EDN

computer hardware In this Issue

lusively for designers and design managers in electronics

EEE

Energy Storage Solves Long Timing Problems

A CAHNERS PUBLICATION

JUNE 15, 1971

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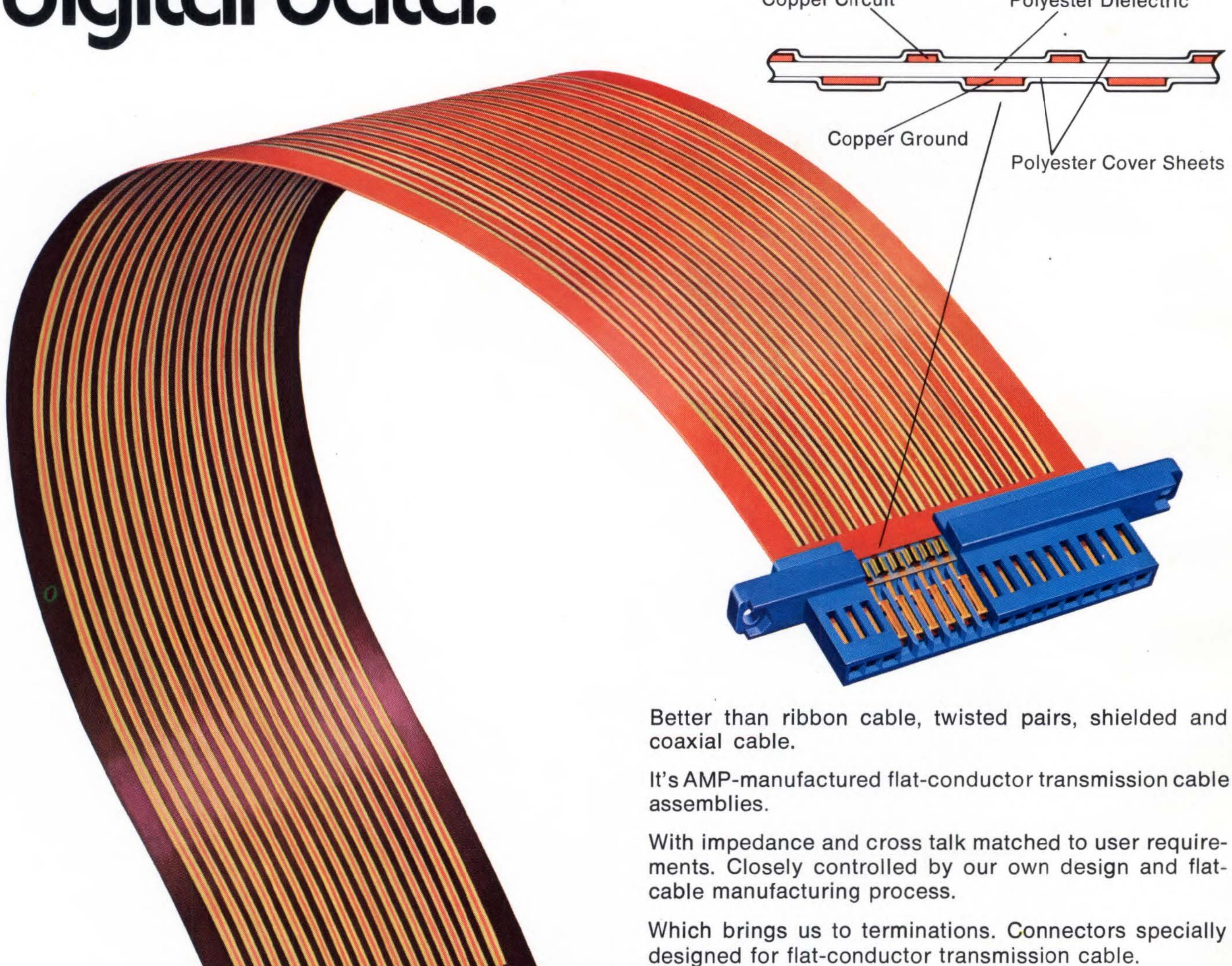

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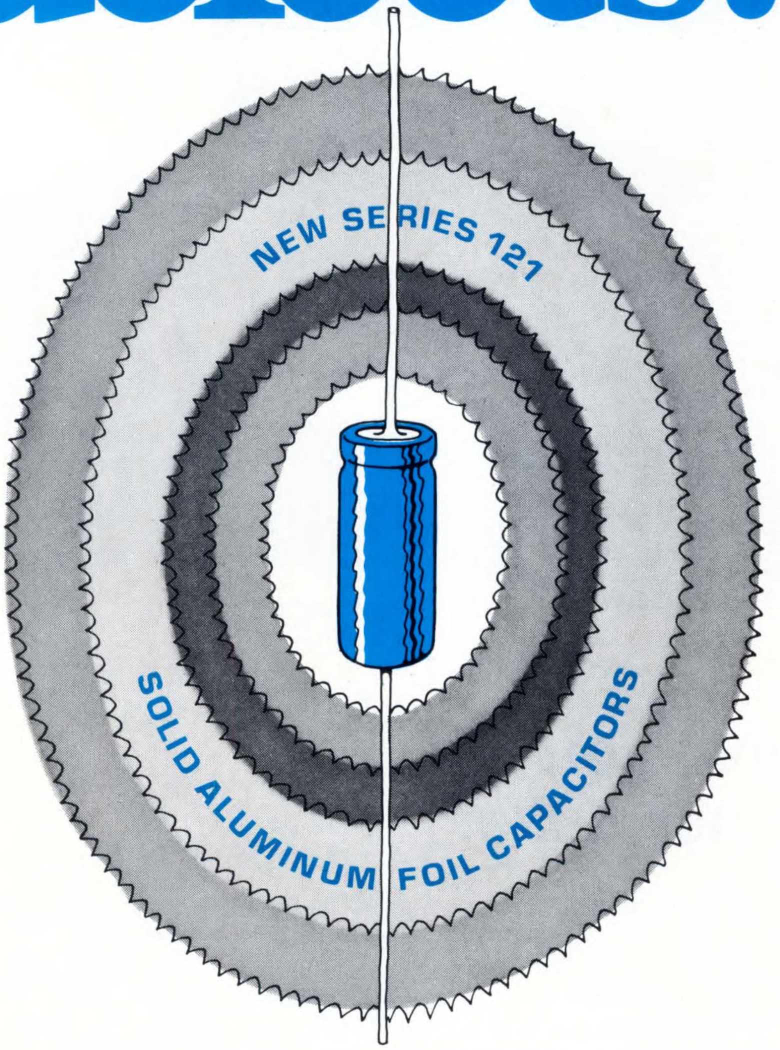
CIRCLE NO. 1

An electrolytic capacitor with zero defects?



After 26 million component hours of testing without a single catastrophic failure and 400 million hours of actual field testing, Amperex announces a solid electrolyte aluminum foil capacitor. This new capacitor fills the gap between dry aluminum and solid tantalum electrolytics where long life, high reliability and stability over a wide range of temperatures are critical design factors. With electrical characteristics similar to solid tantalum types, the new Series 121 capacitors offer higher reliability than either dry aluminum or solid tantalum.

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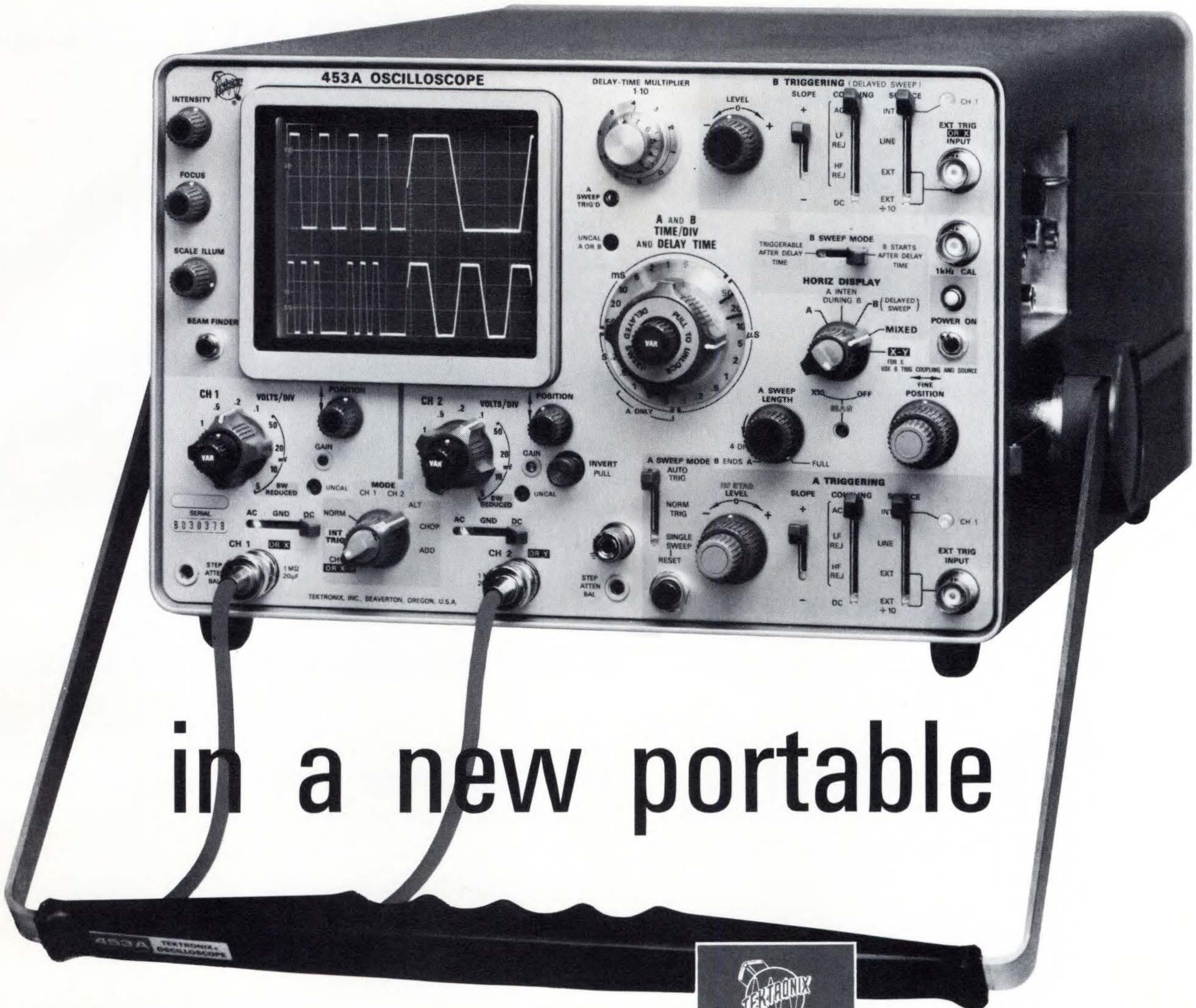
CIRCLE NO. 3

laboratory performance



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- **Brighter displays**
- **Larger CRT**
- **Calibrated mixed sweep**
- **1 mV/div single trace**

A new model of the most widely used portable oscilloscope is now available with even more performance. All the features which made that oscilloscope so popular are retained, many others are expanded and a lot of new ones are added. The result is the 453A, a new oscilloscope which enhances the field-proven ruggedness, performance and portability of the pace setting 453.

The 453A has a new 8 x 10 div (0.8 cm/div) CRT which gives you 1/3 more measurement area. 14 kV gives you bright displays when you measure low-repetition rate pulses in applications such as disk measurements.

Dual-trace bandwidth is increased 20% to 60 MHz at 20 mV/div. It's 50 MHz at 10 mV/div and 40 MHz at 5 mV/div. When you want even more gain just cascade the amplifiers for 1 mV/div to 25 MHz. Sweep rates are 0.1 μs/div to 5 s/div. The X10 magnifier increases the rate to 10 ns/div.

The 453A has calibrated mixed sweep. With this new feature you expand the right portion of dense displays and "unwind" the pulses, one at a time, for detailed examination—or to make calibrated measurements.

Making the measurement is easier and quicker with controls which are functionally color-coded. Faster measurements save your most valuable asset—TIME.

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453A OSCILLOSCOPE $2050

U.S. Sales Price FOB Beaverton, Oregon
Tektronix lease programs are available in the U.S.

CIRCLE NO. 4

New S-D expandable counters.

The most sensible new approach in counter design since 1960!

New 6150 series expandable universal counter-timers.

S-D developed this line to handle almost every counter/timer requirement—bench and systems. Four basic models cover frequency ranges of 50, 200, 512 MHz, and fully automatic 3 GHz. Buy for current requirements and upgrade frequency range at any time. These instruments were designed from scratch for **programmability:** single line or binary, total control including attenuators, and analog or digital trigger level control.

You can add most expandable features by inserting a new PC card. S-D's expandable counter protects you against obsolescence for years to come.

6150 options and features: Choice of 100 nsec or 10 nsec TIM resolution—choice of five oscillators—four types of BCD output—up to 9-digit readout — versatile remote programming — 3½" height in full rack width—10mV rms resolution to 0.1 Hz.

6050 series frequency counters.

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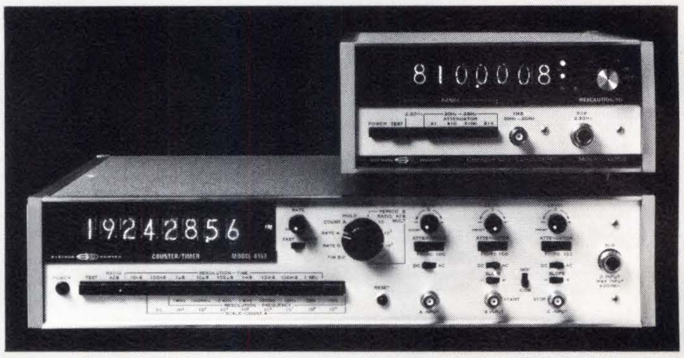
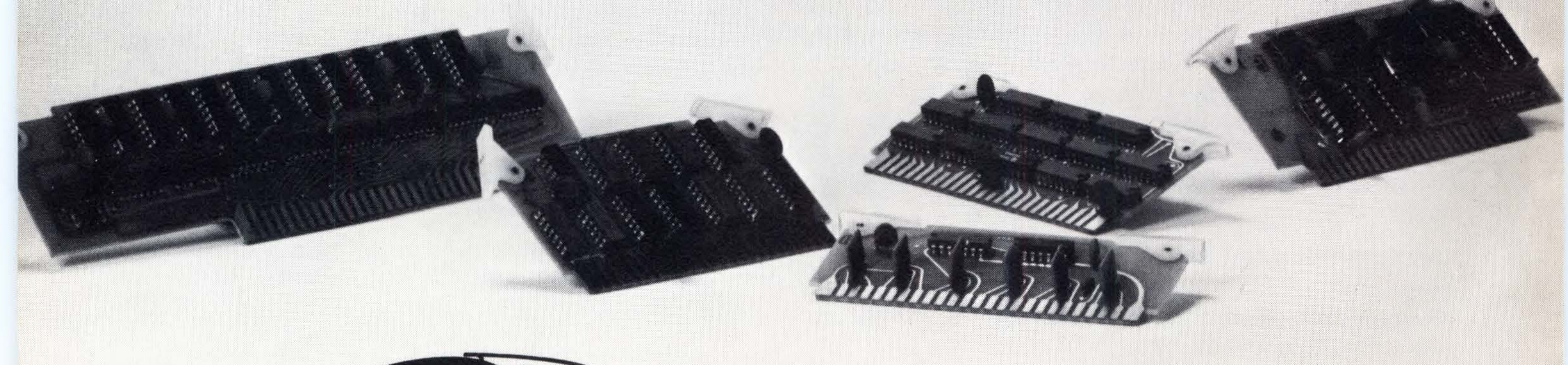
6050 series features: Automatic operation right up to 3 GHz—small 3½" height in ½ rack width—10 mV rms sensitivity to 200 MHz, 50 mV to 3 GHz—resolution to 0.1 Hz—expandable to 9 full digits—programmable options.

Call your Scientific Devices man today for a demo or contact Concord Instruments Division, 888 Galindo Street, Concord, CA 94520. Phone: (415) 682-6161.



		50 MHz	200 MHz	512 MHz	3 GHz
Frequency Counters	Model:	**6050**	**6051**	**6052**	**6053**
	Price:	$ 770	$1050	$1550	$2295
Universal Counters	Model:	**6150**	**6151**	**6152**	**6153**
	Price:	$1195	$1475	$2150	$2995



SYSTRON DONNER

JUNE 15, 1971
VOLUME 16, NUMBER 12

EDN/EEE

EXCLUSIVELY FOR DESIGNERS AND DESIGN MANAGERS IN ELECTRONICS

Speakout—Steve Levy of Motorola, speaks out on controversies in the IC industry, p. 38.

Cover

Cover photo depicting Gould Ionics' ESD symbol was created by free-lance photographer W. R. Eastabrook. The hour-glass shown is symbolic of the long timing problems that are easily solved with components like the energy storage device (ESD) described in the article starting on p. 23.

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Then call your local CORNING authorized distributor for fast off-the-shelf delivery. He not only stocks components for guys who are demanding, but he offers service to match, too.

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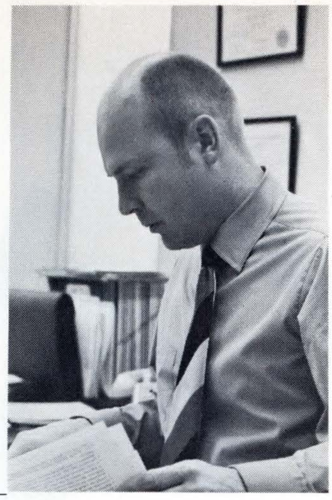
CIRCLE NO. 6



Editorial

An Ounce of Human Engineering Is Worth a Pound Of Sophistication

Why do people buy? Why do people not buy? There is a raft of reasons, and even after many years of formal research, the answers to these questions remain obscure.

Probably the most serious problem facing the technical community today is a marketing problem. A few short years ago, who would have thought that the public would no longer be buying the space program? Who would have thought that projects such as the SST would be dropped? Who would have thought that tens of thousands of able engineers would be out of work?

There are many who say that the flagging aerospace industry should redirect its efforts toward solving the nation's domestic problems. But listen to Dr. Morris A. Steinberg, deputy chief scientist for Lockheed Aircraft Corp.

"The problem is simply that the market for these activities (high-speed ground transportation, communication and information systems, water purification . . .) either does not exist at all or, if it does, it is so highly fragmented that it can be cultivated only at costs too great for any private organization under the present circumstances."

And it is a fact that many aerospace companies have invested heavily in high technology solutions to domestic problems only to find there is no visible market.

If the public sector continues to be the reluctant or nonexistent customer, the next logical market is the private sector —business, industry and consumer. Indeed, these customers are buying in spite of current economic problems. Computers, calculators, entertainment products and industrial controls all are moving at a brisk pace.

Since customers are changing, our approach to the marketplace must change. There is ample evidence that expensive complex solutions to large complex problems aren't selling. There also is evidence that cost-effective electronic solutions are selling in business and industry. But there is another very human angle to the new marketplace that is worth paying attention to. The tip comes from one of our regional editors and is offered verbatum from a recent memo.

"The designer should be certain that he understands the equipment operator's behavior and should see to it that his electronics does not add extra work rules. I have heard this point made over and over by those who seem to be successful in today's markets. Let LSI make the lazy, stupid, unmotivated operator appear brilliant, fast and accurate! Then you will sell product at profit."

G. Boe
Editor

Staff

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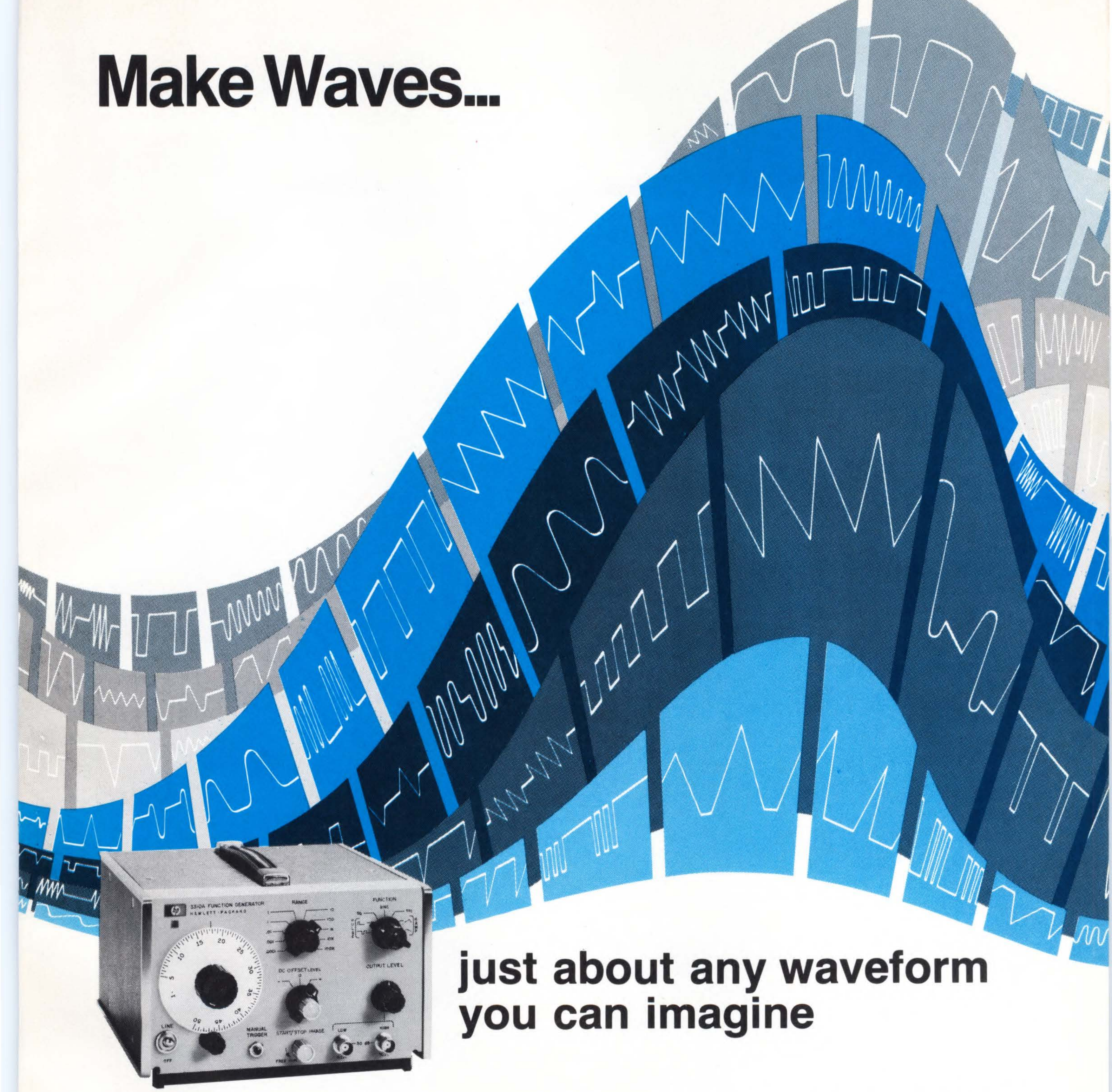


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*LSI devices produced by an Allen-Bradley affiliate, MOS Technology, Inc., Valley Forge, Pa.

Flat-Panel Displays Will be Here by '72

That long sought dream, the X-Y addressed flat-panel display, will be ready for designers in '72, according to Owens-Illinois, Inc., Toledo, Ohio and Burroughs Corp., Plainfield, N. J. The Owens neon-type display is a 512 by 512 matrix of 262,144 dots, all of which can be randomly and individually addressed, and have memory so that no electronic refresh cycle is needed. The price for Owen's present prototype is $15,000 each, but when Owens starts turning out displays in 100-unit batches in 1972, the price should begin to move towards $2500.

The Burroughs Co. also has a neon-type matrix display, and there is a strong likelihood that they, too, will have a graphics-quality panel for designers by 1972. Burroughs so far has not announced a panel of the size and dot resolution to qualify for full graphics applications, but a Burroughs spokesman told EDN/EEE: "Each year we have doubled our display area and halved our dot spacing. It is logical to assume that we are working to be competitive with Owens in '72."

The fineness of the dot pattern is really what determines whether a panel is just an oversized alphanumeric readout or has useful graphic display qualities. The Owens display has been refined down to a 60-dots/inch resolution. This is the dot fineness found in low-grade newspaper halftones, though it must be remembered that halftones have grey scale while, so far, the commercially-available plasma displays don't. A fine dot pattern is important when viewing a small display close up; even the 60-dot/inch pattern of Owens has compromise "zig-zags" in lines at angles other than 90 or 45°.

Burroughs' largest panel at present is a roughly 80 by 200 matrix of 16,000 dots. These dots, spaced at 25/inch, make the resolution about typical home TV quality. However, Burroughs has built prototypes with 33 dots/inch and expects to do better. Burroughs also uses only a partial XY addressing scheme. Rather than a full random on both X and Y, it uses a repetitive 60-Hz stepped scan cycle on the X axis. This simplifies the drive circuitry, but requires the use of a recirculating MOS memory.

Burroughs is hardly ashamed of these compromises. They point out that it is these features that make it possible for them to deliver their "Mini-display" essentially out of stock right now for less than $600 in quantity.

Both Owens and Burroughs are of-

This flat-panel display will be commercially available in production quantities in 1972, according to its maker, Owens-Illinois, Inc. The display panel itself is so thin (an inch or so) that it could be hung as a picture on the wall. The housing is deeper here because a rear slide projector and a hard copier are incorporated behind the conveniently transparent panel.

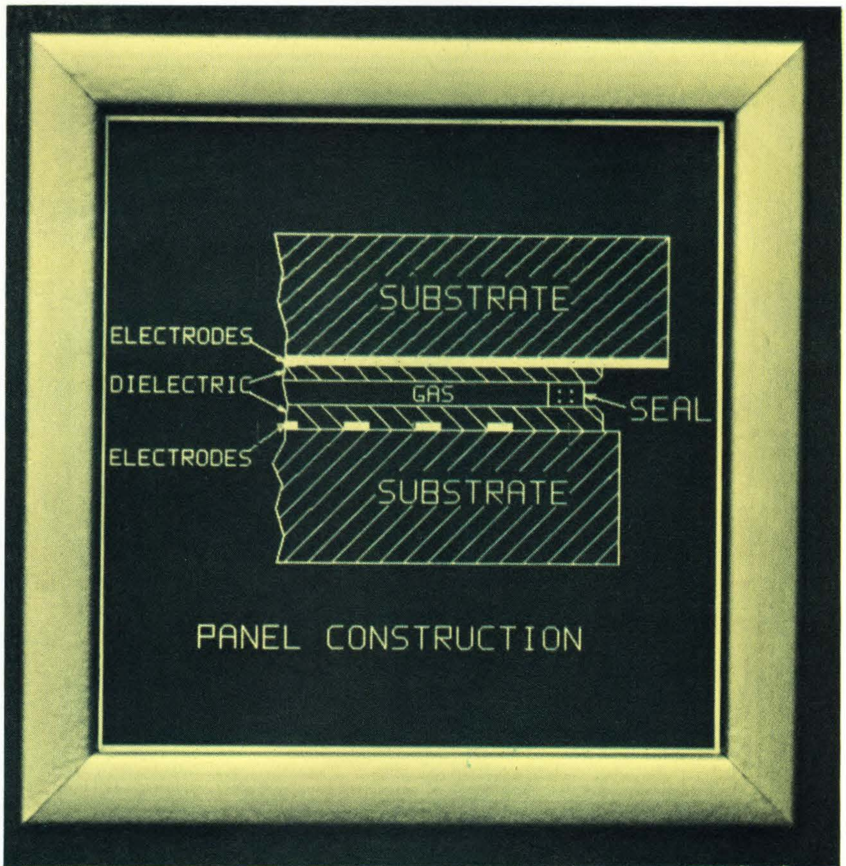
fering their displays as complete stand-alone subsystems. The designer has only to supply them ASCII code at T²L logic levels. All the high-voltage drive and refresh and character generation is contained inside.

Impressive Visual Quality

EDN/EEE was favorably impressed by the visual quality of the Owens panel, as shown in a motion picture of the display presented by Owens engineers during a session of the recent (May) meeting of the Society for Information Display (S.I.D.) at Philadelphia. The fine dot size made the characters easy to read and the 180-character/sec writing rate seemed more than adequate for most applications. Demonstrations of the Burroughs 80 by 200 matrix also have impressed us. The larger dot size almost seems an advantage when you are viewing this display from a distance and it is surprising how much graphic information you can show, despite the granularity.

Both Owens and Burroughs have some definite applications in mind for their panels. Owens is already installing prototypes as student teaching terminals at the Univ. of Illinois (the PLATO IV project). Burroughs is convinced that their lightweight, compact displays are perfect for the terminal-in-a-briefcase market and, in fact, they now are building six of these into 5-inch thick Samsonite suitcases for their salesmen to carry around as demos. Burroughs also foresees the day when these will be built into every typewriter so the girl can look ahead before she commits herself to ruining that so-far perfect business letter, and into every cash register for similar reasons.

The main future thrust for both Owens and Burroughs now seems to be to develop grey scale and color. Laboratory progress has been reported on both counts, but it is not likely that products with these features will be available in quantity in '72.



The panel displays its own cross section. This illustration was generated on an actual Owens panel and photographed.

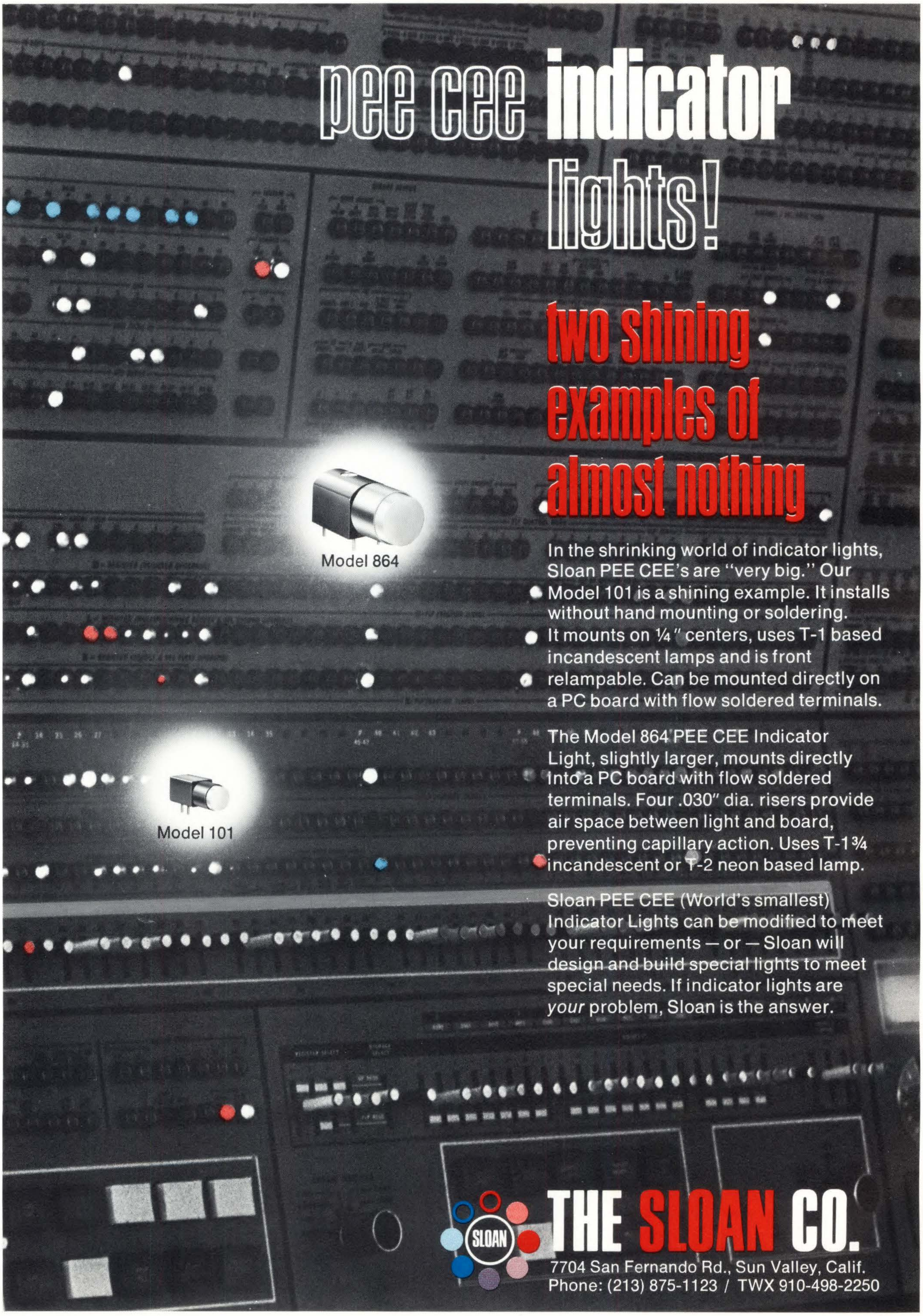
Owens Panel Operation

The Owens display is most ambitious. Yet, in principle, its operation is simple. Two films of glass are spaced 10 mils apart to form a big 8-1/2- by 8-1/2-inch cavity for the neon-type gas. The rows of X and Y addressing lines are laid down outside this glass, the X lines being on one side and the Y on the other. (As cross-section diagram indicates, the lines are actually deposited on thick glass substrates and the thin dielectric glass film applied over them.)

AC voltage (140V, 50 kHz) is applied continuously across the cavity by these lines. This "sustaining" voltage is not enough to fire the gas.

To fire the gas at any of the 262,144 locations, additional voltage pulses are superimposed on the X and Y lines that intersect at that point. The panel remembers that the point was fired and keeps it glowing after the pulse and despite the reversing ac drive. The trick here is that when the gas breaks down, it transports charges across the cavity and charges the walls of the cavity at that location. This local charge provides the added voltage to keep refiring that dot. The glass walls of the cavity, in combination with the X and Y electrodes, serve as 262,144 tiny memory capacitors.

To turn the spot off, a different type of voltage pulse is superimposed on the X and Y lines crossing at that point to "kill" the memory charge.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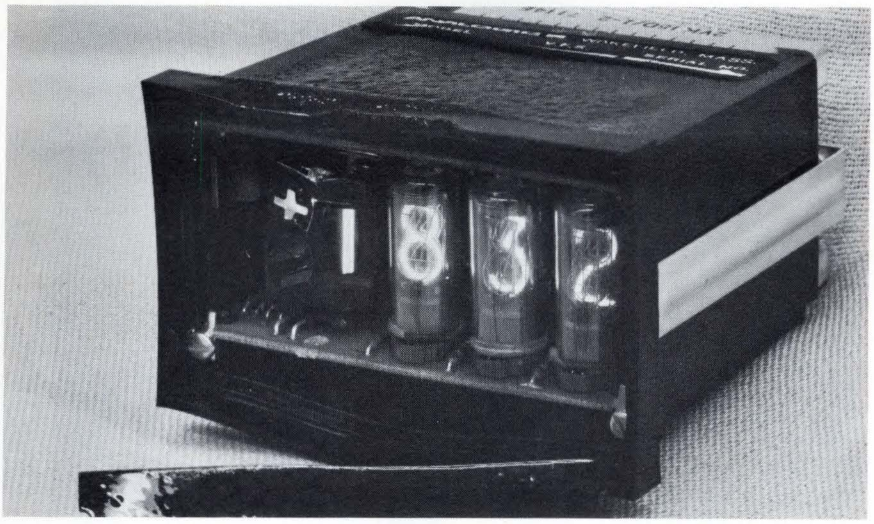
CIRCLE NO. 10

American Products Come Through When the Heat's On

EDN/EEE has published many articles relating to component derating in design. However it's seldom that we receive a story based on just the opposite; the ability of products to withstand subjection to unusually higher than rated temperatures. This story will give you an example of the quality of products now being supplied by American manufacturers and should go a long way toward making you feel more comfortable about those derating figures you've been using.



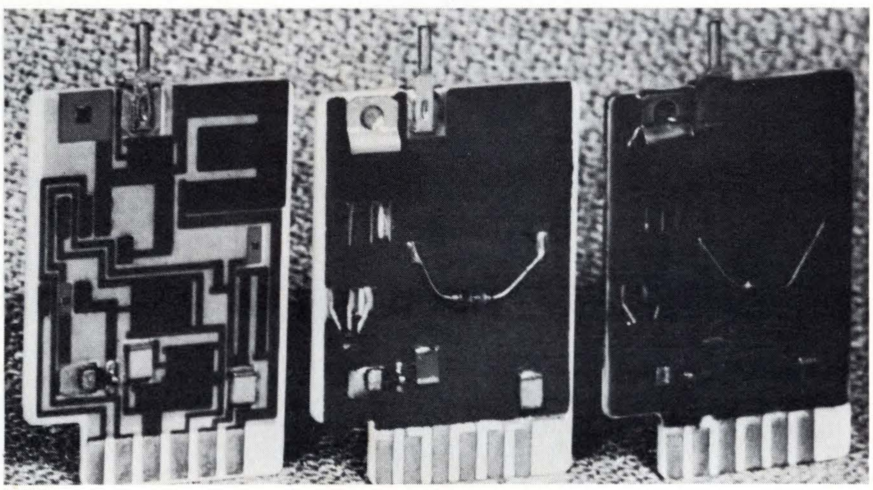
Recently, an Analogic technician inadvertently subjected nine 60°C rated digital panel meters to a temperature of +185°C for 20 min. All nine, when re-tested, were within ratings on every specified electrical parameter.

The particular meter involved was the Analogic AN2510. This meter is specified at +60°C operating and +85°C nonoperating. Maximum nonoperating temperature is determined mainly by the temperature survival characteristics of the individual components used within the unit. Although only the finest components are used in the AN2510, only a few are actually rated as high as +185°C. The case material is Lexan, which is well-known for its excellent heat-resistance properties.

After the initial excitement had died down, a tenth unit was subjected to the same treatment. However this time the test was carefully monitored. At +162°C the injection molding stresses in the Lexan case announced their presence via a series of bulges and warps, but still no creep or flow. At about +168°C things really started happening to the case, and the plastic viewing filter popped out exposing the innards to view. The temperature crept steadily towards 185°C and stabilized. Twenty minutes later the AN2510 was removed from the oven and allowed to cool back to ambient temperature. The unit then was connected to a standard test fixture to detect any sign of a heartbeat. With power applied, and a 1.972 mV input signal applied from a precision voltage source, the display flipped instantly to 1.972 and stayed there. Then the complete test cycle was performed to determine whether the extreme heat had affected such critical parameters as accuracy, stability and speed. As with the first nine units, *every* electrical parameter was found to be within specifications.

Thick Films Move Into Consumer Products

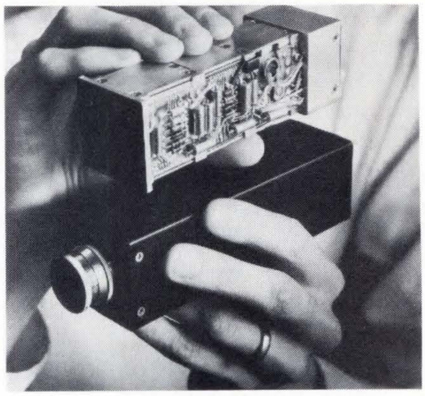
Increased reliability, leading to a broader warranty program, and the promise of lower manufacturing cost were cited by RCA as the primary reasons for turning to thick-film hybrids in color TV. Up to 12 separate hybrid modules are used in each of six different new models which encompass an 18-inch portable at the low end and a 25-inch console at the high end.



Among the functions being performed by thick-film hybrids is video driving. Photo shows three stages of production of video driver circuits based on Du Pont film compositions.

Design Briefs

Mini-TV Camera Fits In 0.0065 Cubic Ft



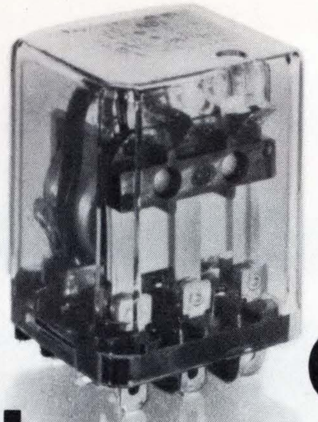
Only 5 inches long and 1-1/2 inches square, Westinghouse's new TV camera is claimed to be the smallest ever built. It was described by its designer, James H. Meacham, at the National Aerospace Electronics Conference held last month in Dayton.

In addition to small size, the camera boasts unusual performance capabilities: it has a switchable sync format enabling use of either American or European standards, automatic light control and built-in sweep failure detection. It consumes only 6W at 12V.

Report Solution To Field Connector Failures

According to Bennett W. Brachman, vice president for Amphenol Space and Missile Systems Div. of Bunker Ramo, more than 75% of electrical connector failures can be avoided easily.

How? Simply by ordering cabling and connectors as a total package rather than buying connectors and building your own cables. Bennett estimates that 90% of all failures occur in the assembly of cables to connectors—a function usually performed in the field. Several contracts for entire cabling systems fulfilled by Amphenol lend support to this claim. In such cases, field failures were "almost nonexistent".

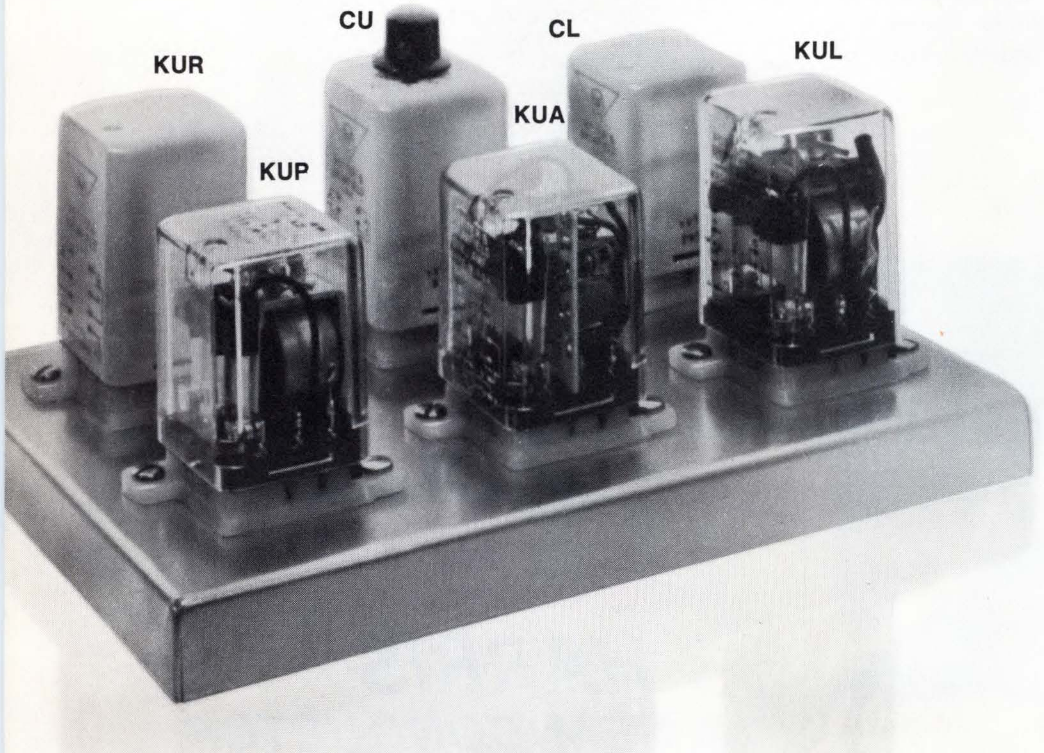


Our KUP general purpose relays

switch up to 10 amperes...reliably

KUP-type relays

will sense 60 microwatts, latch, switch alternately or delay time. It's all in the family



First off, our KUP relays save you money. More than $2.00 each, compared with octal-type pin terminals. Then, to make your design job easier, the range of optional features includes a slotted case for direct-to-chassis mounting; sockets with solder, printed circuit, quick-connect or screw terminals; push-to-test button; indicating lamp; choice of .187" or .205" terminals. U/L recognized. Contact arrangements to 3 Form C. Rated 5 or 10 amperes. Coil voltages to 120 VDC, 240 VAC. List $4.50 to $6.40. The KUP spawned a remarkable family of switching devices. They are housed in the same case (some 1/4" higher), use the same sockets, cover a wide variety of control functions:

KUA Amplifier-Driven Relay. Standard sensitivity: 60 microwatts. DPDT contacts switch 5 amperes at 28 VDC or 120 V 60 Hz., 80% PF. Features continuous operation, built-in polarity protection. Recommended for interfacing low-level logic circuits and work-performing loads such as motors, contactors, solenoids. As low as $14.25 list.

KUL Magnetic Latching Relay. Takes half the space of mechanically-interlocking latchers. Provides permanent memory, continuous duty operation. DPDT contacts switch 5 to 10 amperes. Contacts remain in last position without power. $5.45 to $7.10 list.

KUR Alternate Action, Impulse Relay. Features unique combination of KUL single coil magnetic latching relay with solid state flip-flop circuit drive. Pulse width of 25 milliseconds will effect switching. Contacts switch 5 or 10 ampere loads. List price, $15.10 (DPDT).

CU Time Delay Relay. Low cost solid state relay for timing increments from 1 to 120 seconds. Switches 10 amperes and comes in 3 AC or DC versions: fixed time delay on operate; resistor-adjustable; knob adjustable. Priced as low as $14.20 each, list.

CL Time Delay Relay. Provides a delay on operate. Won't false operate. Times as low as 0.1 second. Otherwise similar to CU. $17.35 to $21.15 list.

Standard versions of these relays are available now from your electronic parts distributor. For complete information, call your local P&B representative or Potter & Brumfield Division of AMF Incorporated, Princeton, Indiana 47570. Telephone: (812) 385-5251.

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P&B performance. Nothing else comes close.

CIRCLE NO. 11

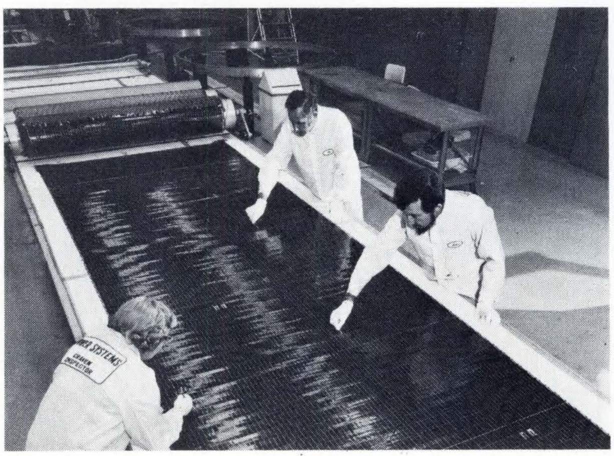
5000-Square-Mile Solar Array Could Power U.S.A.

Given a boost by a Univ. of Arizona scientist and his wife, the vision of pollution-free power is one step nearer reality. Proposed by Dr. Aden B. Meinel, UA Optical Sciences Center director, and his wife, the system would collect the sun's energy, heat liquid sodium and ultimately convert the energy to electricity via conventional steam turbines. The 5000-mile^2 facility could produce four times the power now consumed in the U.S. and, as a by-product, could desalinate 50 billion gallons of seawater per day.

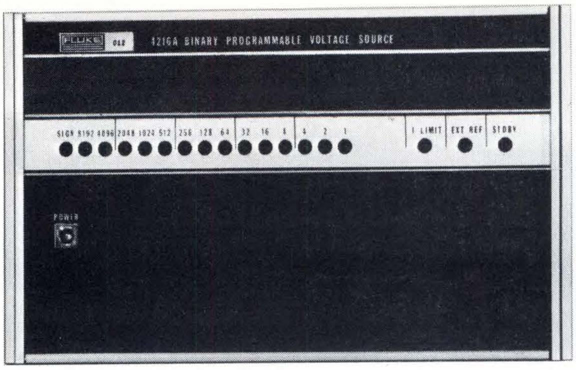
Crucial to the system's feasibility is development of suitable thin-film materials to be used to pass the sun's radiant energy and keep it from reradiating. Research has progressed to where the system's feasibility can be demonstrated within the next 2 or 3 years. Meinel's plan calls for a 100 MW demonstration unit by 1976, the first 1 GW station by 1982 and a 1 terawatt installation by 2076.

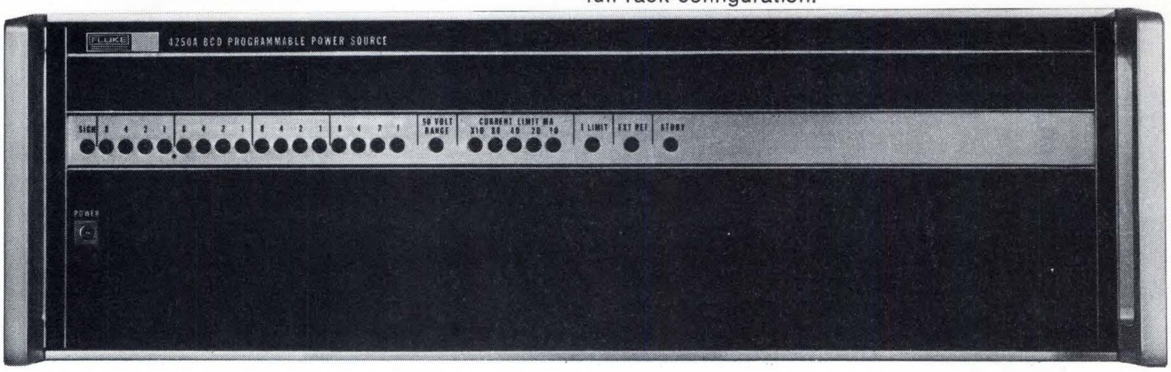
As it now is envisioned, heat from solar collectors would be carried to a large molten salt reservoir via liquid sodium. The salt reservoir's capacity would be such that power output could be maintained during periods of darkness or curtailed sunlight. Molten salt at 1000°F would be used to convert water to steam for conventional steam turbines.

Solar Cell Array Delivers 1.5 kW



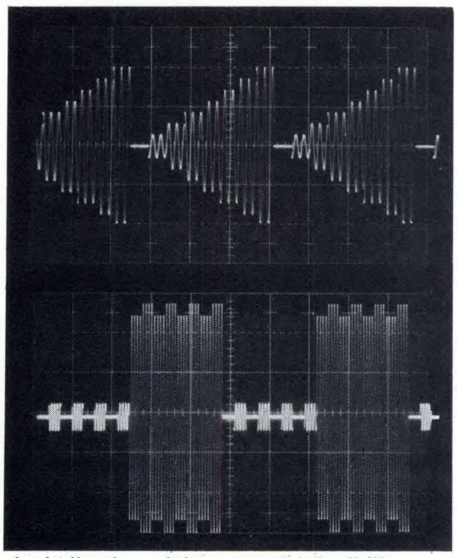
Scheduled to fly late this year aboard a USAF satellite, the silicon solar-cell array shown will deliver 1.5 kW of power. Capable of being rolled up onto one 10-inch-diam drum, the twin array contains a total of 34,500 solar cells and unfurls to an overall length of 32 ft. The system, called FRUSA (Flexible Rolled-Up Solar Array), was developed by Hughes El Segundo for the Air Force.





