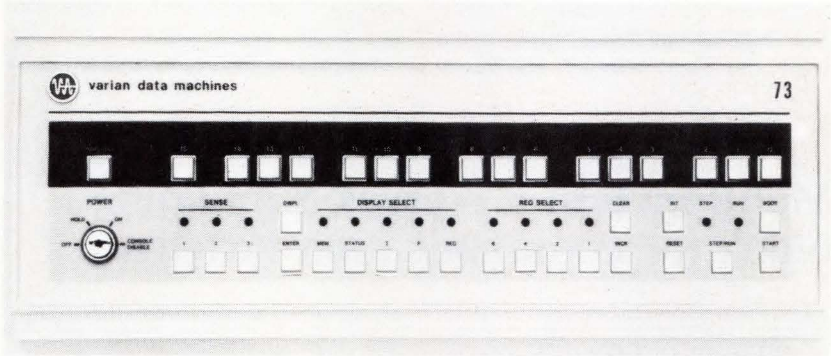


Fig. 1—New minicomputer provides user-accessible microprogramming and a fast, flexible dual-port memory system.

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

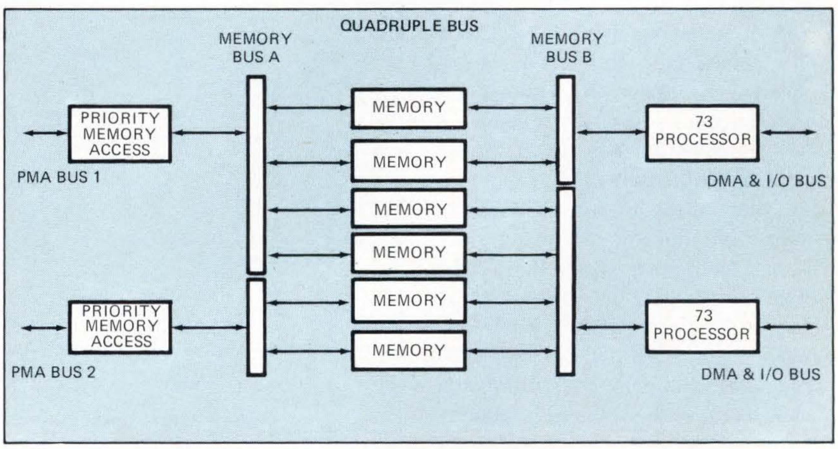


Fig. 2—Quadruple-bus structure features completely overlapped operation between two processors and two PMA channels. Additional processors can share the busses.

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**, additional 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 conled 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.

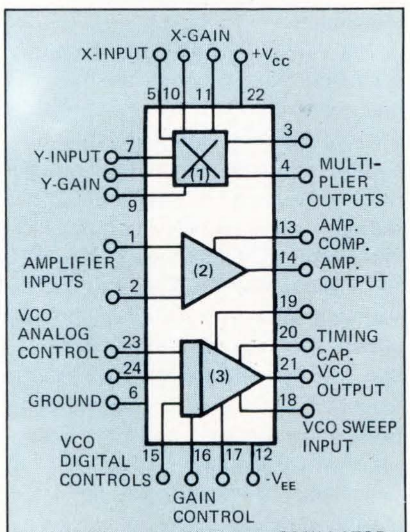
Each of the three functional circuits incorporate a large number of design options, and they can be used either independently or in conjunction with each other. They can be externally interconnected in any respective order without requiring either external biasing or interface circuitry.

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 ±5V to ±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-μsec 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 available in plug-in modules. The firm's MP2913A and MP2914A 13 and 14-bit converters come in 2 × 4 × 0.39-in. Modupac modules and are rated for total conversion times of 8 and 9 μsec 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 ±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 ±7 ppm/°C and an offset TC of ±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-μsec 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, ±5V, ±10V or 0 to +5V. Input impedence is 125Ω/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.

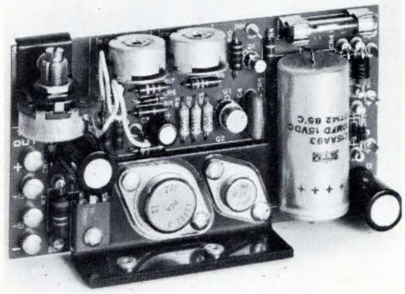
After the design engineer has the power requirements specified, he need only select a proper heat sink, transformer, and "CM" Series model (from the 25 standard stock models available), and then:

- 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.