Instrument photos show Model 4216A Binary Programmable Voltage Source in half-rack version at top and Model 4250A BCD Programmable Power Source in full rack configuration.

New Fluke programmable power sources put it all together. One instrument does the work of a whole rack of equipment.



An indication of the powerful flexibility of the Series 4200 can be inferred from the scope photos.

This family of systems instrumentation represents an entirely new approach to automatic test and process control equipment. They serve as husky power supplies, fast digital-to-analog converters, programmable attenuators, power amplifiers, and even dynamic loads.

Either BCD or binary programming with internal memory is offered. Accuracy is 0.01% throughout. All models feature dc or ac external reference capability programmable in or out, 50mv peak programming noise, isolated control logic to eliminate digital noise, and complete digital display.

Brief specs of the first four models:

	4210A	4216A	4250A	4265A
V_o	10v	16v	65v	
I_o	100ma		1a	
Settling Time	30μs		100 μs	
Basic Unit*	$995		$1295	

*Options extra

More data. Full data sheets and complete applications information are available from your Fluke Sales Engineer who will also be happy to arrange a demonstration at your convenience. Or you may address us directly if it's more convenient.

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CIRCLE NO. 14

HOW BIG IS A 50-FARAD CAPACITOR?

If you are unfamiliar with the "energy storage device", you'll be pleasantly surprised to find that a 50-farad ESD fits in a cylinder only 1 inch in diameter and 1/2 inch tall.

JOHN CONNELLY, Gould Ionics Inc.

The ESD is an electrochemical capacitor. Unlike conventional capacitors, it does not contain a dielectric. Instead, its capacitance derives from the electrical double layer that exists at an electrode/electrolyte interface. Its main advantage is that it offers much higher capacitance per unit volume than the dielectric type.

Introduced slightly more than a year ago, the ESD today is available from 1/4 inch diam (0.01F) up to the 50F 1-inch unit with a prototype quantity price tag in the $30 range and production quantity prices in the $1-3 range.

With its large range of capacitance, from the larger unit down to 500 μF formed on an IC substrate, the ESD has wide application. Other attributes include high charge capability at low voltage, high leakage resistance, a noncatastrophic failure mode and a wide temperature range of operation. Both its symbol and equivalent circuit at low frequency are shown in **Fig. 1**. For a complete explanation of this device, see boxed information entitled "What is an ESD?".

Integration

One of the most useful characteristics of the ESD is its highly repeatable charge/discharge characteristic. When charged at constant current, a nearly linear voltage-time ramp is produced. When discharged at constant current, a similar voltage-time negative-slope ramp is produced. This triangular wave can be used for a wide variety of integrating functions.

Based upon the ESD's capability as an integrator, a series of timing modules has been designed. One very small module is completely logic compatible, requires only one 5V dc power supply, is highly noise immune and can produce time periods with 0.1% repeatability up to 100,000 sec as standard and up to 5 million sec without problem. The module takes up about 3 inch^3 in its standard form, but it can also be provided where required in a single 16-pin dual in-line hybrid with the ESD mounted externally.

Because the ESD has a highly repeatable constant-current charge/discharge characteristic, many timing points may be selected from one basic timing unit. This will enable the buildup of as many time sequences as are required for any multitime process control or monitoring system. Times for a completed cycle anywhere between 10 and 100,000 sec can be produced readily.

Power Sources

Because the ESD has very high capacitance coupled with high leakage resistance, it is a good power store. Where more than 0.5V is required, series-connected cells provide higher voltage. This scheme is quite practical as ESDs are manufactured with a tolerance of better than ±5%, and the 0.5V per cell voltage rating is well below the material decomposition potential.

(Continued)

Fig. 1—**Symbol and equivalent low frequency circuit** of the energy storage device (ESD).

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(Continued)

Ten 1-inch 50F, 0.5V cells will fit into a 1-inch-diam package with a height of less than 2.5 inches to produce a 5F, 5V unit.

Its capability to give up energy to an external circuit depends entirely upon the equivalent series resistance (ESR) of the cell. A 1-inch-diam ESD has an ESR of about 0.8Ω at room temperature (ESR will decrease with increase in temperature). The 5F, 5V unit described above would have an ESR of about 8Ω. This obviously limits the efficiency and capability of the ESD when delivering high currents to a load.

ESR is inversely proportional to the cross sectional area of the ESD. This means that ESR can be reduced by increasing device diameter. Cells can also be connected in parallel in the normal capacitor manner with a corresponding increase in capacitance and decrease in ESR.

The ESD has application in standby power, filtering and decoupling. The high value of capacitance enables the design of a very simple standby power source (**Fig. 2**).

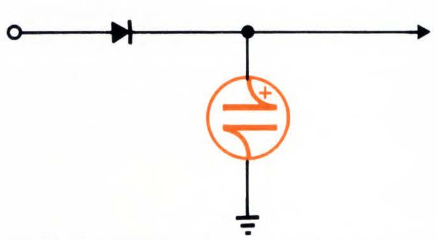


Fig. 2—**Simple circuit configuration** for using the ESD as a source of power.

This circuit could be incorporated directly onto a PC board or subassembly. Under normal operating conditions the ESD would charge to the power supply voltage, minus the diode drop, and provide normal filtering and decoupling for the circuit. A 5F, 5V ESD will provide 1 mA for more than 1 hr with less than a 1V drop. It could, of course, provide a greater current for a shorter time. It could provide standby power, for instance, for a volatile semiconductor memory or other circuit where power loss would be inconvenient.

IC Compatibility

Formation of large value capacitors inside the IC package is now feasible. ESDs have been formed directly onto IC substrates. The ESDs so formed can be used for many circuit functions including power supply decoupling, timing, integration and active filters.

A particular single cell ESD so formed was 0.032-inch-in-diam and 0.020 inch high providing a capacitance of over 500 μF with an ESR of about 100Ω. Work is under way to develop this technique to a commercial level and to produce chip ESDs for hybrid circuits. There is every indication that the ESD can provide small size, high capacity devices that will remove one of the major restrictions in hybrid circuit design.

Memories

Memory modules based on the ESD are being developed that will store for hours or days with access times of seconds to minutes. Power supply removal does not affect the state of store.

The ESD also can be used as a digital memory. A fully charged ESD could represent a logic one, a fully discharged ESD a logic zero. For small programmable memories, the 0.01F ESD could be programmed (charged) in about 0.5 sec from a 10-mA current source, and would have a time constant of $RC = 0.01 \times 10^{10}$ or 10^8 sec when isolated. Even when loaded with a switch leakage of a nanoamp, it would take more than 10,000 sec to reduce from 500 to 400 mV—still a recognizable state.

For many simple memory applications, the miniature ESDs formed on a substrate would be very useful. Development is under way to form 15 cells of more than 10,000 μF each at 0.5V in a standard 16-pin dual in-line package. This could have use in industrial control systems, weapon systems and many other areas where an inexpensive, programmable, simple memory is required.

Charge/Discharge Characteristics

When the charge or discharge of an ESD is interrupted, two phenomena occur (**Fig. 3**). First, there is a step voltage change, V_1, caused entirely by the IR drop, $I_{ESD} \times ESR$, which in the case of a 1-inch ESD being charged at 1 mA is less than 1 mV. However, for higher currents with smaller diameter devices, V_1 can be quite large. This can be compensated for quite readily.

Another voltage change, V_2, which is less easy to define, is shown as an exponential of amplitude V_2 with a time duration of t_1. Both V_2 and t_1 are proportional to the magnitude of the charging current and the length of time charging current was applied before interruption. The magnitude of this effect for low currents of

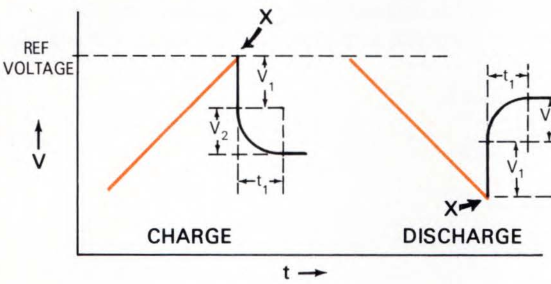


Fig. 3—**Charge/discharge characteristic** of the ESD when the constant current charge or discharge is interrupted at X.

about 1 mA is only a few millivolts and can be completely eliminated with extremely low currents. Constant voltage charging is probably the most accurate way to keep these effects to a minimum, except that in keeping the maximum current low, the time constant is quite large. For a maximum current of 1 mA, a 500-mV device would be charged through 500Ω and have an RC time of 500 × C, which in the case of the 0.01F device would be 5 sec. In the case of the 50F device —25,000 sec. To charge to within 1% of aiming potential would take approximately 4.6 time constants and to within 0.1% would take approximately seven time constants.

Where time available to store information is relatively long, i.e., up to seven time constants from a fairly high source impedance, information can be stored very accurately.

When charged, the ability of the ESD to maintain stored potential is limited by its leakage resistance ($>10^{10}\Omega$) and by external circuitry. A 0.01F ESD charged to 500 mV and isolated from external circuitry would lose 1% of charge (5 mV):
in

$$\left[t = \frac{CV}{I} \qquad I = \frac{0.5}{10^{10}} \text{ amps}\right]$$

$$t = \frac{0.01 \times 5 \times 10^{-3}}{0.5} \times 10^{10} \text{ sec}$$

$$t = 10^{6} \text{ sec} \approx 270 \text{ hrs}$$

A 50F device would take 5000 times longer. External circuitry will be the main source of leakage for these devices.

When information is required to be stored less accurately but is required to be stored more quickly, a constant current charge or discharge circuit can be employed using a comparator to determine the cutoff point.

Actual circuit techniques in both cases are quite inexpensive and simple. Stored voltage can be maintained even in the event of a power failure by the use of an isolating circuit; for example, a relay contact series connected with the ESD and the coil connected to the power supply will isolate the ESD during power shutoff but will be available when power is restored.

Typical Circuit Usage

The high energy storage capability of the ESD at low voltages makes it an ideal device for use with opera-

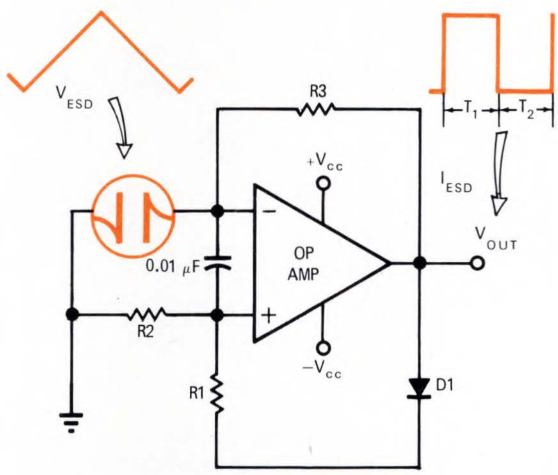


Fig. 4—**Simple multivibrator** or sawtooth generator. With ESD discharged, output is V_{out} positive. CR1 forward conducts; causes potential V_{ref} (> zero, < 500 mV) at noninverting input.

ESD then charges from V_{out} positive through R_3 at almost constant current. When voltage across the ESD is more positive than V_{ref}, op amp changes state. CR1 is now reverse biased; voltage at the noninverting input is zero. ESD then is discharged from V_{out} negative through R_3. When voltage across ESD becomes negative, op amp changes state and cycle repeats.

Circuit shown is symmetrical. Adding one diode and one resistor gives separate control for ON and OFF times. A 500 sec ON, 500 sec OFF multivibrator was constructed. During a several day period of test, time repeatability under fixed conditions was better than ±0.5%.

(Continued)

WHAT IS AN ESD?

The ESD is an entirely solid-state device utilizing the highly conducting solid electrolyte, $RbAg_4I_5$. $RbAg_4I_5$ has a bulk resistivity at room temperature of $\approx 4\Omega$-cm. Conductivity is caused by Ag^+ion migration. It thus has an extremely high electronic resistivity ($>10^{11}\Omega$-cm), and leakage rates are correspondingly low. A penalty incurred by elimination of a dielectric is that the maximum voltage per cell is considerably reduced, i.e., to below the decomposition voltage of $RbAg_4I_5$ (0.66V). This feature obviously has a strong influence on circuit design.

How Does It Work?

In its most usual polar form, the ESD is represented by the electrochemical cell system:

Ag / $RbAg_4I_5$ / Carbon
– +

During charge and discharge, the processes that occur are illustrated in **Fig. 5**. During charge, Ag^+ ions migrate from

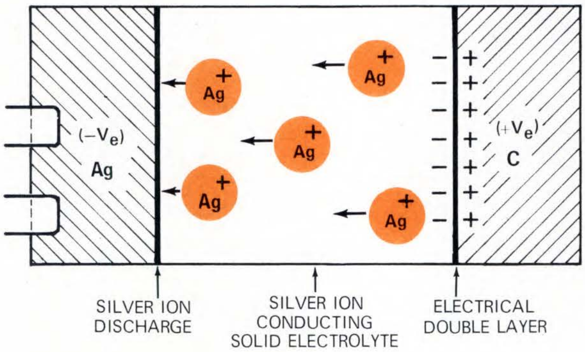


Fig. 5

right to left across the electrolyte layer. In moving away from the positive electrode, a charge separation is effected across the so-called double layer at this electrode. Carbon is electrochemically inert in the system so long as its potential is maintained within a voltage range prescribed by the discharge of Ag^+ ions to form Ag metal at the negative end and the discharge of iodide ions to form iodine at the positive end. Within this range it is ideally polarizable and thus functions as a capacitive element. Ag^+ ions reaching the silver electrode are discharged to form Ag metal. The voltage change at this electrode is negligible compared with the voltage change at the carbon electrode, so the silver electrode can be considered as ideally nonpolarizable or, in other words, it has infinite capacity (cf., the platinum black electrode in a wet tantalum capacitor). During discharge, exactly the reverse takes place: Ag metal is oxidized to form Ag^+ ions which then return to the positive electrode.

The separate charge/discharge characteristics for each electrode are plotted together in **Fig. 6**. The charging curve for the carbon electrode is essentially linear up to 500 mV. Above this value, a pronounced curvature is observed as a result of the onset of electrolyte decomposition. An arbitrary limit for operation of the device therefore is 500 mV.

The values of capacitance that can be achieved in an electrochemical capacitor are intrinsically higher than those where a dielectric is employed. Capacity density is further

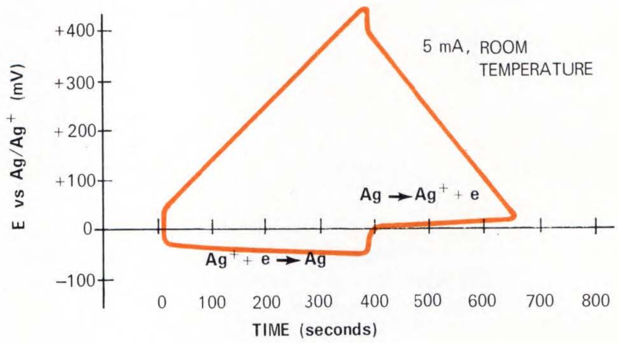


Fig. 6—**Half-cell charge/discharge** of polar electrochemical capacitor.

increased in the ESD by use of a carbon electrode structure with a very high roughness factor. The actual capacitance value is controlled by the weight of this electrode material.

Construction

All the active materials are chemically stable powders. These are pressed into pellets (see **Fig. 7**), assembled and encapsulated in a metal can, resulting in an extremely rugged component. Although the ESD has a positive temperature coefficient of capacitance in the range of 0.1%/deg C, it functions as a capacitor over a very wide temperature range. The maximum operating temperature is in excess of 400°F. At the low end, life tests are being conducted at −65°F, but much lower temperatures are theoretically possible.

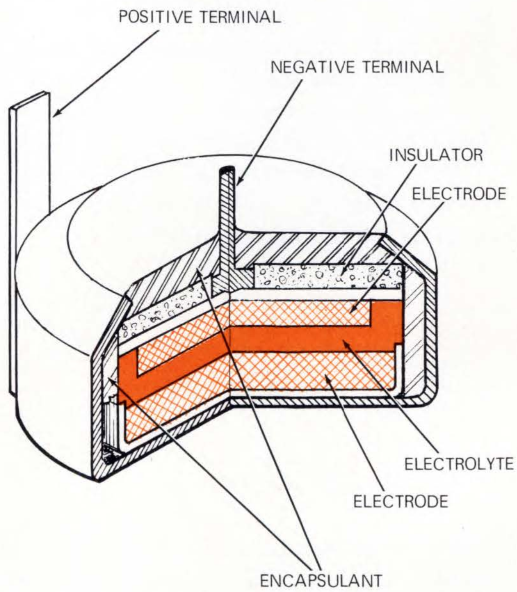


Fig. 6—**Physical construction of the ESD cell.**

HOW DOES IT COMPARE WITH CONVENTIONAL DEVICES?

Voltage

Although the ESD is essentially a low-voltage device, cells may be stacked to provide higher voltage multicell capacitors. Cells follow the familiar laws of capacitors when connected in series or parallel.

Capacitance

Comparisons between the ESD and the more familiar electrolytic capacitors are illustrated in the following table

CAPACITOR TYPE	RATED VOLTAGE	CV (Coulombs/in^3)	1/2 CV^2 (Joules/in^3)
ESD (single cell)	0.5	80	20
Tantalum Wet Slug	6	0.063	0.19
Aluminum	5	0.044	0.11
Ceramic	1000	0.0016	0.8

Leakage

Leakage current for the ESD is dependent on the electronic conductivity of the electrolyte which is less than 10^{-11} $(\Omega\text{-cm})^{-1}$. Its leakage characteristic is compared to two types of electrolytic capacitors in the table below.

CAPACITOR TYPE	CURRENT LEAKAGE (amps)	ESR at 25°C
Single Cell ESD 50 farad 1inch diameter	0.5 nA max	0.8 ohm
Multi Cell ESD 5 farad 1 inch diameter	0.5 nA max	8.0 ohms
Tantalum Wet Slug	1 μA and up	3.0 ohms
Aluminum	0.1 μA and up	0.1 ohm

tional amplifiers. A simple free-running multivibrator was designed (**Fig. 4**) using an ESD, an IC op amp, a diode and a few resistors. Times from 1 sec to several million seconds are easily obtained.

This circuit is of widespread benefit, since it can become the timing element of time-delay relays or electronic timers by adding only a few extra components. The basic circuit is inexpensive, simple and accurate. It uses proven components that are economically available from multiple sources.

Conclusion

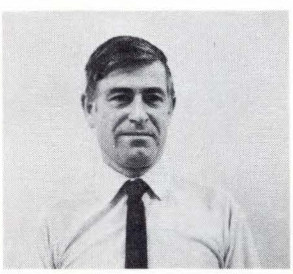
In its high capacitance form, the ESD may be used as a standby power source for volatile semiconductor memories or other circuits where loss of power supply is inconvenient; in this application the ESD also provides decoupling for power supply line transients.

The smaller value, very small size ESD has application as a power supply decoupler when formed directly onto an IC substrate or mounted in a hybrid package in chip form.

As a memory, the ESD can provide a unique voltage store because of its high values of capacitance and high leakage resistance. Its highly repeatable charge/discharge characteristic coupled with its 'memory' capability, enables integration of both a linear and discontinuous nature to be performed.

In timer applications, the actual times available with the ESD are many orders greater than with conventional capacitors and the repeatability can be as high as 0.1% with extremely simple circuitry.

Ability of the ESD to provide high energy at very low voltages makes it very useful when used with low voltage linear circuits. In addition to the free running oscillator shown in **Fig. 4**, many other circuits are being considered in this area. Examples include high linearity (long times) ramp generation, low frequency filters and general low frequency waveform generation. ▭



John Connelly has been with Gould Ionics for 1 year where he is an applications engineer. He previously was with Autoscan Inc. in Los Angeles. Connelly attended Wimbledon Tech and Letchworth College of Technology in England. He has been granted two patents.

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Bipolar Memory: We Delivered 8 Million Bits For Illiac IV Alone. How Many Do You Need?

The truth is we are the largest supplier of Bipolar Memory in the business.

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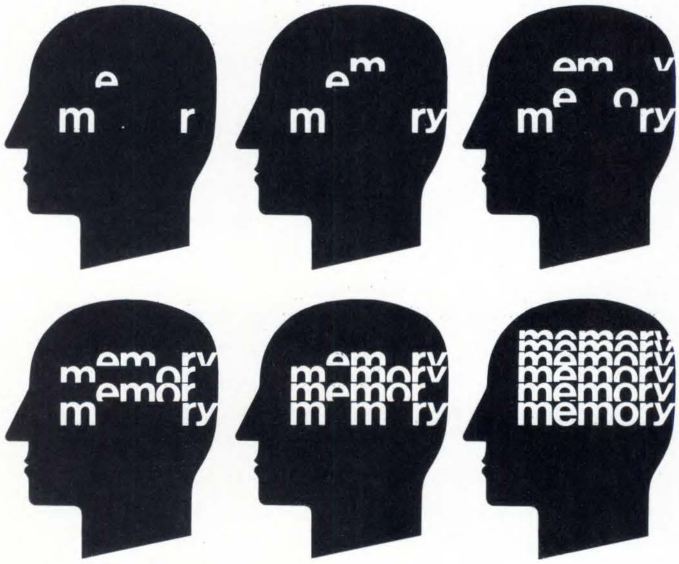


For smaller capacity, higher speed storage, we're also supplying production volume of the industry-standard 64-bit and 16-bit RAMs (see chart). These can be delivered in as little as 48 hours. Other devices may take slightly longer. But just slightly.

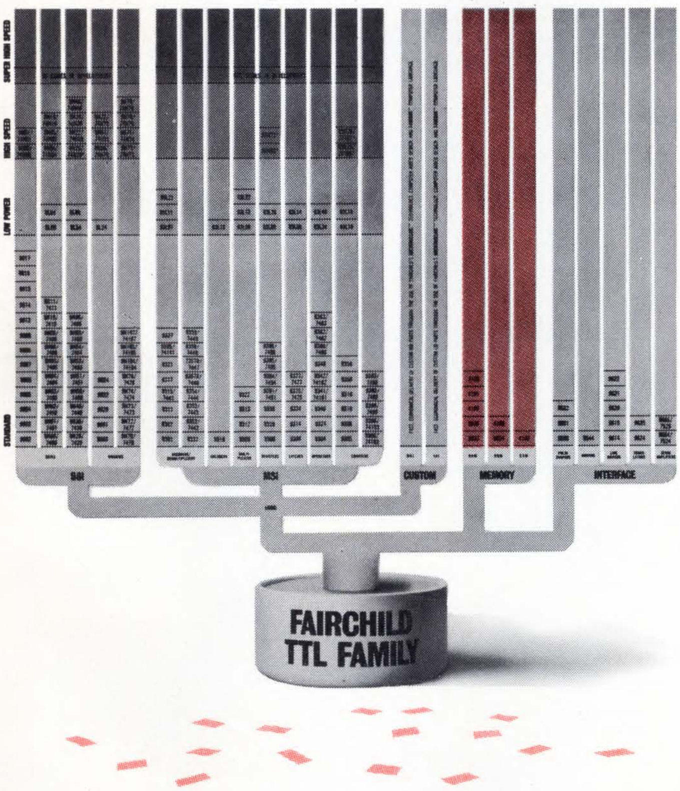
So you can count on the availability of Fairchild Memory devices for your current production systems.

Looking ahead, almost all our major new design activity in Bipolar Memories is committed to our recently announced Isoplanar process. For you, that means freedom to take advantage of devices at least five times faster than functionally comparable MOS devices, yet priced competitively with them. It also means freedom from problems in design complexity arising from the use of MOS in mainframe memories.

Our memories are not fantasies. They are in our factory warehouses. In our distributor warehouses. In quantity. For your current or upcoming systems. We also have data sheets and application notes on all of them. Yours for the asking.

FAIRCHILD TTL FAMILY TREE: MEMORY BRANCH

Our Bipolar Memories are another example of how the Fairchild TTL Family provides designers everywhere with freedom now. The kind of freedom that comes from the broadest range of products, packages, and speed/power trade-offs anywhere.



93400 SERIES TTL MEMORIES

Organization	Address Scheme	Access Time	Fairchild Part No.
Random Access (Read/Write)			
16 Bits (16 words x 1 Bit)	Coincident Select	18 ns	93407
16 Bits (16 words x 1 Bit)	Coincident Select	18 ns	93433
64 Bits (16 words x 4 Bits)	Full Decode	45 ns	93403
64 Bits (16 words x 4 Bits)	Coincident Select	22 ns	93435
256 Bits (256 words x 1 Bit)	3 of 6 Decode	70 ns	93400
256 Bits (256 words x 1 Bit)	3 of 6 Decode	100 ns	93400B
Read only			
256 Bits (32 words x 8 Bits)	Full Decode	30 ns	93434
Content addressable / associative			
16 Bits (4 words x 4 Bits)	Linear Select	20 ns	93402

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CIRCLE NO. 15

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Sperry displays are bright, crisp, and very easy to read. The attractive orange glow provides excellent character definition and is strong enough for easy reading in direct sunlight . . . as well as under all types of indoor lighting conditions. And, they're the only segmented devices on the market that appear as solid, unbroken figures.

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Offering a character height of 0.33″ with 0.375″ centers, Sperry displays have the appearance of printed figures. Uniform spacing is maintained even when stacked end-to-end. Reduced overall size also saves critical housing space.

Wider viewing angle —
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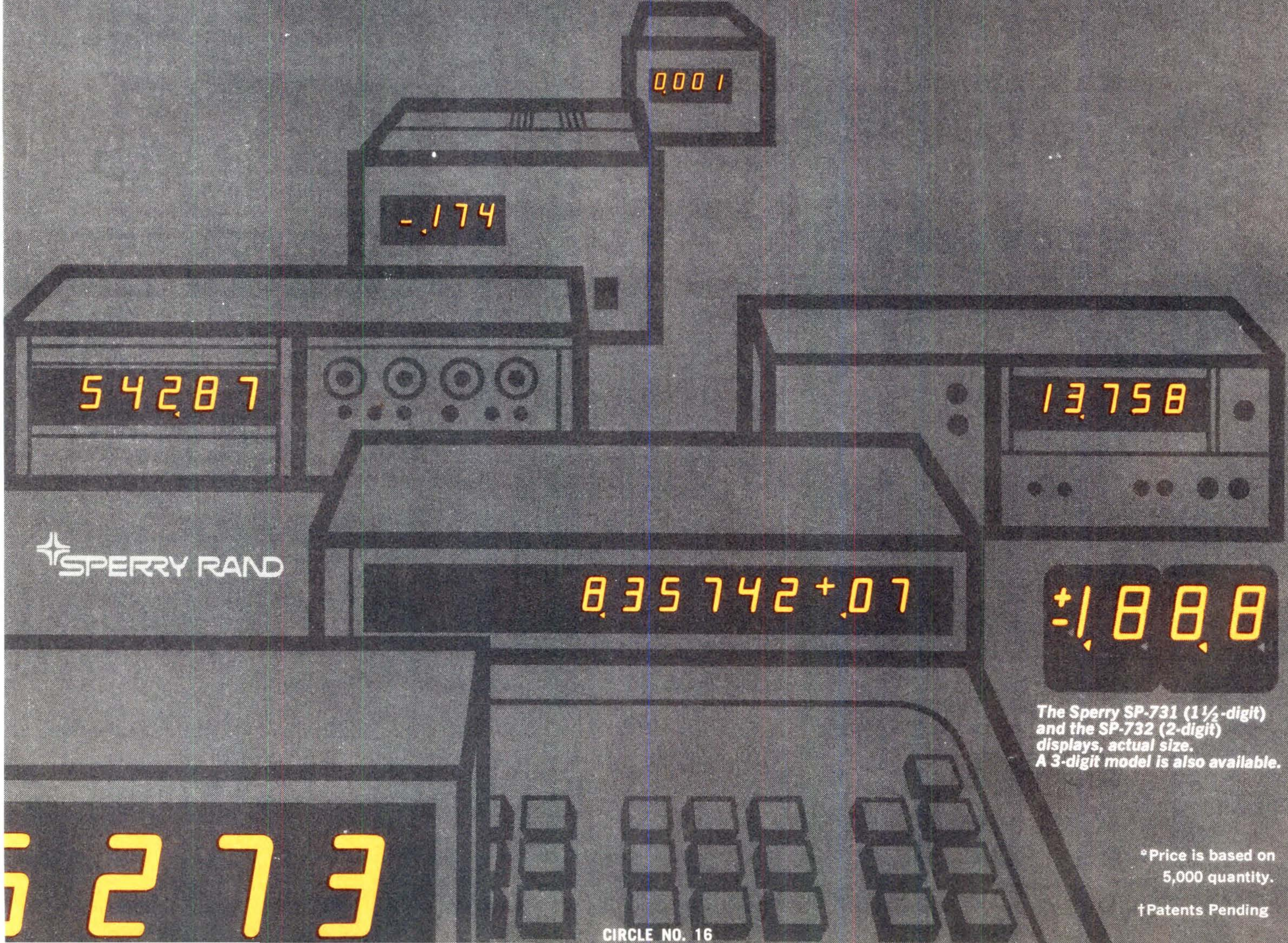

The Sperry SP-731 (1½-digit) and the SP-732 (2-digit) displays, actual size. A 3-digit model is also available.

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CIRCLE NO. 16

STANDARDIZED THERMAL TESTING
THE NUMBER ONE WAY TO EVALUATE SEMICONDUCTOR COOLING

Because semiconductor life is critically dependent on keeping device operating temperatures within safe limits, the importance of properly measuring these temperatures, and consequently heat dissipator effectiveness, cannot be over emphasized. Here we will detail the best ways to measure true operating temperatures and dissipator effectiveness.

DONALD F. GOETTER and WILLIAM ANDERSON, International Electronic Research Corp.

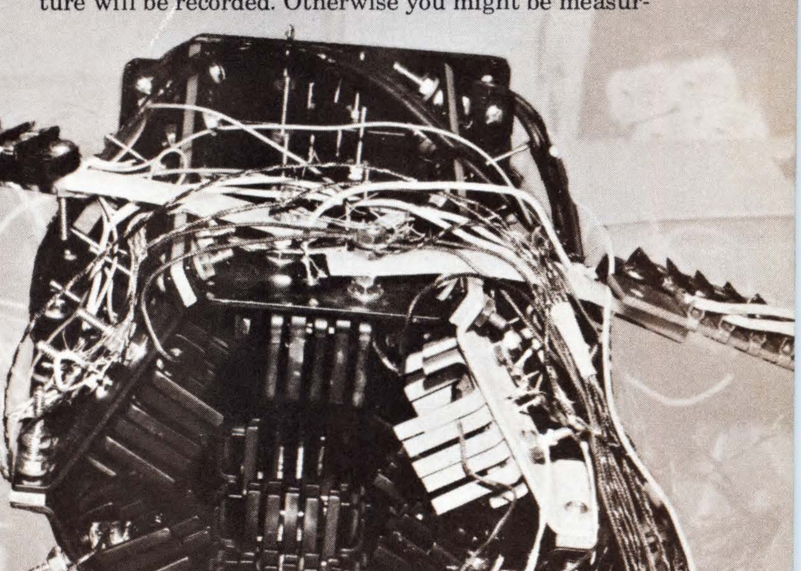
"Look-alike" heat dissipators may be very different in their actual performance. That is just one reason why standardized test methods and data presentation format are needed, and why actual tests must be made. Another contributing factor is the wide variation in heat transfer properties between the various styles of SC cases.

This thermal trio—the SC case, the thermal dissipator and the testing that is needed to determine true heat dissipation—has been the subject of much standardization effort.

In July 1969, for example, EIA issued Components Bulletin No. 5, "Recommended Test Procedure for Semiconductor Thermal Dissipating Devices". It sets forth standard methods for evaluating SC thermal dissipators, and covers measurements of case temperature, dissipator temperature and chassis temperature. It also discusses forced air cooling.

Study of Bulletin No. 5 makes it apparent that the primary measurement point is most often the semiconductor case. A case is, after all, the most convenient point to make measurements, and usually the point yielding best measurement repeatability. (See EIA-NEMA Standard on Thermal Resistance Measurements of Conduction Cooled Power Transistors, March 1968, [EIA RS-313/NEMA SK 508-1965] for the procedure to use when actual junction temperatures are required.)

Measuring Case Temperature. For this job, the most important things are the correct location of the temperature sensing element and the way in which its proper thermal contact is assured. At IERC, iron-constantan closed-junction thermocouples are used. These are generally inserted in small holes drilled as close as practical to the semiconductor dice. To insure best results, only the thermocouple junction should be in electrical contact with the case material. It is not important that electron flow be possible, but good electrical contact does assure that the true case temperature will be recorded. Otherwise you might be measur-



ing that of the air or other contents of the drilled hole.

Closed-junction thermocouples are usually preferable because they are easier to handle, and because they reduce the possibility of interaction with other

(Continued)

circuit currents. When practical they should be spark welded to the inside of the hole, although wedging the junction in the hole with piano wire or securing it with low-temperature solder are useful alternatives. **Fig. 1** compares proper and improper thermocouple junction retention with piano wire.

Thermocouple wire should be small enough to prevent heat transfer through the wire from influencing the temperature being sensed. A minimum gauge of #36 (5 mil diam) is suggested for low-power tests to 5W, while #30 (10 mil diam) is suitable for higher-power tests.

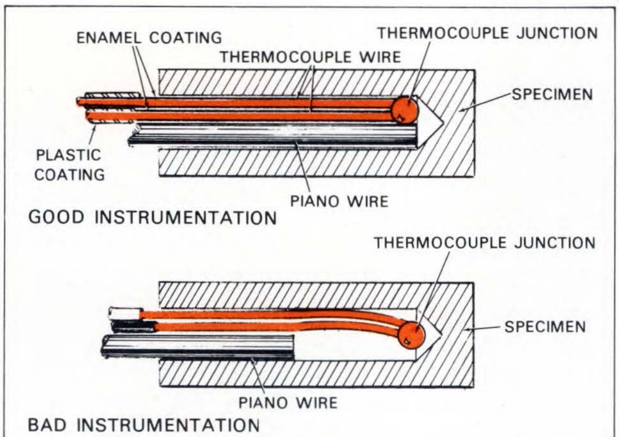


Fig. 1

Each SC Case is Unique

Stud mounted SC devices are probably the easiest ones to instrument. Generally the SC chip is mounted on the stud, so if a hole is drilled up through the center of the stud, the thermocouple can be located just below the dice (**Fig. 2**, method 2).

Sometimes, particularly when the hole length in a stud would make accurate thermocouple placement difficult, it is best to drill the hole through the side of the hex base (See **Fig. 2**, method 1). Deep-flange cases such as the TO3 or TO66 are best handled this way, but be sure that the drilled hole is no larger than necessary. Also, caution is in order not to let the drill drift. If it does the mounting face may be distorted and the chip damaged or the thermal interface degraded.

Some SC constructions, such as those of the TO5 or TO18 case units, don't have any real tie point near the junction or chip of the semiconductor. Units with nonmetal headers often are made like the one shown in **Fig. 3**, right. With such construction, except when the bottom seal is glass, a small hole drilled through the center of the device up to the supporting

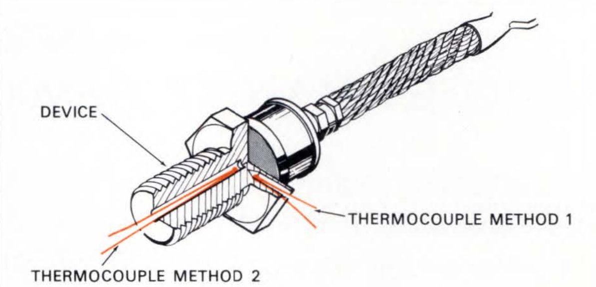


Fig. 2

metal will permit mounting the thermocouple directly under the chip.

When the header is glass sealed, or when a metal-header type is involved (such as the one on the left in **Fig. 3**) the thermocouple should be attached to the outside of the case as shown. Either soldering or welding may be used for this.

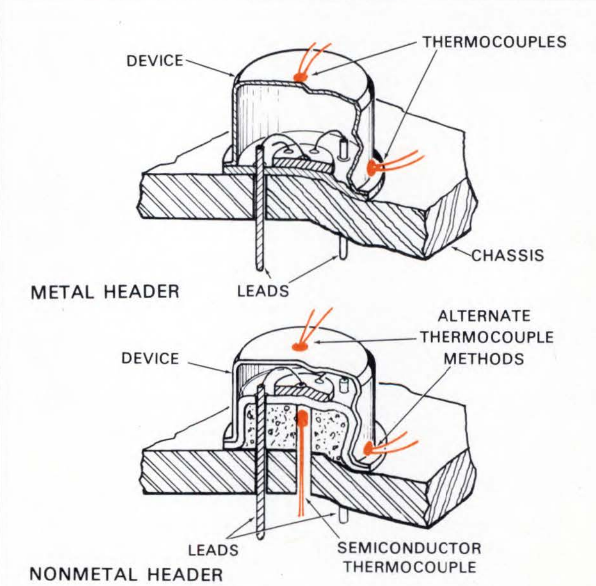


Fig. 3

Plastic packaged units. Instrumentation methods for this package type have been developed since Bulletin No. 5 was issued. In some of these devices the discrete semiconductor or IC chip is attached to a metal substrate (and to its leads) prior to being epoxy coated. In others a "sandwich" construction is used, with ceramic or epoxy chips placed outside the substrate-and-lead assembly before cementing the whole together with epoxy.

Both epoxy and some ceramics generally have poorer thermal conductivity than metals. Because of this, thermocouple placement near the metal substrate is considered better than attempting a "case" measurement through the epoxy. Such substrate measurements should be labelled "substrate temperature" rather than "case temperature", to describe their true nature more accurately.

When instrumenting epoxy types at IERC, a small-diameter hole is drilled to the substrate at a location as close as possible to the chip without degrading its operation. The thermocouple is then welded to the metallic substrate and the weld retained with a thermally-conductive, low-temperature-coefficient-of-expansion type one-part epoxy (See **Fig. 4**). Usually it is necessary to destroy at least one test specimen in order to pinpoint the substrate location accurately. Fortunately, locations are generally consistent, so once they are determined, it is easy to perform subsequent instrumentation on like units.

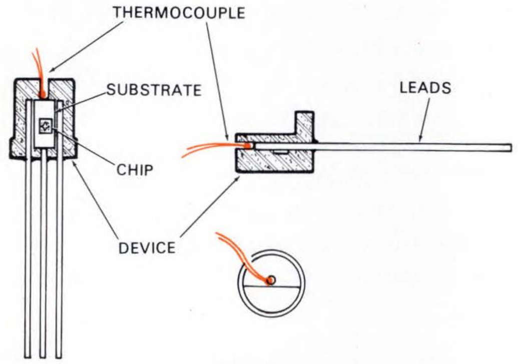


Fig. 4

Rectangular plastic packages, such as the Data X-51 case shown in **Fig. 5**, require a similar approach. The thermocouple placement is shown on the chip side, but if there is concern over chip damage it can be changed to the other side. Similarly a 14-lead DIP, as shown in **Fig. 6**, is best instrumented by carefully drilling a hole through the bottom of the plastic package to a point on the chip substrate near the center.

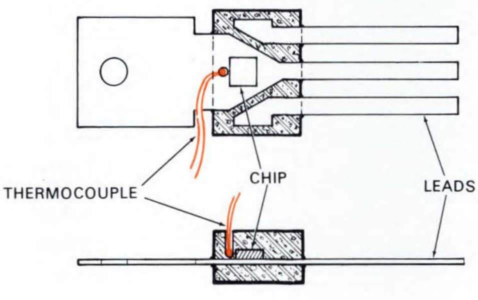


Fig. 5

Ceramic Substrates. As with the plastic package, instrumentation techniques for ceramic substrates also have been developed since components Bulletin No. 5 was issued. Accurate measurements with thermocouples in the area of major heat flow are often not practical when ceramic substrates are used. The ceramic material, usually alumina, is very difficult to drill, and in addition can cause thermal interface problems if stress-relieved.

Therefore, when the substrate is a ceramic material or the package is an integrated circuit, a thermal model is recommended for the determination of accurate junction temperatures.

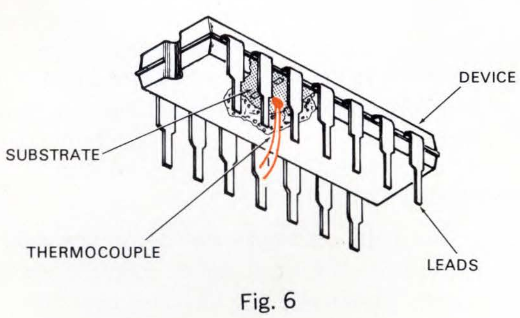


Fig. 6

Thermal Models

Thermal models should be developed so that the semiconductor placement is similar to that in the operational circuit. It is essential that the model circuit duplicate as closely as possible the size and location of the hottest anticipated thermal junction in the operational circuit. Complete electrical isolation of the die chosen for junction-temperature measurement is required. Also, a heat source separate from the sensing semiconductor is preferred. This allows a reduction in

(Continued)

the amount of test equipment and time involved.

Device-to-Dissipator-to-Chassis. When instrumenting to measure the effectiveness of heat dissipators, the thermocouples should be placed on the transistor and dissipator in such a way that measurement is across a heat flow interface.

Chassis, if metal, should be made of natural color mill-finish aluminum that has a maximum thickness of 1/8 inch. Maximum sizes for 3W, 30W and 50W power levels should be 2 by 2, 4 by 4 and 6 by 6 inches. The size is limited to avoid changing dissipator efficiency (too large a chassis can double dissipator efficiency, thus introducing an unwanted variable).

Non-thermally-conductive chassis, such as those made of G-10 or G-11 material, also should be size limited. Here, too large a chassis will actually hinder the dissipator's effectiveness. Maximum size of 6 by 6 by 1/8 inch is specified.

Constant-temperature Heat Sink. When the highest practical dissipation of which a semiconductor device is capable is needed, the device must be mounted on a constant-temperature copper or aluminum heat sink such as that shown in **Fig. 7**. Control should be provided to keep the sink temperature rise less than 5°. The sink shown has been used for loads up to 50W, but for lower power (say below 25W) short segments of the standard IERC E-4 liquid-cooled extrusion do a good job.

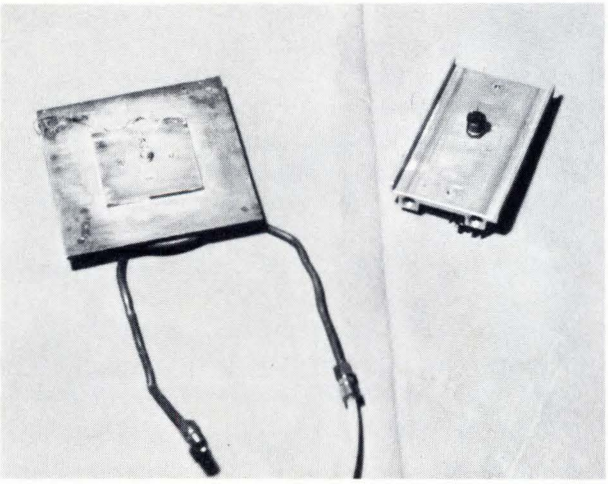


Fig. 7

Keep Them Out of Drafts! A true natural convection test can't be made if there are uncontrolled air flow patterns in the test area. Such things as doors opening or air conditioner circulation can really upset an otherwise well-planned thermal dissipation test.

One good way to get away from the effects of unwanted air currents is to enclose the test setup in a clear plastic cover (**Fig. 8**). This must be large enough (say 1 ft on a side) to allow adequate temperature stabilization. Usually an opening is provided in the top to permit a controlled circulation to prevent temperature buildup. The ambient temperature within it should be measured with a thermocouple placed at least 6 inches away from the dissipator and at the same level, shielded to prevent it from absorbing radiation from the dissipator.

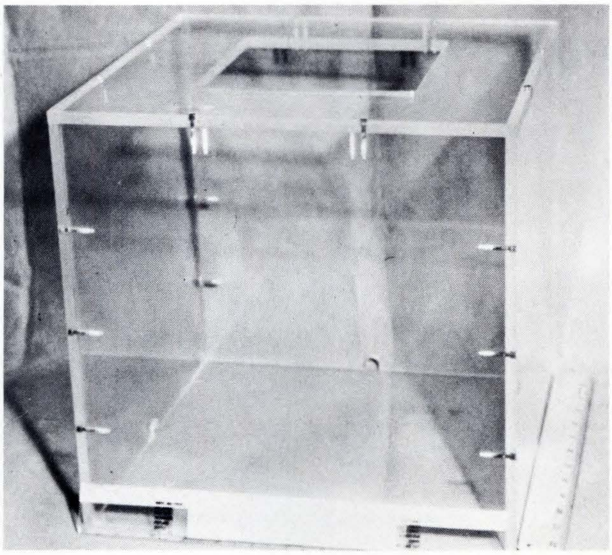
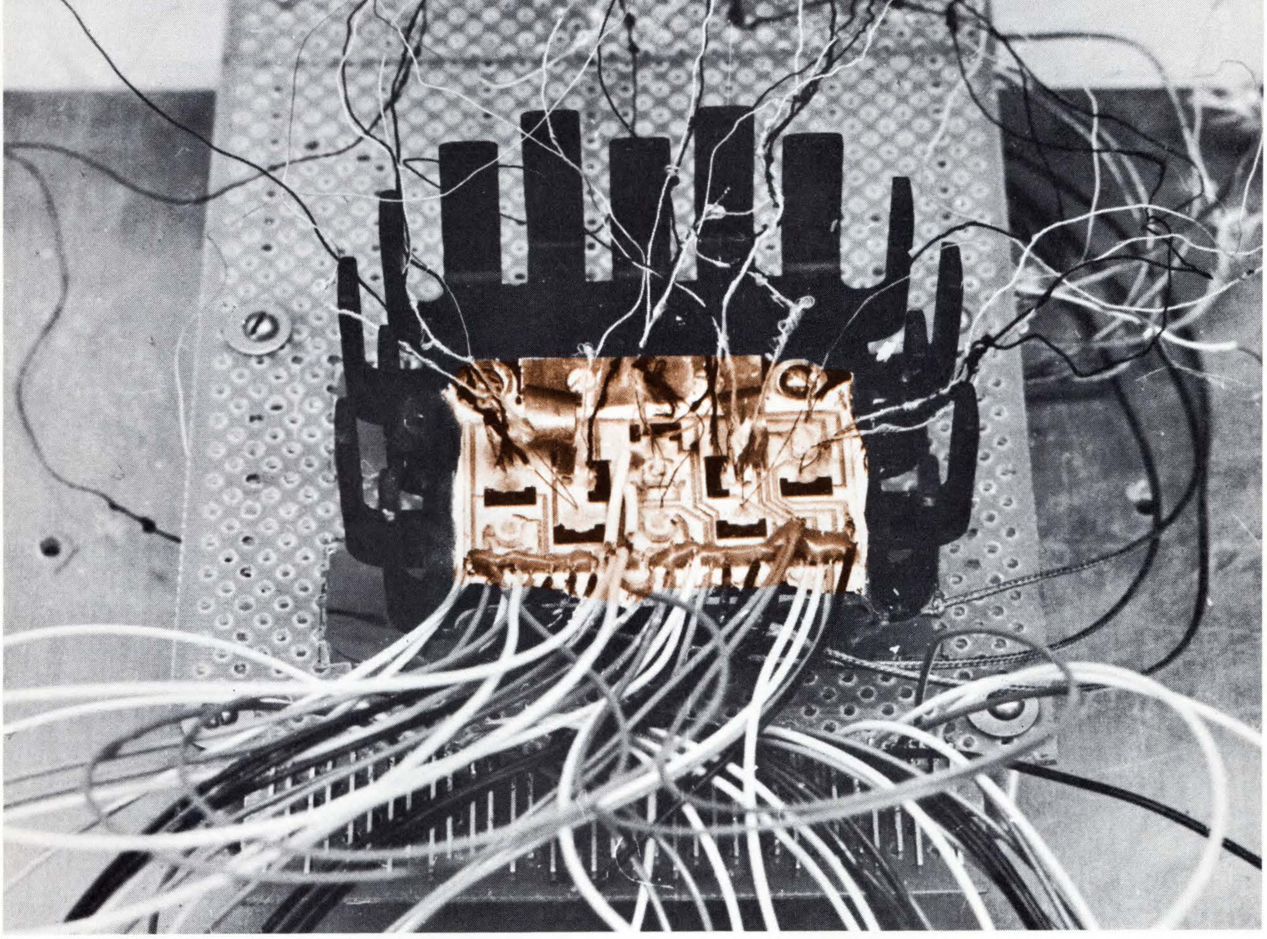


Fig. 8

Forced Air Convection. Bulletin No. 5 details specific conditions to be met when forced-air convection is used to increase the dissipator cooling. The dissipator is to be mounted on an epoxy chassis that is then placed completely inside one end of a round or square duct. The ratio of the duct cross-section area to that of the dissipator must be greater than two. Also the velocity gradient as measured in the test area without dissipator is to vary less than 10% from the average velocity (bends, buffers or air straighteners are generally used to achieve this). In the setup of **Fig. 9** velocity can be adjusted by controlling either the fan motor voltage or the air intake area.

Dissipator Hints

Up to this point, primary emphasis has been on proper placement of the test sensor thermocouples. In each instance, placement was chosen to get meaningful readings that could be correlated with the true semiconductor junction temperatures.



Multiple thermocouple sensing on a hybrid substrate tests heat sink effectiveness under operating conditions.

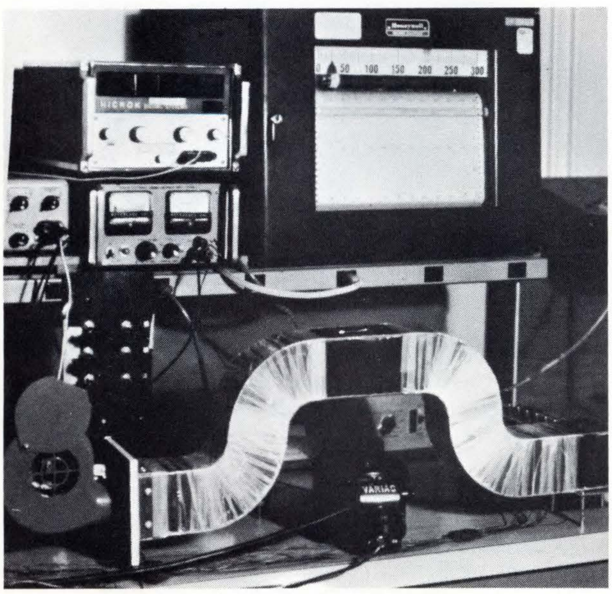


Fig. 9

Now let's place the emphasis on the determination of dissipator effectiveness. The procedure is essentially the same – only the objective differs. Our main concern is with the quality of the interface between the semiconductor and the dissipator, and that between the dissipator and the chassis (or heat sink) on which it is mounted.

The quality of a thermal interface is affected by the finish of the facing materials, the contact pressure, and by what has been used to aid the thermal transfer (for instance, silicone grease or other thermal transfer medium).

Instrumenting the dissipator as shown in **Fig. 10** will permit proper assessment of its efficiency, and also give a good check of the interface quality. The thermal resistance of a TO3 interface, for instance, should not exceed 0.5°C/W. A higher figure would be cause for investigation.

Evaluation Procedure. Bulletin No. 5 specifies that

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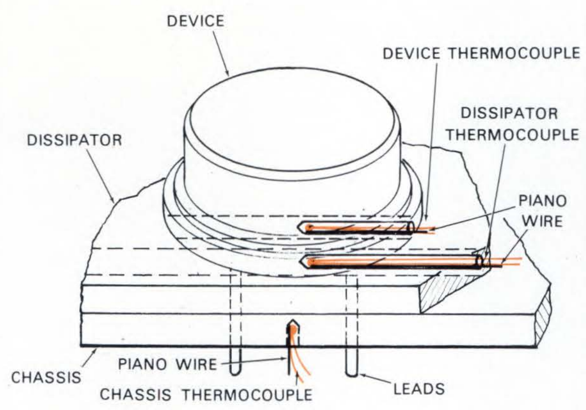

Fig. 10

to obtain technical data on the operation of dissipating devices, they are to be tested under certain specific conditions. These include 1) a control test of the semiconductor, without dissipator, mounted in normal manner on a 6- by 6- by 1/8-inch or smaller epoxy board (**Fig. 11**, curve A), 2) the same with a dissipator added (**Fig. 11**, curve B), 3) semiconductor and dissipator mounted on a metal chassis, 4) semiconductor and dissipator mounted in an air duct and tested with at least two different air flows (such as 500 and 1000 CFM (**Fig. 11**, curves C and D) and 5) when applicable, semiconductor and dissipator on a constant temperature heat sink. Note that the graphical format shown in **Fig. 11** is the standard one for data presentation of temperature vs power.

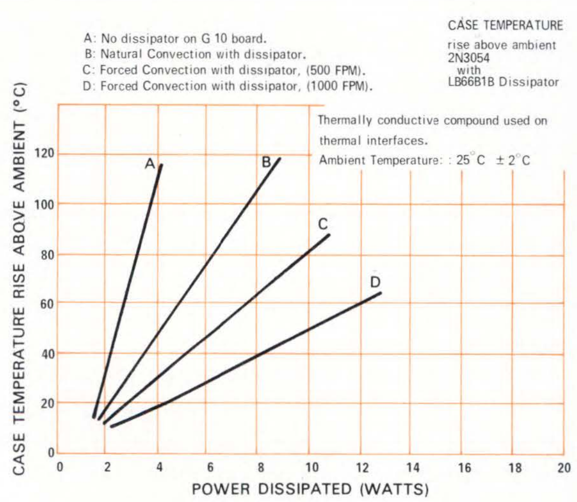

Fig. 11

All test conditions, in addition to temperatures and power should be properly noted. Included, if applicable, should be the type of thermal grease used, the finish of the surface on which the semiconductor was mounted, the presence of insulating washers, the semiconductor type, the mounting torque, the position of dissipator during test, the amount of air used for forced convection tests, the duct size and the location and mounting method of the instrumentation used.

Presenting Data. Either tabular or graphic form may be used when presenting test data, or it may be converted to thermal resistance form before presentation. In all instances the key word is completeness. Too frequently, otherwise valuable data is made unusable by sins of omission.

In Retrospect

Semiconductors are extremely unforgiving about being subjected to even short-term thermal or electrical overloads. Unlike their vacuum-tube predecessors, they have a general ability to destroy themselves on short-term overload. That's why so much importance should be attached to proper heat dissipator selection, and why standardized thermal testing and data presentation become so necessary.

A good motto might well be "Beat the heat and you've got it made!" ▭

Donald F. Goetter (left) is a project engineer with 5 years at IERC, where he develops heat dissipating hardware. He attended Pacific States Univ. at Los Angeles and is a member of IEEE.

William Anderson (right), engineering lab. supervisor at IERC for 9 years, holds a B.E.S.E.E. from Brigham Young Univ. and is a member of IEEE. Bill performs and supervises testing of heat dissipating components.

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CIRCLE NO. 17

Steve Levy of Motorola

Speaks Out on Controversies in the IC Industry

Today, many controversial statements can be made about the future of integrated circuits. For example, I might predict that MOS will conquer the world—or that bipolar LSI will become as inexpensive as MOS—or that semiconductor memories will quickly replace core memories—or that silicon LSI memories will give way to newer memory technologies—or that transistor-transistor-logic will never give way to emitter-coupled-logic.

Obviously, these statements are generalities. They are greatly oversimplified and based on an unfortunate mixture of both fact and fantasy. Let's take a look at today's controversial semiconductor technologies and see how IC technology is likely to advance during the next few years.

The MOS Market

Last year, MOS integrated circuit sales totaled about $75 million and represented approximately 15% of the total IC market. By 1974, MOS circuits should account for significantly more than 30% of the total integrated circuit market. The principle driving force behind this rapid growth of MOS use will be, of course, the very low cost per logic function performed.

If you doubt this statement, consider that the cost of an MOS logic gate function, as part of an LSI chip, is presently only a third to a fifth as much as a typical TTL bipolar logic function. In the memory area, an MOS fully decoded random-access memory is also only about one-fifth as expensive, per bit, as a bipolar random access memory. Obviously, MOS can't match the speed of bipolar, but in many applications today the cost per bit, or cost per logic gate, is far more important to the user than speed. The dramatic growth of MOS ICs can be partially explained by the fact that users are not simply applying these devices as replacements for bipolar or discrete semiconductors in existing equipment. Rather, completely new electronic products are being created with MOS.

The electronic calculator is a good example. About 10 years ago, many companies started to manufacture electronic calculators for the engineering, scientific, and business accounting markets. These early electronic calculators were, in general, bulky and expensive because of the large number of logic gates required to perform the calculating functions. The advent of MOS technology created a revolution in the calculator business. Within a year it will be difficult to find an electronic calculator that won't use MOS/LSI circuits to perform its logic.

In addition, the tremendous reductions in logic cost made possible by MOS circuits has greatly broadened the potential market for calculators. As the costs of MOS devices continue to move downward, resulting primarily from growing production volumes, the market for calculators will continue to grow in size.

Memory Arena

The use of semiconductor memories will provide another stimulus to further MOS growth in the years that lie ahead. The access and cycle times of present MOS memories already exceed the performance obtainable from a typical memory core, and MOS speeds are being further improved through the continuing refinements of processing techniques. As the art advances, semiconductor memories will begin to replace magnetic cores as the principle means for storing digital information in all types of computers, terminals, calculators, and digital logic equipment.

While the cost of semiconductor memory is already competitive with magnetic cores, the growing demand for semiconductor memory will drive production costs even lower during the next 2 or 3 years to the point where semiconductors will literally dominate the memory market. Today, MOS random-access memories are being offered at one cent per bit in large volumes, and this price will go down to about one-tenth of a cent per bit by 1974.

Certainly, one of the controversies presently being sharply debated in the semiconductor industry centers is whether MOS or bipolar technology will ultimately play the major role in serving the semiconductor memories market.

In projecting the future cost of any integrated circuit, the size of the silicon area employed must be taken into account. There is a direct relationship between cost and chip area. In memory products, they key question is, "How many square mils are used per bit of information stored?" A typical, present-day bipolar memory requires about 30 square mils per bit in a storage array. By taking advantage of some of the newer developments in the

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bipolar processing technology, it is expected that this figure will be reduced to 10 or 15 square mils per bit. A bipolar memory of this size will require an access time of about 80 nsec and consume approximately 2 mW of power for each bit in the array. If you compare these figures with a static MOS memory of approximately the same complexity, 256 bits for example, it is obvious that the bipolar memory is not significantly larger in area, but is 10 times faster; a comparison that is cited frequently by advocates of bipolar memory technology.

However, the unique advantages of the MOS transistor, such as its ability to store charge and information for appreciable periods of time on its insulated gate, has led to the development of an entire new class of dynamic random access memories which require only 6 to 7 square mils per bit. These MOS devices are smaller than the bipolar devices used in random-access memories, yet contain at least four times the number of bits per chip and require only one-twentieth the power. MOS memories built with these devices are widely available today, and at prices fully competitive with magnetic cores.

Coming—New Technologies

During the next few years, we will see a succession of new MOS technologies. Silicon gate complementary MOS is already here, and n-channel techniques are being applied in the development of very high-speed, low-power MOS random-access memories.

With each step forward in MOS technology, definite improvement in the performance of a particular device can be anticipated. At the same time, however, it is also likely that there will be a corresponding increase in associated processing cost. Ion implantation, for instance, can be employed to increase the speed or reduce the size of MOS devices, but this process also increases manufacturing cost because it adds another step in the processing cycle. Changing the technology involved in building MOS devices to improve performance, increase speed, or reduce the size of the device also tends to decrease the cost advantage of MOS over bipolar circuits.

The real world of semiconductor integrated-circuit selection is not made up of a black-and-white choice between MOS or bipolar, but of continuous investigation of a multitude of combinations of performance, speed, size, or cost.

Obviously, we are not dealing with just a single MOS technology, just as there is no single bipolar technology. Only when the equipment designer explores all of the alternatives available to him, and keeps in mind that there are considerable performance-speed-cost trade-offs involved in his choice, is he likely to make the optimum selection.

What about amorphous semiconductor glasses and magnetic bubble effects? Will these new technologies provide yet another generation of semiconductor memories? I believe it's quite clear that the next generation of memory systems will be built using the kind of bipolar and MOS semiconductor random-access memories that are already being made today. There are two important reasons for this. First, the design and manufacturing technologies for current memory circuits are very well developed. Second, all of the interface circuitry and design technology needed to address these circuits, to refresh them, to write into them, and to read them are well developed and thoroughly understood.

Reliability—a Key Factor

A very important factor, however, which cannot be overlooked in evaluating a new memory technology is, of course, reliability. Because of the very large number of bits which go into most memory systems, reliability is critical. The reliability of integrated circuits is certainly well documented, and much of the equipment which is now commonplace owes its success to the high reliability which ICs have been able to provide.

Will new technologies provide the same degree of reliability? Will it be possible to build new devices in high volumes without sacrificing quality? Can the new devices be successfully fabricated in a production line environment rather than in a controlled laboratory environment? These very important questions remain to be answered.

Let's move on now to another semiconductor controversy—transistor-transistor-logic vs emitter-coupled-logic. At this time, the TTL logic family is entering the mature phase of its primary life cycle, although the emergence of Schottky-diode TTL will help perpetuate the use of TTL logic to a limited extent.

Soon, designers are going to have to turn to a faster, nonsaturated logic family in order to attain the speeds they're talking about for the next generation of equipment. The most likely prospect continues to be emitter-coupled-logic.

Trying to run saturated logic at the desired high speeds, as you know, can result in some severe problems, such as systems noise.

A Look at ECL

Emitter-coupled-logic has been with us since about 1963, and one of its early drawbacks was that it was too fast, too soon. In other words, designers didn't require the speed it had to offer. But the situation has been changing, and, as proof, look at the sales of emitter coupled logic products; sales grew by over 48% from 1969 to 1970. An additional growth of about 10% is predicted for this year. The growth of ECL is continuing, primarily to meet needs of computer manufacturers. However, a growing number of general logic applications are also emerging, such as the front ends of high-speed counters, that are beginning to undergo conversion to emitter-coupled-logic.

Granted, when emitter-coupled-logic was first introduced, it had several negative aspects that quickly became evident to equipment designers. There was a lack of complex functions. There was relatively high power dissipation. There was little or no multiple sourcing available. And, the cost of this high speed, nonsaturated logic was high.

Today, all of these problems can and are being solved by the semiconductor industry.

The original lack of complex functions can be blamed directly on the semiconductor manufacturers. The majority of early emitter-coupled-logic design efforts were centered in high speed, custom programs, somewhere in the 1 and 2 nsec region. Most of this custom work was for large computer manufacturers. As a result, the industry's efforts were diffused. Many custom programs were conducted where comparatively simple elements, such as quad two gates, were duplicated in many different ways, and employing every possible configuration of pin connection, power voltage and logic level. Whatever could possibly be varied was varied. There was absolutely no sense to all of this since the duplication benefited neither the customer nor the manufacturer. As a result of this diffusion of effort, emitter-coupled-logic still has fewer complex elements than TTL, but the situation is rapidly changing. Several manufacturers are now using the knowledge gained in their custom programs to build a line of standard complex emitter-coupled-logic functions.

Less Power Needed Now

The drawback of high power dissipation is being solved by cutting the current switching power of ECL devices in half. This not only reduces the power dissipation but also makes the logic easier to use, and reduces the cooling and power supply requirements in the system. One major computer manufacturer, for example, found that by using new emitter-coupled-logic, the need for cooling its computer with refrigerated air was eliminated. Since ordinary room temperature is adequate for cooling the machine, a significant cost saving has been realized.

The lack of multiple sources for emitter-coupled-logic also originally stemmed from the fact that the early emphasis was placed on custom design. This problem will solve itself as more and more standard ECL circuits are introduced and the market continues to grow.

The remaining problem—the high cost of emitter-coupled-logic—is also being quickly solved by the industry. Today, several standard emitter-coupled-logic circuits are being offered at prices comparable to Schottky-diode TTL. And, as semiconductor manufacturers are able to move this logic family into higher volume production, prices can be expected to drop lower.

The growth of TTL over the past few years has laid the groundwork for the present rapid development of emitter-coupled-logic. In addition, an advantage that emitter-coupled-logic has over TTL is that it is basically an open-ended technology. There are still significant improvements that can and will be made in emitter-coupled-logic. At present, emitter-coupled-logic accounts for approximately 10% of the total integrated-circuit market, but this percentage should grow dramatically during the next 5 years.

We will see major developments taking place in the MOS, bipolar, and emitter-coupled-logic technologies in the years that lie ahead. With so many different developments in the semiconductor technology taking place at the same time, the equipment designer will have to keep abreast of the developments as they occur and attuned to how each change affects the important cost/performance ratio for his particular product.

Motorola's Steve Levy

Stephen L. Levy became vice president and general manager of Motorola's Semiconductor Products Division in August 1968, when C. Lester Hogan left to head up the Fairchild Camera & Instrument Corp. Levy joined Motorola in 1964, progressed to a corporate vice presidency in 1967, and became assistant general manager of the semiconductor operation in February 1968.

Prior to coming to Phoenix, Levy held managerial posts with Philco and Sylvania. He was at one time manager of transistor operations for Philco's Lansdale Division. Earlier in his career he taught at RCA Institute in New York.

Levy has a long active record of service with Electronic Industries Association (EIA) committees which includes several semiconductor group chairmanships.

Born in Manhattan, Levy grew up in Cedarhurst, Long Island, and then attended Brooklyn Polytechnic Institute. Steve and his wife Sophia have two children, Barbara Jo, 15, and Susan Carol, 13.

Bill Hittinger of RCA
Also Sees Major MOS Thrust

The system designer today already has a variety of technologies from which to choose and his choices will expand as MOS, linear, bipolar and power hybrid technologies move into greater relative prominence during the next 5 years. Newer integrated circuits will not cause the demise of older forms; rather, they will lead to more elegant applications and hence wider application of electronics in the world at large.

I feel that the greatest growth will occur in MOS. This segment of the IC market will grow from about $100 million in 1970 to about $500 million in 1974 in domestic and export business. In addition, the rate of growth in MOS production in Europe and in the Far East will at least equal the U.S. rate, although the base will be significantly smaller. These figures may turn out to be conservative, since MOS integrated circuits are opening some new markets, such as semiconductor memories in mainframe computers and automotive applications.

To date MOS integrated circuits have been substantially p-channel devices, which have been applied narrowly in certain unique uses such as desk calculators and peripheral memories. Today the application spectrum is as wide as the entire electronic industry.

The MOS thrust will develop through a combination of performance gains and greater cost effectiveness. The technology for producing high-performance devices is available now. Competance has been demonstrated in such techniques as shallow diffusions, silicon gate, ultraclean oxides, ion implantation, and new dielectrics. As a result, MOS devices offer a combination of compatability with DTL and TTL, extremely low power consumption, high packing density, and unique circuit functions resulting from the ability to combine logic and memory with ease in the same chip. Complementary MOS in particular offers quiescent power dissipation which typically is many orders of magnitude less than that of comparable p-channel MOS and bipolar integrated circuits, negligible change in operating characteristics over wide temperature extremes, insensitivity to a wide range of the single-bias supply voltage, exceptionally high ac and dc noise immunity and logic speeds up to 10 MHz without premature turn off. With the advanced low threshold complementary MOS available today, the circuit designer has the simplest, most flexible logic building block available for all but very high speed functions.

MOS cost effectiveness has been demonstrated for highly complex circuits through a combination of improved process technology and manufacturing techniques such as design automation, automated mask making, and highly effective and improved dc and functional test equipment. These techniques, that have been improved greatly within the last year and will continue to advance, will make it possible for the supplier to cope with the logistics of supplying a multiplicity of circuits at the same time in an economic way.

Although MOS will provide the major IC thrust in this decade, saturated and nonsaturated (ECL) bipolar logic and memory capabilities will certainly increase.

Higher packing densities are being achieved with transistor cells in the 1 to 12 sq mil range. Clearly such high density, when achieved in large manufacturing volume, combined with high speed will find major application in advanced systems of the decade.

Linear ICs will continue the steady growth of the past few years. The processing advances mentioned before for MOS have also made it possible to design circuits that interface easily with other parts of electronic systems, either directly or with many fewer outboarded components. Truly it is possible now to provide the functional devices spoken of with expectation some years ago. Such new components of great potential utility as operational transconductance amplifiers and high performance analog switches are now becoming available.

One can also expect the application of integrated-circuit concepts, particularly hybrid technology, to be applied to power devices. It is now possible to design cost-effective power systems through the use of thick-film techniques and standard active power device chips that will make for more stable, compact power supplies at lower cost than can be done with discrete devices.

All of these advances in the integrated-circuit market will be paced by packaging technology. It is quite clear that present packaging methods, whereby IC chips are placed into individual containers such as the DIP ceramic package and then assembled onto printed-circuit boards, are limiting in cost effectiveness. Today the hermetic package often represents the largest element of cost in a complex circuit. Additionally, the multiplicity of wire bonds required per device limits the reliability when quantities are involved in large systems. A major effort will be required in the 1970s to overcome present limitations. Such concepts as beam-lead sealed-junction chips assembled onto ceramic substrates with film interconnections will have to be incorporated to remove the limitations of present techniques. Fortunately, such concepts are in the engineering stage today and will be practical in the near future. ▭

RCA's Bill Hittinger

William Hittinger was named vice president and general manager of RCA's solid-state division in April 1970. A pioneer in the semiconductor industry, he played a leading role in the investigation of germanium properties before the invention of the transistor at Bell Telephone Labs. While at BTL, he helped develop the intrinsic barrier transistor and the first diffused junction transistor (1956).

In 1966 he was installed as president of Bellcom, a jointly owned venture of AT&T and Western Electric. Bellcom is best known for its systems engineering involvement in the manned space flight program. After 2 years at Bellcom, Hittinger moved into the presidency of General Instrument, a post he held for the 2 years prior to his joining RCA.

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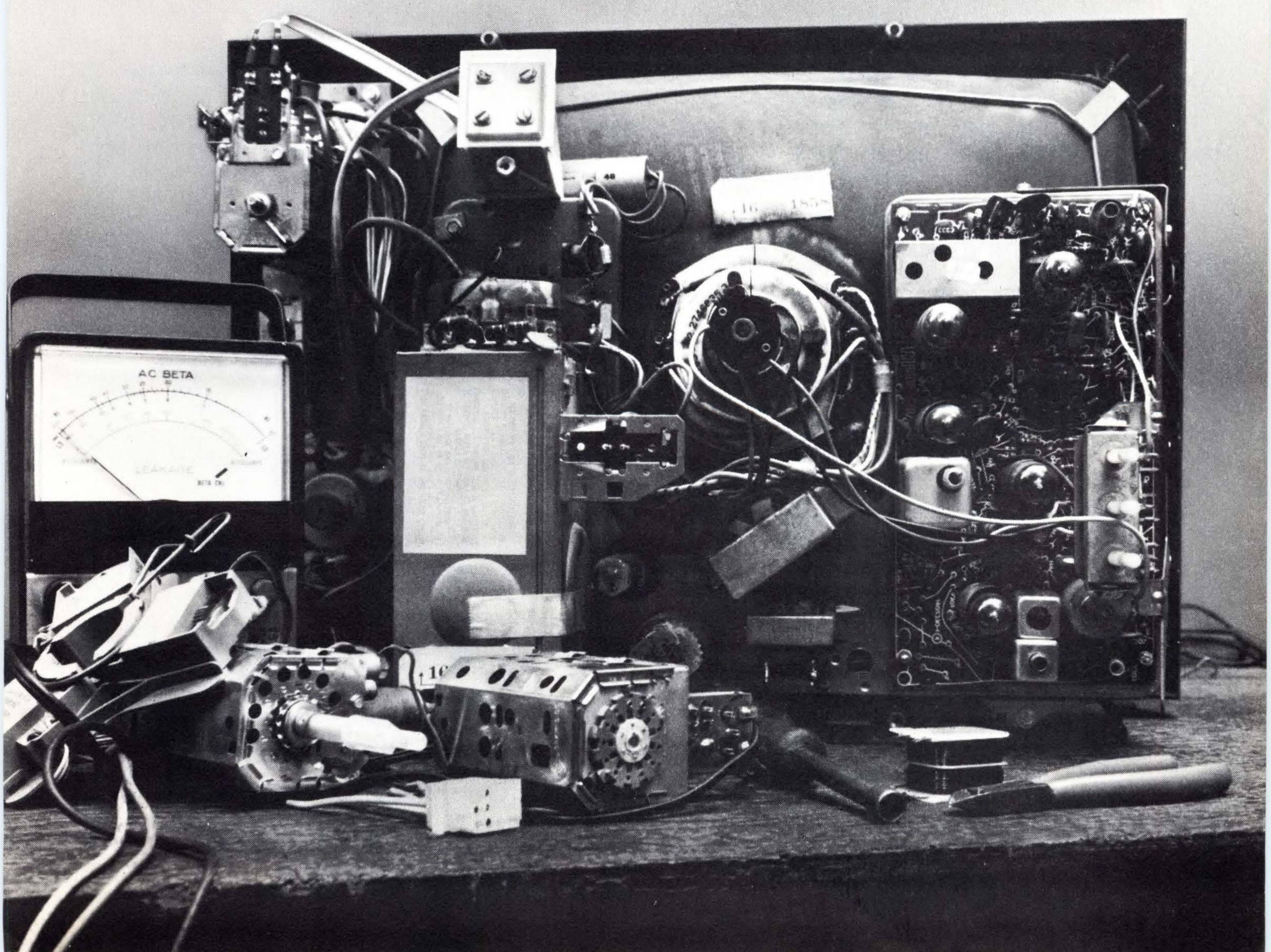

The Design Of a Wideband DC Coupled Differential Switch

by Don N. Lee

The dc-coupled differential switch is widely used for the processing of low-level signals. This circuit must have a wideband response and a high common-mode rejection ratio. In addition, no pedestal should be generated due to switching action. The circuit to be described meets these requirements and has the following specifications: bandwidth from dc to over 100 MHz, common-mode rejection of over 40 dB at 100 MHz, gain linearity of 0.5%, maximum turn off and turn on times of less than 50 ns, dc stability better than ±0.2 mV/8 hr, equivalent series Z greater than 20 MΩ shunted by 3 pF and a pedestal of less than 50 mV.

Why use a broadband switch?

In signal processing, the signal of interest is often immersed in high level noise. For example, in the testing of magnetic core and plated wire memories, the true signal applied to the sense amplifier is usually preceded by disturb signals created by the previous write and inhibit drive currents. In many cases, the disturb signals are orders of magnitude larger than the true signal. Typically, the magnitude of the disturb signals is greater than two volts while the true signal is less than 50 millivolts. In these applications, the sense amplifier will be severely overloaded by the disturb signals and must be fully recovered before the arrival of the true signal. For fast memories, the total cycle time is often less than 500 ns, this implies that the recovery time of the sense amplifier should be less than 100 ns in order to achieve results which are independent of the timing of the drive currents. Unfortunately, even the fastest sense amplifiers require 600 ns or more to recover from the severe overloads which are encountered in memory testing, especially in the testing of memories having common sense and digit windings. For these applications, it is necessary to isolate the sense amplifier from the sense winding during the disturb signals. One way of doing this is to place a normally open switch in series with the sense amplifier input and gate it on just prior to the arrival of the true signal. Thus, the sense amplifier is prevented from being overloaded and the maximum repetition rate of the system is only limited by the speed of the switch.

Switching devices

A number of devices can be utilized to switch low level signals. These include reed relays, bipolar transistors, field effect transistors and diodes. Reed relays have slow turn on time and induced noise caused by contact bounce. Bipolar transistors operated as on-off switches have sizable offset voltages which are typically in the millivolt range. FETs possess the advantage of zero offset

Author: Mr. Lee is manager of research and development at Computer Test Corporation in Cherry Hill, N.J.

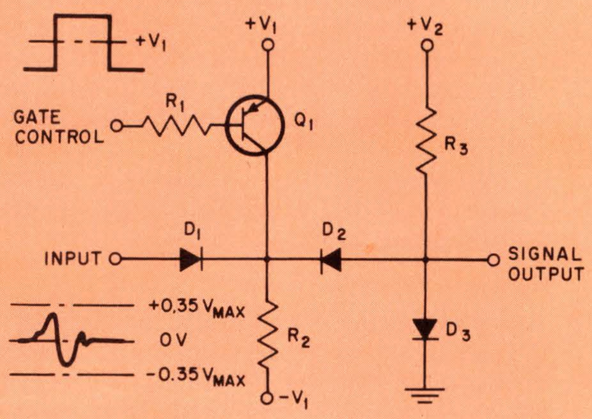

Fig. 1A. Basic diode gate.

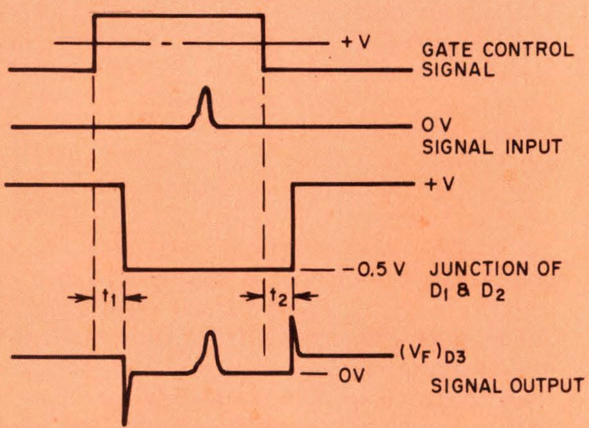

Fig. 1B. Timing diagram of gate.

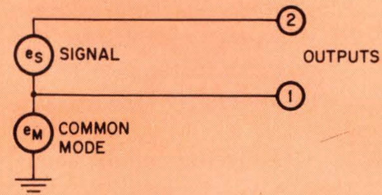

Fig. 2A. Differential signal with common mode.

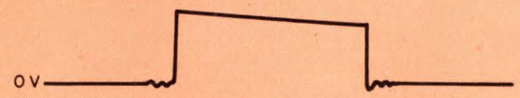

Fig. 2B. Signal at output 1 with respect to ground.

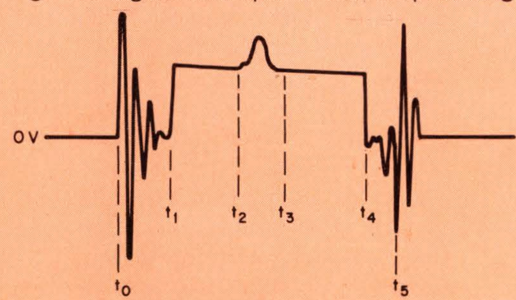

Fig. 2C. Signal at output 2 with respect to ground.

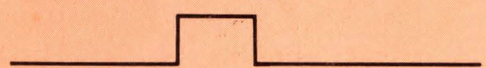

Fig. 2D. Gate control signal.

Fig. 2E. Gate output signal.

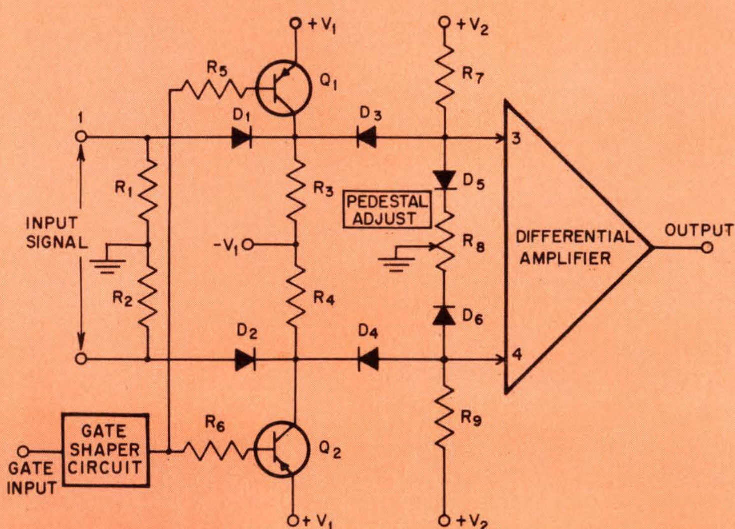

Fig. 3. Differential diode gate.

voltage, but have the disadvantage of capacitive feedthrough of the switch voltage. Diodes are extensively used to gate high frequency low level signals. They have been applied in sampling oscilloscopes and sample and hold equipment. In these applications, the diodes are bridge connected and require push-pull strobe circuitry. However, if the gating response time required is slower than 10 ns, a simplified diode gate circuit can be used.

Single-ended broadband switch

This circuit is shown in Figure 1A and consists of two diodes, D_1 and D_2 connected back to back. The circuit is only intended for low level signals and the maximum positive signal transmitted is limited to +350 mV by the clamp diode, D_3. The switch is controlled by the Gate Control signal. When the Gate Control signal is less than $+V_1$, Q_1 is on and forces the junction of D_1 and D_2 to be approximately at $+V_1$. This causes D_1 and D_2 to be reverse biased and disables the switch. When the Gate Input signal is greater than $+V_1$, Q_1 is turned off and the switch is enabled. For proper operation, $+V_1$ must be more positive than the maximum signal input encountered. Input signals greater than $+V_1$ will be transmitted independent of the Gate Control signal. The timing diagram of the circuit for a positive input signal is shown in Figure 1B. Note that there is a time delay between the actual opening and closing of the switch and the Gate Control signal. This is primarily caused by the on-off delay of Q_1 and is minimized by using a fast device for Q_1. A major disadvantage of this circuit, is the change in the output dc level when the circuit is gated on and off, as illustrated in the output waveform of Figure 1B. This gating pedestal is equal in magnitude to the forward voltage drop of the clamp diode D_3, and can be very objectionable. The pedestal is eliminated by connecting two gate circuits in a differential connection and using their outputs to drive a differential amplifier.

Broadband differential switch

In magnetic memory testing, the majority of the signals processed are differential as shown in Figure 2A. The signals are between two output lines in conjunction with large common mode disturbances. Figures 2B and 2C, show the signals on outputs 1 and 2 as they appear with respect to ground. The common mode disturbance appears between t_1 and t_4 while the true signal appears between t_2 and t_3. The objective is to design a circuit, which upon application of a Gate Control signal, shown in Figure 2D, results in the desired output signal of Figure 2E. In this application, the differential switch must reject the common mode signal during the time it is enabled. Such a circuit is shown in Figure 3 and consists of two diode gates connected differentially with their two outputs driving a differential amplifier. The operation of each gate is identical to the circuit previously described with the wave-

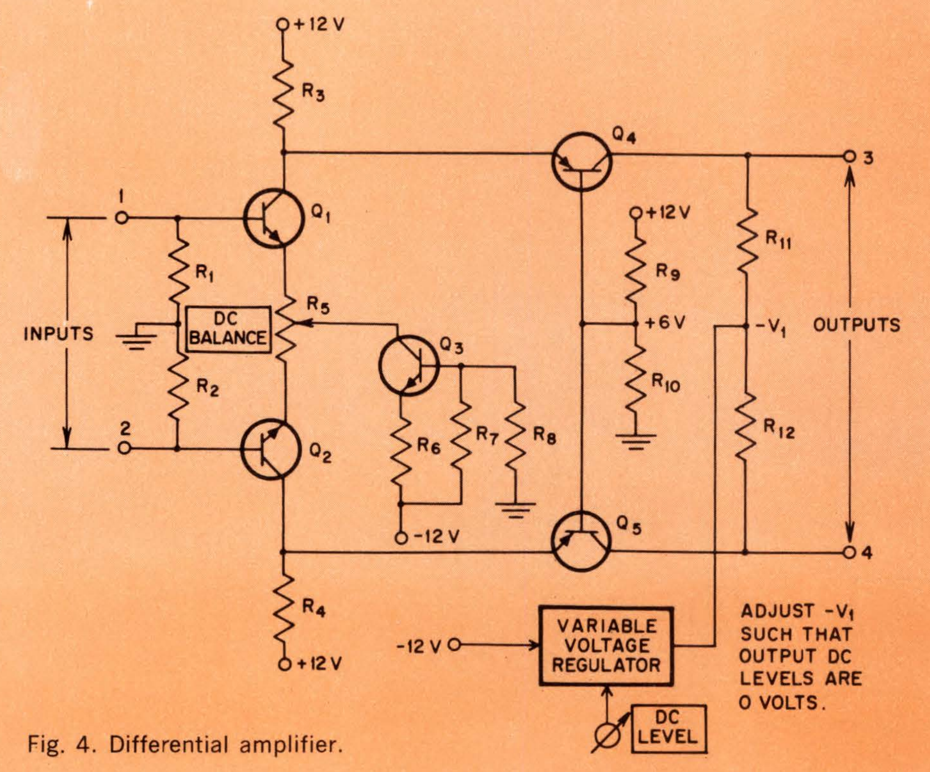

Fig. 4. Differential amplifier.

forms similar to those shown in Figure 1B. However, in this circuit, the differential amplifier sees only the difference between the two outputs. Since the gating pedestal appears on each output, it is treated by the differential amplifier as a common mode signal and is rejected. For maximum cancellation, both pedestals must be equal and R_8 is provided as an adjustment to equalize the two amplitudes. The entire circuit is balanced and thermal drifts in the components tend to cancel. By using a matched quad for diodes D_1 through D_4 and a matched pair for D_5 and D_6, the overall circuit can be made extremely stable with respect to temperature and time. The spikes generated at each output during the leading and trailing edges of the Gate Control signal appear as common mode to the differential amplifier and tend to cancel. Maximum cancellation of these spikes is achieved by matching Q_1 and Q_2 for equal values of C_{OB} and on-off times. In practice, exact cancellation is not critical if sufficient time (at least 20 ns) is allowed for the switching transients to settle out before the true signal appears.

To obtain wide bandwidth, fast diodes must be used. A good choice of diodes for this application would be hot carrier devices matched for equal forward voltage drop over a range of forward current and operating temperature. These diodes have the desired characteristics of low capacitance, low stored charge and high conductance. One of the limiting factors in bandwidth are the time constants formed by the C_{OB} of Q_1 and Q_2 with R_3 and R_4. Therefore Q_1 and Q_2 should be chosen first on the basis of low C_{OB} and second, on the basis of low storage time. The primary limitation in bandwidth is the differential amplifier. For good results, the differential amplifier must have these properties: 1) high frequency response, 2) high frequency common mode rejection, 3) thermal stability, 4) good gain linearity, 5) low noise, and 6) zero dc offset.

A circuit which meets the above criteria is shown in Figure 4. Specific voltage values are called out to simplify the circuit descriptions, however, other values of voltages will work just as well. This circuit is a straightforward cascode differential amplifier composed of the differential pair, Q_1 and Q_2, and the grounded base stages, Q_4 and Q_5. To provide the high common mode rejection required, the emitter currents for Q_1 and Q_2 are supplied by Q_3 connected as a constant current source. The positive level shift caused by the npns, Q_1 and Q_2, is negated by using pnps for Q_4 and Q_5. The output dc levels are adjusted for zero volts by varying the value of the voltage applied to the junction of R_{11} and R_{12} $(-V_1)$. This voltage is supplied by a variable voltage regulator and should be adjusted so that its output magnitude is equal to the voltage developed across R_{11} and R_{12} by the quiescent currents of Q_4 and Q_5. Slight mismatches in V_{BE} of Q_1 and Q_2 will cause the output dc levels to be unequal. A dc balance control, R_5 is provided to equalize the two outputs.

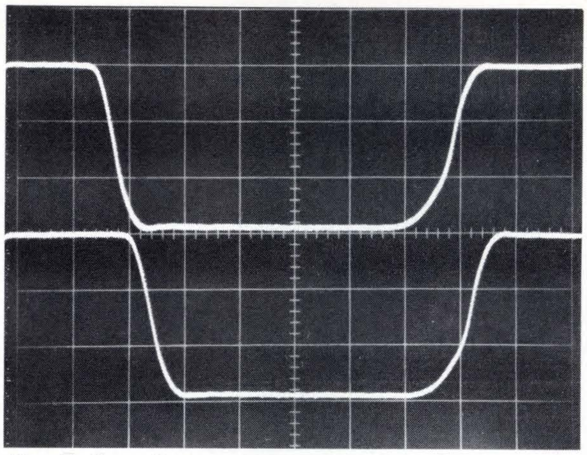

Fig. 5. Sampling scope presentation of input versus output where the horizontal scale is 10 ns/div and the vertical scale is 5 mv/div. The upper trace is the input and the output is the bottom trace.

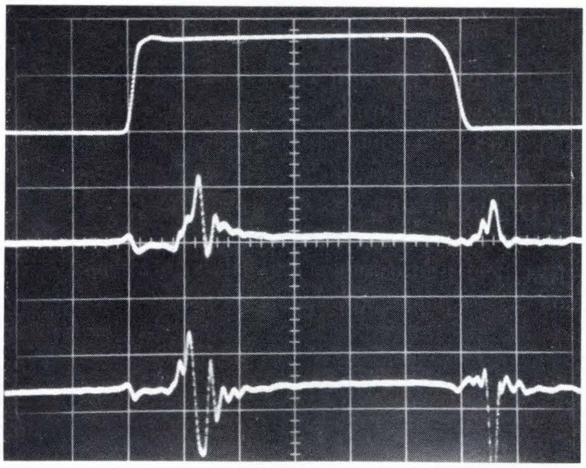

Fig. 6. Sampling scope presentation of switching transients. The top trace is the gate input, with a vertical scale of 2 V/div and a horizontal scale of 20 ns/div. The middle trace is output 3, with a vertical scale of 50 mV/div. The bottom trace is output 4, with the same scale factor as output 3.

The differential switch and differential amplifier were combined in a switch developed by Computer Test Corporation for use in its memory test systems. Production units of this type exhibit exceptionally clean pulse response as shown by the waveforms obtained on a sampling oscilloscope in Figure 5. Notice the absence of ringing and other forms of pulse aberrations on the output waveforms. This indicates that the high bandwidth of the switch was obtained without the use of peaking techniques commonly employed in high-frequency amplifiers. The gating transients at the output of the switch is shown in the sampling oscilloscope presentation of Figure 6. This photograph shows that the gating transients last for a duration of less than 20 ns and that the gating pedestal is virtually nonexistent.

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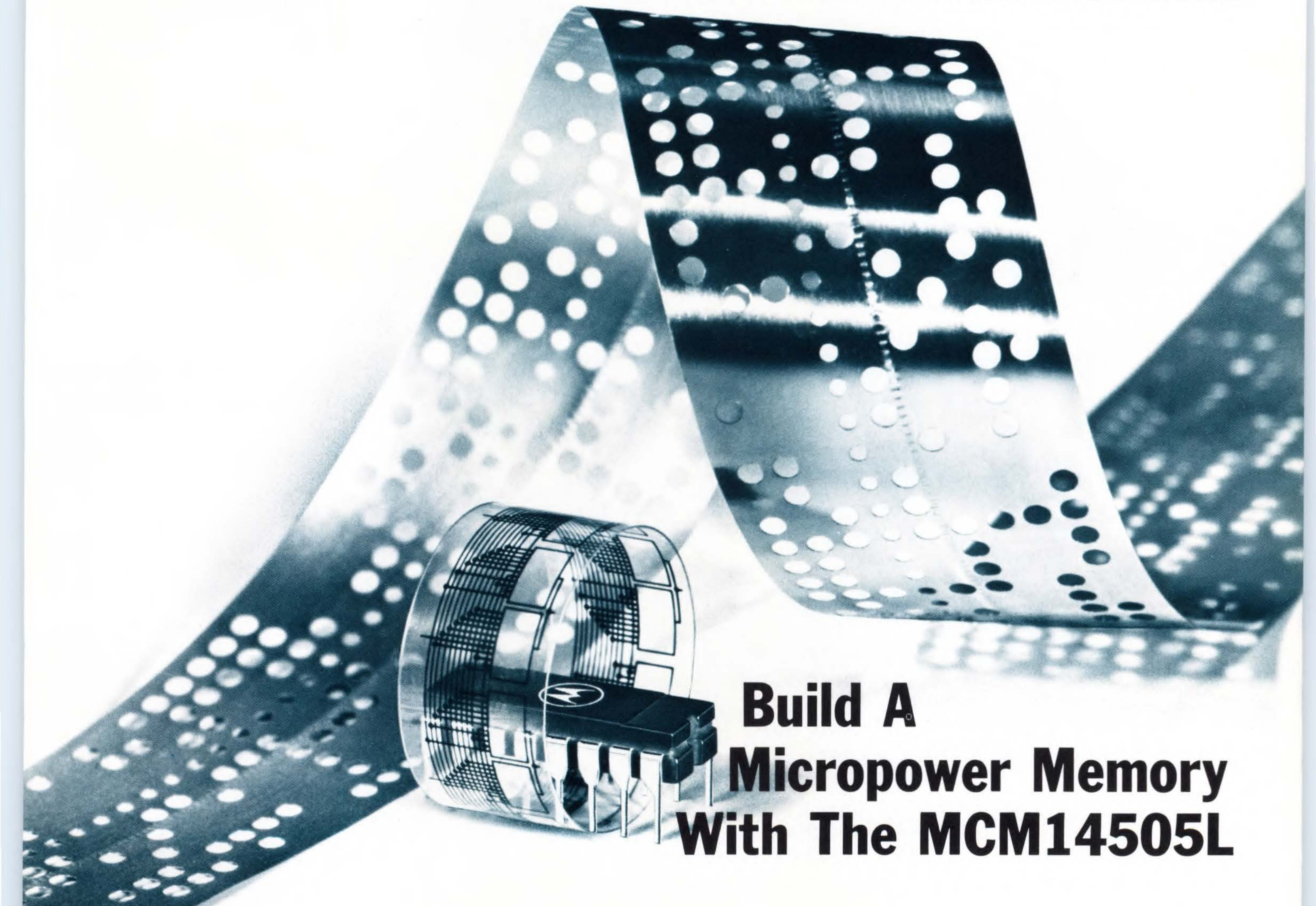


Build A Micropower Memory With The MCM14505L

The solution to the problem of developing a micropower, random access memory system of medium speed is simply to use the best complementary MOS building block. And the new 64-bit read-write MCM-14505L is simply – the best.

This fully decoded McMOS memory is unparalleled for use in battery powered systems. Operation at a 1 MHz cycle rate requires only 2 mW of power while at 1 KHz, dissipation is down to 25 μW. In a static state the power requirement drops to less than 1 μW (typically 0.3 μW).

Other outstanding McMOS features are also shared by the new memory: noise immunity is equal to 45% of V_{DD} (typ), and a 4.5 to 18 V supply voltage range that can be lowered to 3 V on special order. Single supply operation, either polarity, is standard for McMOS.

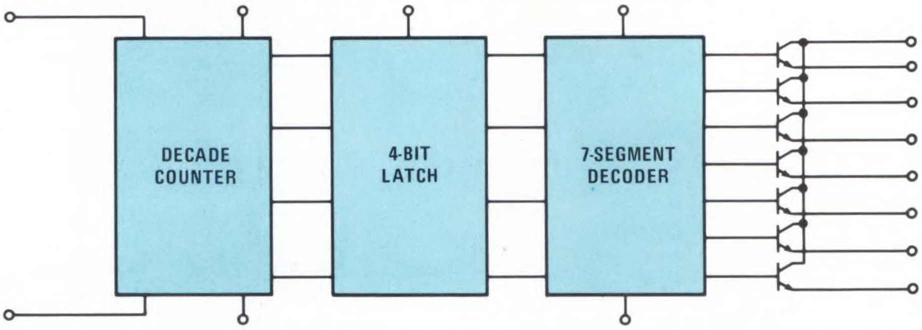
As a basic unit for medium-speed systems – typical MCM14505L times are 200 ns access, 275 ns cycle – wired-OR output capability and triple enable lines make the device flexible enough for easy expansion into a variety of memory configurations.

Separate input/output lines and a single read/write control line are provided. All inputs have diode protection and are fully buffered.

The MCM14505L is available now from Motorola distributors in 100-up quantities at only $25.00 per memory.

For details, circle 51

MC4051 Features "One Chip" Driving For Digital Displays



The new MC4051 Counter-Latch-Decoder joins the previously announced MC4050 CLD to provide designers with a current sourcing device for use in active high systems as well as a current sinking, active low part.

The MC4051 includes on a single chip, a decade counter, a four bit latch, a seven-segment decoder and display drivers. In operation, the counter generates a count-sum in natural binary coded decimal format. The four bit latch holds the data during a sampling period while the decoder/driver generates outputs suitable for switching most solid-state monolithic seven-segment displays having separate anodes and a common cathode connection.

The MC4051 differs from the MC-4050 in that it operates in the active high mode and sources current: up to 40 mA at a 10% duty cycle or 15 mA at a 100% duty cycle.

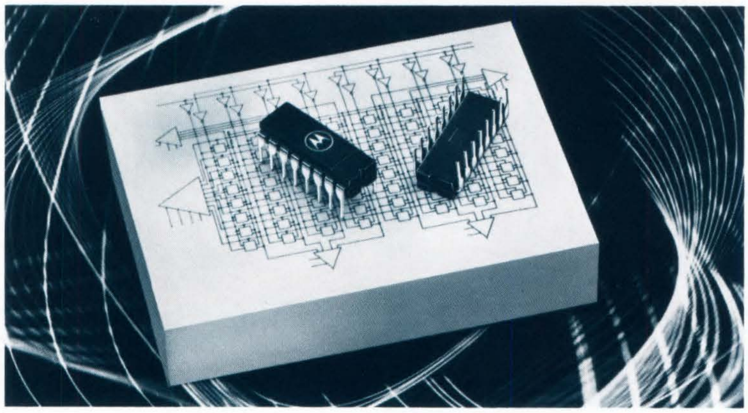
Like the MC4050, the MC4051 provides lamp blanking for intensity modulation, a lamp test input for segment verification, and automatic suppression of leading zeroes for easier display reading.

The MC4051 is available in the economical 16-pin plastic dual in-line package. Its 100-up price is $9.80.

These devices can bring you immediate savings of 30% per display, reduced wiring costs and increased connection reliability. Switch over to "one chip," driving – you'll appreciate the savings.

For details, circle 52

MCM4064L is an economical bipolar element for high-performance memory systems. Its full TTL compatibility and fanout > 9 lead to simple, efficient application.



MCM4064 64-Bit MTTL RAM Offers Speed, Price Advantages

Designers of high speed cache or buffer memories can now call upon a versatile bipolar element – Motorola's new MCM4064L 64-bit RAM. Organized as a 16-word by 4-bit array, the MCM4064L utilizes Schottky-diode-clamped transistors for fast switching speeds, and Schottky clamp diodes on all inputs to minimize line reflections. Minimum access time is 15 ns and maximum is specified at 60 ns.

Address decoding is performed on chip providing 1-of-16 decoding for the four address lines. Separate data in and data out lines, together with a Chip Enable input, facilitate easy expansion of memory capacity. A Write Enable is also provided that permits data presented at the data in lines to be entered in the address storage cells. When writing, the Data Out level is the complement of Data In.

Large system designs can be readily accomplished through use of the Chip Enable feature and the memory's wired-OR output capability. A 512-word by 8-bit memory system is detailed on the MCM4064 data sheet illustrating the versatility of the device.

Available in the 16-pin dual in-line ceramic package (suffix L) the MCM-4064L is priced at $11.55 (100-up price), approximately 50% less than you're paying. Call your Motorola distributor for evaluation devices today.

For details, circle 53

1024-Bit MOS RAM Provides Low Cost, Memory Capability

Beat core and plated wire size and cost in your mini-computer, main-frame or bulk storage with Motorola's MCM-1173L 1024-bit MOS read/write memory. Its 1024-word by 1-bit organization provides maximum word capacity, and bit expansion is simply a matter of connecting additional MCM1173L's in parallel.

The memory is designed with an array of tiny three-transistor storage cells and associated support circuitry arranged as 32 rows by 32 columns of dynamic storage elements. Dynamic information storage is achieved through use of MOS gate capacitance.

Low address-line capacitance of 2.5 pF (typ)improves systems speeds and, with the output circuits' high ON/OFF current ratio, simplifies bipolar interfacing. Drive power requirements are low compared to other high-threshold MOS, and power dissipation is way down at 50 μW/bit. Access time is specified at 40 ns and cycle time at 800 ns.

An important reliability factor is contributed by diode protection on all inputs. The chip select clock signal is not required to refresh stored information. The MC1173L is available in both 24 and 22-pin dual in-line ceramic packages. Pricing is attractive . . . $28.00 in 100-999 quantities, and even in medium quantities prices are below 1¢ per bit.

For details, circle 54

IC Hammer Driver Bangs Out 6 Amp Pulses

Take the hybrid integrated circuit route to single-unit operation of high-current loads from either TTL or DTL inputs. Motorola's new 120 V MCH2890 hybrid IC dual hammer driver handles high speed printers and paper-tape punches, and operates stepping motors, relays, and computer-controlled plotters.

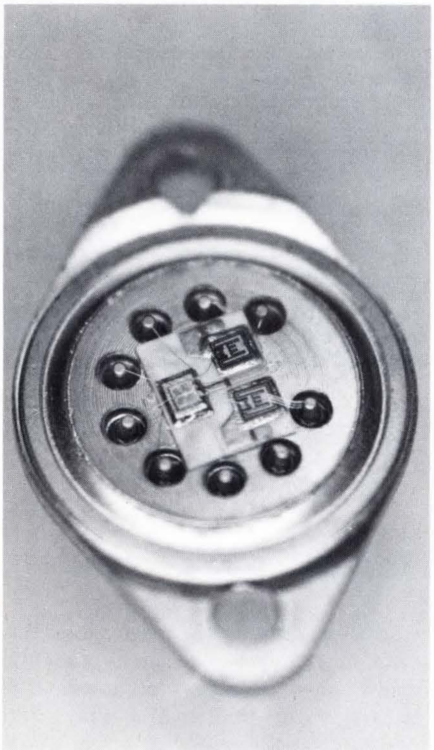
This dual power driver is intended for six amps pulse operation and can take surges to 8 amps. I_C (peak) is 6 A (max) and I_C (continuous) is 1 A (max). As indicated, the breakdown voltage is 120 V, and $V_{CE(sat)}$ 2.5 V (max) @ I_C = 6 A.