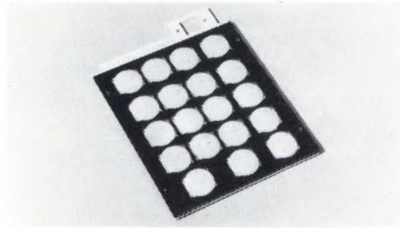
A unique feature of the sub-module is the low-level logic-control input for shutdown of the output voltage. The unit is unconditionally guaranteed for one year.

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.

COMPUTER PRODUCTS

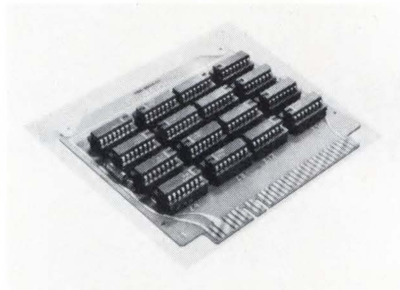


CALCULATOR KEYBOARD PROVIDES TACTILE FEEDBACK. A new keyboard system provides snap action feel and sound feedback. The 1KS KLIXON series has a profile of 0.150 in. and is offered in complete arrays up to 20 switches. All contact surfaces are gold, providing low impedance for MOS interfacing. Switch life 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**

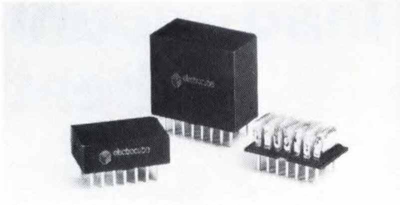
MEMORY OFFERS MULTIPLE CHOICES. The CC-150 is sold in four product configurations—as a core array with 65k words, as a 65k submodule with core array and all drive and sense electronics, as a module with up to 8 submodules and a single additional board containing all required timing and control electronics, 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 MINICOMPUTER 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**

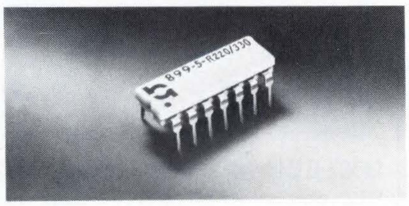
TAPE CONTROLLER FOR PDP-11. The *data path* Series 1X15 is available as a complete tape memory subsystem or as controller interface. It provides complete control of data flow between the PDP-11 and up to four transports (7- or 9-track compatible) and controls generation of tape format. I/C driver subroutines 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**



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**



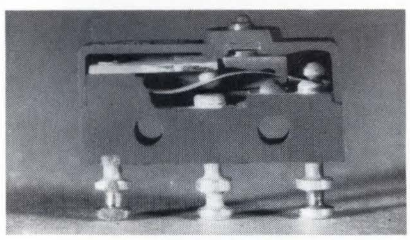
RESISTOR PACKAGES, CONSISTING OF 24 OR 28 THICK FILM RESISTORS, are designed primarily for pulse squaring networks or logic terminators. The resistors are placed in groups of two hooked together in series having a common line for power and a common line for ground. The center point of each pair is brought 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 Northwest Hgwy., Des Plaines, IL 60016. Phone (312) 824-1188. **189**

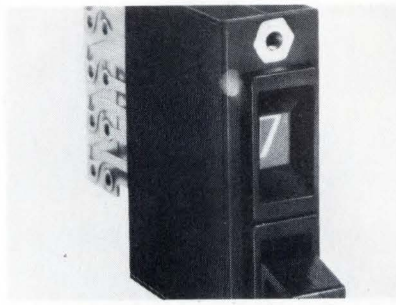
TRIGGER TRANSFORMERS ARE DESIGNED FOR USE IN SCR POWER-CONTROL CIRCUITS. Designated the 505 Series, this new line is available in 3 basic case styles: open or encased for lower-cost applications, or encapsulated construction for special humidity or military applications. Both standard and custom versions 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**