The 10-pin TO-3 was chosen to house the MCH2890 because of its superior power handling capability, its rugged hermeticity, and its longtime popularity as a standard industrial power package.

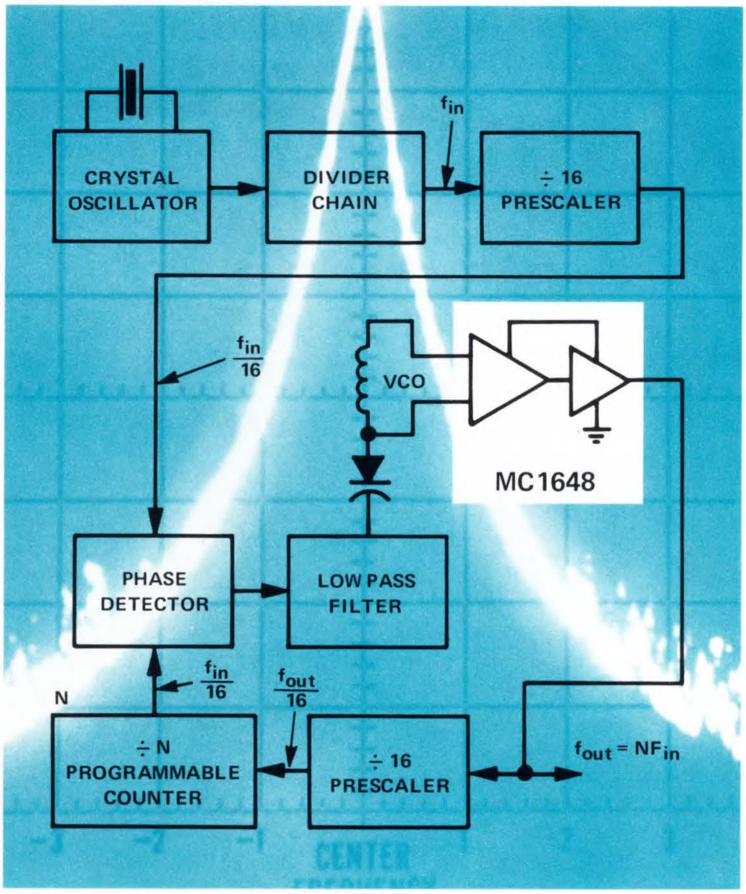
Typical switching times for the dual hammer driver are t_d — 40 ns, t_r — 20 ns, t_s — 600 ns, and t_f — 200 ns. Thermal resistance is 7.5°C/W for single channel operation and 5.0°C/W for dual channel operation.

The MCH2890 is available now for $7.95 each from your Motorola distributor in 100-up quantities.

For details, circle 55



The MCH2890's two power transistors and an IC predriver pulse out a fast six amps for many driving jobs.



A principal application of the MC-1648 Emitter-Coupled Oscillator will be as a voltage-controlled oscillator in communications-frequency systems employing phase-locked loops.

MC1648 Extends Frequency Synthesis To Communication Frequencies

Now you can generate frequencies well into the communications area by applying Motorola's new MC1648 Emitter-Coupled Oscillator to phase-locked loop designs. The MC1648 offers output levels compatible with MECL III and MECL 10,000 logic levels and operates up to a maximum frequency of 225 MHz typical. In addition to frequency synthesis, the MC1648 is recommended for applications requiring a fixed or variable frequency clock source of high spectral purity and for applications in the 60-225 MHz range needing a stable oscillator.

As illustrated, the MC1648 acts as a voltage-controlled oscillator in the frequency synthesizer approach commonly used in FM broadcast tuners, general aviation, maritime and land-mobile communications, amateur and CB receivers. The system operates from a single +5.0 Vdc supply.

The output frequency of the synthesizer loop is determined by the reference frequency and the number set into the programmable counter; $f_{out} = NF_{in}$. The channel spacing is equal to the reference frequency (f_{in}).

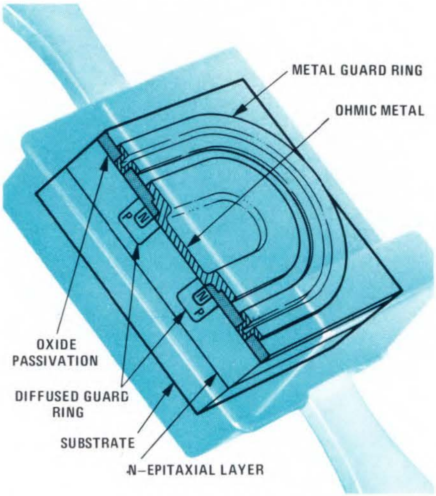
Frequency generation of this type offers the advantages of single crystal operation, simple channel selection, and elimination of special circuitry to prevent harmonic lockup. Additional features include dc digital switching (preferable over RF switching with a multiple crystal system) and a broad range of tuning (up to 180 MHz, the range being limited by the varactor diode).

Motorola now can supply IC devices for practically every phase-locked loop application. See your local Motorola representative for application assistance. And to evaluate the MC1648 call your nearest Motorola distributor. The MC-1648 is available in the 14-pin DIP package and the price is $2.50 (100-up).

For details, circle 56

High-Voltage, Hot-Carrier Diode Pair In Low-Inductance MINI-L Package

The 50-volt MBD502 and the 70-volt MBD702 hot-carrier detector and switching diodes offer designers the same outstanding qualifications as their high-



efficiency TO-92 encapsulated predecessors, MBD501/701, and *then some!*

Which is to say that they are now packaged in the MINI-L plastic case that features new lows in both inductance and capacitance. Typical series inductance is 3 nH and capacitance @ 1.0 MHz is 0.1 pF (typ).

The MINI-L features an L-shaped ridge running across one end of the package that clearly indentifies the cathode lead. In addition, this ridge helps make automatic handling and mounting of the MINI-L so easy that commercially-available equipment can be readily adapted for this use. Its axial leads, formed with a combination detent/stop near the case, provide the options of flush or standoff mounting.

One of the biggest benefits of the new package design is in its assembly and encapsulation on Motorola's proven, TO-92 type stripline, high-speed, high-volume production facilities to bring you industrial performance at consumer prices.

Although designed primarily for video detector and switching applications, the MBD502 and 702 are suited for many other fast-switching RF and digital applications.

The Schottky barrier void-free construction provides ultra-stable characteristics by eliminating the cat-whisker and S-bend contact. Both devices have an extremely low minority carrier lifetime (15 ps typical) which is responsible for the very high speed of these highly-efficient diodes. They also feature a high reverse voltage of 50 V for the MBD502 and 70 V for the MBD702, and low reverse leakage of 200 nAdc (max) for both devices.

The third, and recently-introduced member of this MINI-L hot-carrier diode family, the MBD102 (also available as the TO-92 cased MBD101) is designed for UHF mixer applications but is also suitable for use in detector and ultra-fast switching circuits.

MBD502, 702 and their sister part, MBD102, boast some of the most appealing 100-up prices in this field: MBD102 — 65¢; MBD502 — 71¢ and MBD702 — 77¢.

For details, circle 57

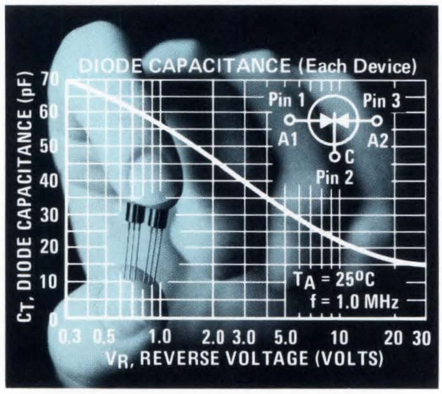
First Domestic Dual VVC Cuts Distortion, Saves Space

Where sharp tuning and minimum signal distortion are required, here's a dual, back-to-back, voltage-variable capacitance diode, type MV104.

This silicon EPICAP device is rated at 32 volts and provides between 37 and 42 pF diode capacitance at V_R = 3.0 Vdc. A manufacturing technique that produces diodes whose characteristics match within ±1% over the specified tuning range makes it possible to offer, on special order, sets of MV104 diodes matched to within ±1.5%. Result? You can minimize distortion and detuning in your design.

But that's not all. Because it's supplied in the proven TO-92 package you can depend on the MV104 in rugged environments. And, the dual configuration of the MV104 saves board space.

Now that the MV104s are available,



you don't have to look to Europe for the BB104. And at 59¢, 100-up, you can afford to give it a try.

For details, circle 58

High-Gain RF Amplifiers Give "More Horses" To UHF Land-Mobile Designs

Now you can really move on out of the medium-powered land-mobile neighborhood with the new 2N5944-46 series . . . offering at least 2 dB more power gain for your 12.5 V land-mobile RF outputs, drivers and predrivers than existing UHF amplifiers!

Designed for large signal applications to 520 MHz in industrial/commercial FM equipment, the new units offer these P_{out}/G_{PE} performance advantages at 470 MHz: 2 W/9 dB for the 2N5944; 4 W/8 dB for the 2N5945 and 10 W/6 dB for the 2N5946 . . . each affording from 1 to 2 dB *greater* gain than any other comparably-priced device. This gain in gain means fewer devices in the amplifier chain — saving you the cost of additional units and their installation.

Actually capable of much higher output levels, the series has been characterized at conservative levels for ruggedness and to ensure good performance after subjection to mismatch conditions.

These devices are loaded with other reliability features, too: nichrome protected overlay construction, strip-line-opposed-emitter technology and stud-mounted ceramic packaging.

Collector efficiency is a high, 60% (min) at 470 MHz and rated power gain levels — you save more dc.

Send for data on the most completely characterized and tested, high-gain series of its kind — and receive complete strip-line test fixture information that offers *repeatable* results plus test circuits with 1:1 scaled layouts for your easy work-bench reproduction.

To aid in your microstrip amplifier design, large signal input and output impedances measured in a representative microstrip amplifier are also given.

Prices range from $8.00 for the 2N5944 (100-499) to $24.20 for the 2N5946 (25-99).

For details, circle 59

PNP Uniwatt Darlington Transistors Perform Low-Power Amplifier/Driver Jobs

Motorola's new MPS-U95 PNP silicon Annular Uniwatt Darlington transistor, like its NPN complement, the MPS-U45, is characterized by one of the highest current gains in the industry, with typical ratings of 35,000 at 500 mA.

High gain means base drive requirements will be lessened in many of your low-power amplifier, driver and control applications. In addition, the MPS-U95's excellent linearity, like its complement, will provide your audio amplifiers – up to 5 watts – with the benefit of low distortion.

Emitter-base breakdown voltage is a high 10 Vdc (min), providing adequate protection against most transients. And $V_{CE(sat)}$ at 1 Adc is typically 1.2 Vdc. C_{cb} at 10 volts is 2.5 pF (typ). Collector-emitter breakdown voltage is identical to MPS-U45 – 40 Vdc (min) at 100 μAdc. Also identical are the total power dissipation figures for the devices: 1.0 W at $T_A = 25°C$ and 10 W at $T_C = 25°C$.

By eliminating predrivers, the MPS-U95 and its complement can reduce space requirements in your circuit layout.

The MPS-U95 is packaged in the exclusive Uniwatt plastic case. Its tab-lead is readily adaptible to custom forming for special mounting requirements, including heat sink needs.

Ample factory and distributor warehouse stock of these versatile transistors are available at 100-up prices of $0.84 for the MPS-U95 and $0.76 for the MPS-U45. Send for data today.

BV_{EBO} Volts Min	C_{CB} pF Typ/Max	h_{FE} Min/Typ/Max	@ Ic mA
(1)10	(1)2.5/12		
(2)12	(2)2.5/6.0		
		25K/65K/150K	200
		15K/35K/—	500
		4K/12K/—	1.0 A

(1)MPS-P95 (2)MPS-U45

For details, circle 60

Solid-state power gets a real "lift" with the advent of the 2N4361-78 SCRs. These 110 amp. devices are designed for those industrial appications requiring tough, reliable performers.

110 Amp SCR Boosts Control Reliability

There's no substitute for quality in a high-current SCR that really has to "take it" in controls for high-power industrial/consumer welders, motors, space heaters, electric trucks and other power/speed jobs . . . and there's no substitute for the new 110 A (RMS) 100 to 1,400 V 2N4361-4378 series in those designs.

For example, you'll find pressure-contact encapsulation ensures permanent electrical and thermal conduction to the mounting base despite the most rigorous thermal cycling. Additional freedom from thermal fatigue is afforded by matched-expansion mounting of the chip providing long-term stability and reliability. And, low, 0.28°C/W thermal resistance affords higher case operating temperatures and smaller heat sinks.

When you stress it with repetitive current/voltage conditions, center-fired gates give high repetitive di/dt and fast turn-on. Specified minimum 100 V/μs dv/dt means optimized protective, voltage-wave shaping networks. Low maximum V_F – 1.6 V – and high surge protection – 1,600 A – simplify heat sink and safety/fusing considerations.

You can torque this SCR to 130 inch-pounds without distortion because its high-stress copper allow resists stud damage and provides excellent heat transfer to boot.

Inside you'll find the highest quality piece parts in the industry: high-temperature alloy materials life-tested at 300°C . . . hermetic ceramic seals . . . high-density refractory material . . . and all diffused junctions contoured for longest possible voltage creepage distance.

The 2N4361-78 series is available in both flexible lead and flag-tab packages – send for your data sheet today!

For details, circle 61

NEW PRODUCT BRIEFS

DUAL COMPARATORS

– Match Four-Bits – Economically

Here's two MTTL devices that can provide address comparison for use with multiple sequential memories or uniquely match separate input data against a common reference. Basically, the new MC4021 and MC4022 Dual 4-Bit Comparators compare four bits of input data to four bits of reference information. When both correspond bit-for-bit, the comparator output assumes the high state. Any other condition produces a low output level.

The MC4021, 22 are unusual in that the four reference inputs serve both comparators. There is no interrelation between the dual data input sections. A separate output is provided for each comparator. The MC4021 has open collector outputs for wired-OR applications while the MC4022 has totem-pole outputs.

The unique configuration of these dual devices could mean a savings in space, parts, or price in your design. Evaluate them now! They're available in the 16-pin DIP package for the 100-up price of $2.45 – either comparator.

For details, circle 62

SILICON GATE MOS SHIFT REGISTERS

– Provide Low Power Drain and Bipolar Interface Capability

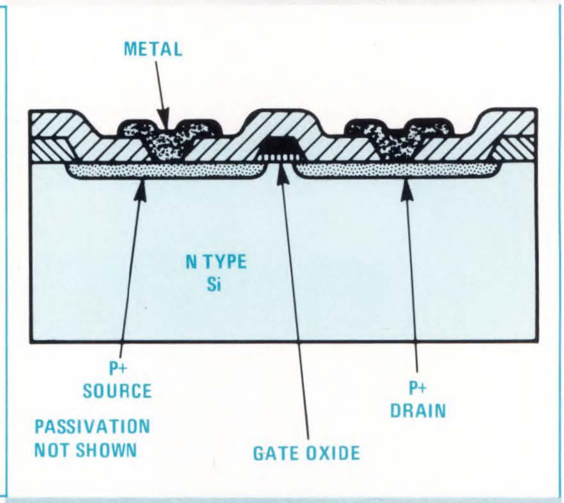
Motorola's MC2380G and MC2381G dual 100-bit dynamic shift registers provide low power consumption and direct bipolar interface capability for digital applications. Dual-512, quad-256, and 1024-bit registers also from silicon gate technology are scheduled for early second-half '71.

Both the MC2380G and MC2381G provide bipolar compatibility at inputs and outputs and both utilize low-voltage circuitry and a two-phase clock for minimum power dissipation. The MC2380G has open-drain outputs for high drive capability and the MC2381G achieves direct MOS compatibility with output pulldown resistors.

Performance features include 3 MHz operating frequency, 0.4 mW/bit power dissipation @ 1.0 MHz (typ), operating temperature range of −55°C to +125°C, 40 pF clock input capacitance, and typical output impedance of 400 ohms.

In 100-999 quantities the price of either the MC2380G or the MC2381G is $3.95. Each is supplied in the 8-pin metal case.

For details, circle 63



IMPROVED SILICON PLASTIC QUAD MEMORY-DRIVERS

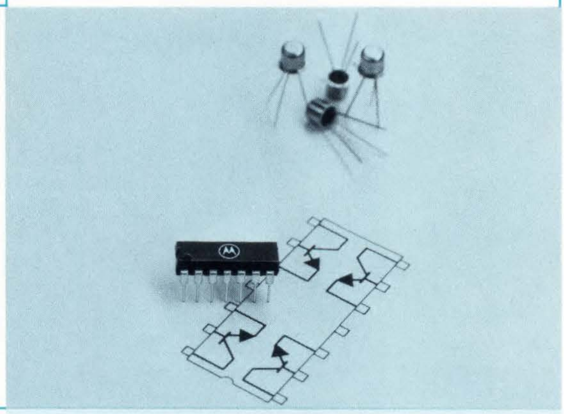
– Offer High Power Rating and Increased Temperature Range

Originally introduced in the dual in-line TO-116 plastic package with a copper lead frame as 600 mW devices, the MPQ3725 and MPQ3303 quad memory driver transistors now offer the rating of 1.0 watt per single device or a collective 2.5 watts. And the operating and storage junction temperature range is now −55 to +150°C.

MPQ3725	20 ns t_{on} (typ) @ I_C = 500 mAdc	50 ns t_{off} (typ) @ I_C = 500 mAdc
MPQ3303	15 ns (max) @ I_C = 1.0 Adc	20 ns (max) @ I_C = 1.0 Adc

Consider the new specs together with the MPQ3303's low collector-emitter saturation voltage and the MPQ3725's high collector-emitter breakdown voltage and you've got a system cents/space satisfying quad pair for your plated wire and core driving jobs. Either device is only $3.75, 100-up.

For details, circle 64



ISOTHERMAL LAND/MOBILE RF TRANSISTORS

– Reduce Heat Buildup 50%

The new 2N6080 family is designed for 12.5 V operation to 225 MHz and features minimum gains from 4.5 to 12 dB and 50% collector efficiency at rated power and 175 MHz.

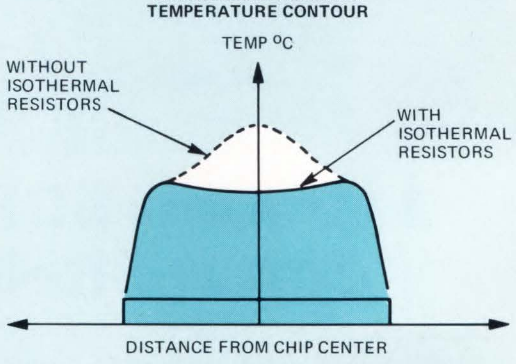
Devices in this series are ideal for high band land/mobile, VHF marine and amateur radio (2 meter) applications where higher gain and increased ruggedness are needed in predrivers, drivers, and output stages.

4-40 WATT LAND/MOBILE RF TRANSISTORS

TYPE	P_{in}/P_{out} WATTS	Power Gain dB	Price 100-up
2N6080	0.25/4	12.0	$6.00
2N6081	3.5/15	6.3	9.25
2N6082	6/25	6.2	18.50
2N6083	8/30	5.7	21.00
2N6084	14/40	4.5	36.00

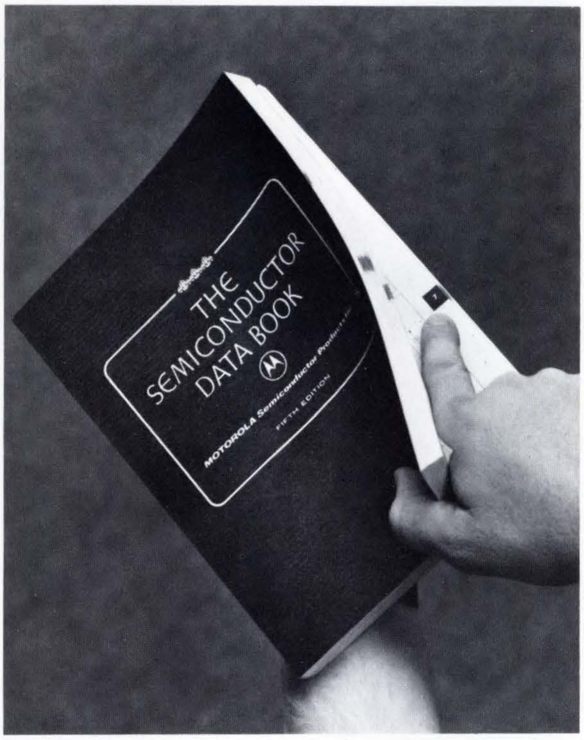
For details, circle 65

ISOTHERMAL RESISTOR TEMPERATURE CONTOUR



Asymmetrical emitter-resistor path design apportions heat evenly.

LITERATURE BRIEFS



First Supplement To Semiconductor Data Book Available

It seems like the Fifth Edition of the Semiconductor Data Book is just barely off the presses and already it has its first supplement – 370 pages of supplement – a book in its own right. Actually, the Fifth Edition celebrated its half birthday this April and, at Motorola, six months now sees the introduction of nearly as many useful new products as were developed in its first six years.

Supplement 1 provides complete specifications for 150 new 1N, 2N, and 3N EIA registered devices plus 212 Motorola devices. As in the Fifth Edition, Supplement 1 is thoroughly indexed to provide easy entry to the characteristics of the device you want. Programmable unijunction transistors, field-effect transistors, thyristors and EIA registered types each have their own numerical index in which short-form specifications are given. There is also a device selection index listing the new semiconductors by product category. Another index handily presents all devices carried in both the Fifth Edition and Supplement 1 indicating those for which specifications are to be found in the supplement. Anyone who has ever wandered bewildered through an inadequately indexed catalog will appreciate Motorola's data books.

You can obtain Supplement 1 for $1.00 a copy by using the coupon on the outside edge of this page. You may also use the coupon to: 1. purchase the Fifth Edition; 2. subscribe to the updating service which entitles you to Supplement 1 plus any others published during the life of the Fifth Edition to keep it current and up to date – a minimum of two.

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LITERATURE BRIEFS

Umbilical To Microelectronics Book Cut— MTTL Data Book Born

The designer working on a system using principally one form of logic will swear the idea for Motorola's new IC data books was conceived just for him. And he'll very nearly be right!

The MTTL Data Book is the first in a series intended to divide the data for Motorola's ever-expanding IC population into manageable segments. We think you'll find this volume — and subsequent data book shelfmates — more convenient and easier to use if you work with one logic type or the entire family of integrated circuits.

The 552 pages of the MTTL Data Book are divided into general information, selector guides, application note abstracts and seven technical data sections. An interchangeability guide and packaging information are given in the general information section while the selector guides section provides a quick look at the major characteristics of all MTTL devices. The application notes section given abstracts of current notes explaining the use of MTTL.

Inside the front cover a tab index instantly points the way to the tabbed sheets of the technical data section of interest. These seven data sections constitute the main portion of the data book — 366 pages — and each provides an index to its devices plus all data sheets, in numerical order.

Use the coupon on the outside edge of this page to order your copies of Motorola's spanking new MTTL Data Book.

NOTE: If Motorola's Literature Request Coupon is missing, use magazine's standard Reader Service Card.

'Window' Comparator Indicates System Status

Stable, reliable indication that a voltage does or doesn't fall between two acceptable limits is provided by this tested system. Readout is by color coded indicator lights.

J. C. NIRSCHL, USAECOM—Fort Monmouth

For checking a system's status, it is often necessary to determine whether a reference signal lies within, (go), or outside, (no-go), a prescribed voltage limits "window". Such a determination serves as a confidence check on the system's operational readiness.

The comparator circuit of **Fig. 1** was designed for an airborne system application that had desired lower and upper reference signal limits of approximately $E_l = 1.9$ and $E_u = 2.1V$. Two monolithic linear ICs are used for threshold sensing, and two transistors serve as relay drivers. Using IC op amps for A1 and A2 insures good temperature stability for the lower and upper threshold levels.

Op amp A1 has input bias conditions such that, for input signal $e_s < E_l$, it is clamped, via diode D1, near ground potential. This produces a low positive output level. By a similar arrangement op amp A2 also is clamped (via diode D2), but in a "floating" manner, that is its output level (when $e_s < E_u$) depends on the input signal, e_s. This relationship is expressed by.

$$e_{oB} = -\left[(V_s + e_s)\left(\frac{R5 + R6 + R7}{R5 + R6 + R7 + R8}\right) - e_s + V_D\right]$$

where

V_s = magnitude of supply voltage (15V)

V_D = forward voltage drop of diode D2 (approximately 0.5V)

As the portion of the input signal, e_s, that is applied to both op amps rises, first to E_l and then to E_u, the op amp outputs successively will switch to their respective saturation levels (of opposite polarity). This action is illustrated in **Fig. 1b** which shows the circuit signal levels at points A, B, B′, C and E in the circuit diagram.

Load resistors R10 and R11 join the op amp outputs, producing a sum signal at point C that has the desired window comparator characteristics with respect to e_s. Diode D7 prevents possible negative levels in amplifier A2 from producing an erroneous "go" signal, if e_s happens to assume a large negative value as the result of a system fault condition.

Lower and upper threshold levels are determined by:

$$E_l = \left(\frac{R1 + R2 + R3}{R1 + R2 + R3 + R4}\right) V_s$$

and

$$E_u = \left(\frac{R5 + R6 + R7}{R5 + R6 + R7 + R8}\right) V_s$$

Because the threshold voltage depends directly on that of the −15V supply, this must be well stabilized to insure threshold level stability. In this application the ±15V supply lines were regulated by LM-100 IC voltage regulators, and the stability requirement was thereby considered satisfied by the resulting typical long-term stability of 0.1%.

Zener diode D3 couples the sum output signal to the following buffer stage (Q1), while providing proper level shifting (V_z = 26V).

Q2 acts as a switch in series with the relay which, when energized, causes the status indicator light to shift from no-go to go. The latter occurs, of course, only when the input signal e_s satisfies the condition:

$$E_l \leq e_s \leq E_u$$

Capacitor C1 slows down the circuit response to minimize the possibility of relay chatter when e_s closely approaches one of the threshold levels. The zener diode circuit of D5, D6 and R15 eases the demand on the ±15V regulated supply by providing a separate 25V power supply for the buffer and relay driving transistors.

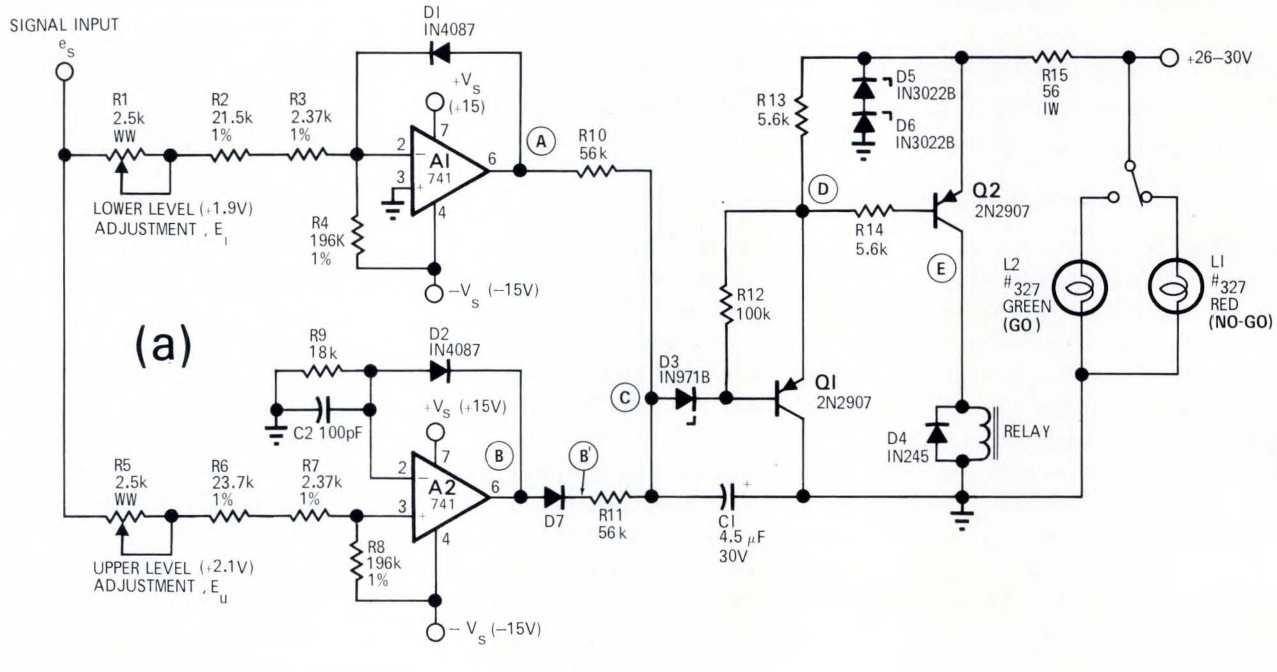
This comparator circuit's performance was repeatedly tested at +55°C and −55°C, and **Fig. 1c** lists typical results. Stability of the E_l and E_u threshold levels is seen to be within 0.6% over the cited temperature range. The data in **Fig. 1c** represent the temperature—induced changes of the comparator threshold levels, assuming constant (±15V) supply voltage. In actual system operation, at the respective temperature extremes the temperature coefficient of the regulated plus and minus supply lines has an added effect on the threshold levels. Typically this was found to double the percent changes indicated in **Fig. 1c**, and was considered acceptable for the intended application.

(Continued)

Joseph C. Nirschl is an electronic engineer and team leader in the Combat Surveillance Laboratory USAECOM Fort Monmouth, N. J. He holds a Dipl.-Ing. from the Institute of Technology, Munich, and has been granted one patent.

Comparator (Cont'd)

The circuit described can be readily adapted to monitor an input signal of negative polarity by appropriate inversion of the polarity of the (V_s) bias return (via R4 and R8) and of the op amp inputs. Likewise, this scheme can be expanded to provide multiple comparator windows for monitoring several independent input signals, each signal being applied to a pair of IC op amps. Their outputs are applied to an AND gate such that the relay is only actuated (go) when all signals are within their prescribed voltage limits. ▭



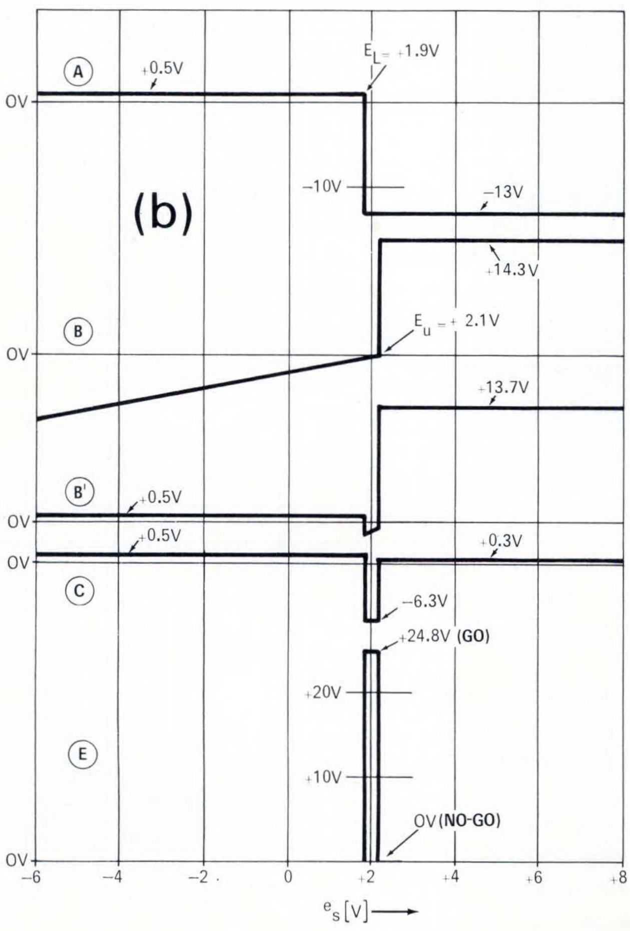


Fig. 1—Window comparator for system confidence check a) schematic b) signal levels c) performance.

(c)

TEST DATA

CHAMBER TEMPERATURE	−55°C	+26°C	+55°C
Lower threshold, E_l	1.913V (+0.6%)	1.901V	1.900V (−0.1%)
Upper threshold, E_u	2.113V (+0.5%)	2.104V	2.103V (−0.1%)

Notes: 1) Threshold levels were adjusted to approximately the nominal 1.9 and 2.1V at room temperature.

2) Threshold levels at −55 and +55°C. were determined by slowly increasing the input signal level and noting the value when the indicator lights switched.

3) Supply voltage was held at a constant ±15V.

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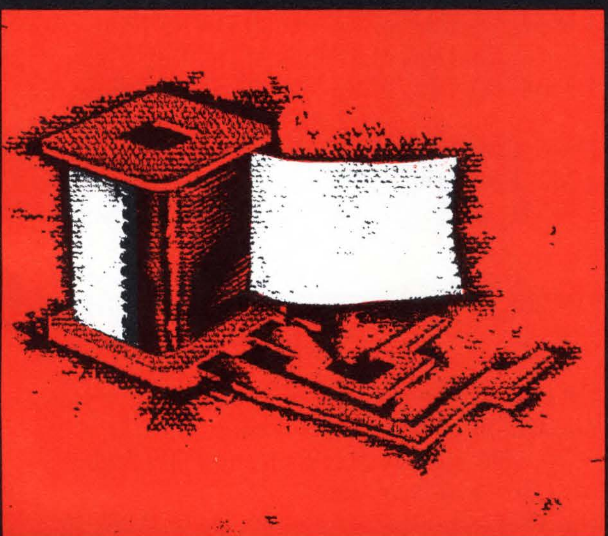

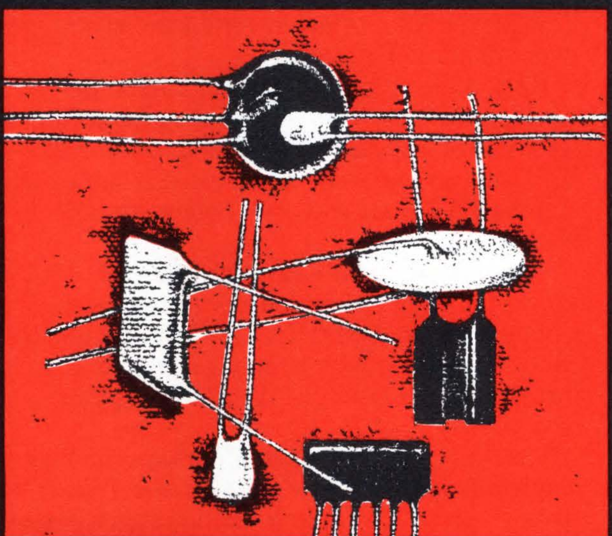

LOW POWER TTL CRAM COURSE.

Low power TTL isn't exactly a household word yet among design engineers. So we'd like to offer a quick summary of low power TTL. What it is. Who uses it. Why. Why not. Plus, a list of our products.

After reading this page, you'll probably decide to specify low power for your next system. (If not, you'll at least have lots of cocktail party material.)

PART ONE: A DEFINITION

Low power TTL is an offshoot of the 54/74 family which is fully compatible with DTL and TTL. It is specifically designed for applications requiring very low power dissipation.

PART TWO: WHO USES IT

The military's been using low power TTL for four years, but it's also catching on in portable equipment, data terminals and other industrial applications as well.

PART THREE: ADVANTAGES

Low power TTL offers several nice advantages over standard TTL logic.

First, even at frequencies of 12MHz the devices dissipate very low power and generate less heat on the chip. As a result, low power TTL has proven to be much more reliable than standard TTL. (If you don't believe us, ask NASA.)

Then there's power savings. Typically, low power TTL gives you a *factor of 10* power savings over standard TTL. Which means you can use a 2.5A power supply, for example, instead of a 25A supply. Which means you save money.

Speaking of saving money, perhaps the biggest single advantage to using low power TTL is the money you save in your overall systems costs.

For example, low power TTL eliminates the need for a fan. Which eliminates the need for a thermostat. Which eliminates the need for a filter. And so on and so forth. (In fact, one of our customers says that the fan alone costs them enough money that even if they had to pay 200% more for low power devices in their systems, their overall systems costs would still be less expensive!)

PART FOUR: PRODUCTS

Right now, we have 21 off-the-shelf low power TTL devices (including four MSI functions):

DM54L00/DM74L00	Quad 2-Input NAND Gate
DM54L01/DM74L01	Quad 2-Input NAND Gate, Open Collector
DM54L02/DM74L02	Quad 2-Input NOR Gate
DM54L03/DM74L03	Quad 2-Input NAND Gate, Open Collector
DM54L04/DM74L04	Hex Inverter
DM54L10/DM74L10	Triple 3-Input NAND Gate
DM54L20/DM74L20	Dual 4-Input NAND Gate
DM54L30/DM74L30	Eight-Input NAND Gate
DM54L51/DM74L51	Dual 2-Wide AND-OR-INVERT Gate
DM54L54/DM74L54	Four-Wide 3-2-2-3-Input AND-OR-INVERT Gate
DM54L55/DM74L55	Two-Wide 4-Input AND-OR-INVERT Gate
DM54L71/DM74L71	R-S Flip Flop
DM54L72/DM74L72	J-K Flip Flop
DM54L73/DM74L73	Dual J-K Flip Flop
DM54L74/DM74L74	Dual D Flip Flop
DM54L78/DM74L78	Dual J-K Flip Flop
DM54L86/DM74L86	Quad EXCLUSIVE-OR Gate
DM54L90/DM74L90	Decade Counter
DM54L93/DM74L93	Binary Counter
DM54L95/DM74L95	Four-Bit Right Shift Left Shift Shift Register
DM76L70/DM86L70	Eight-Bit Serial-In Parallel-Out Shift Register

(NOTE: All devices are available in cavity-dip, molded-dip and flat-pack configurations.

We also plan to announce some Tri-State* MSI low power devices.

This ends our cram course. If you'd like to learn more, we'll be happy to send you a free copy of our full course — the liberally-diagrammed, specifications-packed, 36-page National Low Power TTL Brochure. Plus any of our Tri-State or 54/74 product data.

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NATIONAL

CIRCLE NO. 21

Phase of Digital Data Fixes Shaft Angle

Designing an all-electronic synchro-to-digital converter has attracted a great deal of attention in the past few years. The design described uses a two-step process—generate an analog signal representing the shaft angle and then determine the phase digitally.

ROBERT W. KLATT, Scan-Optics, Inc.

Three samples per cycle are sufficient to define a sine wave—based on the principle of temporal sampling. Conversely, the amplitudes of three voltages or signals proportional to them can be used to synthesize a sine wave. If a synchro transmitter generates (by synchronous demodulation and filtering) three voltages, designated e_1, e_2 and e_3, and these voltages are sampled at equal intervals, the phase of the resultant signal will equal the synchro-transmitter shaft angle (see **Fig. 1**).

A control transformer sums three magnetic vectors with 120° *spatial* phase differences to generate a magnetic vector whose *spatial* phase angle equals the transmitted shaft angle. However, the system shown in **Fig. 2** was developed on the principle of adding three phasors with 120° *time* phase difference to obtain a resultant phasor whose *time* phase equals the shaft angle. This is possible because each sample impulse is repeated at a rate of 1/T and has a fundamental frequency component at this frequency. Since the impulses are separated in time by T/3, their fundamental frequency components have 120° phase separation.

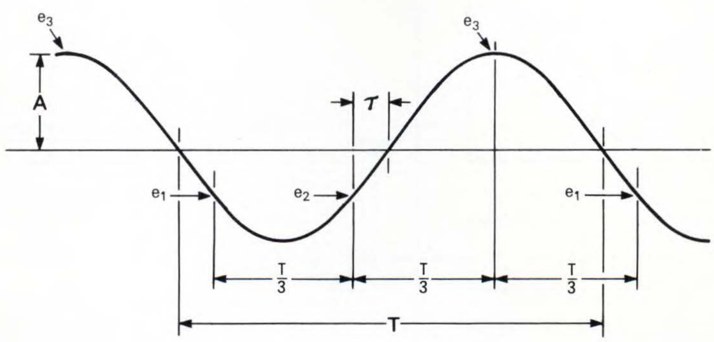


Fig. 1—**Equations for the amplitude** of the output signals from a synchro transmitter are:

$e_1 = \mathbf{A} \sin(\Theta_s - 120°)$

$e_2 = \mathbf{A} \sin \Theta_s$

$e_3 = \mathbf{A} \sin(\Theta_s + 120°)$

These equations also represent the sampling of a sine wave, with an amplitude equal to the synchro-output amplitude, at a rate of three times the sine wave frequency. For convenience, consider the sample pulses in groups of three, with each group occurring at a frequency equal to the sine wave frequency. Expression $2\pi\tau/T$ defines a phase angle. (**T** is the period and τ is the time between the second sample and the positive going zero crossing of the sine wave.) This phase angle equals the shaft angle that generates e_1, e_2 and e_3. Obviously, the requirement that the magnitude of the synchro outputs equal the sine wave magnitude is not necessary. Ratios between the three voltages—independent of magnitude, both for the synchro signal and its analog—carry the angle information.

Signal Converter

The signal converter in **Fig. 3** translates the analog signals e_1, e_2 and e_3 into a signal whose phase defines the input shaft angle. This signal will be designated the *system signal*. A master clock and a digital counter, called the *three-phase counter*, control the FET switches that sample the filtered outputs of the demodulators. (Techniques of synchronous demodulation will not be discussed.)

It was previously implied that sampling was accomplished with impulses, but in actual practice there are advantages to having wider samples. First, the amplitude of the fundamental-frequency component of the pulse increases. Second, the pulse width determines the harmonic content, and if, as illustrated in **Fig. 3**, the sample-pulse width equals the time between adjacent samples (1/3 of basic sampling period), the third harmonic and all its multiples will become zero. This becomes important when measuring the phase. The only disadvantage is the generation of a 60° fixed phase shift that must be eliminated. The fundamental frequency component of the system signal (and its harmonics) appears at the summing point (**Fig. 3**).

(Continued)

Phase Detection

The method of measuring the *system signal* phase is similar to the operation of a synchro-control transformer. Basically, the transformer rotor is a sampling loop that is rotated until its output is zero. The system in **Fig. 4** has a synchronous detector that determines the *system signal* phase. In effect, an FET switch multiplies the *system signal* with a square wave having a period **T** and an amplitude 0 or 1. If the switch output is integrated and the integrator is reset when the switch is open, then the switch and the integrator are analogous to the control transformer rotor. The phase of the square wave reference, relative to the *system signal*, is adjusted until the integrated signal is zero at the completion of each switch closure. Variations in the relative phase about this zero point generate a bipolar voltage that is used as the error signal. If the harmonic content of the signal is low, the relative positions of the reference and the sample pulses when the error is zero yield the phase of shaft-angle information.

This approach has an additional advantage in controlling the error caused by harmonics. Only those frequencies present in both the *system signal* and the reference contribute to the error signal. All even-order harmonics are missing from the reference. Therefore, the only harmonics that can cause errors are the odd harmonics greater than and including the fifth. For improved accuracy, filtering reduces the amplitudes of these harmonics. A three-pole active Butterworth filter inserted between the signal converter and the phase detector was used in the breadboard. However, this filter introduced a phase shift that required correction.

Control System

A master clock, control circuits and two counters make up the control system shown in **Fig. 4**. The master clock operates both the *three-phase counter*,

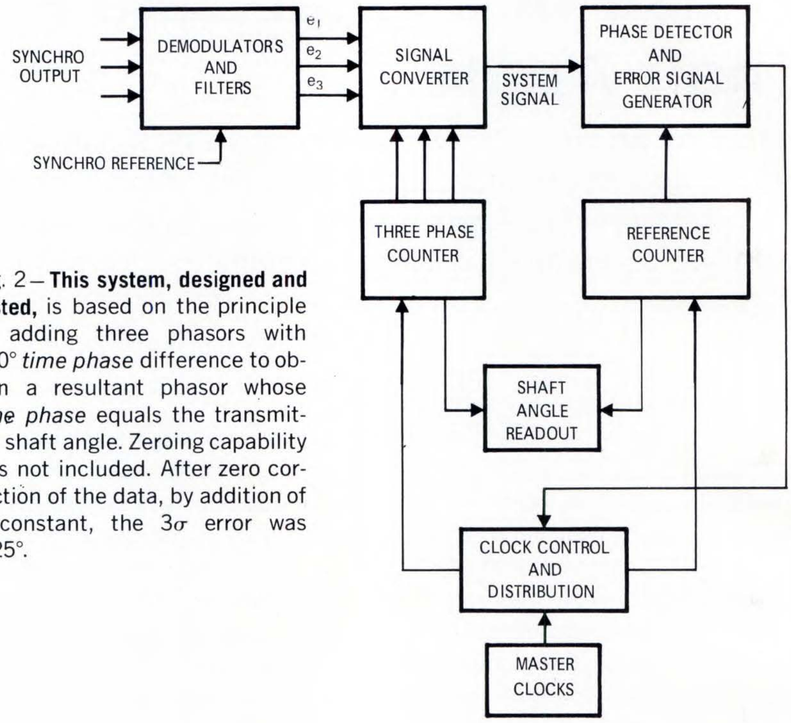


Fig. 2—**This system, designed and tested,** is based on the principle of adding three phasors with 120° *time phase* difference to obtain a resultant phasor whose *time phase* equals the transmitter shaft angle. Zeroing capability was not included. After zero correction of the data, by addition of a constant, the 3σ error was 0.25°.

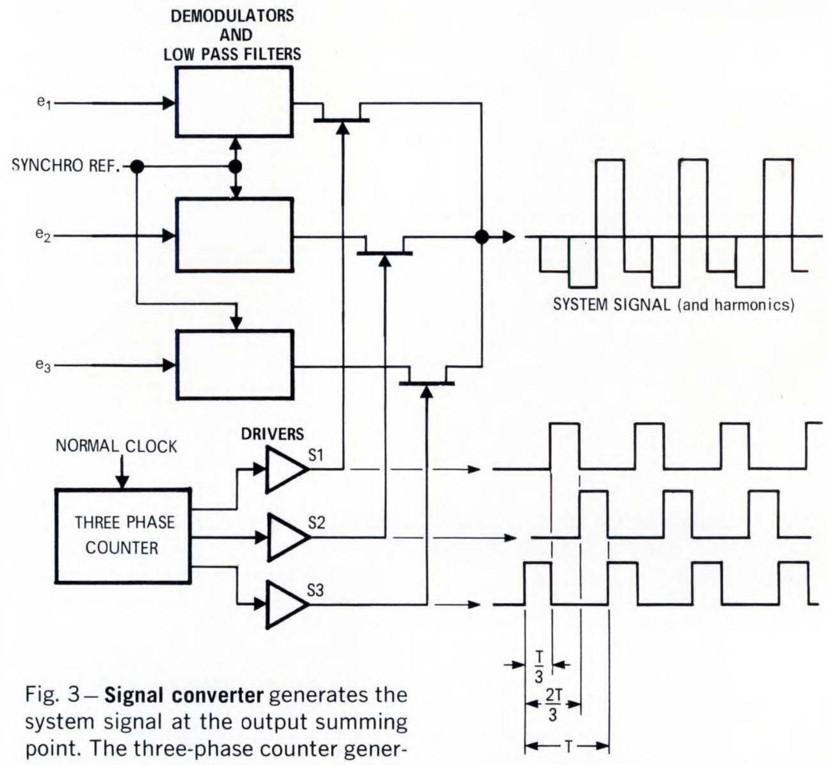


Fig. 3—**Signal converter** generates the system signal at the output summing point. The three-phase counter generates control signals that sequentially enable the FET switches, connecting the filtered outputs of the demodulators to the common summing point. Resultant waveform is as shown.

which runs continuously at the normal clock rate, and the *reference counter* which generates the square-wave reference. When phase-detector switch (Q_1) is closed, the reference counter operates at the normal clock rate. When the switch opens, the integrator output (or error signal) determines the reference counter input frequency. The comparators determine the sign and magnitude of the error signal. If the error is within the dead band (essentially zero), the *reference counter* continues to run at the normal clock rate and the phase relationship between counters remains unchanged.

The sign of a non-zero error determines whether the *reference counter* clock input is doubled or reduced to zero. It also switches the integrator input to a reference voltage which linearly reduces the error signal magnitude to zero. At which time, the reference clock rate returns to normal and the system awaits the next closure of Q_1. Since the error signal is proportional to the amplitude of the synchro output and the sine of the error, the control system is nonlinear. The breadboard operates satisfactorily both in acquisition and tracking. The analysis of a simplified mathematical model of **Fig. 4** describes the basic operation of the breadboard.

Factors for Consideration

The frequency of the master clock and the counter output are somewhat arbitrary, but the following factors have some influence:

– The greater the bandwidth of the input signal (shaft angle), the higher the required *system signal*

(Continued)

Fig. 4 – **Control system** is nonlinear. However, analysis of a simplified linear model using a step input conveys its basic operation. Assume ϕ_0 indicates the initial amplitude of the error and $\Delta\phi$ is a correction proportional to the error, applied after each error measurement. The following equations describe the operation for "n" cycles:

$$\phi_1 = \phi_0 - \Delta\phi = \phi_0 - K\phi_0 = \phi_0\,[1 - K]$$
$$\phi_2 = \phi_1\,[1 - K]$$
$$\vdots \qquad \vdots$$
$$\phi_n = \phi_{(n-1)}\,[1 - K]$$

Dividing the left and right products by the common factors yields:

$$\phi_n = \phi_0\,[1 - K]^n$$

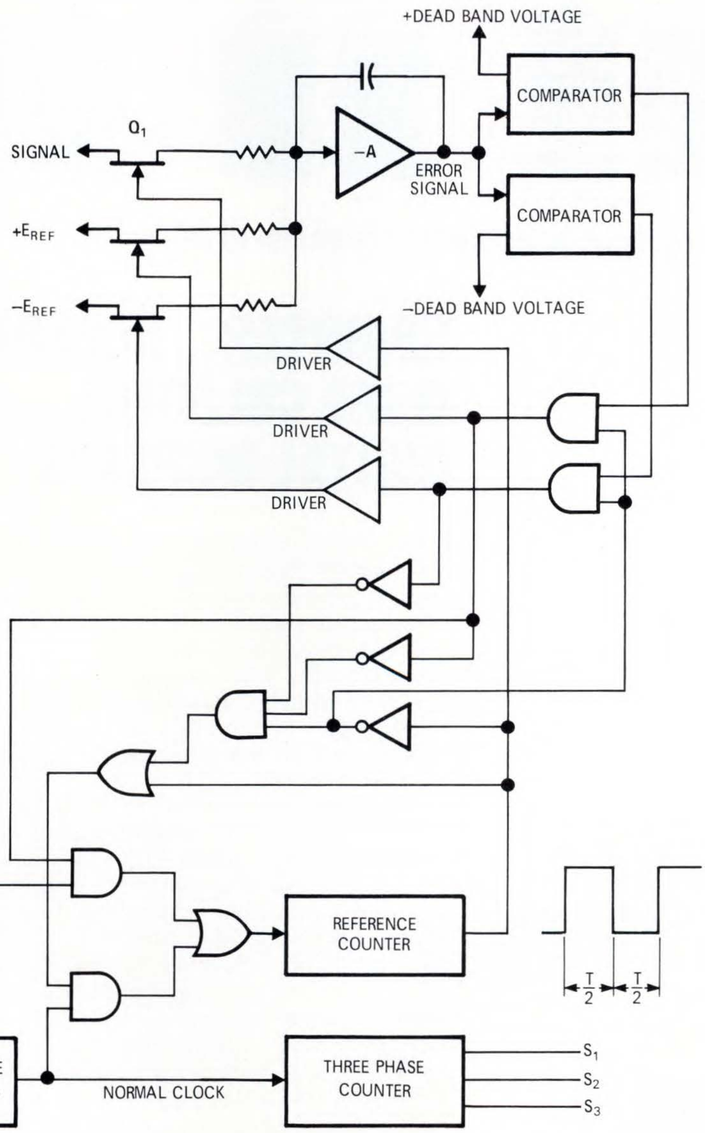
If $[1 - K] < 1$, the system is stable and three possible conditions are:

$0 < [1 - K] < 1$ {error monotonically approaches zero

$-1 < [1 - K] < 0$ {error polarity oscillates and the magnitude approaches zero

$[1 - K] = 0$ {error becomes zero in one cycle.