COMPONENTS/MATERIALS

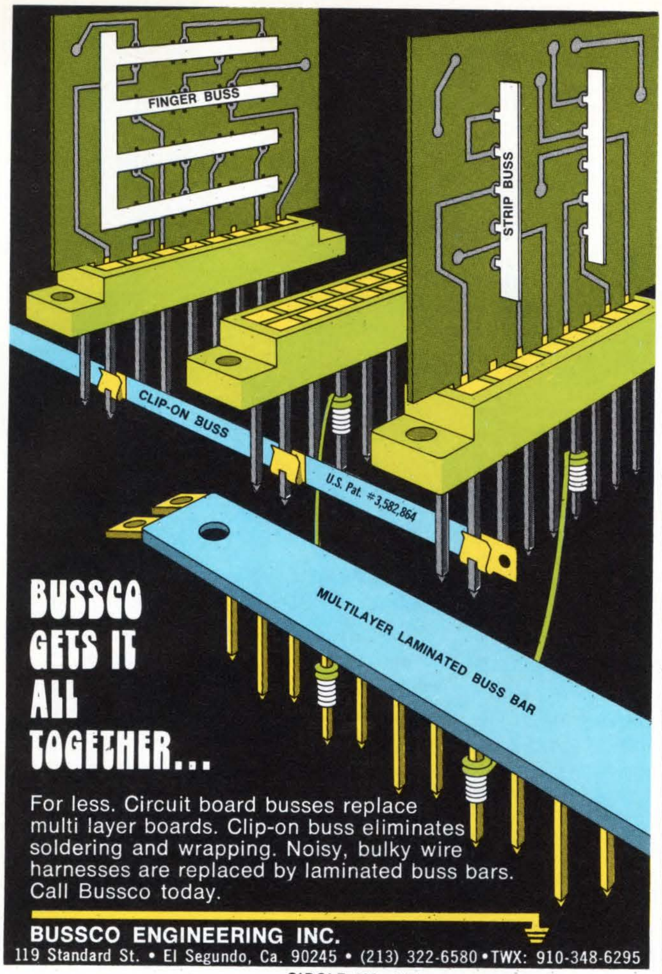


BI-DIRECTIONAL TOGGLE SWITCH IS FRONT-PANEL SEALED AGAINST HARSH ENVIRONMENTS. The dial numbers of the switch are completely visible during switch operation, and the fingertip-detent action and short arc between positions makes precise setting more rapid than standard thumbwheel switches. Available as 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. × 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**

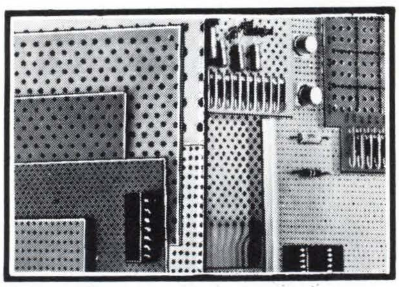
MINIATURE TWO-PIECE CONNECTOR BOASTS A BROAD RANGE OF ADAPTABILITY. The new series, called 8229, is available in five discrete sizes; 6, 9, 10, 12 and 15 single-row contact positions, all on standard 0.100 in. centers. The connector features wire-crimp/removeable mini-Vari-lok^{TM} contacts in a flame 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**



CIRCLE NO. 35

VECTORIZE YOUR CIRCUITRY



CUT CONSTRUCTION DELAY WITH .... PRE-PUNCHED MICRO-VECTORBORD ®, PLUGBORDS AND PUSH-IN TERMINALS.

Make circuits the fast, easy way . . . simply insert Vector push-in terminals (wide variety available) and component wires into pre-punched Micro-Vectorbord and Vectorbord, or use new matrix type boards with etched I.C. pads and busses. New Micro-Klip and Mini-Wrap wirewrap terminals available. Twelve punched patterns available with .025", .042", .062", .093", holes in XXXP phenolic, glass silicone, glass, paper epoxy and copper clad. Plugbords supplied in many sizes with etched pads, .040" dia. Edge-Pins or Elco Varicon contacts.

Send for complete literature

Vector

ELECTRONIC CO., INC.
12460 Gladstone Ave., Sylmar, California 91342
Phone (213) 365-9661 • TWX (910) 496-1539

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 scalers, 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$\frac{1}{16}$" deep, 6¾" wide, 2¼" 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 10^6 per year and 5 digits of TTL-compatible BCD output . . . for only **$500.***

HEATH
Schlumberger

HEATH/SCHLUMBERGER SCIENTIFIC INSTRUMENTS
Dept. 531-233
Benton Harbor, Michigan 49022

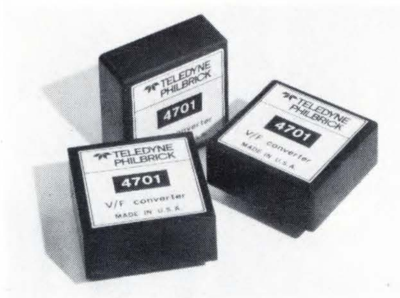
☐ Please send additional information on the SM-114A Scaler.
☐ Please send latest Scientific Instruments catalog, which includes SM-104A & SM-105A information.