These conditions are analogous to overdamping, underdamping and critical damping for a linear, continuous system.



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(Continued)

Phase *(Cont'd)*

frequency.

- In part, the system accuracy depends upon the accuracy of the sampling and reference pulse widths and timing. Therefore, high accuracy requires a high normal clock rate and a large division ratio. Also, high-speed logic is desirable.
- Counter outputs provide possible readout signals and the division ratio will determine the resolution.
- If the *system signal* frequency is one-half the synchro-carrier frequency, any signal at the carrier frequency or its harmonics that reaches the phase detector will integrate to zero—the phase detector gate is closed for one full cycle of the carrier signal and no error will be generated.

These factors established the choice of a normal clock rate of 720 kHz and a system frequency of 200 Hz in the breadboard (400 Hz synchro) system. The system resolution was 0.1° and the use of TTL logic, the high clock frequency, high-speed drivers and analog switches (JFETs), reduced pulse widths and timing errors to negligible levels. The most significant source of error appeared to be the low-pass filter.

A tentative method for eliminating this error (and other fixed phase shifts) was partially worked out, but not included in this design. Two additional switches in the signal converter permit simulation of an input signal corresponding to a known shaft angle. This signal may be generated periodically and the error determined by the system response and stored. Subsequent measurements are then automatically corrected, thus making the system self-calibrating. ☐

Robert W. Klatt is Director of Analog Systems at Scan-Optics, East Hartford, Conn. His duties involve the development of analog and electro-optical systems for optical character readers. He is a member of IEEE.

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LED modulator

To Vote For This Circuit Circle 161

by Greg Schmidt
San Diego State College
San Diego, Calif.

A COMMON difficulty in high-speed pulse modulation of Gallium Arsenide Phosphide LEDs is providing a low driving-point impedance. This is required for fast turn-on. In addition, dynamic current limiting is needed to prevent excessive current overdrive.

This circut overcomes these two difficulties. Transistor Q_1 is an amplifier that supplies a dc level as well as modulation information to emitter-follower output stage Q_3. Output current is sensed and limited by Q_2. Current limiting occurs when the voltage drop across R_7 forward biases CR_1 and draws base current from Q_2. For the values shown, current limiting occurs when LED current is about 30 mA. Since the LED is dark for voltages below 1.5 volts, turn-on time for full brightness is 12 ns. ■

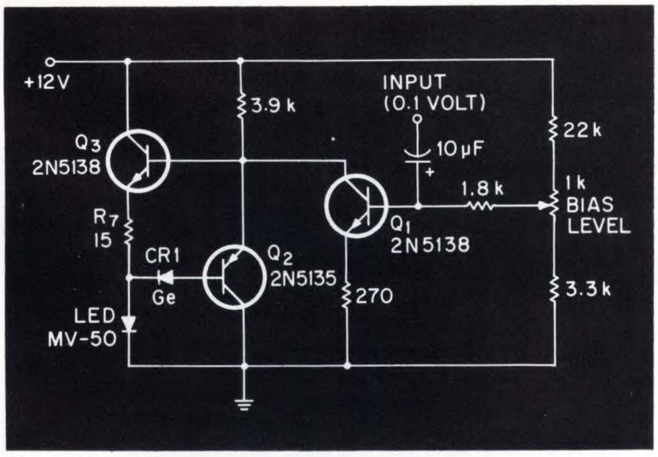


Fig. 1. This circuit provides a low-impedance, current-limiting, high-speed driver for a LED modulator.

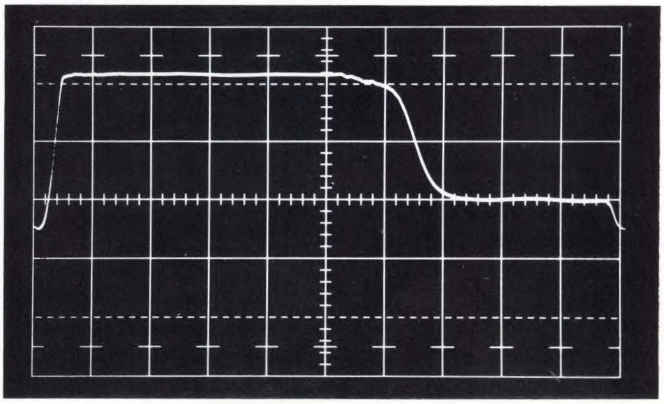


Fig. 2. LED voltage at a 1 MHz rep rate. Vertical scale is 0.5 V/div and horizontal scale is 0.1 μs/div. Zero volts dc is 1 division below the center line.

Stepped-sawtooth tone generator

To Vote For This Circuit Circle 162

by Heinrich Krabbe
Analog Devices
Norwood, Mass.

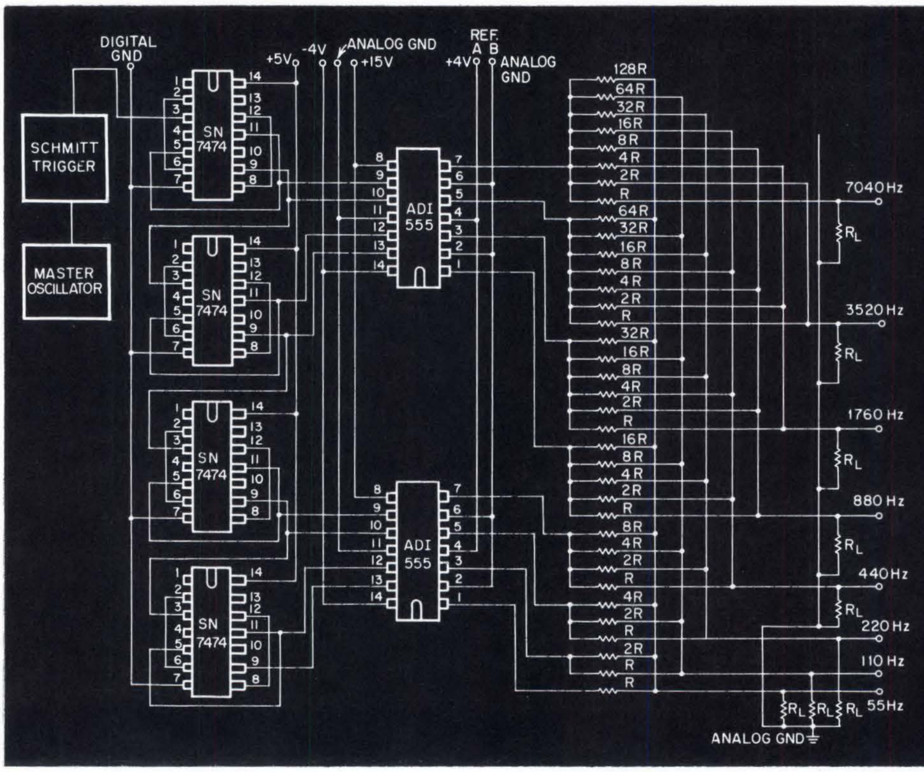
THE CIRCUIT shown uses a digital approach in producing a sawtooth waveform for tonal color generation in an electronics organ. A sawtooth waveform is useful since it contains all odd and even harmonics on a monotonically decreasing basis.

The sawtooth is generated from binary divider outputs, two μDAC voltage switches and a handful of resistors.

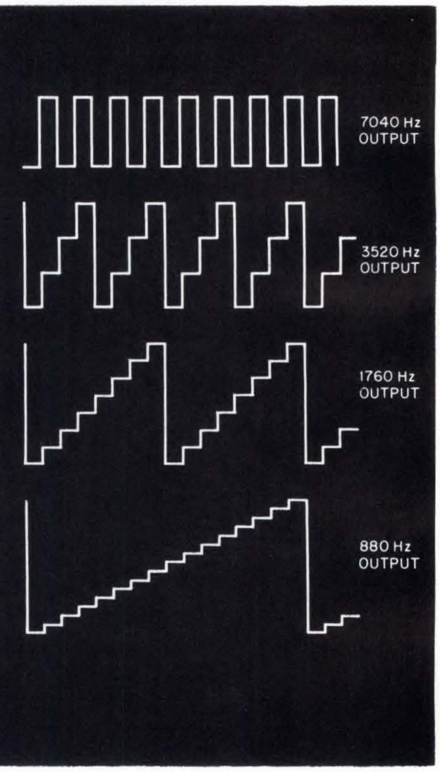
The figure shows a complete circuit diagram for the 8-tone generator divider strip. A highly stable L-C oscillator provides a frequency (14,080 Hz) an octave above the highest frequency desired. A Schmitt trigger squares the oscillator output to provide proper drive for the TTL flip-flops. The output of the first flip-flop provides the highest tone output (7040 Hz). All other tones are derived by the binary counters formed by the string of SN-7474s.

Each flip-flop drives one switch of the AD 1555 quad switch. The switch outputs are then resistively mixed through binary-scaled resistors so that a staircase waveshape results. This waveshape contains all odd and even harmonics up to a point, because the fundamental is mixed with ½ of the second harmonic, ¼ of the fourth harmonic, ⅛ of the eighth harmonic and so on. Since all odd harmonics are present in the fundamental, only even harmonics must be added. The best sawtooth approximation is obtained at the lowest frequency tone. Wave forms become progressively coarser at higher tones. The highest tone is simply a square wave. ■

This tone generator circuit uses a digital approach to generate approximate sawtooth waves.



Typical stepped outputs from the tone generator. Note that the 7040 Hz output is a square wave while all other outputs approximate a sawtooth.



Extraneous pulse detector

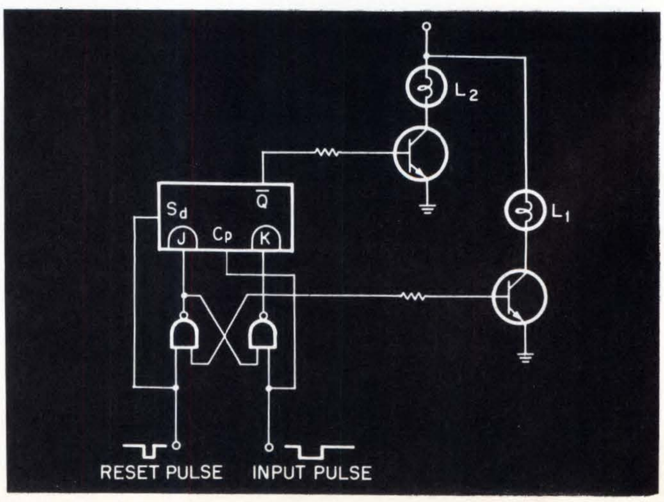
To Vote For This Circuit Circle 163

by Tony Randazzo
Atlantic Research
Costa Mesa, Calif.

THE FIGURE shows a combination of a cross-coupled latch and a JK flip-flop that together form an extraneous pulse detector. Given a reset command, Q goes low and the clock input is inhibited by the "0" present at the K input coming from the latch. When the input pulse goes low, the latch permanently changes state allowing any transients of the input pulse to trigger the JK flip-flop. In this situation, a "1" will be retained at the Q output and the failure indicated by lamp L_2.

Pulses and transients down to 25 ns can be detected by the circuit if series MC800P ICs are used. ■

This circuit indicates an extraneous pulse by turning L_1 and L_2 on. A "clean" pulse turns on L_1 only.



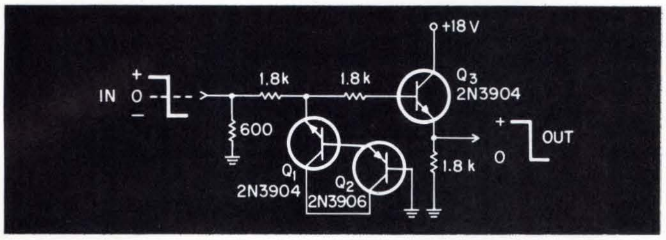
A polar clamp

To Vote For This Circuit Circle 164

by Richard R. Breazzano
Western Union
Mahwah, N. J.

THIS CIRCUIT provides overvoltage input protection for data communications equipment. The polar clamp normally operates with conventional 600-Hz teleprinter signals of ±6 Vdc at 10 mA. However, it can protect against overvoltage input transients of up to ±120 Vdc at 20 mA.

When a positive voltage input exceeds Q_1's emitter-base breakdown, the junction acts like a zener diode whose voltage rating is somewhat greater than the breakdown value. Transistor Q_2 becomes forward biased and input clamping is completed. With a negative input, Q_1 is forward biased and Q_2's emitter-base zener completes the clamping action. Emitter follower Q_3 maintains proper input impedance while delivering a buffered logic output. Q_1, Q_2 and Q_3 are inexpensive plastic transistors. ■



This polar clamp, constructed with an inexpensive plastic transistor, is protected against up to ±120-V at 60-mA transients.

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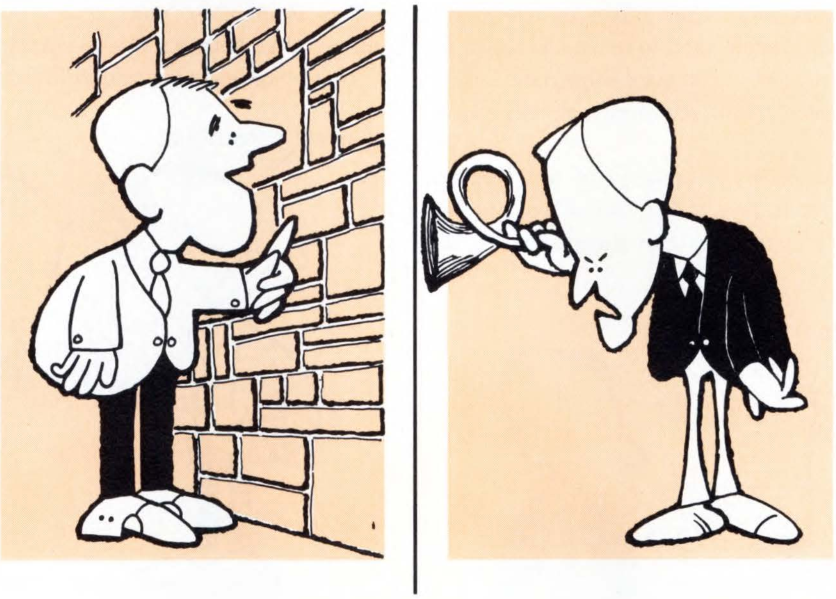


Polite Persuasion: Eight Questions Lead the Way

Next time you try to persuade someone to accept an idea or proposal, it might be easier—on both you and your prospect—if you use this question technique.

RAYMOND E. HERZOG, General Electric Co.

Did you ever get the feeling you were talking to a wall when you tried to get someone to consider an idea or proposal? To get that idea across, you need command of your proposal (know what you're talking about *and* what you want to do with it), yet stay within the bounds of polite persuasion.

If your prospect's "yeah, uh-huh" responses told you "he's not *listening* to what I say", you may have been violating the "wet noodle" principle (it's easier to get a wet noodle through a hole by pulling than by pushing). To gain full acceptance for your idea means that your prospect must make up his own mind. You can't make it up for him; but you can lead him to make it up for himself. Before that can happen, two things are required: mutual agreement on the proposed idea and a basis on which the two parties can work.

This basis for mutual work comes in the form of questions. Questions lead the way to polite persuasion through three means:
—involving the prospect in the discussion
—setting the stage for both parties to have a common view of the proposal.
—motivating the prospect to act on the proposal

Eight types of questions serve as guidelines to exemplify these means. For our illustration, let's refer to the person to whom the idea is being proposed as "the prospect".

Involvement: A Two-Way Discussion

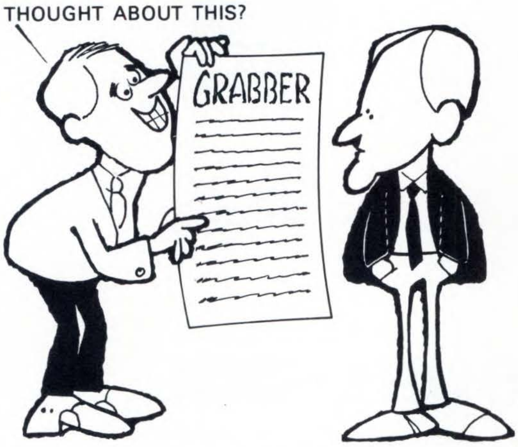
Simply stating your proposal, offering some supporting facts and bluntly asking for your prospect's approval is like poking a sharp stick at him. His first in-

(Continued)

clination is to withdraw. The few times that this technique might work are more than offset by the many that it won't. Because people tend to resist change or to avoid trying something new, you need some means that will draw the prospect into discussion, not make him withdraw from it.

In the first place, before someone can consider an idea seriously, he must give it his full attention. By asking a question, you can get your prospect's full attention:

EVER THOUGHT ABOUT THIS?



At the start of your presentation, get your prospect's thoughts on a meaningful fact to be brought out later in the proposal.

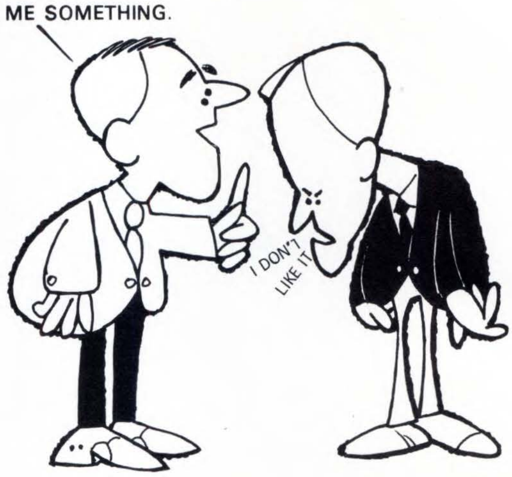
For example, let's say your idea is to standardize the design of all of your company's products by reducing the number of different types of components used in them. As part of your presentation, you would cite the number of different components used throughout all of your company's products. This number, you would point out, is surprisingly high and *could be reduced.* To your prospect, then, a stimulating question would be: "Mr. Smith, how many different types of capacitors would you say we use in all our products?"

Hasten to point out that his estimate will be compared with the actual count (which could be reduced to bring savings) later in the discussion. He should now listen to your proposal more intently. Furthermore, that actual count, given later to dramatize your case, will mean more to him both because his interest in it has been aroused beforehand and because he has had to wait for the answer.

Now, if you pause for a moment after having introduced the idea, you invite your prospect to speak. He'll probably ask about something that you planned to discuss anyway, and the mere fact of his asking helps retain his interest because now the discussion is two-sided. Remember, your goal of mutual agreement requires that both parties participate in the discussion.

So the second question guideline becomes:

ASK ME SOMETHING.



Induce your prospect to ask a question, which in being answered, will involve him more actively in the discussion.

Now is the time to retain your control of the discussion, so you follow up with a two-part question. Known as the "yes/no" technique, the first part is a question that is easily answered by the prospect. This lets him stay in phase with you. The second question is one which the prospect is unable to answer, so he must look to you for further direction.

The "yes/no" principle:

To set up control of the discussion, ask a two-part question: the first answerable by the prospect; the second unanswerable.

Following our design standardization example, the "yes" question might be: "You are aware, I'm sure, of the industry-wide emphasis on a serviceable product requiring standard parts?" Being abreast of current affairs, he should reply readily to that question. Now comes the second or "no" part: "And do you realize that closer design coordination within our engineering groups could not only produce a more serviceable product through standardized parts, but also save us money?"

To this, you'll probably get a response of "I didn't think of it that way; tell me more." And away you go!

On the other hand, if your prospect's response isn't that amenable, his reply can still lead to the fourth question technique. This one assures that both you and he see the matter in the same light.

Toward a Common Goal

It is very important to your presentation to make sure that both you and your prospect see the proposal objective in the same manner. To make sure that he is in step with you, it is a good idea to outline the proposal objective to him and then ask him how he sees it. This starts you off on common ground, but, more important, it helps eliminate those unpleasant little surprises that can come later if he has the wrong impression of what you're heading for.

In effect, this fourth guideline is:

After stating the proposal objective, get your prospect's thoughts on the subject to make sure that you are both thinking of the same goal.

This last point also suggests another persuasion technique. Since it is mutual agreement at which you are aiming, your prospect will find your idea more acceptable if, at the conclusion, he feels the idea was partly his. Toward this end, here's what to do:

Present your idea in a somewhat doubtful manner, inviting your prospect to take up the case sympathetically and, in effect, sell himself.

A quick note of caution: before attempting a doubtful expression, you must have preconditioned your prospect to have some favorable attitude toward the proposed idea.

Continuing with our example, you could say, "One place to begin is with our model XYZ, Mr. Smith. Of the 200 different parts, probably eight could be standardized easily . . . or maybe that's too many . . . perhaps four?"

A point to keep in mind throughout the presentation is that you should always be talking in terms of what your prospect wants to hear and not so much as to what you want him to hear; i.e., keep *his* wants foremost.

A sixth guideline helps to reveal your prospect's feelings better if he doesn't come right out and give them. It involves asking his opinion on a topic somewhat different than the main subject of your proposal, one which can be used to further your intention. It is what might be called the balancing question:

Get your prospect's thoughts on a different subject which he will express himself on. Relate or balance these thoughts with the proposal theme.

Here's how this works. Let's say your prospect voices little interest in your idea or says nothing with which you can carry on. An appropriate thing to do, then, is to change the subject slightly to something he *will* discuss. "Our Marketing group stresses customer convenience in having his product serviced", might bring out your prospect's opinion on serviceability, which in turn is related to standardized design. Thus, you can balance one to the other.

Also, in commenting on a third party you take the focus from yourself. With the idea endorsed by another it is easier to get acceptance.

Objections: Remove Them

With the preceding six question guidelines, your prospect should be pretty much convinced of your idea. It remains to move him into action.

Toward the end of the presentation, most significant facts have been brought out. All this information, having been given in an orderly way, should have helped the prospect to arrive at a decision to accept your idea. But he may hesitate to commit himself because he is unsure of something. This uncertainty will show up as an objection raised to your closing and asking for acceptance.

To meet this objection, there comes yet another question. This one will seek to get his agreement that the objection is really more of a doubt in his mind than a rebuff. It results from having done a thorough preparation before proposing your idea: namely, thinking ahead of some possible objections that might arise.

One of these objections might be that it would be too time-consuming to deviate from regular design concepts. To nullify this notion, a seventh question:

(Continued)

Give forethought to possible objections that may arise. Then, when they do, bring them fully into the open by getting your prospect's confirmation of their basis.

For example, the prospect could be convinced of and desire the benefits of the standardization plan, but he may wonder how to put it into effect. Not really knowing what his possible problem may be he'll just simply say that the idea isn't practical for his group. So with your seventh question, in anticipation of, say, the time factor, you query "Are you saying, Mr. Smith, that the idea is not practical because the extra time needed to research standardized parts would not allow you to meet your design schedules?"

If time is indeed his hangup, his confirmation of this basis helps you *both* to untie the binds preventing full acceptance. It is important to note that, in acknowledging the reason for his objection, the prospect is letting you continue the proposal discussion.

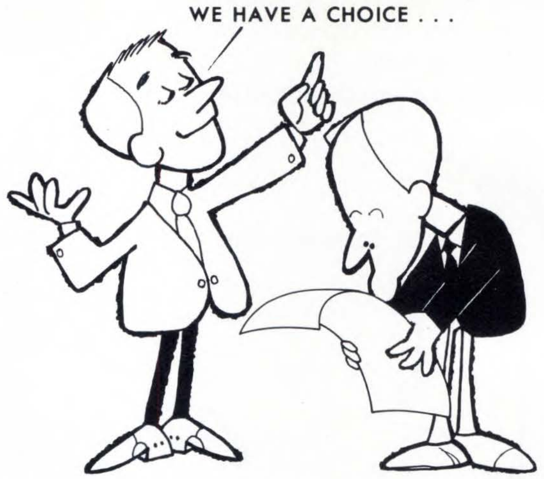
To conclude the proposal, you can refer back to the first question, in which you asked for the prospect's estimate on the total number of different capacitors used in all your products. With his thoughts directed toward standardizing the use of various parts, he now may be wondering just where to start. So, by hinting at a category, you can help him decide.

A final question here can help put over your proposal. This question makes it easier for the prospect to accept your idea by asking for a *choice* of items to begin standardizing—rather than a blunt request to standardize.

Let's assume the aforementioned category of capacitors might offer the greatest area to effect cost savings via standardization. To stress this point you could state the high number of capacitors being used in your company's products. If such a high number comes as a surprise to the prospect, he may decide to begin with capacitors.

On the other hand, he may decide not to standardize capacitors. And this negative response here at the end of the presentation could seriously dampen the chances of acceptance.

Here's where an eighth and final question can help:

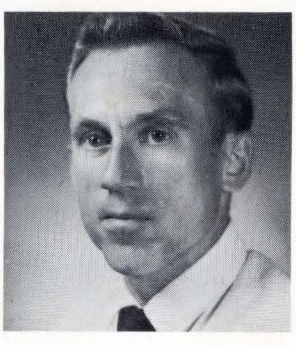


To help assure acceptance of the proposal, offer the prospect a choice of items or actions.

For example, you may wish to have capacitors as the kickoff standardizing category, but from your discussion (especially with the seventh question) you may sense that your prospect might prefer the least time-consuming category. Let's say this is power resistors. So you'd ask "It's agreed, then, that we should standardize our designs with fewer different types of parts. Shall we begin with the 138 different capacitors for a large cost saving, or should we begin with an easier and quicker category like power resistors?"

Let the choice be his. A proposal that ends with the prospect saying what to do should get the project off to a good start. □

Raymond E. Herzog supervises General Electric's TV service parts operation in Portsmouth, Va. With a B.S.E.E. from Indiana Inst. of Tech. he was previously with GE's Apollo Systems Dept. in Daytona Beach, Fla.



computer hardware

FOR DESIGNERS OF COMPUTER MAINFRAMES, PERIPHERALS AND SYSTEMS

Silicon Versus Magnetic Discs

A CAHNERS PUBLICATION / JUNE 15, 1971

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CIRCLE NO. 402

JUNE 15, 1971

computer hardware

EXCLUSIVELY FOR DESIGNERS OF COMPUTER MAINFRAMES, PERIPHERALS AND SYSTEMS

cover

Cover photo by National Semiconductor Corp. presents in abstract form the competition between magnetic discs and their semiconductor counterparts. The article on p. 8 tells about the tradeoffs involving these two technologies.

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minicomputer nabs thief . . . radiating heads increase drum capacity

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'silicon discs' challenge magnetic disc memories 8
Magnetic discs are reasonably fast and economical, but how do they compare with their solid-state counterparts? Already, as indicated in this article, MOS shift-registers are moving into systems capable of storing several million bits.

human factors in vertical panel design 21
Better panel switches can be designed, says H-P's Chris Clare, if we recognize the way human operators are structured.

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what is happening with cores?—

John J. Guyett, Director of Marketing for Core Memories, Inc., Data Products Corp., evaluates the core marketplace in three areas—the core, OEM systems and end-user systems. In the core area, the trend is one of improved mass production and testing techniques. More firms will be using a roll-cut process (patented by Data Products Corp.) to achieve production economies. Present core prices of $1.50/1000 will approach $1.00/1000 in 1972. The design trend is toward smaller 14-mil OD, low drive, fast switching cores.

The trend in core memory systems will continue to be one of increased performance and decreasing prices. Semiconductor memory manufacturers are supplying ever increasing pressure on the small-memory portion of the market. Presently, core systems are sold at a price/bit that semiconductor people quote for chips alone, not including assembly onto printed circuit boards or chassis. Because of decreasing prices in the semiconductor market for logic and sensing circuitry, complete core memory systems will be offered through 1972 at a price/bit equal to that which semiconductor memory companies charge for the memory elements alone.

Memory systems of the 1970s will require a greater data bandwidth. A 2D organization looks better from the price/performance viewpoint due to consistent lowering of prices for semiconductor circuits. A 2D organization lends itself to long data word lengths, such as 72 and 144 bits (typical) per word, that are used in larger computer systems. By using a 2D system with an access time of 200 nsec and a cycle time of 500 nsec, a selling price of 0.75 cent/bit can presently be obtained in production quantities.

Smaller systems, 4- to 8k words × 18 bits, are currently totally integrated module assemblies. These modules not only contain the magnetic storage but also the data and address registers, and internal timing. These assemblies are usually a sandwich of a planar core stack and two or more PC boards containing the associated electronics. The modules may be as small as 8 by 10 by 2 inches for a total 4k-word by 18-bit system. Performance is in the area of 750 nsec with costs about 1.5 cents/bit for the total modular package. The data processing system designer is given the opportunity to incorporate the new modular memory systems by simply plugging the assembly into his standard logic card mounting assemblies. Higher bit density packaging will be accomplished with smaller cores and where semiconductor barriers on thermal limits are advanced.

The recent flourish of offerings by independents to supply plug-compatible memory systems has not been limited to "peripheral storage". Vertical integration practiced by computer OEMs long ago caused the independent to seek a more diverse market place, and during the early and mid 60s, sufficient volume was found in special system houses and those computer OEMs that could not afford development of memory products. In turn, the independent memory supplier now seeks the market place his old customer had a strong hold on, by virtue of his more concentrated skills applied to a narrower product range. So the former supplier now comes into focus as a competitor to the computer OEM in the area of add-on memory.

(Continued)

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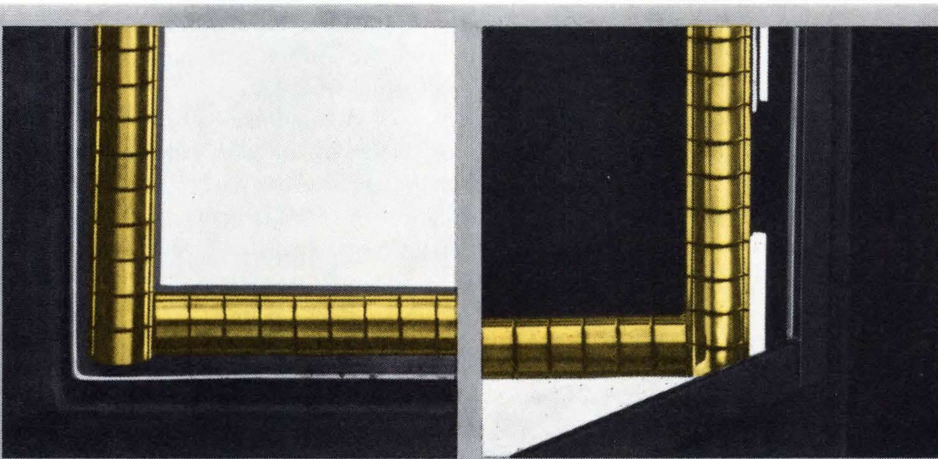

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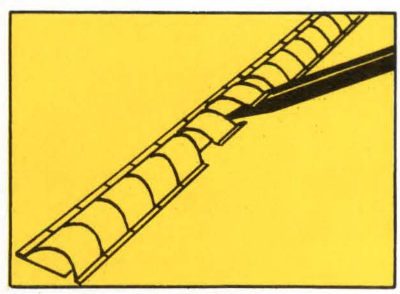

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CIRCLE NO. 404

Without the overhead of software and systems architecture to soften the punch, memory suppliers are providing each other with competition in the largest field of add-on memory—IBM's System/360. Several lines have been announced as targets, including the DEC PDP-10 and Univac's 1108. The proliferation should swell over the next 2 years until the OEMs decide to buy up competition, or until totally integrated memory is assembled within the control processor unit (CPU), comparable to the incorporation of peripheral controllers within the CPU domain as in the 2319 disc system.

But the steady growth of the independents has provided a concentration of design and manufacturing skills that now offer equivalent or better performance at a cost from 20 to 50 percent lower than the OEM memory. Obviously, the end-user cannot continuously ignore such an offering. Even with the newly assumed burdens of field service and broader sales coverage, independents are selling one- and two-million-byte memory systems at 2 cents/bit, including all possible bells and whistles.

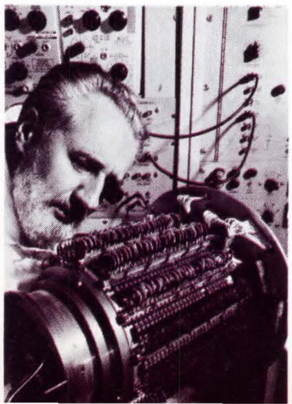
Increased sophistication of the end-user will undoubtedly cause the independent to be more responsive to the user requirement. It is projected that within 5 years, many commercial users will procure or lease a complete EDP system from a shopping list of CPU, memory, peripheral and terminal suppliers, just as was done by research systems people some 15 years ago.

But by 1976, ferrite storage will cost the end-user less than $10,000 for one million bits of on-line main memory with a cycle time of under 500 nsec.

minicomputer nabs thief—

Within 2 hours of being placed in operation, a Data General Nova 1200 minicomputer along with an American Regitel electronic cash register identified a "hot" credit card passer. It just shows how far the mini has come from being an unseen dedicated scientific device to a practical tool in face-to-face public business applications. The system benefits both the consuming public and employees at Bullock's in Los Angeles, for it makes immediate credit checks on charge purchases and also performs all calculations of discounts and taxes, makes price extensions and records the information on magnetic tape for direct automatic billing processing. This is just one small step toward fulfilling the myriad of predictions on how electronics and computers would make things better for the general public.

radiating heads increase drum capacity—



Read-write heads (total of 294) extend out from the outer cylinder of a 15-million-bit memory drum, developed by Hughes Aircraft Co., Data Systems Div., Culver City, Calif. Known as the Mark II, Mod 7 Series, this unit was developed under contract to Texas Instruments Incorporated for the U.S. Air Force and Marine Corps TIPI program to meet increased digital data needs for military aircraft and missile systems. The 294 heads ride on an air cushion while the polished memory drum inside spins at 2400 rpm.

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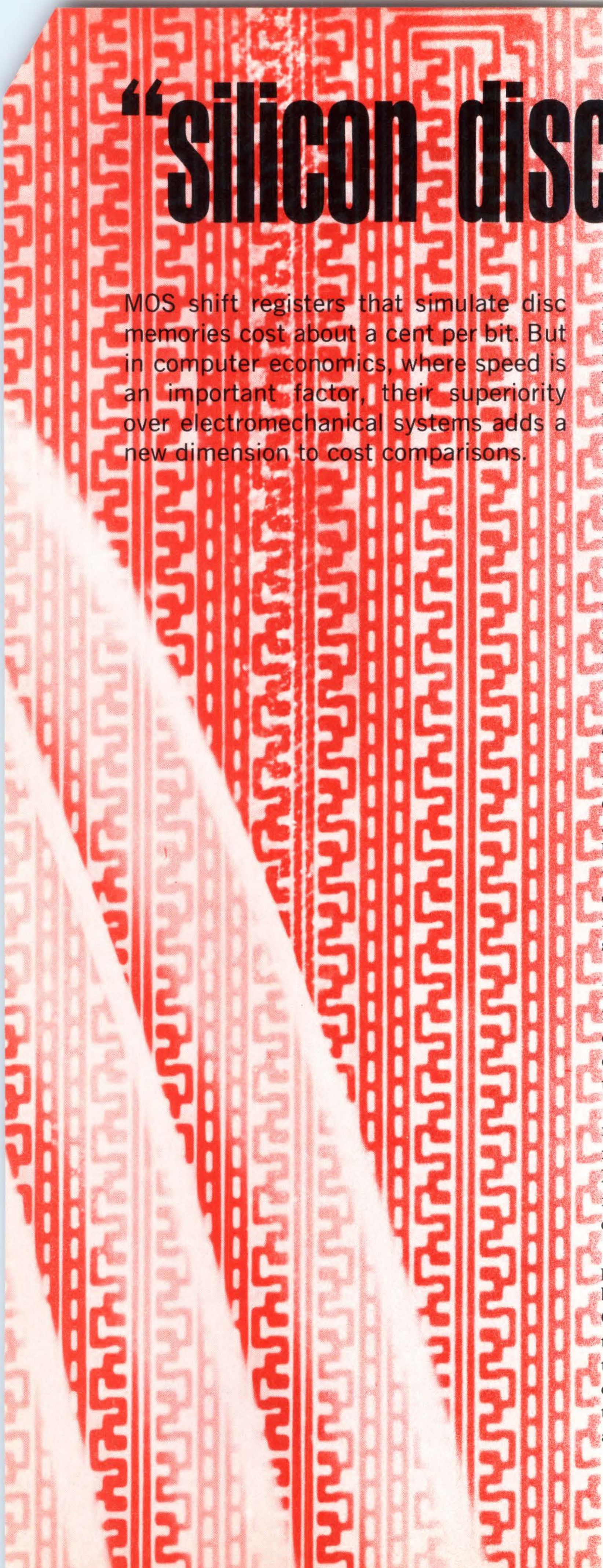
CIRCLE NO. 405

"silicon discs" challenge



MOS shift registers that simulate disc memories cost about a cent per bit. But in computer economics, where speed is an important factor, their superiority over electromechanical systems adds a new dimension to cost comparisons.

Because magnetic discs are reasonably fast and economical, they dominate the peripheral memory market. But are they fast and economical enough to compete with new solid-state memories? Small, drum-type memories built with MOS shift registers already have begun to replace their electromechanical counterparts. Now, large-scale MOS registers are making their move in systems storing up to several million bits—the size at which magnetic discs cost 0.5 cents per bit or less. However, the silicon disc systems based on MOS shift registers help computers perform twice as much work as before by minimizing data-transfer delays.

Earlier shift-register memories achieved high speeds but were expensive with increased capacity. This was partly because register lengths were short and partly because the cost of supporting logic networks grew almost geometrically with capacity.

To limit cost regardless of size, National Semiconductor developed a unit that contains two 256-bit registers plus gating for data-input and output-data steering and three levels of decoding logic (**Fig. 1**). Also, the design features a three-state output configuration that allows many registers to time-share data-transfer buses. Memories storing millions of bits can be built with little more supporting logic than memories with capacities of a few hundred thousand bits. In the latter range, silicon discs are actually less expensive than small electromechanical drums and discs.

The MOS registers keep large systems totally modular and page-organized in a three-dimensional (3-D) memory configuration. Every memory-page sector is directly accessible in microseconds with conventional disc software. If more efficient software is written for the disc, pages are accessed in real time.

Register length (256 bits) corresponds to the popular memory-page size of 256 words in a 3-D recirculating memory. However, any length can be stored. Longer MOS registers are available, but the tradeoffs of capacity versus data transfer times, modularity and system complexity have not been very appetizing.

Furthermore, the design in **Fig. 1** assures that compact, low-power, cool-running megabit systems can be built into the main frames of advanced computers. Operating problems solved range from arc-free operation in hazardous industrial atmospheres to using batteries to retain data during power shutdowns. Power consumption for storing a million bits ranges from less than a watt at idling frequencies to about 10 watts at a 2-MHz word rate.

(Continued)

magnetic disc memories

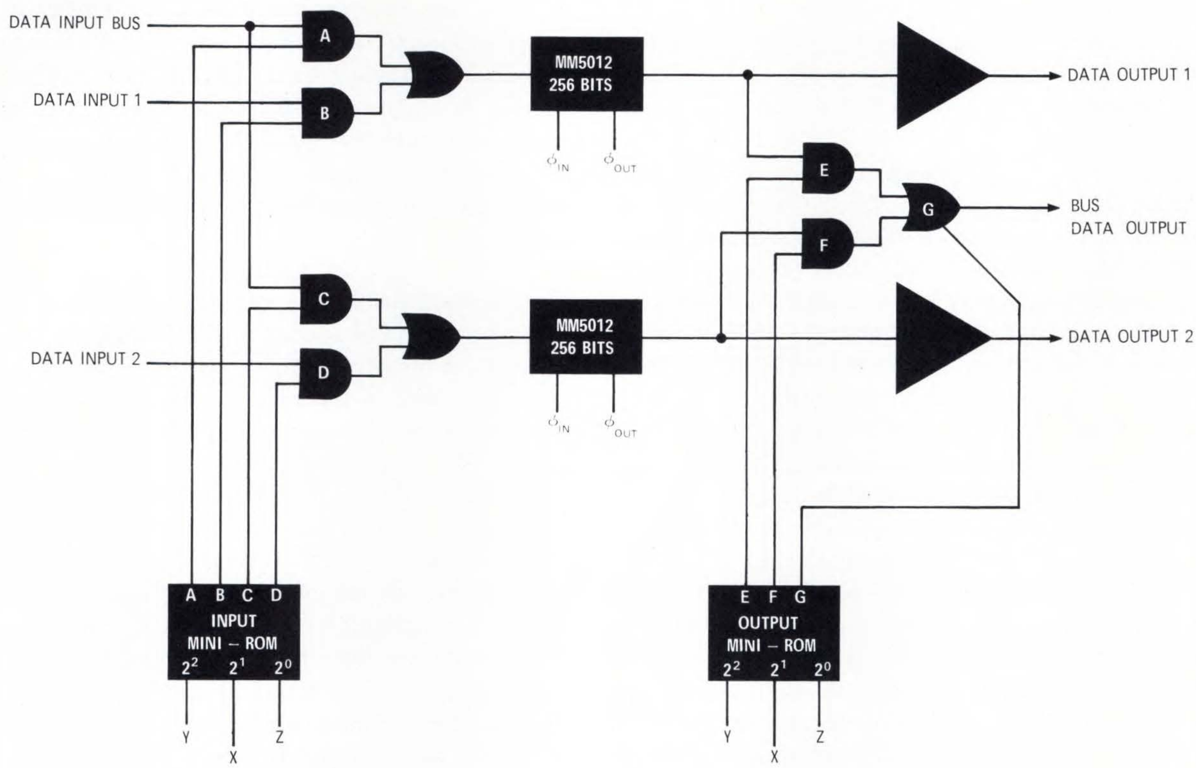


Fig. 1—**Design of the MM5012** lends itself to 3-D organization, outlined in Fig. 2. A 3-bit address applied to the mini-ROMs defines eight pages. At a page length of 256 words, 16 bits/word, one can store 32,000 bits, equivalent to a small drum. No external decoding or input/output steering logic is required.

The reason for time-sharing the MOS outputs is that gate G has three logic states. Two are normal TTL-compatible MOS "1" and "0" states. The third is a high-impedance state that disables the package by in effect disconnecting it from the output bus. This third state, developed by the author and others at National Semiconductor, shunts the gate output stage so that only a small leakage current flows through the output. No data flows through the disabled output—only the selected output transmits on the bus.

The 3-bit address applied to the mini-ROMs are such that two inputs allow package select while one input selects the registers to be addressed. These are:

2^2	2^1	Binary Values with 2^0
0	0	0 and 1
0	1	2 and 3 or
1	0	4 and 5
1	1	6 and 7

Reversing the pins of the "01" type on the printed circuit card layout yields "01" coding.

Input mini-ROM type "00" package, for example, enables gates A and D, and disables gates B and C if the address is 000. Thus, a data-bus input is steered into the top register. If the address is 001, only gates B and C are enabled, steering the data-bus input to the lower register. All other addresses keep gates A and C disabled, and B and D enabled. A page selected in a module such as in Fig. 2 stores new data while all other pages continue recirculating previously stored data.

Similarly, output mini-ROMs steer the data being clocked through the top register through gates E and G for address 000. If address is 001, it steers the bottom register contents through gates F and G. All gating is enabled with true logic levels on mini-ROM output lines, so the gate functions are identical in all register types.

(Continued)

Three-Dimensional Systems. Logically, the device described in **Fig. 1** is most efficient in the 3-D system structure outlined in **Fig. 2**. A 3-D structure renders direct access, page by page, and data transfer in bit-parallel words. It requires no more registers and in general, less external logic than a 2-D configuration. More important, 3-D is very efficient in terms of computer utilization.

Assume either a 3-D silicon disc, an electromechanical disc (**Fig. 3a**), or a drum type, 2-D silicon memory (**Fig. 3b**) is to be used for storing a nominal page length of 256 words, 16 bits/word. The MOS 3-D configuration operates easily at a word rate of 2 MHz – a 32-MHz bit rate. At worst case, the registers take 126 μsec to recirculate to the zero-reference word output of the page. Average latency time (search delay) is 64 μsec and data transfer time is 128 μsec. These figures apply for conventional disc-computer programming. Software written for the silicon disc eliminates the latency interval.

Although an electromechanical disc is physically a 2-D system, each track can be considered a 1-D subsystem. This is because all bits of all words in a page generally are serially recorded along a sector of a single track. A low-cost system takes some 32 msec/revolution, thus latency averages 16 msec. Transfer at the 3-MHz bit rate is about 1.5 msec, an average total time of 17.5 msec. A more expensive high-speed system might exhibit a total time of 10 msec.

A 3-D organization offers many advantages with the biggest savings in computer time. As in any solid-state page-organized design, index and keywords need not be stored or stripped. Logic cost and time are reduced. Capacity can be tailored to application and modularly expanded later, rather than following a binary progression to economize on transducers and analog circuitry. Also, there is a savings in the cost of parallel-serial and serial-parallel conversion in computers equipped for bit-parallel operation. In other words the overhead ratio of stored data for the silicon disc organization is optimum since there is no need to insert additional data for page on track coding intelligance.

Chip Decoding. Three types of shift registers are available – differing only in mini-ROM coding for input and output address bits. Two inputs select the package and one input selects the register being addressed (**Fig. 4**). The input mini-ROM packages steer the information on the data input bus into the proper register. Similarly, the output mini-ROMs control the transfer of data from the register to the output network.

Readout is nondestructive. The register recirculation loops are normally closed by wiring data output 1 to data input 1, output 2 to input 2, etc. Alternatively, registers may be connected in series to store multiple-page data blocks. The data outputs are buffered to maintain good logic levels during recirculation and may be tapped to sample data for house keeping and other functions within the system. The recirculation is not interrupted by changes of the read-out address – only the read-in address will cause changes in recirculation control.

TTL/MOS Compatibility. To operate at high-word rates, bipolar logic can be used to control MOS registers. For example, a bipolar counter establishes the zero-word reference point in the recirculation loop by counting the clock pulses. Also, in large systems, it is convenient to use TTL single-chip circuits for decoding higher-order address bits of an X-Y select matrix.

Therefore, a low-threshold (100) silicon process was used to make the MM5012 registers. This process permits data inputs and mini-ROM addresses to be either MOS or bipolar logic levels. However, the outputs drive a TTL load when the register V_{ss} is bias at the TTL V_{cc} voltage supply. There is no logic inversion through the register. That is, data entered in bipolar format reads out in the same format. However, the mini-ROM programming, previously described, allows the element to accept any TTL-input combinational level.

Almost any number of MOS data-bus outputs can time-share a bus line. Word rate establishes the maximum number because this governs the capacitance output load – a 20 pF load to the selected output. As the capacitance increases, transition times of the output data must increase to maintain good output data levels.

To illustrate, the maximum word rate for 128 MOS outputs tied in common is about 500 kHz – total average transfer time of a 256-word page is less than 1 msec. The frequency can increase, almost proportionally, to about 2.5 MHz maximum if only four MOS outputs (eight pages) are bus-connected. At any word rate, there is no practical limit to the number of packages that can be connected to the data input. This is because TTL gates can supply extremely large capacitive loading without degradation of gate propagation delays.

Tri-state logic is an approach to supplement the MOS outputs in large systems operating at high word rates (**Fig. 1**). These devices act as a buffer for the MOS outputs, as shown in **Fig. 2**. Also TTL can decode the higher-order output-address bits and steer the page

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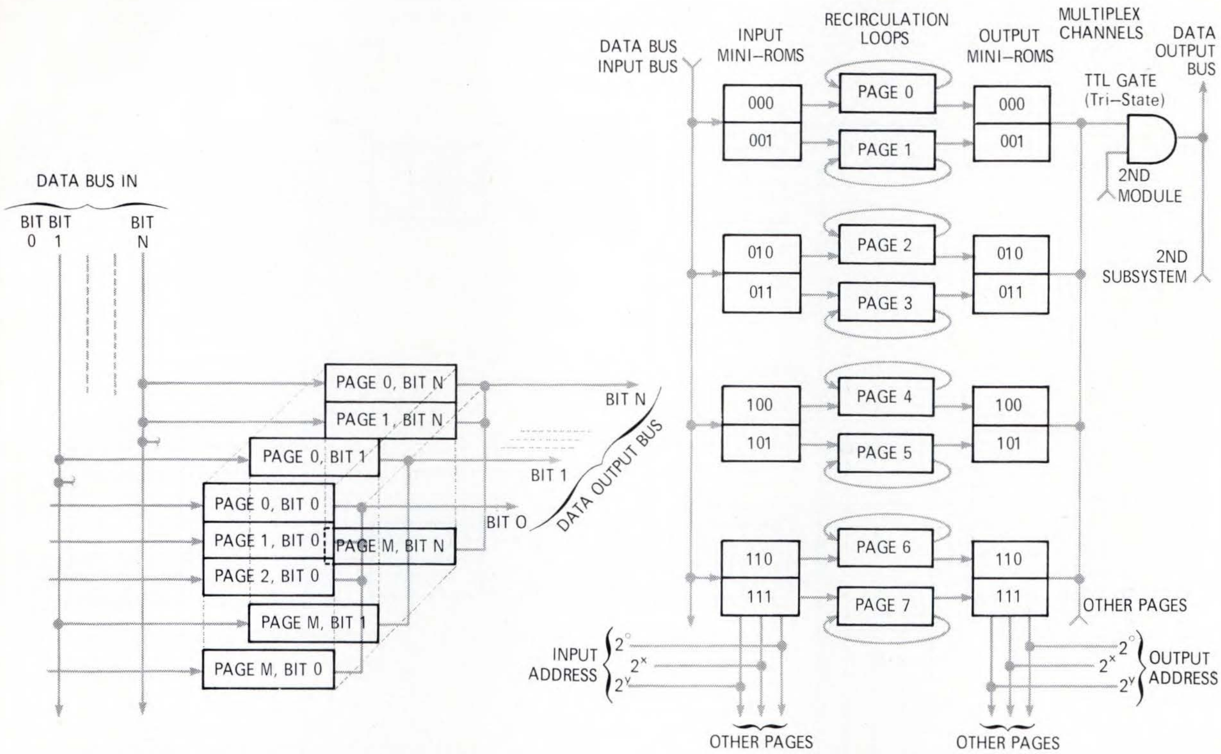
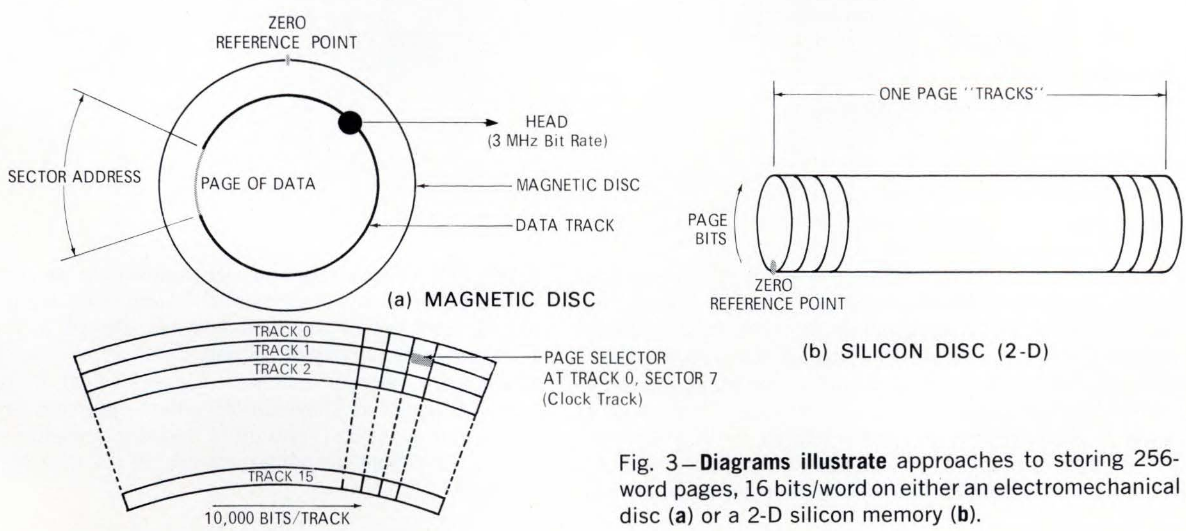


(a) 3-D "ROTATING" MEMORY ORGANIZATION

(b) EIGHT PAGE ASSEMBLY

Fig. 2—**Diagram (a)** illustrates a 3-D system structure with **(b)** showing a portion of one-X-Y plane. Dimension X represents page length in words (register length), Z is bits/word and Y is pages/system or modular assembly.

Clocking the registers to read in, recirculate and read out stored data simulates disc rotation. Control decoding logic for all parallel registers in the Z dimension are addressed in parallel. Hence, a two-page, Z section can be considered the basic system submodule for a 256-bit page size, consisting of as many IC packages as there are bits/word.



(b) SILICON DISC (2-D)

Fig. 3—**Diagrams illustrate** approaches to storing 256-word pages, 16 bits/word on either an electromechanical disc **(a)** or a 2-D silicon memory **(b)**.

(Continued)

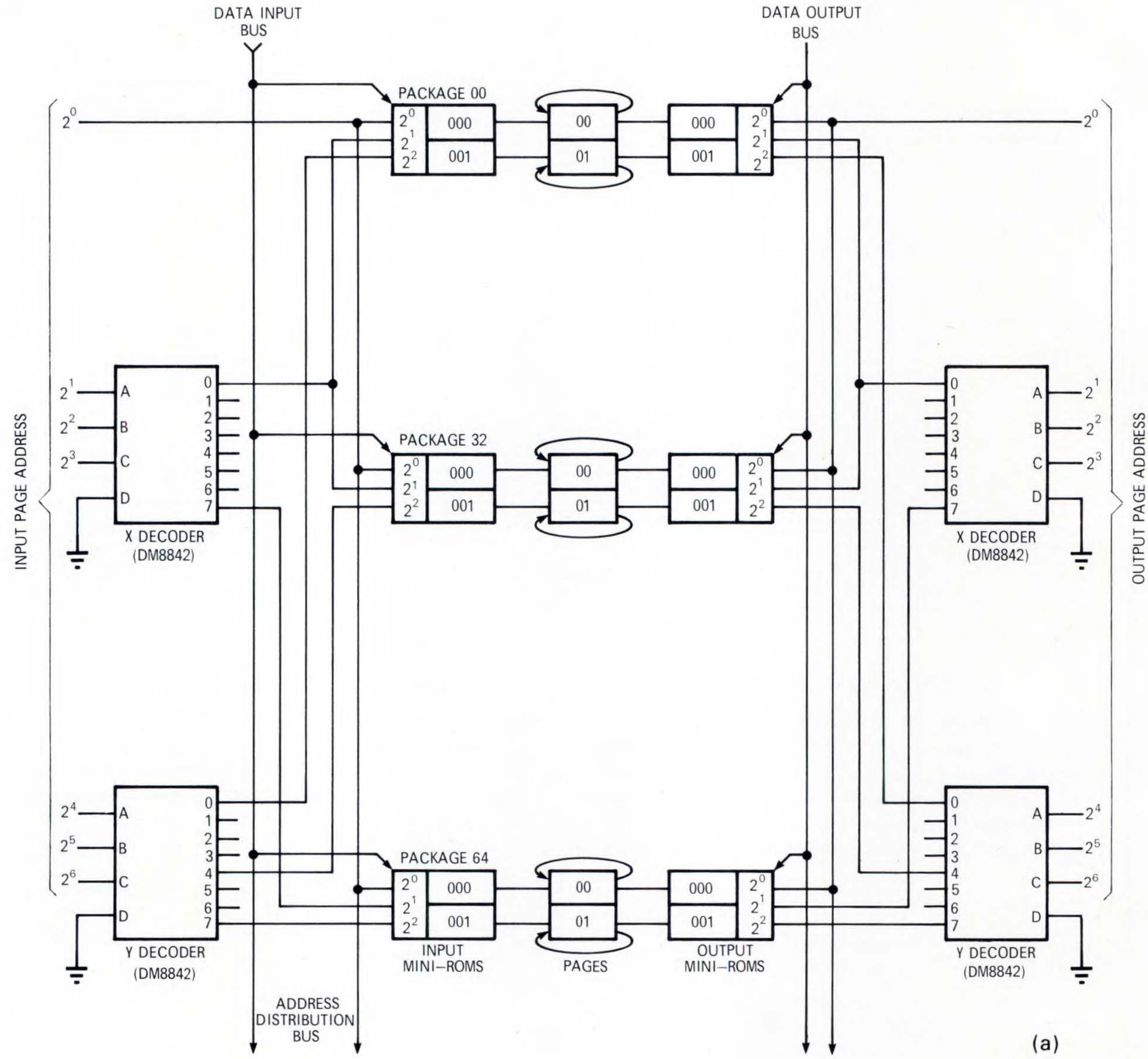
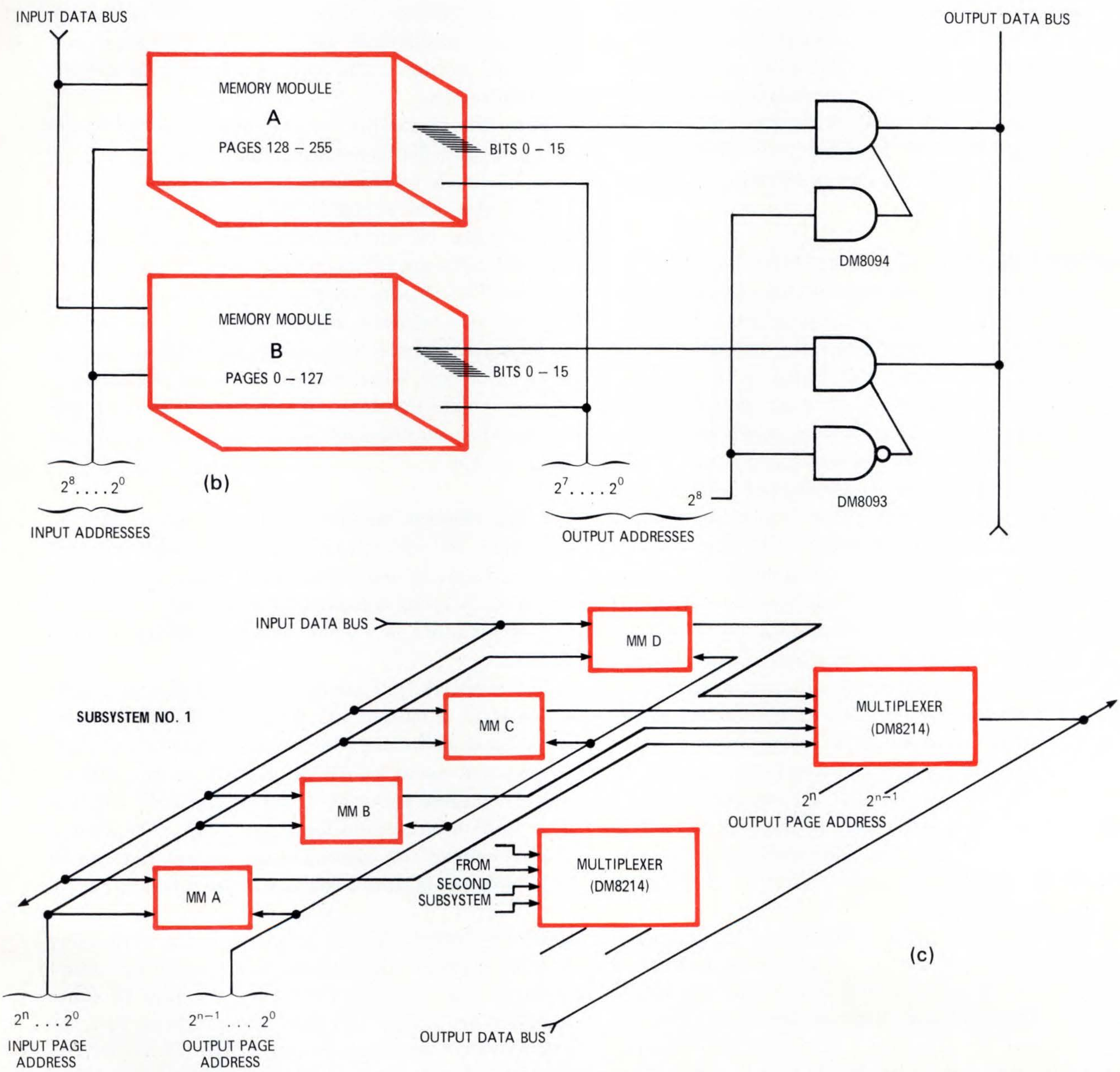


Fig. 4—**Three circuits** that operate on address words longer than 3 bits are straightforward examples of address decoders. In (**a**), X and Y represent partitioned memory address locations as in a planar array of page locations. Dimension Z refers to the number of pages that would be addressed in parallel if tri-state logic were used. Axes X and Y are applied to the 2^1 and 2^2 mini-ROM inputs. Address bit 2^0 may select either page in each of a two-page subassembly. Address decoders DM8842 (BCD-to-decimal) have 10 active-low outputs in a decimal mode or eight outputs in an octal mode.

To decode long binary address words, the octal mode is used. Each bit of the 3-bit address applied to a decoder selects eight packages, 16 pages with 2^0 address. Outputs from one X decoder and one Y decoder select 64- packages on 128 pages as shown in (**a**). Select capability grows in a binary progression if one of 16 decoder elements are used. This is a simple decoding network for a 2-megabit storage system.



With tri-state TTL devices, several pages can be addressed in similar X-Y locations in adjoining modules, using the less significant address bits. The more significant bits select the desired page on tri-state TTL outputs, illustrated in (**b**) and (**c**). In fact, if all mini-ROM coding options are used, large, high-speed silicon discs may be built with little or no output decoders in the modules.

Configuration (**b**) illustrates a use of National's tri-state TTL family—quad gates DM8093 and DM8094. Each of the four gates in a package has a control input and a dedicated data input. A TTL "0" enables the DM8093 output and a TTL "1" enables DM8094. The DM8214 in (**c**) is a dual 4-channel multiplexer. Data routings are selected by binary control signals. A half-package selects from the parallel outputs of four modules. This might represent 4×16 pages of a 2-MHz system. At practical system sizes, submultiplexers would probably be used only to achieve high word rates.

(Continued)

data through a minor data bus to the main output bus.

Like the MOS outputs, the tri-state devices have a high-impedance state that allows only a small leakage current to flow. They can be connected 128-wide to a bus, and operate at TTL speeds. With these devices, many tradeoffs can be made among word rates, memory modules sizes, addressing techniques and so forth. All these tradeoffs can be included in the hardware design without affecting the disc operating characteristics.

Large-System Decoding. So far, it has been shown that up to eight pages can be selected without external decoding and that up to 256 pages (128 packages at 500 kHz) can be assembled in a single module without external data-steering gates. The latter, based on the nominal 4096-bit page, represents a million-bit system with an 8-MHz bit rate. To lower system construction and maintenance costs, to take advantage of design tradeoffs, and for other practical reasons, the designer prefers a more modular form. This is possible without affecting the direct accessibility of each page.

First, there is the matter of decoding address words longer than three bits. Some techniques are discussed in **Fig.** 4. In **Fig. 4a**, X and Y represent the partitioned memory-address locations as in a planar array of page locations. This is a simple decoding network for a 2-million-bit storage system. The number of words per page or bits per word will not change the number of decoders used. All data is addressed by page and all registers of a page are parallel. One might, however, want to replicate the decoding assembly from module to module to simplify the address-distribution bus. Mini-ROMs make this possible. Multi-level decoding networks are not required.

In **Figs. 4b** and **4c**, a Z-axis represents the number of pages that are addressable in parallel using tri-state logic to select the page outputs for transferring data to the main output bus. All input addresses are fully decoded because the input bus is not branched. However, the output addresses need not be fully decoded if the output bus structure consists of tri-state logic. Therefore, tri-state logic performs double duty—increases word rate and simplifies the output decoding network.

Many options available in different mini-ROM formats and decoder modes extend and vary both input addressing methods. The mini-ROM can effectively quadruple the flexibility of the decoder approach. Small systems use the full element decoder.

When considering the efficiencies of the electromechanical and silicon disc memories, we see that within the finite storage system one must also store the sector and page address information as well as the data page intelligence. This requires additional storage, thus adding to the data overhead of the electromechanical disc.

Since the silicon disc is page structured, there are no storage inefficiencies. Only data is stored. All address instructions are available as input or output decoding terminals. Probably, there are cases where the 256-bit page will not be the desirable length, but one can still make use of the control functions and memory storage. This is achieved by connecting external memory registers between the nonbussed outputs and the register data inputs. This allows the memory register to be any length desired, permits the general economy of long simple input/output registers to be used, and retains the usefulness of the input/output decoding for mass storage.

The Long Weekend. Magnetic memories retain data indefinitely. So will silicon discs made with dynamic MOS registers as long as the clock rate is at least a few kilohertz. All that is required during holiday shutdown or power failure is a small battery—thanks to mini-ROMs.

The registers consume about 0.5 mW/bit at 2 MHz or 500W for a million bits run at 2 MHz continuously (which just isn't done). But power decreases with clock frequency to about 1.5 μW/bit at 5 kHz or less. Thus, a nickel-cadmium battery will supply the 1.5W required by a million-bit system for several days. The kind of "long weekend" or power failure circuit that can be used with the MM5012 register is described in **Fig. 5**.

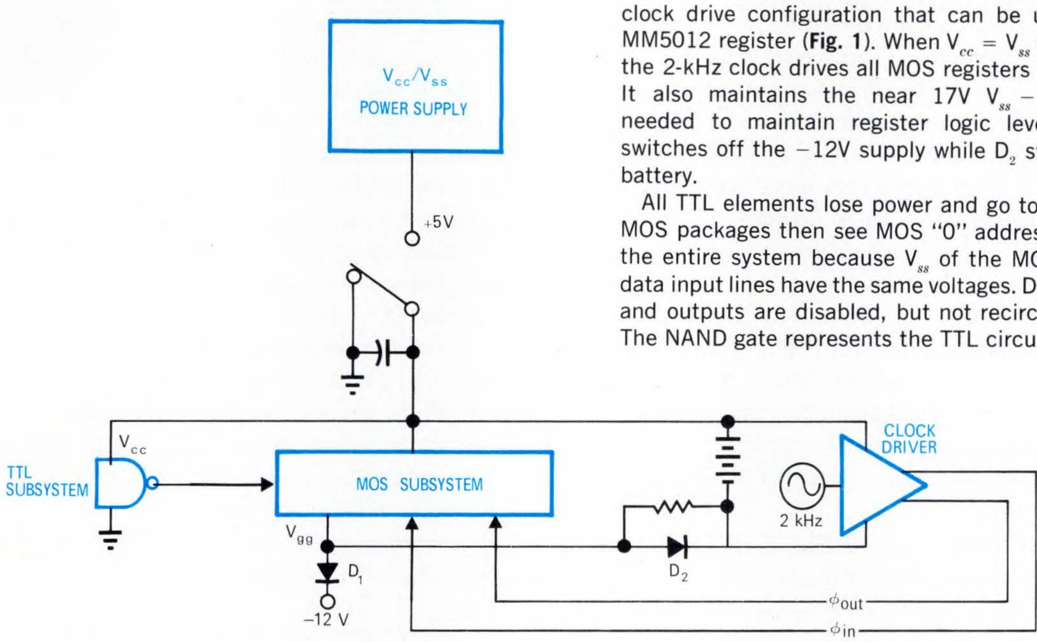
Low-Power System. Clock modulation is the work-a-day version of **Fig. 5**. Data transfers are made in a burst mode of only selected subassemblies while all other registers are idling. However, the computer sees the entire system operating at 1 or 2 MHz. The burst frequency is that required by the computer, and the idling frequency is usually f/256 or f/512—less than 4 kHz. Making the low-frequency a submultiple of the transfer frequency will transfer a page of data within one clock interval of the low-frequency clock interval. This simplifies the memory housekeeping in maintaining synchronization of all discs.

This mode reduces MOS power consumption to about 1 to 2W in the addressed two-page segment and 0.5W in the remainder of the system. A generous allowance

(Continued)

Fig. 5—**"Long Weekend"** or power failure circuit is a clock drive configuration that can be used with the MM5012 register (**Fig. 1**). When $V_{cc} = V_{ss}$ becomes zero, the 2-kHz clock drives all MOS registers in the system. It also maintains the near 17V $V_{ss} - V_{GG}$ potential needed to maintain register logic levels. Diode D_1 switches off the −12V supply while D_2 switches in the battery.

All TTL elements lose power and go to 0V (low). The MOS packages then see MOS "0" address, throughout the entire system because V_{ss} of the MOS device and data input lines have the same voltages. Data bus inputs and outputs are disabled, but not recirculation paths. The NAND gate represents the TTL circuits.



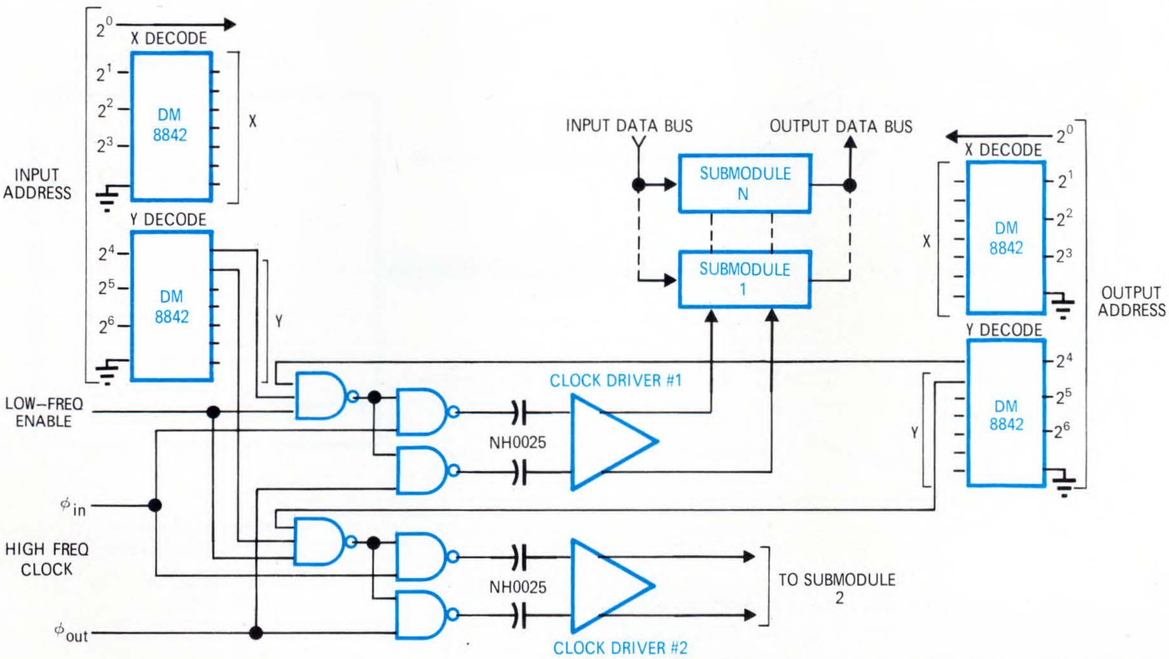


Fig. 6—**Burst mode technique** is developed with a few gates added to the clock drive lines of whatever size assembly one driver can operate (this also varies widely with burst frequencies). High- and low-speed clocks are bused at minimum power levels. When an X-Y select is made, the gates enable the high-speed clock to the driver. Search and transfer can be achieved in one clock period if the high/low ratio is twice the page length. Loss of synchronization is only one clock period at worst if the ratio is the page length. Detection of a possible loss of synchronization is required and the additional clock pulse is added if required to the address memories so as to maintain total synchronization of the disc memory system.

(Continued)

for bipolar circuits bring this up to about 10W/megabit. The main purpose is to avoid excessive heat dissipation in the very dense circuitry. Operating a fraction of a millisecond in a burst mode hardly warms up the registers. Among other benefits are improved performance from the clock drivers, more compact system packaging and simpler control logic. The logic, such as clock counters, is simpler because the pages stay synchronized when an access is made. An example of a circuit that provides burst-mode operation is illustrated in **Fig. 6**.

Real-Time Access. A conventional disc begins readout with the zero-bit of a page or data block. On the other hand, a silicon disc can start readout at any word location because no extraneous data is read between the end and beginning of a page if register length equals page or block length.

Writing a program based on **Fig. 7** will eliminate latency or search time. When the silicon disc receives a read command, for instance, the clock counter detects the word N-X as being the next word available at the output of the register. The computer is so informed. Readout starts immediately and is addressed to location N-X in the computer's random-access memory. Readout continues through word N, word O, to word N-X-1, completing the transfer.

Word rates multiplied by interlace techniques, similar to register multiplexing methods in other MOS systems, achieve effective clock rates of 10 MHz or better. Random addressed multi-page transfers can be made with pages in parallel to adjoining random-access memory sectors without a hold interval between pages. The logical flexibility of a silicon disc offers many such options. While today's computers may not be able to handle data at these rates, higher rates may be required to attain full useage of a computer with high-speed, bipolar random-access memories.

Just as word transfer is equivalent to reading several magnetic tracks in parallel, page-parallel operation is

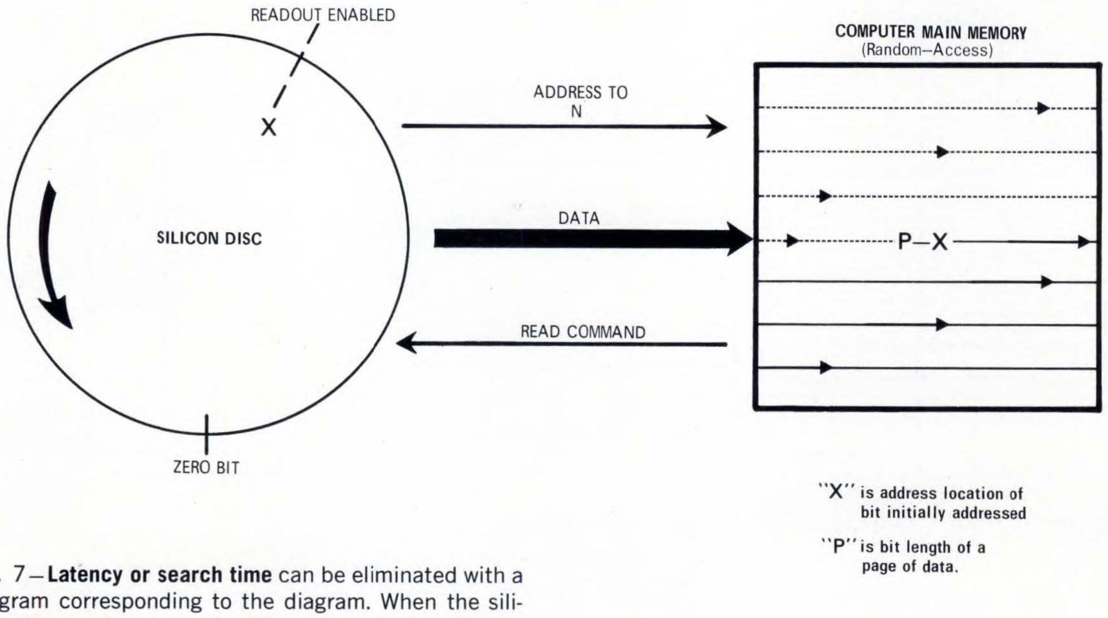


Fig. 7—**Latency or search time** can be eliminated with a program corresponding to the diagram. When the silicon disc receives a read command, the clock counter detects word N-X as being the next word available at the register output. Computer is alerted. Readout begins immediately and is addressed to location N-X in the computer's random-access memory. Readout continues through word N, word 0 to word N-X-1, completing the transfer.

like operating several discs in parallel. These discs, built with logic ICs, are not mechanically limited to any particular capacity or recirculation rate. As small a disc as a two-page subassembly may operate either synchronously or asynchronously within the main disc system. The data outputs of the small discs can be accessed through the buses or by sampling the recirculation loops. Housekeeping, repetitive test routines and other functions that ordinarily require core storage or dedicated disc or drum may be obtained at much less cost.

In the future, silicon discs will probably be built within the computer main frames to serve as buffers between slow, but cheap, mass memories and high-speed random-access memories. The first applications are expected to be supplementing core memories, helping small computers operate efficiently with 8k instead of 16k core memory and an electromechanical disc a possibility. These introductions are anticipated because discs are less expensive than random-access memories.

Furthermore, a silicon disc goes into places that the electromechanical cannot—explosive atmospheres (all motors arc occasionally), aerospace and military environments, and computer housing, for examples. This opens up new horizons for disc memories. A quick comparison of the cost of maintaining an electromechanical disc with the cost of a silicon disc also indicates significant advantages.

Dale Mrazek is Manager of Digital Systems Applications with National Semiconductor Corp., Santa Clara, Calif, and is involved in MOS and bipolar digital applications. He received a B.S.E.E. from the University of Denver, and is a member of IEEE.

'WHAT'S A MEMORY WORTH?' or 'CHEAP AT TWICE THE PRICE'

Hardware, software and overhead can easily make a $20,000 computer worth $50,000 to its owner. Consequently, any peripheral that helps that computer do 20 to 50% more work is worth $10,000 to $25,000.

That, not coincidently, is the price range of 1 to 2.5-megabit silicon discs—a penny a bit. You might say they are given away free to anybody who can use them—that is, anybody who can use submillisecond transfer times.

Who's that? Owners of process controllers and small time-share systems, for example. Think of a small computer's peripheral as the tail that wags the dog. The process controller is slaved to the peripheral about 20% of the time, while program changes are being made. The time-share computer usually processes a request for 20 msec, transfers a program in the next 10 or 20 msec, processes the next request for 20 msec, transfers another program, etc.

The cycle is typical of a computer dependent on low-cost electromechanical discs. To ease the problem, the owner may buy extra random-access memory modules at much more than 1¢ a bit. Neither of these memories is free, literally or figuratively.

Little electromechanical discs cost about 2¢ a bit, megabit discs about 1/2¢ a bit, and big ones 1/4¢ or less. These fractions aren't as small as they look, however.

Conventional discs are made in size increments —0.4, 0.8, 1.6, 3.2 million, and so forth. You pay extra if the capacity requirements fall between the cracks. You pay extra for the track capacity used for indexes, key words and gaps, and if you can't use it, for the logic designed to find small track sectors. You pay extra twice if you estimated wrong and bought too small a disc. The only guarantee against downtime for mechanical repairs is a spare. There's another 1/2¢ a bit.

On the other hand, silicon disc capacities are modularly expandable in increments of a few pages. They can be maintained on the card or module level. If a card is out, those addresses simply can be forbidden while the rest of the disc is running.

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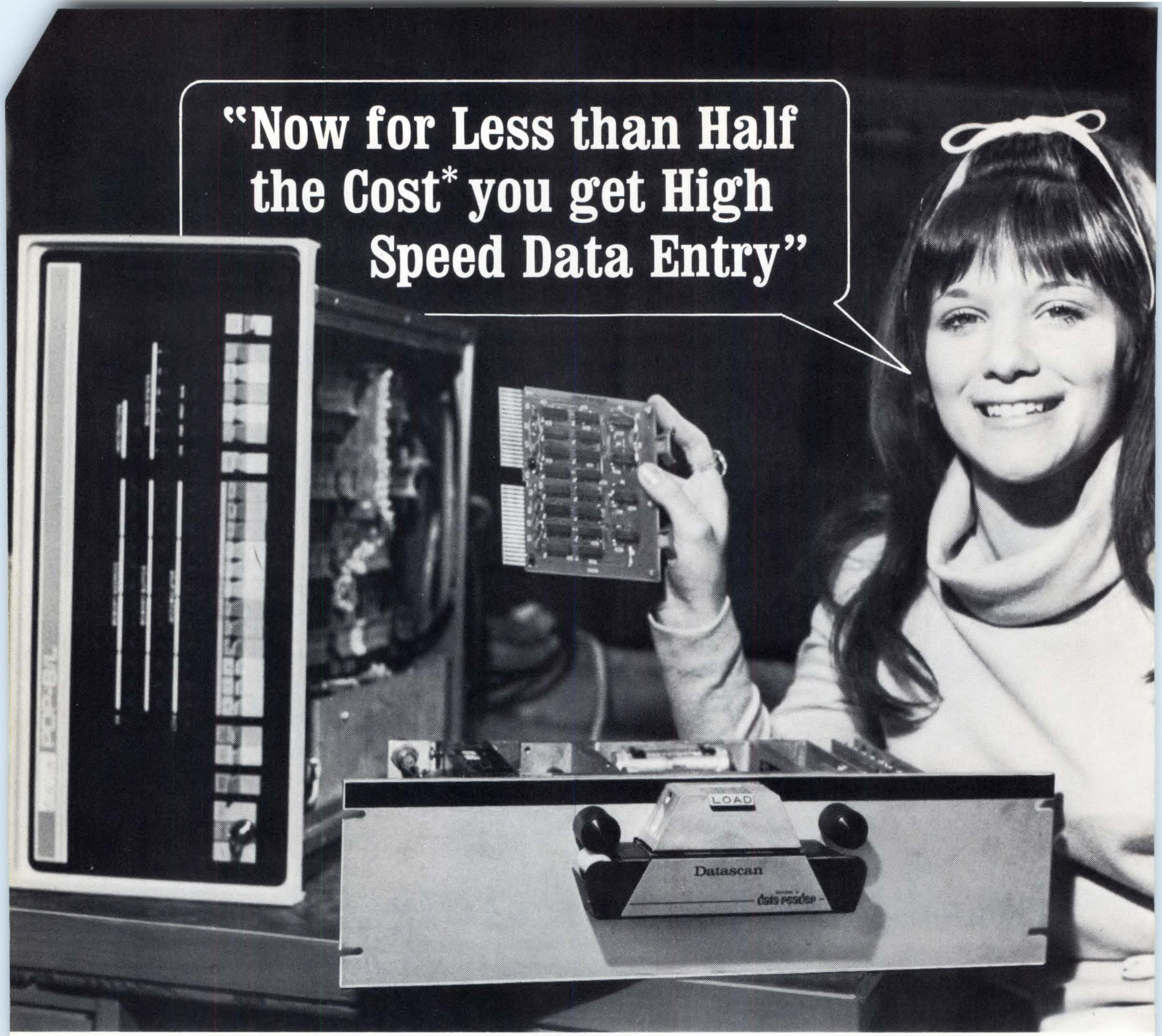

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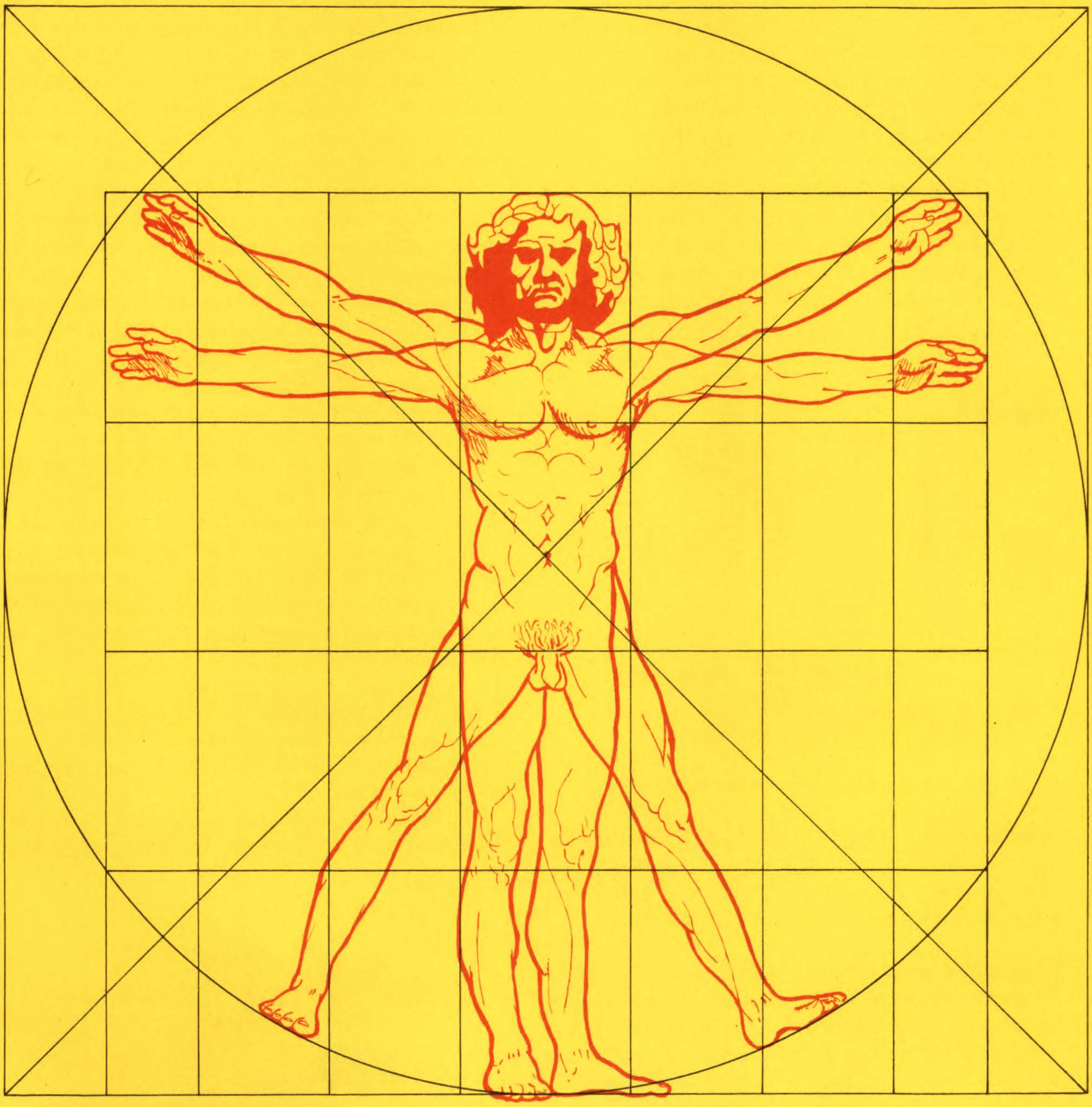
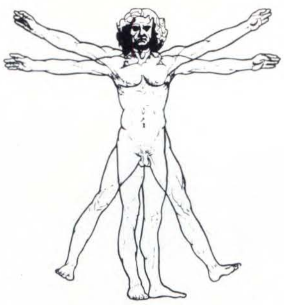
human factors in vertical panel design



Analysis of anatomical structure and psychological factors can be used to design better panel switches as well as keyboards.



Principles of tactile and audible feedback, preferred direction of force and natural hand angles (see "human factors in keyboard design", computer hardware, Dec. 15, 1970) also find application in the design of switches for vertical panels.

From the previously cited discussion, it would seem that if the fingers were fully extended, a vertically-moving key would provide optimum tactile feedback, or "touch". There is a mechanical problem to providing such an action on a vertical panel, however, because we are generally called on to design with a short lever pivoted close to the back of the panel. Such a structure moves through an arc which changes the angle of action with its position.

The traditional pushbutton is simply a keyboard switch that lies in a vertical plane, rather than a horizontal one. It would be a fine answer to most needs if the operator's plane were rotated 90°, too, but that's not usually the case. As it stands, a pushbutton is uncomfortable to push. **Fig. 1** illustrates a position for the knob and pivot which could provide a reasonable compromise "feel" on a panel key where a pushbutton might have been used or a pivot key misused.

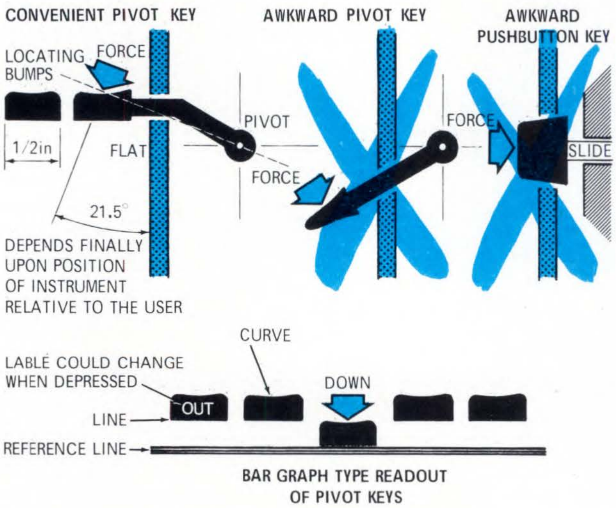


Fig. 1—**Ideas on convenient panel switch design.**

A Special Problem The thumb presents a special problem because it prefers to move horizontally with respect to the fingers. The preferred orientation of the hand is with the fingers in a horizontal plane, so that the thumb movement is lateral to them in a horizontal direction. Rotating the hand so that the thumb will move vertically is a poor solution, not only because it is contrary to the preferred hand position, but also because vertical movement of the thumb does not produce as much kinesthetic feedback, and close control is diminished.

Fig. 2—**Desired motion** on keyboard plane.

Bistable controls pose a special problem for feel and indication of position. A panel toggle switch on a vertical panel does not fit any of the requirements for convenience except that the "down" movement is generally easier, since it fits the general requirements of forefinger movement in a downward direction. The "up" movement is awkward by comparison, however, no matter whether the thumb or forefinger is used, since upward operation with either one requires twisting of the hand or arm to reach a moderately comfortable and sensitive position. The same statements can be made about a panel switch on a plane with the arm.

Figure 2 shows the preferred directions of motion on a keyboard plane. Note that here, for the first time, we have begun to take into account whether the switch is to be operated with the right or left hand or both, and whether the operator is right- or left-handed.

A bistable switch could be designed to comply with the requirements of both forefinger and thumb preferred motions in the configuration shown in **Fig. 3**. This is only one of many possible solutions, and it should be noted that it is applicable only for the right hand, since the required motions are directly contrary to the thumb and forefinger preferences for left-handed operation.

Capitalize on Disadvantages The fact that some motions are more awkward than others could be used to "code" the desirability of certain functions, making them more or less easy to use.

The "erase" function on an oscilloscope, for instance, could have some attribute that detracts from its ease of

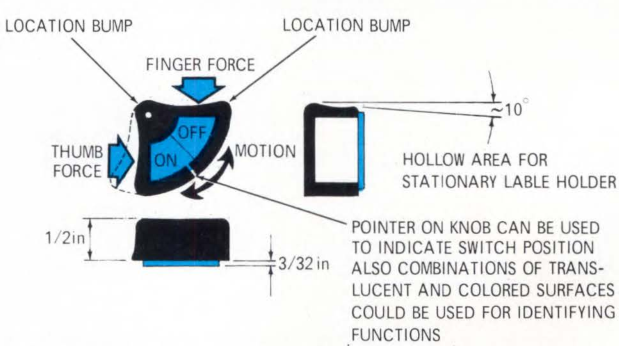


Fig. 3—**A bistable switch control** satisfying both desired thumb and finger movement for right hand.

use. Stiff or unpleasing action, a less desirable motion than other controls in its vicinity, or color, shape or texture variations that make it feel less desirable than others would tend to inhibit its use and make every "erase" action a positive and deliberate one on the part of the operator.

Both thumb and forefinger should be used on functions that require continuous or discrete positioning control, in order to give a two-dimensional "feel" of the control. In general, the control/display ratio (c/d ratio) determines how effectively the operator can sense the movement of the control visually. In these terms, then, the lower the c/d ratio, the more sensitive or "touchy" the control, and the more difficult it is to manipulate accurately.

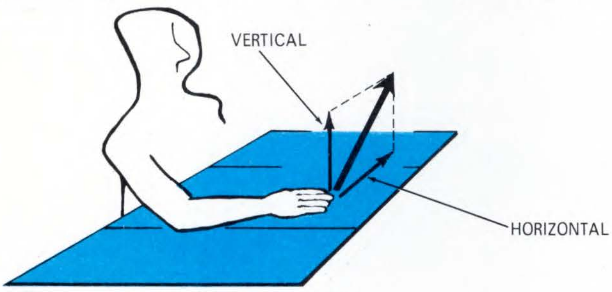


Fig. 4—**Desired grasping movements.**

Static friction is detrimental to accurate control, because of the sudden and often unpredictable movement that results from applying enough force to overcome it. Resistance during movement, however, is a desirable factor. Inertia is more desirable than friction, in this sense, because it feeds back rate information to the operator.

The shape and movement of a positioning control should encourage the use of the thumb and forefinger. When these members are used, hand movement is limited and other parts of the arm "train" must be used for the action. Wrist movement, elbow movement and shoulder movement combine to produce the desired movement in two directions. This combination of arm "train" movements is represented schematically in **Fig. 4**.

Some of the knobs and their movements that result naturally from the motions in **Fig. 4** are shown in **Fig. 5**. These are by no means all the possibilities, but they indicate some of the potentialities of design that takes preferred motion into account. The differences between **Fig. 1**, **Fig. 3** and **Fig. 5** should be clear. **Fig. 1** represents a single-action key operated by one finger. **Fig. 3** is a bistable key operated by either a finger or thumb, depending on which switch state is desired. In **Fig. 5**, the control is operated by finger and thumb used in combination to give continuous control. These differences demonstrate a basic principle of switch design: each type of control requires a different kind of movement to maximize the desirability of that particular key operation.

A basic premise for design of vertical panel switches then would be that anything that conforms to the natural position and movement of the finger-hand-arm train will enhance the use of that switch. Conversely, anything that requires position or movement that is unnatural or uncomfortable will depress the use of that switch. Thus a slide switch is more desirable than a sidewise rotary switch, since the rotary switch is often awkward with respect to the desired motion.

By applying these principles, the designer can reduce the chances of accidental operation and can increase the accuracy with which other controls can be used.

While they are beyond the scope of this discussion, there are many more methods of enhancing or depressing the use of controls. Most of these are combinations of visual and kinesthetic feedback signals to the operator, and they influence the selection of knobs and other actuating surfaces, depending on whether the controlled function should be depressed or enhanced.

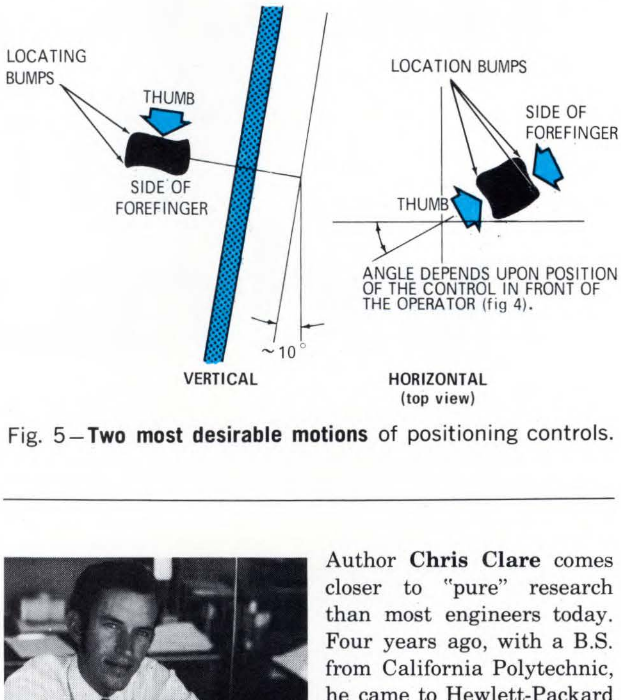
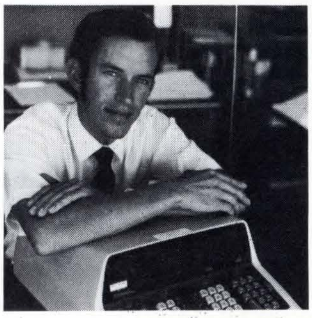


Fig. 5—**Two most desirable motions** of positioning controls.



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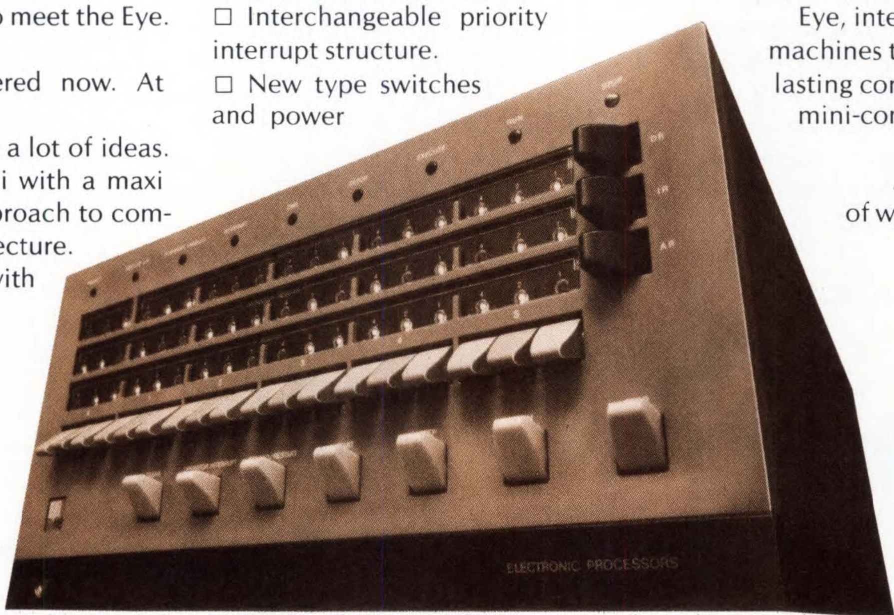

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Prospective authors must submit an informative, unambiguous abstract, without figures, appropriate to a 20-minute paper before July 16, 1971. The abstract must be submitted on a double-spaced, typewritten page exactly as it may appear in the program of the meeting. The heading must include title, author(s), company affiliation and city and state of the company location. Send to: H. Dean Toombs, Texas Instruments, Box 5012, MS 922, Dallas, TX 75222.

birth of a keyboard

Feedback from users—the most reliable way to go about designing a new product or improving an old one. This was the technique used by Maxi-Switch designers when they set out to design a new keyboard.

From this survey which asked users what they disliked most about available keyboards, the major complaints lodged were:

—Keystems are too flimsy and weak.
—Keyboard is supported by the PC board.
—Poor button alignment caused by individual assembly of each key station.
—Difficulty of specifying a flat or stepped keyboard without requiring modification to the button or mounting base of individual switch modules.
—Use of double-sided PC boards raises cost.
—Field maintenance of individual keystation elements is difficult.
—Cross magnetic bias problems are common on reed type keyboards.
—Tooling for special legends on double-shot buttons often adds to costs.
—Illuminated keys often are not available on standard keyboards.
—High current power contacts are not usually available on standard keyboards.
—Special function buttons (such as interlatch and lockout) are not readily available.
—Most keyboard designs are not suitable for automatic assembly.
—Many designers use plastic-to-plastic and metal-to-metal wear surfaces that exhibit galling.
—Reed switches require careful selection for pull-in and drop-out values to insure consistent accurate operation.
—Quality keyboards are not available at low cost.

From these user comments certain basic groups emerged for preliminary design study.

These were:

—Mechanical design and construction
—Application Design
—Magnetic Circuit
—Life and Reliability
—Cost
—Aesthetics
—Additional Features

After considering several design options within each basic group, a study was made to determine how each option would relate to the other groups, and that design option which best satisfied the greatest number of the basic groups was isolated.

One design goal category dealt with the solution of these problems:

—Keystems too flimsy and weak
—Poor button alignment
—Metal-to-metal and plastic-to-plastic wear points cause galling and

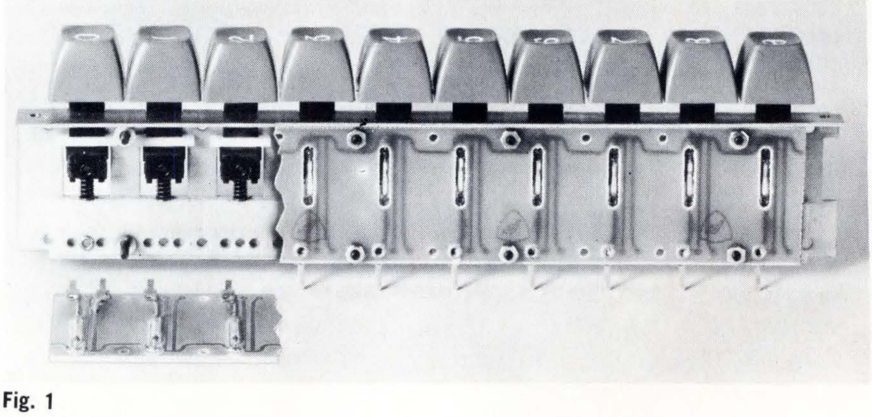


Fig. 1

friction.