Name____________________
Title____________________
Company/Institution____________________
City__________ State__________ Zip__________

*Mail order prices; F.O.B. Benton Harbor, Michigan
Prices and specifications subject to change without notice. EK-338

CIRCLE NO. 37

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, N J 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 ±6 minutes of accuracy and output over-current and short-circuit protection. They convert any two dc inputs from −10 to +10V 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 = 0.1V) is 20 kHz and large-signal bandwidth (D = 10V) is 60 kHz. The Model 4290 operates over −25 to +85°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**

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 100Ω to 10 MΩ 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**

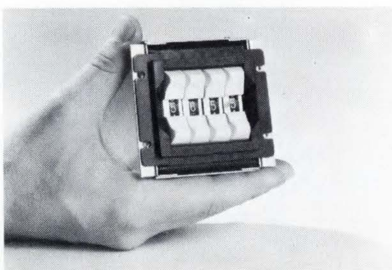
$1295 5-1/2-DIGIT DMM FEATURES 1-μV AC/DC RESOLUTION. Model 2540/A1 with 18 ranges measures ac and dc from 100 mV to 100V fullscale (+20% overrange), resistance from 100Ω to 10 MΩ fullscale and dc ratio from ±1.00000:1 to ±100.000:1. Accuracies and stabilities are said to be equal to or better than those 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 × 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 50Ω. 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 μV 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 0.01Ω TO 10 MΩ. 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 999Ω to 9.999999 MΩ. Precision wirewound resistors are used throughout with TCs of +3 ppm/°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 ±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/μsec and the output settles to within 30 μsec to ±0.01% of final value. Temperature coefficient is less than 0.1 μV/°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 × 4 × 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**

For Op Amps & Companion Logic

Outputs are ± 15 VDC (tracking) @ 50 ma and 5 VDC @ 250 ma. All outputs have regulation of $\pm 0.1\%$, ripple of 1.0 mv, and are short circuit protected. Only 3.5″x2.3″x1.0″. Mounts directly on a PC board. Order Model 5E25D-D15E05. Price: \$88.00 (For ± 12 and 5 VDC, Model 5E25D-D12E05. Same price. Other voltage and current ratings also available.) Shipment: Three days.

Acopian

Acopian Corp., Easton, Pa. 18042
Telephone: (215) 258-5441

CIRCLE NO. 12

A REQUIRED *volume for every manager of an R&D laboratory, engineering or scientific team . . .*

MANAGEMENT OF RESEARCH, DEVELOPMENT AND DESIGN IN INDUSTRY

By T. S. McLEOD *Technical Coordinator, Plessy Co., Great Britain*

Budgeting, organization, cost effectiveness and day-to-day management problems treated in a practical, workable, professional method based on the author's experience in reorganizing 50 laboratories of diverse disciplines in over 50 different geographical locations and involving over 6,000 specialists. \$12.50

— — 15 DAY FREE TRIAL EXAMINATON PERIOD — —

Cahners Books

EDN

89 Franklin St., Boston, Ma. 02116

Please send me____copies of MANAGEMENT OF RESEARCH, DEVELOPMENT AND DESIGN IN INDUSTRY at \$12.50

( ) Bill Me ( ) Bill Company

( ) Check Enclosed (We Pay Postage)