The Design To minimize these four problems, a one-piece, half-hard steel frame was designed (**Fig. 1**). It is produced on a precision stamping die that may be programmed for strip lengths of from one to 20 stations. The solid one-piece frame supports the switches and does not transmit pressure or weight placed on the keys to the PC board. All keystems are attached to this frame providing permanent button alignment of ±0.010 inch.

Keystems are full hard cold rolled steel, carried in molded acetyl copolymer resin guides. This design eliminates the problem of weak and flimsy keys, as well as providing metal-to-plastic wear surfaces.

Biasing To eliminate cross-magnetic biasing of reeds and reduce the need to select reeds by pull-in/drop-out value, a novel method for reed switching was devised. As shown in **Fig. 1**, the magnet actuating the reed is placed on the solid steel keystem that is used as a reference pole. In the non-actuated position, the magnetic flux is at right angles to the reed axis. With the flux path at right angles to the reed, a total accumulation of flux from several magnets cannot combine to produce an overall keyboard magnetic field. Consequently, there is no problem of spurious magnetism "leaking" through to adjacent reeds and holding them in the operated position or affecting their pull-in/drop-out values. This flux position also polarizes both reed tips with a like polarity in the unoperated position, making them repel each other, and further cancelling any stray flux influence. When the key is operated, the polarity of one reed tip is reversed, causing the "unlike" reed tips to attract. Because of the push-pull effects of the magnet on the reed, the influence of pull-in and drop-out characteristics of the reed are minimized. Magnetic switches that use this scheme are characterized by fast, crisp and consistent switching action.

Cost Aspects Another design goal was to reduce cost without sacrificing quality. Assembling multiple pushbutton stations, and mounting each in a frame can be a time-consuming and expensive process. Because the keystrips contain an average of 14 pushbutton stations on each strip (**Fig. 2**), assembly of components and reeds may be accomplished rapidly by automated techniques. In addition to savings in time and labor, it is generally acknowledged that repetitive automatic assembly operations maintain a higher quality standard than operator assembly.

Keystrip reeds are mounted on a PC board which is part of the keystrip. One side of each reed is bussed common on this printed-circuit strip, and the common connections are removed from the mother board, reducing its complexity, reducing the area required for all the common circuits, and reducing the number of connections from the switch stations to the mother board. These reductions eliminate the need for a double-sided board, and improve reliability in proportion to the reduction in solder and plug-in connections.

Wear Close tolerance parts are required in keystrip construction to assure smooth action with low operating force. Moving part interfaces in this design are acetal copolymer resin-to-metal. Heat treating, plating and dry lubrication are used to minimize friction and wear.

Options As a consequence of this keystrip construction method, a wide variety of options are available to the keyboard designer. Keystrips may be supplied with illumination for each station (**Fig. 3**). Buttons may be chosen from a number of styles and types. Contacts may be reed switches, crossbar palladium leaf switches or snap action power contacts with up to 15A

(Continued)

Fig. 2

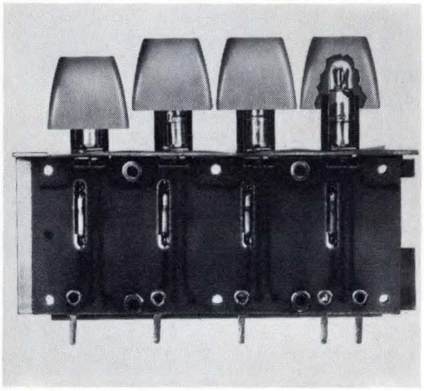


Fig. 3

(Continued)

keyboard (Cont'd)

capacity. Key stations may be either stepped or sloped on the keyboard face. Encoding format may be USASCII, EBCDIC or a custom code to meet special requirements. Output data may be transmitted in up to nine data bits. Keyboard termination may be printed-circuit connectors, dip solder lugs or pierced solder terminals.

When more than one keystrip is used, as in a standard keyboard, all keystrips can be made to interact in a single functional unit. Thus, the capabilities of the individual keystrip are extended to the entire assembly.

Applications Keystrips are designed to allow the addition of such features as interlatching, lockout, alternate action, solenoid lockup or accumulative latch to the basic keyboard strip. A system using a keyboard to input information to a computer might requite that each input signal be validated. If a garbled or erroneous code is received, the system could be equipped to send a nonvalidate signal to the keyboard, mechanically locking all keys, and preventing the transmission of further data until the error is cleared.

For applications requiring slow, deliberate keyboard entry of data, (such as in phototypesetting, map making, or data comparison) where each character must be accepted and acted upon before the next character may be transmitted, a mechanical latch can hold the depressed key in the operated position. The key is released when action is completed on that input character. During the latched period, all other keys are mechanically locked out.

More information on this line of keyboards and a copy of a bulletin "Glossary of Pushbutton Switch Terms" is available from Maxi-Switch Co., 3121 Washington Ave., North Minn, Minn. 55411. **420**

ROM offers new ideas

A new concept in storage devices has been introduced by Memory Technology, Inc., Sudbury, Mass. Named the PDP-ROM and designed for PDP-8I/L users, the system provides for 2048 to 32,768 additional words of storage. According to Marketing Vice President, Paul Rosenbaum, either programs or data tables may be stored in the PDP-ROM and loaded directly into core in block transfers initiated under program control. For program storage, a comprehensive "loader" program is included.

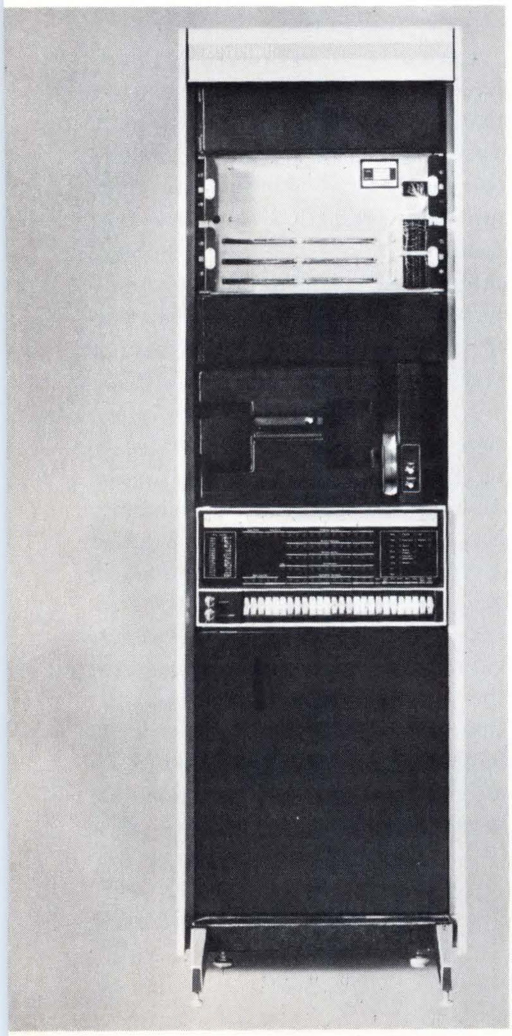
For storing tables of data, the PDP-8 can access the contents of the memory within 1.6 μsec and transfer the data at a rate up to 1.6 μsec/word. When programs are stored in the PDP-ROM, they can either be treated as a table of data and transferred to core or called up by name and transferred to core using the optional loader program.

With the loader program, the user simply initiates the routine by entering the program name on the "Teletype" keyboard. No tedious switch set-ups or paper tapes are required. An operating program may also transfer another program into core from the PDP-ROM. Programs that are too long to fit into the core storage can be segmented and stored in the PDP-ROM and then chained for continuous calling into core. A tape generator program is available that takes the normal binary program tapes and produces a specially formulated output tape to be used in manufacturing and testing the PDP-ROM contents boards to user specifications.

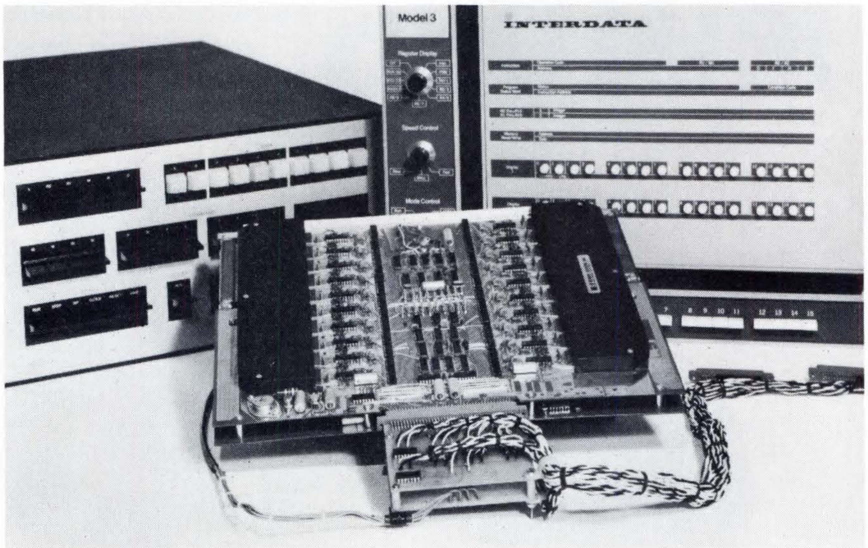
Physically, the system consists of a rack mountable chassis occupying 10.5 inches of rack space in the Digital Equipment Corp. cabinet. The basic chassis contains a power supply, the control board and two memory boards – all on printed circuit boards. Because each memory board has a 1024 to 4096, 12-bit word capacity, the basic chassis contains the first 8192 words of storage. To expand, an extender chassis is used and each extender, occupying only 5.25 inches of space, adds a total of 12k words. A maximum of two extenders (total capacity of 32k words) can be added, using the same control board and power supply as the basic chassis.

Other specifications include: transfer rates of 1.5 μsec (PDP-8I) and 1.6 μsec/word (PDP-8L), random access storage, 1- to 4096-word transferred block sizes and power requirements of 105 to 125V ac, 0.5A rms, 60 to 400 Hz. Memory Technology, Inc., 83 Boston Post Rd., Sudbury, MA 01776.

421



"plug-compatible" ROMs grant on-site updating



A series of "plug-compatible" electrically-alterable read-only memories, developed primarily for today's popular minicomputer systems, has been introduced by Memory Systems, Inc., Hawthorne, Calif. These units, called OmniROM, provide the user with a new freedom—the ability to modify on site, in real time, under keyboard or console control the contents of his ROM—and to do so as many times as is necessary to debug or to optimize his software. After the modification, the write circuits are disconnected and the unit operates as a true ROM. Because of its nonvolatile property, the ROM retains the data indefinitely—even through power shutdown.

Each unit of the OmniROM family has a special interface at the end of a paddle card that plugs into the mainframe card slot of the controlling computer. Consequently, the units are fully compatible with the host computer and appear as peripheral interfacing according to the manufacturers rules. A bootstrap loader is included on the adapter card to allow startup with an "empty" OmniROM.

A standard OmniROM configuration is 1k × 16 bits, expandable to 4k. Initial units are available for the Micro 800, CIP 2000, Nova and Super Nova, and Interdata Models 2, 3 and 4. Full clock speed is maintained as well as interface compatibility according to manufacturer specifications. Service and warranty are provided in the purchase price. In OEM quantities, prices range from 5 to 10 cents/bit, depending on configuration. Memory Systems, Inc., 3341 W. El Segundo Blvd., Hawthorne, CA 90250. **422**

Updated Tester Checks New Linear ICs

PROGRESS IN INSTRUMENTATION

There is a new front runner in the LIC tester sweepstakes. (See "High-versatility LIC tester . . .," *EEE*, August 1970, p. 30.) Signetics has jumped into the lead by updating its Model 1420 with two new program boards. This instrument, which formerly could check only op amps and comparators, can now check voltage-regulator and sense-amplifier ICs. And, at press time, Signetics announced that it has also added program boards to testing IC phase-lock loops and video amplifiers such as the μA733. No internal electrical or mechanical modifications are needed to add these options. Simply insert the appropriate new program board into the 1420's input socket and the tester is ready to go.

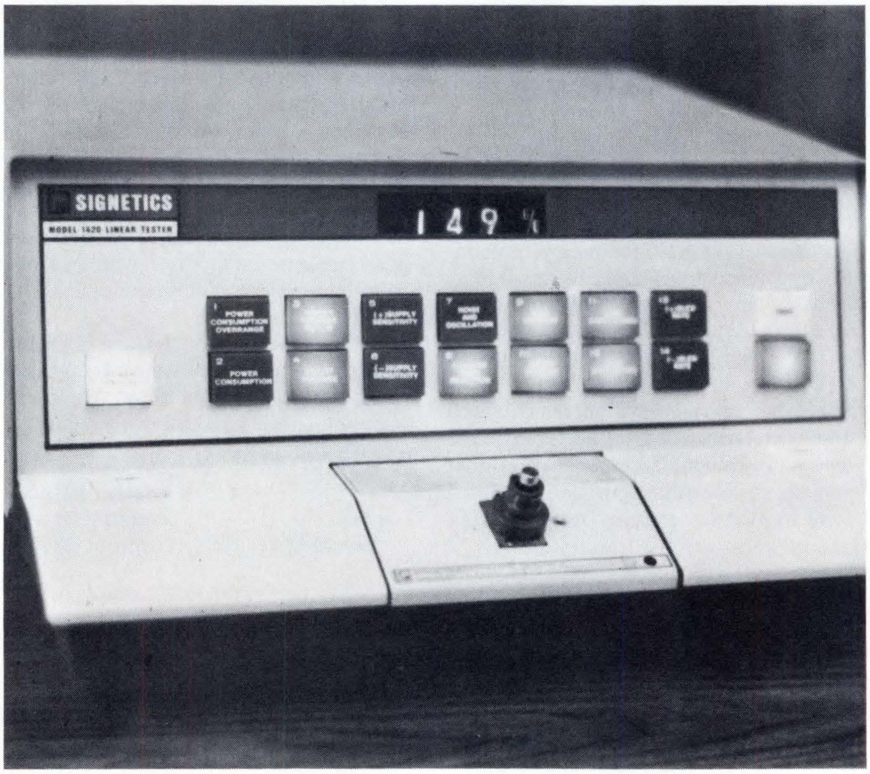
Signetics offers two voltage-regulator program board options, each of which tests five critical parameters between certain specification tolerance bands. Either a 1% or a 5% board is available. Each regulator board tests standby-current overrange, standby current, reference-voltage tolerance, input regulation and output regulation.

Popular monolithic voltage regulators which can be tested include the Signetics 5700 Series, all National and Fairchild monolithic regulators and Motorola's MC 1400 and 1500 Series. Units manufactured by many other manufacturers can also be tested. Both the voltage-regulator and sense-amp boards accept all standard IC packages up to 16 pins.

Sense-amplifier boards also come in 1% and 5% versions. Sense amplifiers are tested for power-consumption overrange, power consumption, strobe, "0" positive threshold, "0" negative threshold, positive common-mode voltage, negative common-mode voltage, bias current, offset current and positive and negative "1" thresholds. Sense amplifiers that can be tested include Signetics' 500 and 7500 Series, National's 5500 and 7500 Series, TI's 7500 Series and Motorola's MC 1440 and 1540 Series.

The original 1420 had 14 lighted pushbuttons to identify various tests. This arrangement won't do for the updated multimode 1420. So, rather than changing lenses for each different LIC or printing four legends per button, Signetics has decided to leave the original op-amp callouts on each lens cap and add an additional number (1-14) to each lens cap. Each new program board (comparator, voltage regulator, sense amplifier) will have a series of tests corresponding to these identifying numbers.

One-percent and 5% regulator testing boards cost $300 and $150, respectively. Sense amplifier testing boards are more expensive, with a 1% board costing $475 and a 5% board costing $275. Basic cost of the 1420 (without program boards) is $7950. Signetics Corp., 811 E. Arques Ave., Sunnyvale, CA 94086. **170**



Signetics' 1420 LIC tester can now test voltage-regulator and sense-amplifier ICs in addition to op-amp and comparator ICs.

Three High-Performance Instrumentation Amplifiers

PROGRESS IN PACKAGED CIRCUITS

Three impressive new instrumentation amplifiers have been announced by Burr-Brown. One of the new modules, Model 3620, boasts the lowest drift of any such amplifier — a maximum of of ±1 μV/°C. A second unit, Model 3621, has an input impedance of $10^{13}\Omega$ and a typical common-mode rejection of 120 dB at high differential gains. The third new amplifier, Model 3622, has a gain-bandwidth product of 300 MHz (at a gain of 100) and offers excellent common-mode rejection at high frequencies.

Back in 1967, Burr-Brown introduced the industry's first modular instrumentation amplifiers (other companies had previously offered larger rack-mounting instrumentation amplifiers). Since that time, several other companies have introduced this type of amplifier and there have been gradual improvements in performance and reductions in cost.

Basically, Burr-Brown's instrumentation amplifiers are differential input, single-ended output, modules whose gain is set by a single resistor. All feedback resistor networks, except for the gain-defining resistor, are contained within the module. Primary applications are as transducer amplifiers, as differential amplifiers for recording instruments, or as buffer amplifiers for low-level multiplexers in data-acquisition systems.

The low drift of the type 3620, combined with its input noise of only 0.5-μV pk-pk and its input bias current of ±10 nA, may justify Burr-Brown's claim that it's "the best low-level amplifier for source impedances up to 50 kΩ." The circuit has an input impedance of 5000 MΩ and common-mode rejection in excess of 100 dB.

Burr-Brown achieved high performance in the 3620's input stage by using a drift-matched pair of low-noise IC op amps. Because the IC op amps are also individually low in drift, the warm-up drift and offset shifts due to thermal transients are minimal. By use of an internal second-stage amplifier and heavy negative feedback, the 3620 is able to maintain its linearity of 0.02% for all gains from 1 to 10,000. This, Burr-Brown says, is an order of magnitude improvement over earlier amplifiers. Another important feature of the 3620 is its versatility. The user can, merely by simple changes of internal connections, employ output sensing, output zero suppression (offset) and active filtering.

The new high-input-impedance amplifier, Type 3621, has a bias current of only 10 pA and the bias current remains low even with ±10 Volts applied at either input. While other amplifiers have offered this sort of performance in the past, they have been much more expensive than the 3621 which costs only $39 for the "J" version in small quantities.

The new wideband instrumentation amplifier, 3622, has an excellent combination of high input impedance, wide bandwidth and wideband common-mode-noise rejection — typically 70 dB at 100 kHz. The gain-bandwidth product varies with gain level, without the need for internal compensation. Amplifier gain is flat (within ±1%) to greater than 100 kHz.

Prices for the new amplifiers are shown in the table of specifications. Small quantities are available from stock. Burr-Brown Research Corp., International Industrial Park, Tucson, AZ 85706.

No. 171

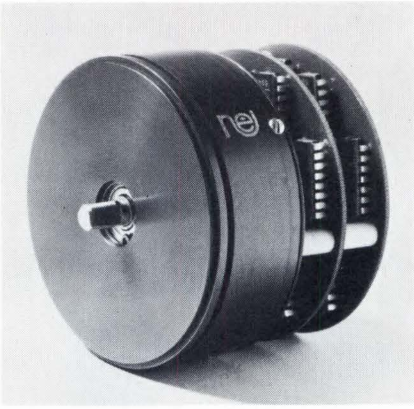
Performance Of New Burr-Brown Instrumentation Amplifiers

Specifications	Model 3620K	Model 3621K	Model 3622K
Range of Gain	1 to 10,000	1 to 2000	1 to 1000
Rated Output	±10 V at ±10 mA	±10 V at ±10 mA	±10 V at ±20 mA
Small-Signal Bandwidth ±3 dB (gain = 100)	20 kHz	20 kHz	3 MHz
Slew Rate	1 V/μsec	1 V/μsec	200 V/μsec
Input Impedance	5 × 10^9 Ω	10^{13} Ω	10^{11} Ω
Voltage Drift	±1 μV/°C	±20 μV/°C	±20 μV/°C
Input Bias Current	±20 nA	−10 pA	−25 pA
Package Dimensions	2 × 2 × 0.4 in.	1.12 × 1.12 × 0.5 in.	2 × 2 × 0.4 in.
Tentative Prices (1-9)	$125.00	$45.00	$99.00

Low-Cost Digital Shaft Encoder

PROGRESS IN ELECTROMECHANICAL COMPONENTS

At one time, potentiometers were widely used as low-cost shaft-angle transducers in measurement and control systems. In the last few years, however, the growing use of digital circuitry has favored other types of transducers such as optical encoders, brush-type encoders and synchros with external code converters. Now a potentiometer manufacturer, New England Instrument, has decided to fight back. NEI has introduced a new type of digital transducer that is essentially a pot—with built-in conversion circuitry.



New England Instrument's low-cost Type 300DT digital transducer is essentially a pot with a built-in A/D converter. The complete unit has an outside diameter of 3 inches and is 4 inches long. Other configurations are available.

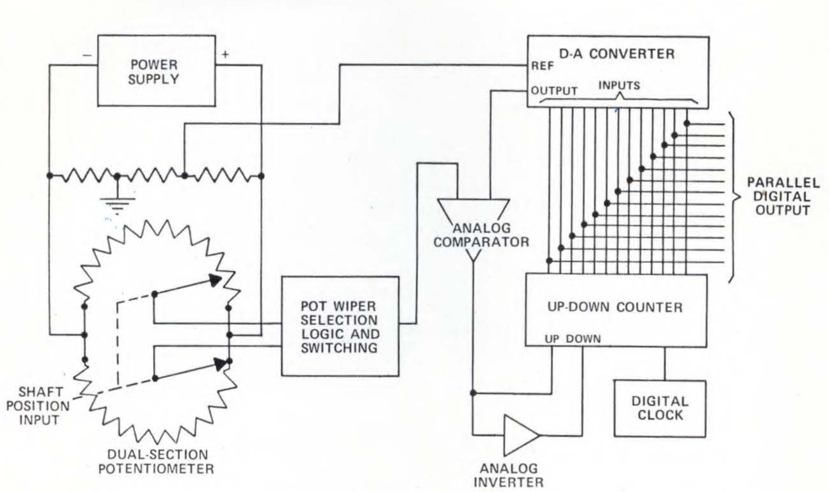
As one would expect, the major advantage of NEI's new Type 300DT transducer is low cost. At less than $500 for a single unit, the 300DT beats competing digital transducers offering comparable performance. Synchros are cheaper, but they need costly external converters to provide digital codes. Brush-type encoders are relatively inexpensive, but, at around $1000 each, they still cost more than the 300DT. Optical encoders offer better performance but they are also very expensive.

Ratiometer Technique

NEI has done more than merely add an A/D converter to a conventional pot. By careful design, the company has largely overcome many of the traditional disadvantages of pots. Problems of temperature coefficient and absolute accuracy have been avoided by sensing the ratio between one resistance position and the next, rather than by using the absolute resistance of the pot to measure rotational change. Thus the 300DT could more correctly be described as a digital ratiometer rather than a digital pot. Also, the high input impedance of the ratiometer (100 MΩ) minimizes the effects of contact resistance and loading. Another important design feature is that the reference and the signal for the ratiometer are both derived from a common dc power supply (see schematic diagram) thus minimizing the effects of power supply variations.

The basic potentiometer elements in the 300DT are based on NEI's Resistofilm conductive-film technique, as used in the company's conventional precision pots. Current film-manufacturing techniques limit accuracy and resolution to approximately 12 bits in a single turn, though greater resolutions can be achieved by multispeed gearing. Versions that operate continuously through a full 360 degrees of rotation are available.

In the 300DT, the potentiometer is trimmed to provide a linearity of 0.025%. The absolute encoder is available with either parallel binary or BCD output codes. For binary outputs, a built-in 12-bit A/D converter divides the 360 degrees of pot rotation into 4096 words (equivalent to 5 minutes of arc resolution). The specified accuracy for the binary version is ±10.6 minutes of arc.



The 300DT consists basically of a ratiometer driving a counter-type A/D converter. Because the reference and analog signal voltages are derived from a single power supply, power-supply variations have a minimal effect on absolute accuracy.

Proven Reliability

According to NEI, the pot in the 300DT has a life expectancy of over 100 million revolutions (about the same as a synchro), and the pot will operate reliably at shaft speeds up to 1000 rpm. NEI has tested pots by dithering them continuously over small rotational angle at speeds of up to 60 Hz for over 200 million cycles without noticeable degradation in electrical characteristics.

The 300DT has an operating temperature range of 0 to 70°C and a temperature coefficient of ±15PPM/°C (full scale). Dimensions of the basic Model 300DT are 3 inches (diam) by 4 inches (length). Standard shaft diameter is 1/4 inch. Other mechanical configurations are available, including versions with linear potentiometers.

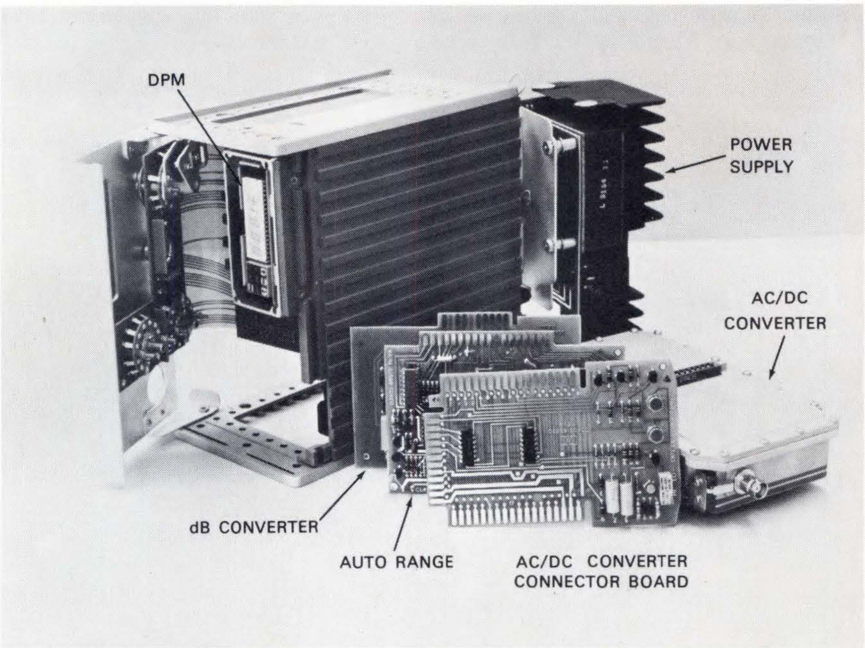
Exact price depends on the configuration requested. The basic 300DT costs less than $500. Delivery is 8 weeks for the standard model and about 12 weeks for custom versions. New England Instrument Co., 14 Kendall Lane, Natick, MA 01760. **172**

Two DVMs for Way-Out Frequencies

PROGRESS IN INSTRUMENTATION

The next company to offer a high-frequency voltmeter will need something special to beat two new Hewlett-Packard digitals—a true-rms voltmeter and a multimeter.

The true-rms instrument, the 3 digit-plus-90% overrange 3403A, covers a startling 2 Hz to 100 MHz, plus dc. At the upper end, it tops the 20-MHz peak of earlier DVMs and reaches into the domain of analog RF voltmeters (that don't dip into low audio frequencies). Its accuracy depends on frequency, voltage range and measurement function. Basically it is (±0.1% of reading ±0.2% of range).



The 3403A breaks apart quickly for easy servicing. The power supply is at the right rear, the true-rms/dc converter in the sealed module below it. The three cards in the foreground are, from the front: the ac/dc converter connector board, an optional autorange board and an optional dB converter.

The 3403A responds to the true-rms value of almost any waveform. It measures ac only, ac + dc, or dc only, and delivers a proportional analog output in addition to the digital display. Its light-emitting-diode readout has a ± symbol, a movable decimal and 3 full digits plus a fourth for 90% overrange (on all but the 1000V range, which accepts 1500V peak).

The meter has five ranges, 100 mV to 1 kV, for all its measurements, and a sixth, 10 mV, for ac only. Front-panel annunciators warn a user to change range when a reading goes below 10% of range or beyond 190%.

The basic 3403A costs $1400. An additional $125 buys an autorange option. There are other options, like BCD output and remote control, but the most unusual one, for $250, displays −60 to +60 dBV or dBm with 0.1 dB resolution. The 0-dB reference can be shifted at least 10 dB.

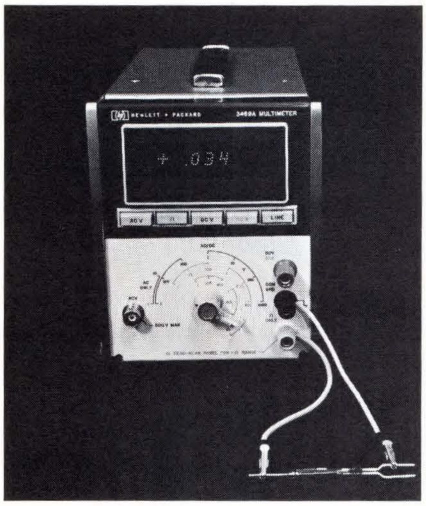
The first true-rms DVM to measure voltages to 100 MHz, the HP 3403A is offered with several options, including one for measuring dB.

When its combination of very wide ac band (+dc), true-rms reading and adjustable-reference dB option are considered, the 3403A is indeed a versatile device.

Another new digital instrument from H-P, the 3469A multimeter, is unique on at least two counts. For ac-voltage measurements, this 3-1/2-digit meter covers frequencies from 20 Hz to 10 MHz, a remarkable top frequency for a modestly-priced DMM. Basic accuracy is (±0.3% of reading +0.3% of range) from 100 Hz to 100 kHz. For resistance measurements it offers ranges from a rather usual 10 MΩ down to a quite unusual 1Ω (0.001Ω resolution).

Prior to the introduction of the 3469A, at $595, a stable 1Ω range has been available only rarely, and generally for a high price tag. This one uses 60 Hz ac excitation on the 1Ω range to prevent offsets caused by thermals. One-ohm ranges can be found in an ohms-only plug-in for Hickok's 3-digit $385 main frame, in Dana's 4-digit $1395 model 4800 and in options for Dana and Cimron 5-digit machines costing well over $3000.

On other counts, the 3469A is most respectable, but not sensational. DC-voltage ranges extend from 100 mV to 1 kV, with 10-MΩ input impedance, 70-msec response time and 40-dB common-mode and normal-mode rejection at 60 Hz. Common-mode rejection is 60 dB at dc. AC ranges cover from 1 mV full-scale to 500V, with input impedance of



Like no DMM close to its price range, the 3469A can make stable measurements of the resistance of closed switch contacts. Here, it's measuring the normally closed contacts of a form C reed switch.

10 MΩ shunted by <25 pF. DC current ranges go from 1 μA to 100 mA, with 100 mV full-scale drop.

All scales permit 100% overrange except for the top voltage ranges. The display, H-P's DPM like that in the 3403, has 3 full LED digits (0.29 inch high) plus a fourth for overrange.

Multiple purpose as well as multiple function characterize the 3469A. It can serve as a lab-performance instrument for ac and dc voltage, dc current, and ohms—or as just a good general-performance multimeter. Price is $595. Inquiries Manager, Hewlett-Packard Co., 1601 California Ave., Palo Alto, CA 94304.

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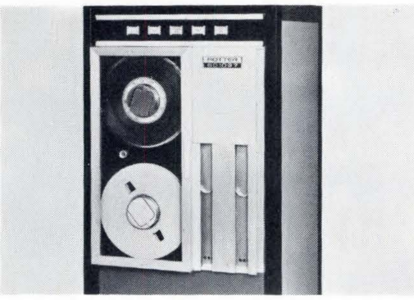
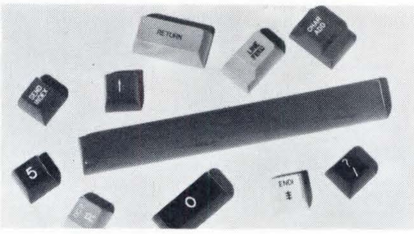
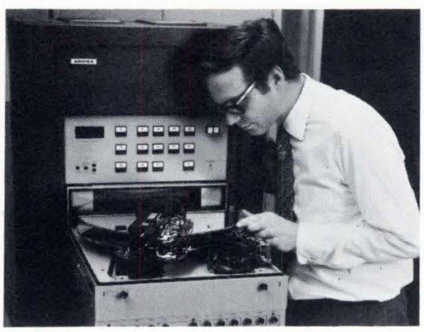


Tape transport SC 1037 features IBM 9-channel compatible read/write operation at densities to 1600 bpi, PE format with bidirectional tape speeds from 20 to 45 ips. The unit offers improved performance over tension arm tape transports, still maintaining a comparable price of $2850. Potter Instruments Co., Inc., 532 Broad Hollow Rd., Melville, NY 11746. **174**



Keytops, C900 Series, have legends molded into the keytop in a two-step operation rather than simply imprinted. Familiar typewriter style keytops are available in seven standard colors and a variety of shapes and sizes. Other features include special function keytops and custom color matching when required. Evaluation samples are available. Clare-Pendar Co., Box 785, Post Falls, ID 83854. **175**



Magnetic disc recorders, MD Series, provide record/reproduce bandwidths up to 12.6 MHz for analog and video data analysis. The units record and reproduce on one or two tracks simultaneously. They are available in 2.1-, 4.2-, 6.3- and 12.6-MHz versions. Laboratory research, radar study and data buffering are typical applications. Ampex Corp., 401 Broadway, Redwood City, CA 94063. **176**

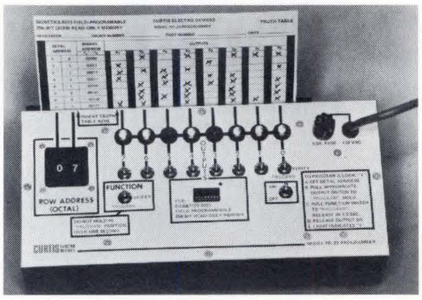
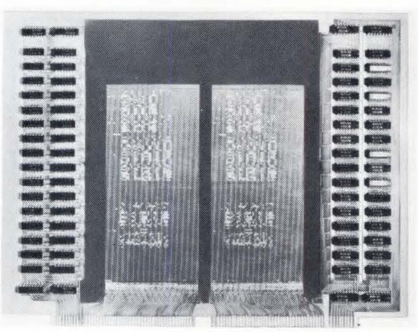


Table-top programmer PR-23 permits fast, error-free programming of the Signetics 8223 256-bit field-programmable ROM. The PR-23 provides a row address selector and lamp indicators for each of the 8-column outputs. Program verification is instantaneous. Price for the 12- by 6- by 3-inch unit is $199.50 in quantities of one to five. Curtis Electro Devices, Box 4090, Mountain View, CA 94040. **177**

Minicomputer Micro 1600 has a typical configuration using 2048 × 16 read-only memory and 8k × 8 core memory. There are 32 general-purpose registers. Through microprogramming, the 1600 operates in a variety of applications. Unit dimensions are 19 by 10.5 by 20 inches. Price is <$5000 in moderate quantities. Microdata Corp., 644 E. Young St., Santa Ana, CA 92705. **178**



Capacitive read-only memory systems, Series 1000, are bipolar compatible and consume <400 μW/bit. A memory capacity up to 131k bits/module is standard. Access and cycle times are approximately 125 nsec. Bit costs of under $0.02/bit are achieved using the technique of capacitive storage in a crossed-wire matrix. Integrated Memories Inc., 260 Fordham Rd., Wilmington, MA 01887. **179**

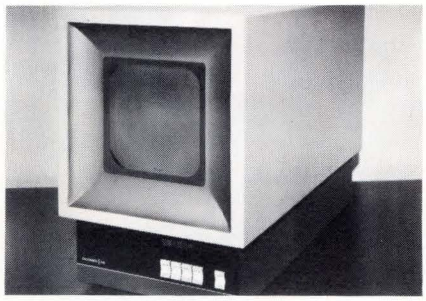
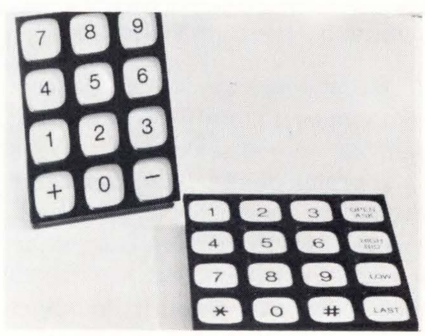


Image display, Model 36, converts digital image information to pictorial form using an array of over 4 million points. Model 36 presents up to four images simultaneously—side by side—on the screen of a storage-type CRT. No refreshing is required and the displayed images are steady and flicker-free. DICOMED Corp., 7600 Parklawn Ave., Minneapolis, MN 55435. **180**

Hexadecimal display unit, Series 1020, features optimum single-plane viewing from 15 ft, optional caption display, one to six messages and a choice of five screen colors. Drive electronics are IC decoders, available for all 16 combinations. Total price is $22–$3.10/display unit, $18.90/chip. Industrial Electronic Engineers, Inc., 7720-40 Lemona Ave., Van Nuys, CA 91405. **181**



Encoded keyboard, Type EF, uses patented highly-conductive elastomer materials and is <3/16 inch thick. Keyboards are available in standard 4-, 8-, 12-, 16-, 20- and 24-key arrays, with a maximum of four encoded bits/key. Standard output codes include single-pole (unencoded), touch-tone and BCD. Quantity prices are as low as $0.25/key. Chomerics, Inc., 77 Dragon Ct., Woburn, MA 01801. **182**

Computer Products

Glass delay line, Model 1024, is 10.24 μsec long and operates at 100 MHz. Insertion loss is typically 20 dB and spurious response is better than 20 dB. Isomet Corp., 103 Bauer Dr., Oakland, N J 07436. **183**

Buffered interface unit, Model 9613, enables the Videojet 9600 printer to store incoming data, character by character, until an entire print line is assembled. Standard buffer size is 200 characters, expandable to 400 characters. A. B. Dick Co., Videograph Operations, 5700 W. Touhy Ave., Chicago, IL 60648. **184**

Modular interface system CIOS-1000 simplifies the adaptation of peripheral devices to the Hewlett-Packard 2114 minicomputer. Three versions accommodate 10, 40 or 56 channels. Control Logic Inc., 3 Strathmore Rd., Natick, MA 01760. **185**

Solid-state programmer consists of a unidirectional photoelectric punched tape reader, two PC boards and a tape bin. Unit uses standard paper and does not require special punch. Datascan, Inc., 1111 Paulison Ave., Clifton, N J 07013. **186**

Small computers, PDP-16, are priced between $800 and $3000 in volume. A programming approach called "Chartware" is used instead of the usual software. These asynchronous machines are available with word lengths of 16-, 12- or 8-bits. Digital Equipment Corp., Maynard, MA 01754. **187**

Minicomputer, called Flexible MAC, can be expanded from 2 to 28k words of 16-bit memory within the computer chassis. Lockheed Electronics Co., Inc., Data Products Div., 6201 E. Randolph St., Los Angeles, CA 90040. **188**

Input/output wire-wrapped tray for Micro 400 minicomputer accommodates up to 232 14-pin IC sockets, 48 16-pin IC sockets and 16 24-pin IC sockets in any combination. Microdata Corp., 644 E. Young St., Santa Ana, CA 92705. **189**

Magnetic data inscriber cartridge is compatible with the IBM Model 50 data inscriber and Model 2495 tape cartridge reader. A unique flanged inner-hub insures less tape wobble. Memorex Corp., 1180 Shulman Ave., Santa Clara, CA 95050. **190**

A 4800-bps data modem, T4800, features self-contained pseudo-random test word generator, an adjustable equalizer, continuous monitoring signal-quality meter and a 1600-Hz bandwidth requirement. Communication Systems, Sangamo Electric Co., Box 3347, Springfield, IL 62708. **193**

Disc memory system 1717 has five models that are plug- and program-compatible with the Honeywell X16-931X drum storage system. Available capacities are 32k, 65k, 131k, 262k and 524k words. Data Disc Inc., 686 W. Maude Ave., Sunnyvale, CA 94086. **196**

MOS/LSI message generator on a 2048-bit ROM, designated TMS2605, generates the international "Quick Brown Fox" message in four binary codes: USACII, EBCDIC, Baudot and Silectric. Texas Instruments Incorporated, Box 5012, M/S 308, Dallas, TX 75222. **191**

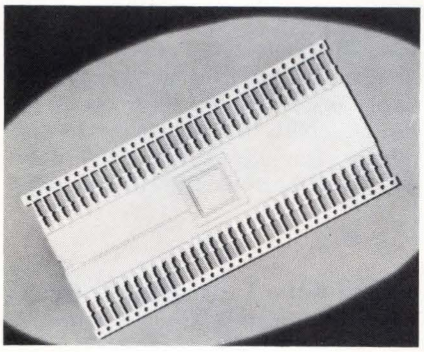
Semiconductor memory systems family, RAM 300 Series, comes in 11 configurations ranging from 2048 to 9216 bits. Access time is 300 nsec and cycle time is 400 nsec. Semiconductor Electronic Memories, Inc., 3883 N. 28th Ave., Phoenix, AZ 85017. **194**

Punched paper tape and edge-punched card reader, Series 1300, accepts punched tapes up to 1 inch wide and edge-punched cards up to a fanfold width of 210 mm. Reading speed is 200 cps. Automated Business Systems, 600 Washington Ave., Carlstadt, N J 07072. **197**

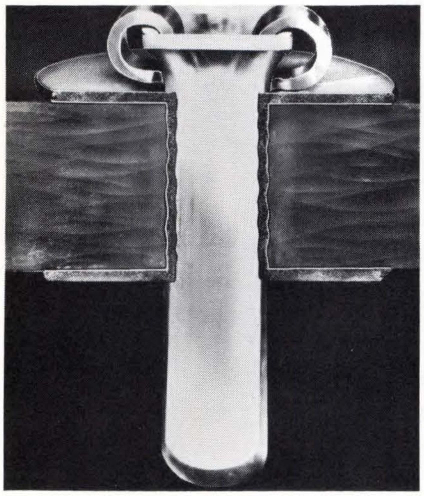
Automated drafting system uses "building block" concept to minimize equipment investment, while allowing individual system components to be formed into specific system requirements. Xynetics, Inc., 6710 Variel Ave., Canoga Park, CA 91303. **192**

Automatic answer modem, Model 300 Autoset, replaces the Bell System data sets and provides economical operation without modification to computers. Unit contains up to 10 channels. I/Onex Div., Sonex, Inc., 2337 Philmont Ave., Bethayres, PA 19006. **195**

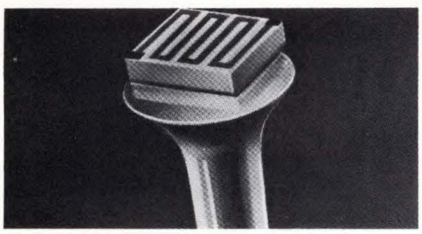
Sixteen-bit, 800-nsec minicomputer MODCOMP I gives the MODCOMP family of computers compatibility from $4000 controllers to $300,000 multiprocessors. MODCOMP I employs the latest MSI and LSI technology. Modular Computer Systems, 2709 N. Dixie Hwy., Fort Lauderdale, FL 33308. **198**



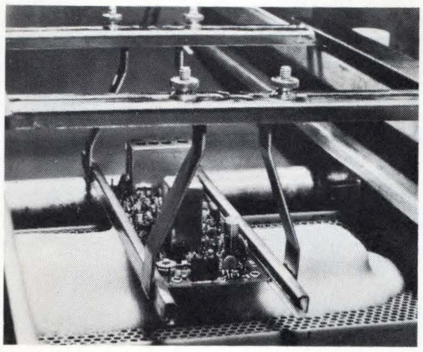
Package for 64-lead MOS has lead row spacing of 0.9 inch and chip mounting area of 0.325 inch^2. Construction is all alumina. American Lava Corp., Manufacturers Rd., Chattanooga, TN 37405. **199**



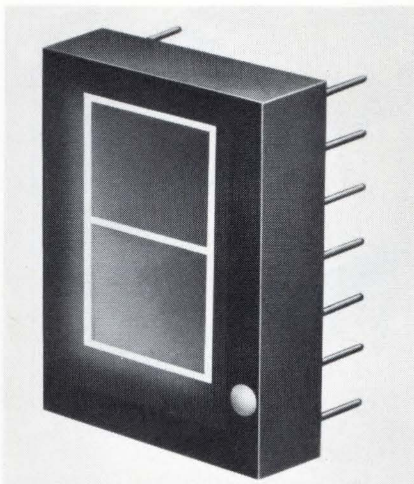
PC socket, the "Minisert", fits into holes sized from 0.048 to 0.058 inch and gives positive retention to a wide range of round or flat leads. Sockets can be furnished in either loose piece or strip form (reels of 25,000). Berg Electronics, Inc., York Expressway, New Cumberland, PA 17070. **200**



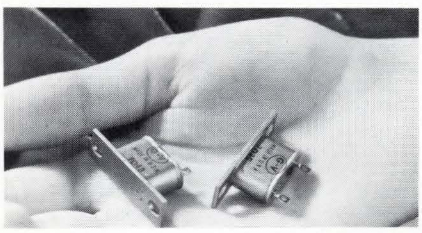
Thin-film chip resistors are available from 1/2Ω to 100,000Ω. Sizes range from 25 mils^2 to 50 by 100 mils. Substrates are 96% alumina, resistor elements are chromium, and they have either gold or solder terminations. Standard TC is ±100 PPM/°C from −55 to +150°C. Prices range between $0.37 to $1.45 depending on quantity and resistance value. Film Microelectronics, Inc., 17 A St., Burlington, MA 01803. **201**



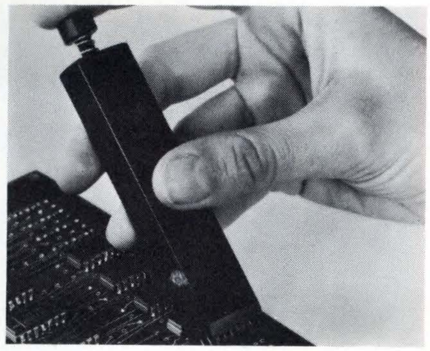
Foam flux, Milfoam 613, contains rosin and is the first to qualify as type A of MIL-F-14256. Residues are nonhygroscopic and insulating. Alpha Metals, Inc., 56 Water St., Jersey City, N J 07304. **202**



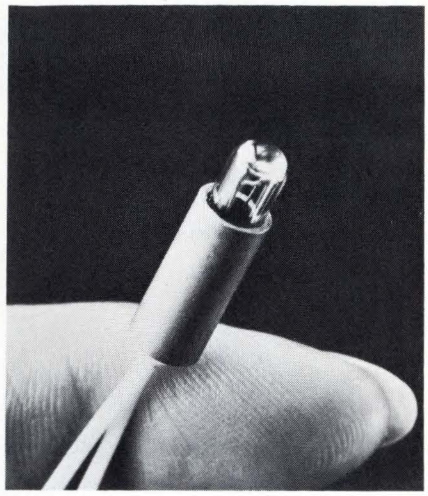
Incandescent 7-segment digital display, the Dip-Lite, is a pin-for-pin replacement for popular LED displays. Features include life to 100,000 hrs, character height of 5/16, 1/2 or 5/8 inch and drive by 5V or less at <20 mA. Price is $5.45 each in 1000 quantities. Pinlites Inc., 1275 Bloomfield Ave., Fairfield, N J 07007. **203**



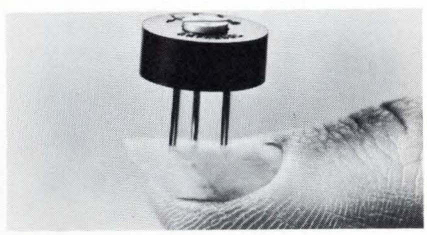
Surface sensing thermostats in crystal can enclosures have SPST contacts and offer twice the force and motion control of competitive units. The VE-2 Series switches withstand shock to 50G for 11 msec or continuous vibrations of 10G at 2000 Hz. Eight hermetically-sealed factory-set models are available covering four temperature ranges. G-V Controls Div., Sola Basic Industries, 101 Okner Pkwy., Livingston, N J 07039. **204**



Tool for inserting ICs, Model 880, permits fast, sure handling and requires no special training or experience. Solder Removal Co., Box 1678, Covina, CA 91722. **205**



Lamps with a spotlight lens, <3/4 inch long, are available for voltages from 2.5 to 6V and currents from 0.18 to 0.35A. Rated life for lamps of the TL line is up to 12,000 hrs. All light a 1/8-inch diam circle at a distance of 0.6 inch from the lens tip. Lamps, Inc., 19220 S. Normandie Ave., Torrance, CA 90502. **206**



Half-inch, single turn trimmers have solvent-resistant nylon cover. Series 6905 cermet-element units are offered from 20Ω to 5 MΩ with 10% tolerance. Rating is 1/2W at 40°C. Series 6900 wirewound units are offered from 10Ω to 50,000Ω with 10% tolerance and power rating of 1W at 40°C. Operating range of both is −55 to +125°C. Amphenol Controls Div., The Bunker-Ramo Corp., 120 S. Main St., Janesville, WI 53545. **207**

Heat dissipators for Motorola MC1600 Series ICs use no conduction base yet double the power rating of the bare-case device. Model LIC-14 is available in 1/4- and 1/2-inch high versions. IERC, 135 W. Magnolia Blvd., Burbank, CA 91502. **208**

Polypropylene capacitors, Type PP, feature low inductance, low TC and low dissipation factor. Capacitance values from 120 to 22,000 pF are offered. Paktron, Div. Illinois Tool Works Inc., 1321 Leslie Ave., Alexandria, VA 22301. **209**

Black alumina ceramic with the same physical and thermal advantages of white serves as a contrasting background in LED alpha-numeric display systems and as an opaque housing for light-sensitive IC circuits. Metalized Ceramics Corp., West River Industrial Pk., Providence, RI 02904. **210**

Manual plotting device with its own built-in ink supply for up to 25,000 impressions sells for $2.50 in snap-open plastic box. Squares, circles and crosses are available. Newton Trading Co., Box 113, Newton Centre, MA 02159. **213**

Cold-cathode numerical readout tube, Model NL-1222, operates in dc, strobe or time-share modes from 170V dc and provides 0.5-inch character height. Basing is available for either solder-in or socket applications. National Electronics, Inc., Geneva, IL 60134. **214**

Opto-isolators, Model MCT 4 phototransistor coupled pair and Model MCD 4 photodiode coupled pair, are offered in four-lead TO-18 package. Model MCT 4 has current transfer ratio of 0.35% and rise and fall times of 2 μsec. Model MCD 4 has current transfer ratio of 0.15% and rise and fall times of 20 nsec. Price ranges from $6.50 each to $3.95 each in 1000 lots. Monsanto Electronic Special Products, 10131 Bubb Rd., Cupertino, CA 95014. **215**

Film-element trimmers of the 800 Series are 1/2 inch long, dissipate 0.3W and are offered from 10Ω to 2 MΩ at ±10% tolerance (from 100Ω through 500,000Ω). TC of these 10-turn units is ±250 PPM/°C. Dale Electronics, Inc., Dept. 860, Box 609, Columbus, NE 68601. **216**

Components/Materials

Logic status indicator, Model LL-4S, provides 4 bits of side-viewing logic status in a dual in-line package. Each input of the TTL/DTL-compatible unit represents only 1 unit load. Price is $6 in quantities of 500. Unique Devices Co., Box 786, Reseda, CA 91335. **217**

IC strip-socket and mating header have 0.1-inch spacing and the standard product size is 25 contacts. Socket and header prices are $1.15 and $2.35 in 100 lots. Robinson-Nugent, Inc., 800 E. Eighth St., New Albany, IN 47150. **218**

Metallized cellulose-acetate tubular capacitors, MKL Series, provide high capacitance/volume ratio and withstand surges up to four times the rated voltage. Capacitance values between 0.1 and 10 μF with voltage ratings between 63 and 250V are available. Siemens Corp., 186 Wood Ave. South, Iselin, N J 08830. **219**

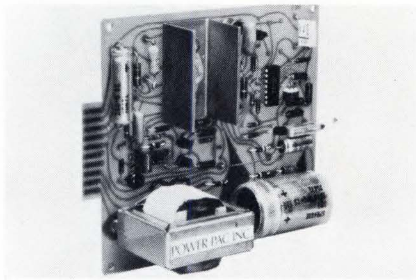
Lighted rocker switch, Series 7100, is offered in SPST at 10A 125V rating and with either neon lamp or subminiature incandescent lamp. Leecraft Mfg. Co., Inc., 21-10 44th Rd., Long Island City, NY 11101. **220**

Readout plus decoder/driver accepts BCD input and provides 7-segment incandescent readout. These units operate on 3 to 5V with current as low as 8 mA, and their life is over 100,000 hrs. Pinlites Inc., 1275 Bloomfield Ave., Fairfield, N J 07007. **221**

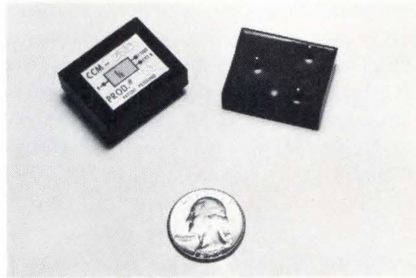
Industrial pilot lights, miniature and oil-tight, are available in standard 110V ac and 24V dc versions plus a model with built-in amplifier that will operate directly from the output of a solid-state logic module. All have patented test feature that permits checking all system pilot lights simultaneously, even during machine cycle, by pushing one button. Design Products Corp., 1925 W. Maple Rd., Troy, MI 48084. **222**

PC connectors with solder eyelet termination and from 6 to 43 contact positions are offered in the new 225 Series. Operating voltage is 600V ac and current rating is 5A. Amphenol Industrial Div., The Bunker-Ramo Corp., 1830 S. 54th Ave., Chicago, IL 60650. **223**

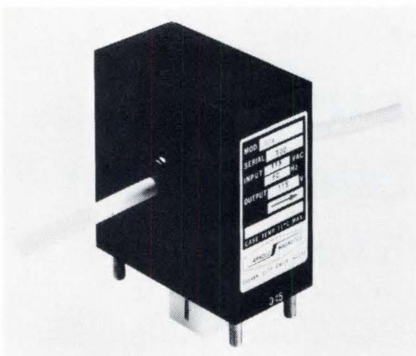
Decimal-to-ASCII encoder, the "Data-Dial", converts older manual-calibration instruments for automatic data logging. A thin cable delivers logic and power supply wires to each knob. Price is $35 each. Write, specifying instrument system to be converted, for information. Electro Scientific Industries, Inc., 13900 N.W. Science Park Dr., Portland, OR 97229.