Name________________

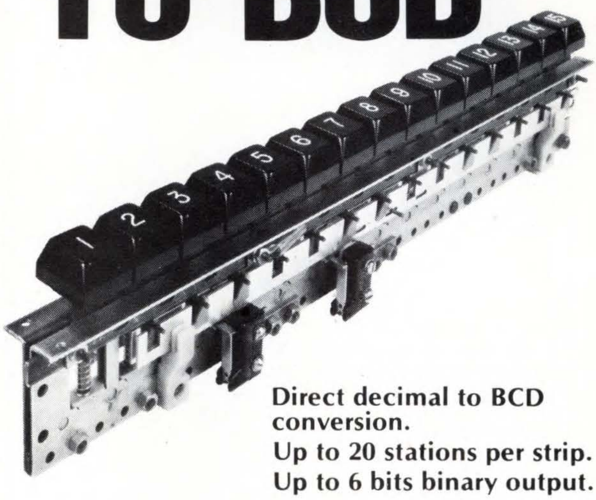
Company________________

Address________________

City/State/Zip________________

Mass. Residents Add 3% Sales Tax

DECIMAL TO BCD

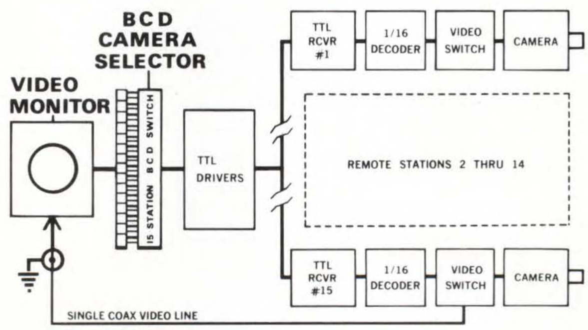


Direct decimal to BCD conversion.
Up to 20 stations per strip.
Up to 6 bits binary output.

Use the Maxi-Switch 1400 Keystrip and eliminate the maze of contacts, diodes and wiring usually associated with encoding. Rigid no-flex steel frame. Low friction mechanism. Design with single Keystrips, or multiple units with cross-bank interlatch and lockout. Snap-action contacts, Form A or C, rated 3 Amperes. KMS optional.

APPLICATION NOTE:

Remote camera selection scheme.
Designed by Ed Tomczak, Control Data Corporation.



This selection system is greatly simplified by use of the Maxi 1400 BCD switch. Switch contacts and wiring are minimized. Only four lines from selector switch to TTL line drivers. One coax line from all 15 cameras to video monitor.

Do you have a good idea for the Maxi binary switch? Tell us about it.

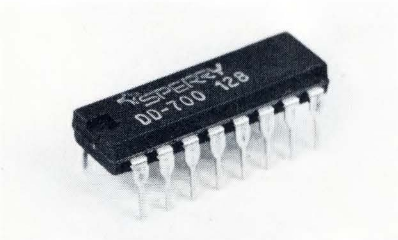
Give Maxi a try.
Write for free literature.

THE Maxi-SWITCH CO.

3121 WASHINGTON AVE. NO. • MINNEAPOLIS, MINNESOTA 55411
612-529-7601

See Maxi in EEM

CIRCLE NO. 43



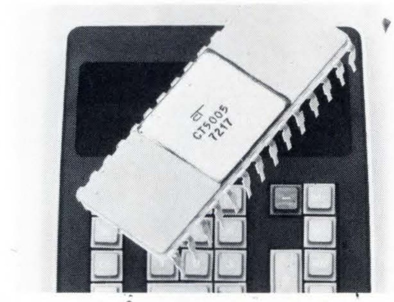
DISPLAY DECODER/DRIVER FOR HIGH VOLTAGE SEVEN-SEGMENT DISPLAYS, Model DD-700, will accept BCD information, and decode it to provide seven outputs for driving each segment. The decoder has a hexidecimal output which provides a numerical readout from "0" to "9" and letters A through F. Available in a standard 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 ±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**

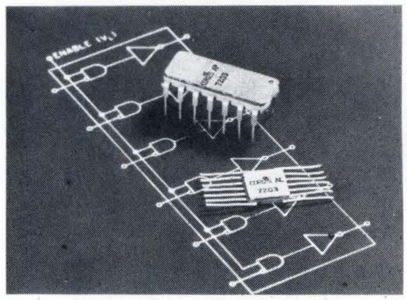
MONOLITHIC-TIMING CIRCUIT is capable of producing accurate time delays, or oscillation. In the time-delay mode of operation, the time is precisely controlled by one external resistor and capacitor. For stable operation as an oscillator, the free-running frequency and the duty cycle are controlled with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



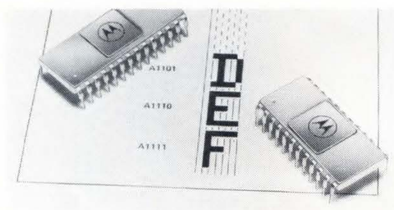
CALCULATOR CIRCUIT FEATURES FOUR FUNCTIONS AND MEMORY ON A SINGLE CHIP. The CT5005 contains over 400 gates and 230 shift-register bits. It has automatic keyboard debounce, leading-zero suppression, and automatic lockout on a P-channel MOS chip with two operation registers as well as the memory. Packaging 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 counter 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**



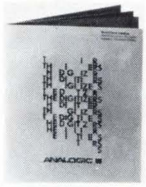
CUSTOM ROMS PROVIDE WIDE RANGE OF MEMORY CAPABILITY. The MCM1100 series of custom-programmable read-only-memories (ROMs) offer memory capability ranges from 2048 to 4069 bits in a variety of word-length configurations. Each of these PMOS, metal gate ROMs is offered as a custom, mask-programmable memory 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 μsec to 100 μsec 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**

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, N J 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, N J 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**

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**

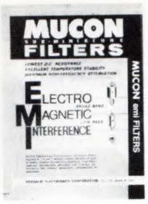
CAMERA-TUBE PRODUCT GUIDE for broadcast, commercial, industrial and educational TV applications. The 8-page guide and its companion broadside provide capsule data to aid customers in their selection of RCA's camera tubes and accessories. Included are a layout and indexing approach that makes it easy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

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, N J 07009. **270**

VOLTSENSOR 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. Calex, 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**

ADVERTISERS INDEX

SALES OFFICE

E. Patrick Wiesner
Publisher
221 Columbus Ave.
Boston, Mass. 02116
(617) 536-7780

Hugh R. Roome
National Sales Director
205 E. 42nd St.
New York City, New York 10017
(212) 689-3250

NEW YORK CITY 10017
Gerry Hoberman, District Manager
Richard Millar, District Manager
205 E. 42nd St.
(212) 689-3250

BOSTON 02110
Richard Parker, District Manager
Hal Short, District Manager
89 Franklin St.
(617) 482-6786.

PHILADELPHIA 19103
Steve Farkas, District Manager
Penn Towers
1819 John F. Kennedy Blvd.
(215) 569-2424

SOUTHEAST
Newman Ladabouche,
Southeast Regional Manager
6065 Roswell Rd.,
Northside Towers – Suite 815
Atlanta, Georgia
(404) 252-7753

CHICAGO
Terry McDermott, District Manager
Frank Sibley, District Manager
15 Spinning Wheel Rd.
Hinsdale, Illinois 60521
(312) 654-2390

DENVER 80206
John Huff, Regional Manager
270 St. Paul St.
(303) 388-4511

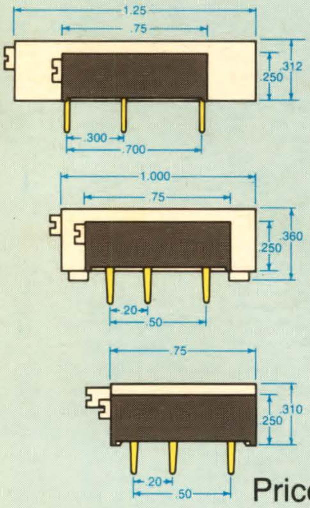
SAN FRANCISCO 94103
William J. Healey, District Manager
1111 Hearst Building
(415) 362-8547

LOS ANGELES 90036
Ed Schrader, Regional Manager
Eli Warsaw, District Manager
5670 Wilshire Blvd.
(213) 933-9525

INDEX TO ADS, PRODUCTS AND LITERATURE

Use card for free product information

Wirewound or cermet—Dale's new low profile trimmers have important design advantages for your circuit.



A full watt in less space—You can increase both part density and power handling ability with either the 2700 (wirewound) or 8700 (cermet) series. Both dissipate one watt at 70° C.

More models—greater interchangeability Choose from three different terminal configurations with pin spacing identical to many larger models. Reduce space as much as 64.6% without sacrificing performance.

20-turn adjustability—Wiper arm adjusts smoothly, quickly. Sits tight under vibration and shock inside an immersion-proof case sealed for production soldering and board washing. Flame retardant SE-0 grade material available upon request.

SPECIFICATIONS	2700 WIREWOUND	8700 CERMET
Resistance	10-50K ohms	10-2 Meg.
Tolerance	±10%	±10% 100-500K ±20% all other values
T.C.	50 PPM/° C	±100 PPM/° C
Wattage	1 watt/70° C	1 watt/70° C
Operating Temp. Range	−65° C to +150° C	−55° C to +125° C
Adjustability	20 turns (with clutch to prevent overtravel damage)	
Dimensions	.25" high by .165" wide by .75" long	

Priced less than 60c in 50,000 quantities. Available fast. Many standard decade values stocked for off-the-shelf delivery. Get the details. Write today or phone 402—564-3131.

DEPENDABLE DALE®

DALE ELECTRONICS, INC.

1300 28th Ave., Columbus, Neb. 68601

A subsidiary of The Lionel Corporation • In Canada: Dale Electronics Canada, Ltd.

CIRCLE NO. 51