Power supplies on PC cards are available in 44 models that include both single and dual outputs. Single output units deliver voltages from 3 to 150 and currents from 10 to 900 mA. The dual output units provide from ±5 to ±24V dc at 120 to 450 mA. Price, including 5-year warranty, ranges from $30 to $53 each. Power Pac Inc., 24 Stage St., Stamford, CT 06901. **226**

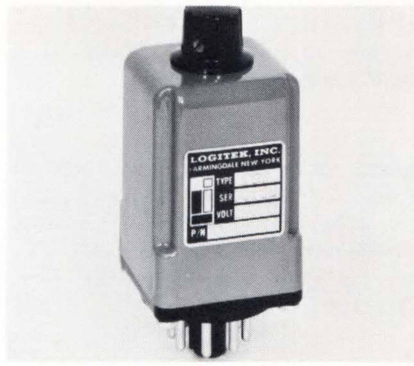


Current regulator modules for preset currents between 100 μA and 1A (within ±1% setting accuracy or better), and for use on operating voltages from 10 to 100V dc, are available at prices starting at $5 each. Response time is 100 nsec, and load stability is typically better than ±1% with a 100% load variation. Modular Systems International, 2621 Rhode Island N.E., Albuquerque, NM 87110. **229**



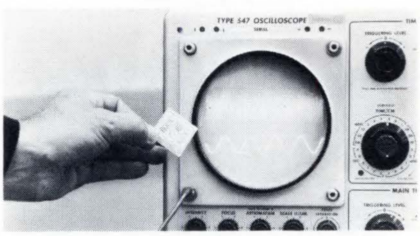
Current limiter, Model RAL, limits ac current in a cable when that cable is passed through a hole provided in the limiter body. Limiting is by duty cycle variation and is noiseless. Operation is from 100 to 140V 60 Hz ac. Currents up to 8A can be controlled. Arnold Magnetics Corp., 11264 Playa Ct., Culver City, CA 90230. **224**

Hybrid FET-input op amp, Model MSF-741, combines matched FETs, matched source resistors and selected "741" op amps, and is completely contained in a TO-91 flat pack. The "A" and "B" versions offer 10 μV/°C and 50 μV/°C respectively. Prices are $29 and $19 each, respectively. Mini-Systems, Inc., Box 429, North Attleboro, MA 02761. **227**

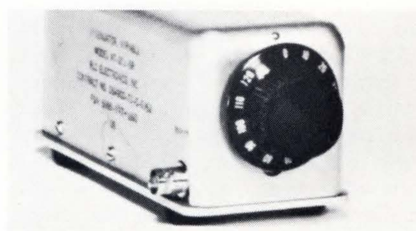


Solid-state time-delay relays have DPDT contacts rated at 2A and operate from −10 to 70°C. Units are available with four delay ranges that cover from 0.1 to 300 sec and for delay on either operate or release. Input voltage is 28V dc or 115V ac. Price, $35 each. Logitek, Inc., 42 Central Dr., Farmingdale, NY 11735. **230**

Electrometer amplifiers, inverting Model 3430 and noninverting Model 3431, have input bias current of 0.01 pA and input noise current of 0.001 pA. Input impedances are $3 \times 10^{11}\Omega \parallel 30$ pF and $10^{14}\Omega \parallel$ 2 pF respectively. Rated output is ±10V, ±10 mA. Unit price is $59 each for the J version and $95 each for the K version. Burr-Brown Research Corp., International Airport Industrial Park, Tucson, AZ 85706. **225**



Digital filter MOS/LSI circuits, including a serial/parallel multiplier, a shift-register/adder and an analog-digital converter are available at $50, $60 and $80 each. Using these, the cost of digital filters that do not need programming and typically operate at 300 mW power, is reduced from several thousand to a few hundred dollars. North American Rockwell Microelectronics Co., Box 3669, Anaheim, CA 92803. **228**



Step attenuator for use from dc to 1000 MHz offers either 0 to 120 dB in 10-dB steps (Model AT-201) or 0 to 12 dB in 1-dB steps (Model AT-200). Each has power rating of 0.5W, 50Ω impedance, maximum insertion loss of 0.75 dB to 500 MHz and 1.5 dB to 1000 MHz and VSWR of 1.3 maximum to 500 MHz and 1.5 maximum to 1000 MHz. Price is $125 each. RLC Electronics Inc., 83 Radio Circle, Mt. Kisco, NY 10549. **231**

Circuits

Pressure transducer, a microminiature "W" type bonded strain gage unit, has all-welded stainless steel construction and is available with sizes from 1/8- to 1/2-inch diameter. Typical outputs range from 1 to 7 mV/psi. Sensotec, Inc., 1400 Holly Ave., Columbus, OH 43212. **232**

Pulse-width modulator, 1F Series, can drive switching transistors where the pulse width on the transistor base is controlled by microampere-range dc signals. Frequency response is up to 10 kHz, typical input is 30 μW and output is 1W. Diameter is 1/2 inch. Price is from $60 to $80. Magnetic Electronics, Inc., Box 25517, West Los Angeles, CA 90025. **233**

Programmable surface-wave tapped delay line operates with dynamic range up to 50 dB (largely insensitive to temperature). Magnavox Co., Fort Wayne, IN 46804. **234**

Solid state relays, Series PSG, are available for switching current loads from 1.5 to 25A at voltages of 115 or 220 ac and 28V dc. Prices range from $4.40 to $19.25 in production quantities. PSG Industries, Inc., Ninth & Ridge Ave., Perkasie, PA 18944. **235**

DC-DC converter, Model PWR-101, accepts 24V input and provides an output of 200V at 30 mA maximum. Load regulation is ±5%. General Dynamics, Electro Dynamic Div., Box 2566, Orlando, FL 32802. **236**

Micro-miniature detectors that operate from 8 to 10 GHz with −54 dBm tangential sensitivity have maximum VSWR of 1.5 and weigh less than 3g. Size is 1/4 by 3/8 by 5/8 inch. Engelmann Microwave Co., Skyline Dr., Montville, N J 07045. **237**

Dual voltage comparator for A/D conversion, the high-speed Model L132, has two isolated comparison channels, each with a separate strobed latch on the output. Price, in 100 lots, is $9 each in TO-86 flat pack or $12 each in TO-116 DIP. Siliconix Inc., 2201 Laurelwood Rd., Santa Clara, CA 95054. **238**

X-band isolator with better than 5 GHz instantaneous coverage measures only 3/4 by 3/4 by 1/2 inch. Typical performance between 7 and 12.4 GHz includes 20-dB isolation, 0.4-dB insertion loss and 1.25:1 VSWR. Micromega Div., Bunker Ramo Corp., 12575 Beatrice St., Los Angeles, CA 90066. **239**

Modules for sensing over or undervoltage on ac lines, Model 825 (over) and Model 826 (under), sense preset values within the range of 80 to 115V and 115 to 150V ac respectively at 50 to 60 Hz with better than 1% accuracy and repeatability. Module size is 2 by 3 by 1 inch, and prices are $48 and $33.60 each in 100 piece lots. California Electronic Mfg. Co., Inc., Box 555, Alamo, CA 94507. **240**

Voltage/frequency sensor detects under/over voltage or under frequency condition and provides a relay closure. Model VFS-1 has overall accuracy of 2%. Price is $128 in unit quantity. OR Electronics, Inc., 475 Watchung Ave., Watchung, N J 07060. **241**

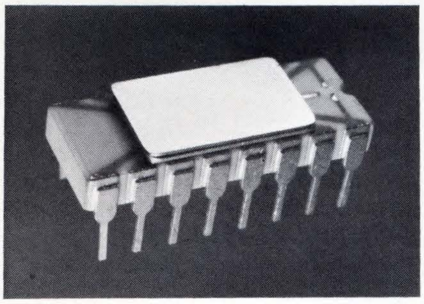
Low-cost PC-card dc supplies feature 0.1% regulation, overload protection and remote voltage sensing. Voltages from 4 to 32 and currents as high as 1.5A are offered. Price is $28.50 each in quantity of 10. ACDC Electronics, Inc., Oceanside Industrial Ctr., Oceanside, CA 92054. **242**

Logic gate, Model 4612, consists of an AND and an OR gate that can be used singly or in combination. Model 4612 is packaged in a single-width NIM-standard format. Ortec Inc., 214 F Midland Rd., Oak Ridge, TN 37830. **243**

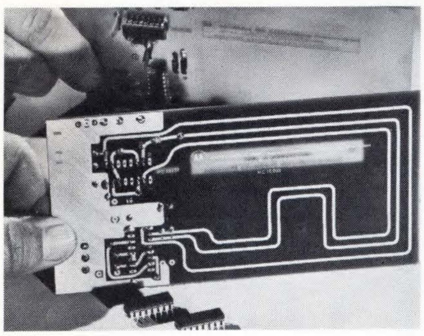
Touch dial decoder does not require resonant reeds, LC tuned circuits or relays and is compatible with AT&T touch-tone signaling systems. Model 301 is field programmable from 1 to 8 digits and provides a total operating capacity of 100-million code combinations. Package size is 3 by 5 by 1 inch. Dynacoustics Inc., 1980 National Ave., Hayward, CA 94545. **244**

Power hybrid circuit products—high-current series voltage regulators, a high-gain current-amplifier pair, and a 100-kHz power amplifier—are now available. These include Model TA7955, 4A 5V series regulator; Model TA8141, high gain, current amplifier pair and Model TA7926, linear power amplifier specified for operation to 100 kHz. RCA/Solid State Div., Somerville, N J 08876. **245**

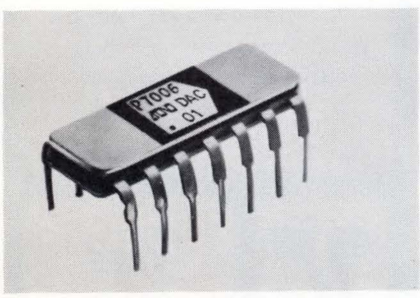
Microchannel amplifiers for X-ray image intensification are available in various sizes up to an active diameter of 40 mm with channel diameters of 40 μm and center-to-center spacing of 50 μm. Typical electron gain is 10^4 at 1 kV. Optics Technology Inc., 901 California Ave., Palo Alto, CA 94304. **246**



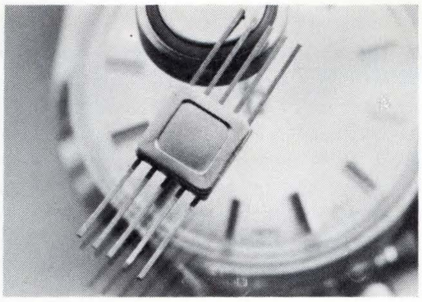
Random-access memory GER 1101 is a 256-bit static unit featuring refractory metal oxide semiconductor (RMOS) processing. The unit features an access time of 1 μsec, power dissipation of 2 mW/bit, operation from 0 to 85°C, and is packaged in a 16-lead ceramic dual in-line container. General Electric Co., IC Products Dept., Electronics Park, Bldg. 5, Room 160, Syracuse, NY 13201. **247**



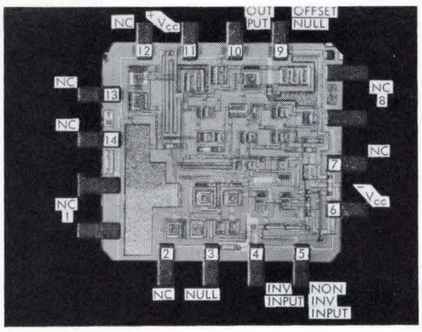
Emitter-coupled logic MECL 10,000 has had added two new devices: a dual 3-input/3-output OR and a dual 3-input/3-output NOR. Price (100-999) is $2.50 each. Technical-Information Center, Motorola Inc., Semiconductor Products Div., Box 20924, Phoenix, AZ 85036. **248**



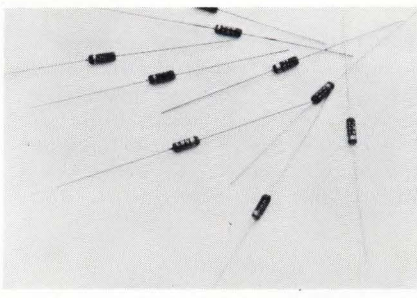
Monolithic D/A converter monoDAC-01HS is a commercial version of a high-speed, 6-bit device. It contains an internal voltage reference, diffused ladder network, six precision current sources, six current steering logic switches and an internally-compensated output op amp. The unit is priced at $9.95 each in lots of 2000 items. Precision Monolithics, Inc., 1500 Space Park Dr., Santa Clara, CA 95050. **249**



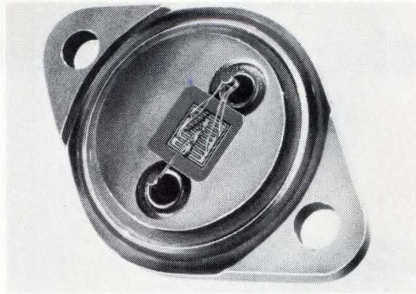
COS/MOS universal timing circuit TA6030 is a 23-stage circuit that operates from any dc power source ranging from 1.3 to 15V. The unit is intended for use in wrist watches, wall clocks, automobile clocks, digital readout clocks and similar timing applications. Operating at 1.3V, power dissipation is typically 4 μW. RCA Commercial Engineering, Harrison, N J 07029. **250**



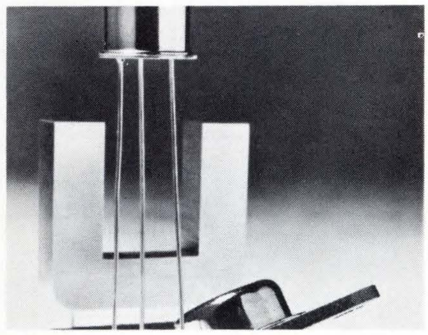
Beam lead op amps, RC741BL and RM-741BL, are commercial and military high gain, internally compensated units that are nitride passivated and are ideal for hybrid applications. Raytheon Co., Semiconductor Div., 350 Ellis St., Mountain View, CA 94040. **251**



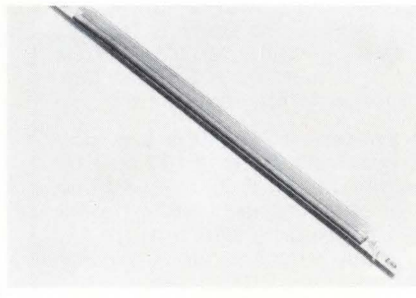
Hyperabrupt HA Series tuning diodes are designed to span an octave in the 2-MHz to 1000-MHz frequency range. Varying bias from 1 to 28V causes a variation in capacitance of at least 4.5:1. Eight units in the Series span from 13.2 to 200 pF at 1V bias. Q is 300 at 1V, 50 MHz and exceeds 2000 at 28V in the low capacitance types. Price, in lots of 100 items, is $8 each. MSI Electronics Inc., 34-32 57th St., Woodside, NY 11377. **252**



Transistors in the SVT 350-450 Series are high-speed, high-voltage switching units that are rated up to 450V and 10A. Typical switching speeds are less than 100 nsec, saturation voltage is 1V and typical beta is 15. Mounted in the TO-3 package, prices start at $11.60 each in lots of 1000 units. TRW Semiconductor Div., 14520 Aviation Blvd., Lawndale, CA 90260. **253**



High-voltage power switching transistors, 2N5660-67 Series, can handle up to 3A dc and have a V_{CER} to 400V min. In lots of 100 items, prices start at $15 each. Inquiry Processing Dept., Unitrode Corp., 37 Newbury St., Boston, MA 02116. **254**



Photodetectors manufactured using double diffused silicon PIN structures offer continuous sensing surfaces of 2, 4, 6, 8 and 10 inches, sensitive areas up to 11.5 cm² and uniformity of ±5%. Typical characteristics of a 10-inch detector are: spectral response from 0.3 to 1.1 μm, output of 0.4A/W at 8500Å and response time of 3.5 μsec with a 1 kΩ load. Solid State Radiations Inc., 2261 S. Carmelina Ave., Los Angeles, CA 90064. **255**

New SC's

Dual 100-bit dynamic shift register IM-7706/7707 is a p-channel MOS unit that operates from 250 Hz to 3 MHz at room temperature. Power consumption is 0.2 mW/bit at 1 MHz, output impedance is 30Ω typical and prices, in lots of 100 to 999, are $6 (military) and $4 (industrial). Intersil, Inc., 10900 N. Tantau Ave., Cupertino, CA 95014. **256**

Hybrid FET-input op amp MSF-741 combines matched FETs, matched source resistors and a 741 IC op amp in a TO-91, 1/4- by 1/4-inch flat pack. Mini-Systems, Inc., Washington Park, North Attleboro, MA 02761. **257**

Building-block MOS/LSI circuits can be combined to form the calculating portions of business and scientific calculators and of other data reduction equipment programmed for up to 1000 steps. North American Rockwell Microelectronics Co., Box 3669, 3430 Miraloma Ave., Anaheim, CA 92803. **258**

MOS dual 100-bit shift registers, Am14/1506 and Am14/1507, offer 30% lower power dissipation than the 0.4 mW/bit at 1 MHz units they replace. Both offer a guaranteed frequency of operation to 2 MHz, and in the 100-up mix quantity, prices start at $4 each. Advanced Micro Devices Inc., 901 Thompson Pl., Sunnyvale, CA 94086. **259**

RF power transistor TM80000 features a high current gain f_T of 1200 MHz (min), output capacitance C_{cb} of 3 pF (max) and a noise figure of 2.7 dB typical. In lots of 100 to 999, price is $1.38 each. Teledyne Semiconductor, 1300 Terra Bella Ave., Mountain View, CA 94040. **260**

TTL/DTL-compatible dual differential line driver/receiver series, QC 7820/8820 and QC 7830/8830, operate on a single 5V supply over the military temperature range of −55 to 125°C. Units are available in the DIL package, chip form or custom configuration. The 100-unit prices are $5.50 and $4.50 each, respectively. Qualidyne Corp., 3699 Tahoe Way, Santa Clara, CA 95051. **261**

IC dividers, SP 601, -2, -3 and -4, were developed to meet the operational requirements of high-speed digital frequency synthesizers and counters. The 602 unit is a 500-MHz divide-by-2 circuit, 603 and 604 toggle at 400 MHz and 300 MHz respectively, and the 601 is a 100-MHz divide-by-4 circuit. Plessey Electronics Corp., 170 Finn Ct., Farmingdale, NY 11735. **262**

Silicon photosensor cells in the "Pik-A-Peak" Series are available at selected wavelengths throughout the blue, green, yellow or red spectral bands. Sensor Technology, Inc., 7118 Gerald Ave., Van Nuys, CA 91406. **263**

Low-power TTL monostable multivibrator SN54L/74L122 has both retriggerable and clear functions. Power dissipation is 55 mW at 50% duty cycle, and prices, in lots of 100 to 999, start at $1.54 each. Texas Instruments Incorporated, Inquiry Answering Service, Box 5012, M/S 308, Dallas, TX 75222. **264**

MOS shift registers now packaged in silicone molded containers include a quad 32-bit register, a 1-to-64-bit variable length register, and a 256- and 512-bit register that are all dynamic, and a dual 100-bit static register. In lots of 100 up, prices start at $4.40 each. Electronic Arrays, 501 Ellis St., Mountain View, CA 94040. **265**

Green light-emitting semiconductor dice PD5033 are gallium phosphide units that have an emission at 570 nm and a typical light output of 300 fL at 10 mA. Units are priced at $1 each in lots of 5000. Ferranti Electric, Inc., East Bethpage Rd., Plainview, NY 11803. **266**

UHF communications power transistors include six new devices for use at 12.5 and 28V and at frequencies of 400 and 470 MHz. All feature ballasted emitter design for extreme ruggedness under load mismatch. The family covers a range from 1 to 20W output, and in lots of 1 to 99, prices range from $6 to $46 each. Solid State Scientific Inc., Montgomeryville, PA 18936. **267**

IC arrays include five npn and pnp IC monolithic units. Three arrays, designated CA3081, -82 and -83, are for high-current applications. The other two, CA3084 and -86, are for general-purpose applications in signal-processing systems. In lots of 1000 units, prices start at $0.49 each. RCA Commercial Engineering, Harrison, N J 07029. **268**

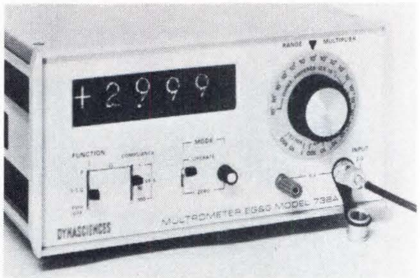
Miniature zener diodes make up a new series of ±5%, 400 mW (at 50°C) silicon planar whiskerless zener diodes packaged in the space-saving DO-35 package. Amperex Electronic Corp., Slatersville, RI 02876. **269**

SCR C602 is reported to be the highest voltage rated SCR in domestic production. It is rated at 2600V and 600A average, and is housed in the pressure-mounted "Press Pak". In lots of 10 to 99, prices start at $186 for a 1000V unit. General Electric Co., Electronics Park, Bldg. #7, Mail Drop 49, Syracuse, NY 13201. **270**

TTL read-only memories are 256-bit units that include the standard DM7488 and the tri-state DM7598 devices. Both store 32 8-bit words that are typically accessed in 30 nsec through on-chip decoding logic. In lots of 100 to 999, prices start at $9.60 each. National Semiconductor Corp., 2900 Semiconductor Dr., Santa Clara, CA 95051. **271**

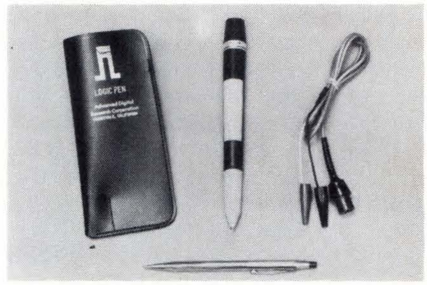
MOSFETs 2N4066/2N4067 feature $10^{15}\Omega$ input resistance, normally off operation with zero gate voltage, and square law transfer characteristics. In lots of 100 items, prices are $5 and $7 each, respectively. General Instrument Corp., 600 W. John St., Hicksville, NY 11801. **272**

Three linear IC peripheral drivers are added to a computer system interface circuits family. Each circuit contains two TTL gates and two transistors capable of sinking up to 300 mA with a 30V breakdown voltage. Prices, in lots of 100 to 999, range from $1.10 to $1.43. Texas Instruments Incorporated, Inquiry Answering Service, Box 5012, M/S 308, Dallas, TX 75222. **273**

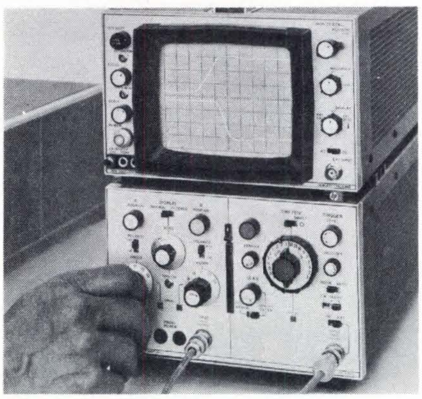


Multifunction electrometer, Model 736A, measures resistance to $10^{14}\Omega$ full-scale, provides current resolution to 10^{-15}A and charge resolution to 10^{-14}C—and it makes voltage measurements from 10 mV to 100V with $10^{16}\Omega$ input resistance. The digital-readout Model 736A sells for $1150. Dynasciences Corp., 9601 Canoga Ave., Chatsworth, CA 91311. **274**

RF oscillator, Model 8651A, provides 22 kHz to 70 MHz signals at levels from 1 mV to 3V into 50Ω. Output flatness is ±3% to 22 MHz, ±5% from 22 to 70 MHz. Features include <3% harmonic distortion, <10 μV leakage, half-rack width and price of $695. Hewlett-Packard Co., Inquiries Manager, 1601 California Ave., Palo Alto, CA 94304. **277**

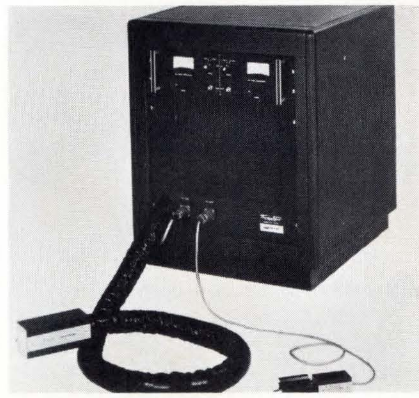


Logic test probe for MOS applications, the "Logic Pen-MOS", indicates high or low logic levels and the occurrence of pulses or pulse trains in MOS logic circuits. Maximum operating frequency is 15 MHz and minimum pulse width detection is 50 nsec. Price is $130 each. Advanced Digital Research Corp., 608 Vaqueros Ave., Sunnyvale, CA 94086. **280**

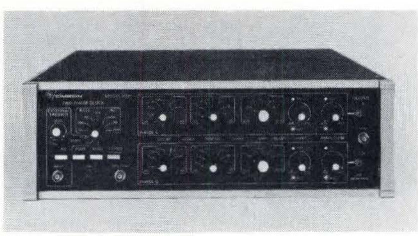


Sampling plug-in for the H-P 180 Series oscilloscopes, priced at $1650, permits 1-GHz operation at lower cost than a real-time scope. Model 1810A is a dual-channel device with 2-mV deflection sensitivity and improved triggering. Hewlett-Packard Co., Inquiries Mgr., 1601 California Ave., Palo Alto, CA 94304. **275**

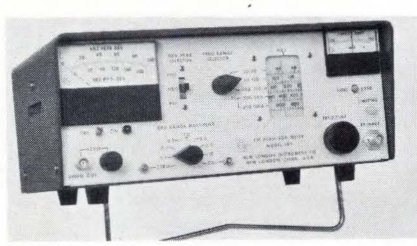
CCTV camera with resolution exceeding 450 TV lines and automatic compensation for illumination over a range of 4000:1 is fully automatic, requires no adjustment except lens focus and retails for only $199.50. Model CTC-4000 is fully solid state. GBC Closed Circuit TV Corp., 74 Fifth Ave., New York, NY 10011. **278**



Temperature controller for "at the tester" cooling or heating of IC devices produces controlled temperatures of −85 to +180°C. Model TP-2100 can cool a 20-lead package, dissipating 500 mW, in a Barnes Carrier to −75°C, reaching −55°C in 40 sec. Temptronix Inc., 591 Hillside Ave., Needham, MA 02194. **281**



Two-phase clock for driving either MOS or bipolar circuits is essentially two independent pulse sources driven by a single clock. Model 3106 provides clock frequencies from 20 Hz to 20 MHz. Pulse amplitude can be varied from 5 to 35V, and the output amplifiers can drive a 100-pF load to 30V with a slope of 1V/nsec. Price is $1795. Cimron Div., Lear Siegler, Inc., 714 N. Brookhurst St., Anaheim, CA 92803. **276**



Frequency modulation monitor for both narrow- and wide-band FM operates over a radio frequency range of 20 to 1000 MHz in five bands. Peak deviation measurement is from 10 kHz full-scale to 1000 kHz full-scale. The ultra-linear detector of the Model 504 has only 0.5% harmonic distortion at 500-kHz peak deviation and 1-kHz modulation rate. New London Instrument Co., 153 California St., Newton, MA 02158. **279**

Economy DPMs, the 3-digit 420 Series and 4-digit 740 Series, are quality checked, burned in for 100 hrs and warranted for 1 year. The 420 Series units feature (0.2% ±1 digit) accuracy, 100 μV resolution and price of $124 each. The 740 Series units have accuracy of (0.05% ±1 digit) and sell for $300 each. There are liberal quantity discounts. Datascan, Inc., 1111 Paulison Ave., Clifton, N J 07013. **282**

Digital picoammeter, priced at $1150, measures direct current from 10^{-12} to 10^{-2}A full-scale. Model 726A features built-in current source and a 3-full-digit display with 200% overrange. Dynasciences Corp., 9601 Canoga Ave., Chatsworth, CA 91311. **283**

IC probing station features exterior loading and is suitable for LSI, MSI or thick- and thin-film probing. Model S-10 is intended as a production probing station. Olson Industrial Corp., 3910 S. Kalamath St., Englewood, CO 80110. **284**

Thermocouple temperature data-acquisition system handles 50 points and may be operated manually or left unattended to collect test data. A digital tape printer records channel number and temperature. Price is approximately $4000. InstruLab, Inc., 1205 Lamar St., Dayton, OH 45404. **285**

DC differential voltmeter/high-impedance voltmeter/calibrator, Model 2901, has calibration accuracy of ±0.002%, delivers from ±100 nV to ±100V dc and has 100 mA current capability. Price is $1350. Electronic Development Corp., 11 Hamlin St., Boston, MA 02127. **286**

Intervalometers with 1% accuracy, Models FRI-1, -2 and -3, are available with pulse rate from 1 pulse/1000 sec to 20 pulses/sec. Input power is 28V dc or 115V 60 or 400 Hz ac. Flight Research, Box 1-F, Richmond, VA 23201. **287**

PCM telemetry system, a 16-channel transmitter and receiver pair facilitates remote acquisition of data. Inmet, Inc., 987 Pinetree Dr., Indian Harbour Beach, FL 32937. **288**

Fetal heart-beat detector uses Doppler principle and provides clear, audible detection of the fetal heart from about the tenth week of pregnancy through labor. Model D-6 that operates from both 115V ac power and self-contained batteries is priced at $595. Chrono-Log Corp., 2583 W. Chester Pike, Broomall, PA 19008. **289**

Portable frequency meter-transducer, Model 300 F, operates on four penlight cells. Frequency range is 0 to 100 kHz (in four ranges) with accuracy of ±1%. Price is $94.50. Compudex Inc., Box 93, Norristown, PA 19404. **290**

Ultrasonic intruder detector operates from either 12V dc or 117, 220 or 240V ac. Size is 5 by 4-3/8 by 1 inch, range is 1 ft minimum, 25 ft maximum and price is $27.80 each in 1000 lots. Orient Electronics, Ltd., Yoyogi Box 38, Tokyo 151, Japan. **291**

Capacitor discharge magnetizer, Model 150-5, develops 56W-sec of magnetizing energy. It can handle all types of PM materials, and can magnetize multipole units. LDJ Electronics, Inc., 741 Owendale, Troy, MI 48484. **292**

Logic card tester handles any digital circuit card regardless of components, including MOS and LSI devices. The Model 4700 requires <5 sec for go/no-go testing of a card. It exercises completely any circuit with up to 1200 independent inputs. Cost is $14,750. Data Test Corp., 822 Challenge Dr., Concord, CA 94520. **293**

Digital displacement meter operates as a ratiometer with system accuracy to ±0.1% ±1 digit. Displacement range is ±0.02 to 5 inches. Price of the complete system starts at $510. Pickering & Co., Inc., 101 Sunnyside Blvd., Plainview, NY 11803. **294**

Digital pH meter, Model 109, while priced at $499 offers resolution to 0.01 pH or 1 mV. Featured are 4-digit "Nixie" readout and pushbutton controls. Corning Scientific Instruments, Corning Glass Works, Medfield, MA 02052. **295**

Decimal counting and display units of the 600 Series are available in 2, 3 or 4 digits with prices starting at $75. Computer Products, Box 23849, Ft. Lauderdale, FL 33307. **296**

Digital counters of the BC 60 Series are bidirectional general purpose accumulators designed for use with Baldwin 5V Series incremental encoders or similar transducers. Accumulation is 6 digit, either positive or negative. Prices start at $520. Baldwin Electronics, Inc., Box 3838, Little Rock, AK 72203. **297**

Laser resistor-trimming kit, Model 6300, allows conversion of air abrasive systems for clean, fast, accurate trimming (including active circuits). Price is $5900. Apollo Lasers, Inc., 6365 Arizona Circle, Los Angeles, CA 90045. **298**

Equipment

Air abrasive generator, the Accu-Trim, provides steady flow, and can use cutting nozzle tips smaller than 0.0007 inch. Industrial Model DB-10 has hand-piece cutting tool holder and foot switch control, Model DB-20 operates with the company's trimming systems and Model DB-30 replaces air abrasive units on other manufacturer's trimmers. M.P.M. Corp., 9 Harvey St., Cambridge, MA 02140. **299**

Analog input system, the wide-range Model RTP7480, uses accurate CR300 Series "CompuREED" switching relays. Full-scale analog input signals from ±10 mV to ±10V are sampled at rates up to 200 samples/sec. Channel selection is completely random-access with no pattern restrictions. Price is $1980 for the common equipment plus $40/channel. Computer Products, 1400 Gateway Dr., Fort Lauderdale, FL 33307. **300**

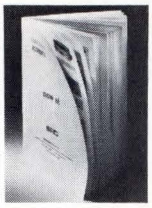
Digitizer, Model 8103, (the electronic portion of an automatic program writer) accepts X-Y coordinated data from any N/C or encoder. Input data is displayed visually and converted into coded information to transmit to a "Teletype". List price is $3600. Summit Engineering Corp., Box 938, Bozeman, MT 59715. **301**

Solid-state counter, Model WM, counts up to 2000 items/min, and has a units count/tens count feature. Counting range on the tens count is up to 9,999,990 units. Peco Corp., 450 Landess Ave., Milpitas, CA 95035. **302**

Spectrum analyzer/digital integrator now has capability to do swept sine-wave transfer function analysis through an added peak mode. Available in Model SAI-52, the new feature is in addition to the conventional nonredundant linear averaging mode. Signal Analysis Industries Corp., 595 Old Willets Path, Hauppauge, NY 11787. **303**

Bi-directional counter-controller with 3 to 6 plug-in decode modules that include readout, Model PC-2, offers a counting rate of 100 kHz. Square D Co., Dept. SA, Milwaukee, WI 53201. **304**

Digital signal analyzer systems, Type 1923, combine the speed of the hard-wired processor with the flexibility of a programmable digital controller. The Time/Data 90A processor is capable of Fourier-transforming a 1024-point time record into a 512-line frequency record in 12 msec. The controller is the DEC PDP-11. Time/Data, 490 San Antonio Rd., Palo Alto, CA 94306. **305**



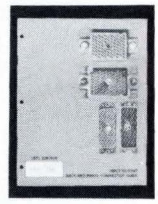
Instrumentation is the subject of this 56-page catalog that covers a complete line of amplifiers, converters, generators, translators, displays, tape search instruments, test equipment and signal conditioning equipment. SRC Div./Moxon Inc., 2222 Michelson Dr., Newport Beach, CA 92664. **306**

Low-power TTL ICs are fully described in this 36-page catalog that includes maximum ratings, guaranteed operating conditions, test circuits, connection diagrams, physical dimensions and ordering information for this 54L/74L family. National Semiconductor Corp., 2900 Semiconductor Dr., Santa Clara, CA 95051. **310**

Transistor dice are covered in a 32-page catalog. Included are small signal, RF power and high-frequency transistor types. Both npn and pnp types are covered, along with wafer testing, QA and reliability programs. Teledyne Semiconductor, 1300 Terra Bella Ave., Mountain View, CA 94040. **314**

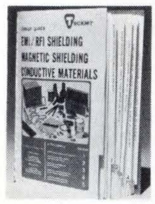
TTL ICs in the RAY III family are covered in this comprehensive 68-page handbook. Major characteristics, design considerations, absolute maximum ratings, package types and applications are included. Raytheon Semiconductor, 350 Ellis St., Mountain View, CA 94040. **307**

EMI/RFI filters, including button, subminiature, miniature and feed-thru types, are detailed in this 17-page catalog. These units meet or exceed all applicable requirements of MIL-F-15733. USCC/Centralab, 2151 N. Lincoln St., Burbank, CA 91504. **311**



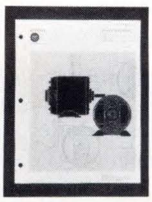
"Input/Output Rack-and-Panel Connector Guide" is a 36-page booklet and covers connectors ranging in size from 2 to 140 contacts and having current ratings of 3 to 20A. A line of installation equipment also is covered. Elco Corp., Willow Grove, PA 19090. **315**

Miniature electronic switches and keyboard assemblies are detailed in this 24-page catalog. Featured are miniature rotaries, pushbuttons and a new rocker series, along with reed switch keyboards and add-on modules. Alcoswitch, Div. of Alco Electronic Products, Inc., Box 1348, Lawrence, MA 01842. **308**



Magnetic shielding materials and products that include EMI/RFI shielding strips, gaskets and tapes, EMI/RFI shield seals, honeycomb, shielding vents, conductive systems and adhesives are part of the complete line covered in this 99-page design guide. Tecknit, 129 Dermody St., Cranford, N J 07016. **312**

Analog/digital/analog conversion units, signal conditioning units and digital display products are covered in this 16-page, short-form catalog that includes basic specifications and descriptive data for an entire line of products. Analogic Corp., Audubon Rd., Wakefield, MA 01880. **316**



Descriptions, applications, dimensions, prices and ordering information for over 500 fractional- and integral-horsepower motors are given in this comprehensive 24-page booklet. Motors rated from 1/20 to 5 hp are covered. Booklet PL 2820 is available from Westinghouse Electric Corp., Westinghouse Bldg., Pittsburgh, PA 15222. **309**

Electronic and electromechanical components/equipment for cutting cost of in-house projects are covered in 116-page Catalog 3-71. Typically priced at 40 to 90% below manufacturer's list, all items are guaranteed to meet the original manufacturer's specifications. Electron Div., American Relays, 39 Lispenard St., New York, NY 10013. **313**

Ovens, refrigerated baths, temperature/humidity environmental chambers and related temperature-controlled equipment are covered in this 216-page, hardbound catalog. Several new vacuum ovens and a new series of portable cooling units are included. Catalog SL-172 is available from Blue M Electric Co., 138th & Chatham St., Blue Island, IL 60406. **317**

Literature

Capacitors and resistors recently introduced are the subject of four-page short-form Catalog EPD DSF-1 from Corning Glass Works, Public Relations Dept., Corning, NY 14830. **318**

Light-sensitive devices are covered in a 32-page catalog from Solar Systems, Inc., 8124 N. Central Park, Skokie, IL 60076. **319**

Eput and timer, Model 6148 capable of 100-MHz operation, is described in two-page Publication 2240B from Technical Information Section, Electronic Instruments Div., Beckman Instruments, Inc., 3900 N. River Rd., Schiller Park, IL 60176. **320**

Silicon photovoltaic cells that peak at 555 nm in the green region of the visible spectrum are covered in a brochure from Sensor Technology, Inc., 7118 Gerald Ave., Van Nuys, CA 91406. **321**

Dual in-line LC filters for PC board mounting are covered in a bulletin from Kappa Networks, Inc., 165 Roosevelt Ave., Carteret, N J 07008. **322**

Signal generation and processing instrumentation equipment, including variable analog filters, programmable digital filters, and frequency and speech synthesizers, are covered in a short-form catalog from Rockland Systems Corp., 131 Erie St. E., Blauvelt, NY 10913. **323**

Modem test sets, test set printers and data interface access panels are detailed in specification sheets from International Data Sciences, Inc., 100 Nashua St., Providence, RI 02904. **324**

Precision miniature instrument motors are covered in a series of six product sheets from Scot, Inc., 2525 Curtiss St., Downers Grove, IL 60515. **325**

Fast-settling and general-purpose op amps are covered in a handy, four-page condensed reference file that is designed for use both as a quick reference to 26 new op amps and as a file for individual data sheets. Dynamic Measurements Corp., 6 Lowell Ave., Winchester, MA 01890. **326**

RF and microwave transistor guide lists 73 devices and includes complete specifications on each. Marketing Services Dept., Fairchild M.O.D., 3500 Deer Creek Rd., Palo Alto, CA 94304. **327**

Extruded vinyl tubing is the subject of a four-page brochure from L. Frank Markel & Sons, Inc., Norristown, PA 19404. **328**

High-alumina ceramics are the subject of an eight-page color brochure that offers design aids for specifying as well as a chart relating comparative properties of ceramics. Diamonite Products Mfg. Co., Div. of U.S. Ceramic Tile Co., Shreve, OH 44676. **329**

Miniature no-bounce relays and switches are covered in 12-page Bulletin 77 entitled "Logcell Mercury Film Relays and Switches" from Fifth Dimension Inc., Box 483, Princeton, N J 08540. **330**

Twelve-position rotary print switches are the subject of a 12-page catalog from C & K Components, Inc., 103 Morse St., Watertown, MA 02172. **331**

Miniature audio/electronic cable-to-panel connectors include 45 units that expand the 91 Series circular line. The family is described in a four-page bulletin, 91-T, from Amphenol Industrial Div., The Bunker-Ramo Corp., 1830 S. 54th Ave., Chicago, IL 60650. **332**

Over 90 new EMI/RFI shielding and fluid sealing gaskets for standard cable connectors are listed in Data Sheet EMC-852 from Tecknit, 129 Dermody St., Cranford, N J 07016. **333**

Analog gate selection chart covers an entire line of junction FET gates. Teledyne Semiconductor, 1300 Terra Bella Ave., Mountain View, CA 94040. **334**

Phase angle and frequency telemetering equipment provides ± 0.05 Hz up to ± 5 Hz measurement of 50 or 60 Hz power frequencies. Center scale accuracy of ± 0.0001 Hz is provided. The equipment is described in an 11-page brochure from Beckwith Electric Co., 1002 Greenfield Ln., Mount Prospect, IL 60056. **335**

RAYTHEON SEMICONDUCTOR. OUR OP AMPS HAVE PARAMETERS WITH TEETH.

Our new products are taking a chunk out of the operational amplifier market with parameters that are easy on designers and tough on competition. All of our dc parameters are specified over the entire voltage range — with no fall-off.

The new RM4131. It's unique in bipolar IC's, with input offset voltage of 2 mV maximum and 0.7 mV typical. Input offset current of 10 namp maximum and 2 namp typical. This high gain op amp has slew rates four times that of 709's and 741's. Typically 2 volts per microsecond with unity gain bandwidth of 4 MHz. And if low current drain at 20 V of 1.6 milliamps maximum is still not enough to put the RM4131 on your purchase order the large voltage signal gain should. It's typically 106 db from 3 to 20 volts.

The new RM4132. It cuts power dissipation by two orders of magnitude and needs no external bias or compensation. This proprietary micropower op amp has typical current drain as low as 22 μA. At maximum, 35 μA. Input offset current is reduced to 0.7 namp. It maintains unity gain bandwidth of 150 KHz. And it means further perfection in your battery operated circuits.

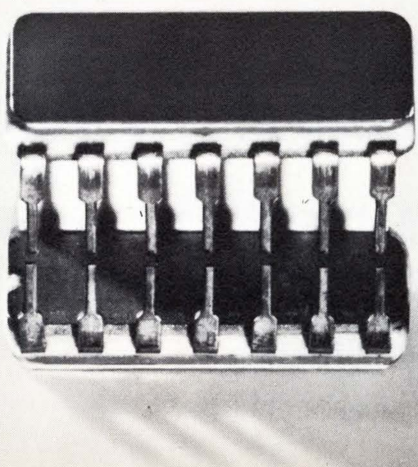
Proprietary linear circuits is one of our great strengths. But it's not our only strength. We're rapidly adding to our extensive line of off-the-shelf linear circuits as well. We provide the tightest parameter specs you can get in monolithic op amps, differential and dual comparators, voltage regulators, line receivers, and sense amplifiers. All available now at franchised Raytheon Semiconductor distributors.

Raytheon Semiconductor has changed. We have a new technical team. And new development programs providing new design tools. We're working on things like new digital analog interfacing that allow active switching and amplifying. Greater integration of external parts in voltage regulators. Greater circuit stability from improvements in temperature tracking. And we're going beyond the parameters established for slew rates, offset voltage, noise, bias current and offset current.

If you haven't been keeping up with us lately you've got a surprise coming. Write for our complete IC catalog and see. Raytheon Semiconductor, 350 Ellis Street, Mountain View, California 94040. (415) 968-9211.

RAYTHEON

CHOMP!



CIRCLE NO. 71

Literature

Environmental camera PB 1984 and TV camera PB 940 are the subject of two data sheets from Nelson-Hershfield Electronics, 1848 W. Campbell Ave., Phoenix, AZ 95015. **336**

Keyboards are the subject of a data package that includes a price list, a keyboards brochure and a molded plastic keytops data sheet. They are available from Mechanical Enterprises Inc., 5249 Duke St., Alexandria, VA 22304. **337**

"Conography", a unique new method of generating computer graphics, is the subject of a six-page brochure from Conographic Corp., 380 Green St., Cambridge, MA 02139. **338**

Tamperproof self-contained TV camera designed for surveillance in adverse environments is the subject of Data Sheet 6-567 which covers the Model 2820 camera. Cohu Electronics, Inc., Box 623, San Diego, CA 92112. **339**

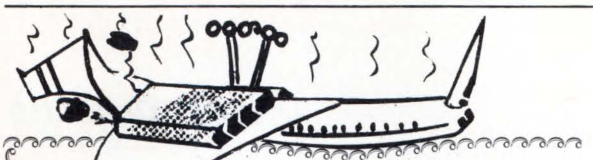
New 94% alumina "CERAM" permits design of substrates up to 12 by 12 inches and even larger. It is described in Data Sheet No. 110 from Ceram Corp., 5345 Timken Square, La Mesa, CA 92041. **340**

D/A converter Model DAC-16QM, which is the industry's first 16-bit unit, is completely described in a six-page foldout data sheet from Analog Devices, Inc., Pastoriza Div., Box 280, Norwood, MA 02062. **341**

"Electronics for Engineering Measurements" is a 20-page instrumentation guide available from Natel Engineering Co., Inc., 8944 Mason Ave., Canoga Park, CA 91306. **342**

High-speed multipoint recorder 816 is covered in four-page Bulletin 944-1B from Gould Inc., Brush Div., 3631 Perkins Ave., Cleveland, OH 44114. **343**

A/D converter Model VHS-630, capable of 6-bit resolution at any random or periodic word rate from dc through 30 MHz, is covered in a four-page brochure from Computer Labs, 1109 S. Chapman St., Greensboro, NC 27403. **344**



Sonic Boom From the SST—

or a statistically insignificant sample of comments about the editorial, 'Endangered Species Goes Belly Up.'

I'm surprised by the childish petulance with which you reacted to the termination of the SST program (Editorial: *Endangered Species Goes Belly Up;* April 15). Do you really believe the program was dropped because "technology is unpopular", or that the engineering and scientific professions are thereby threatened?

The death of the SST isn't symptomatic of the unpopularity of technology *per se*, but of a new attitude toward it in our society. People are coming to view technological progress which does not in the balance improve the human condition as not worth a damn. With respect to major new projects they're asking not only "can we?" but "should we?".

I for one think this attitude is long overdue. Let's stop bellyaching when a boondoggling, anti-social program like the SST goes to a deserved death. There are many opportunities ahead for relevant technology, and the truly professional members of the engineering and scientific communities should welcome the changes that are coming.

R. G. Johnson, Sr. Eng.
Goleta, CA

As a member of an incipient minority group, i.e., an employed electronics engineer, I believe you're overlooking a very important point. With the present emphasis on ecology, I believe engineers should be put on the list of Endangered Species.

Louis H. Garner
Torrance, CA 90505

After reading your editorial column in the April 15, 1971 issue of EDN entitled "Endangered Species Goes Belly Up", I get the feeling that the engineers and scientists are going 'Belly Up' without any concern for their survival. As every profession controls its own destiny, it is necessary for engineers to unite and organize to avoid their otherwise inevitable doom.

Problem

Failure of the SST program is not only a catastrophe for engineers, but also a catastrophe for the nation. Rejecting the SST for reasons such as radiation hazard and ecology is like practicing birth control by abstention. The environmental problems should be solved in parallel with the aeronautical problem. Eventually the ecology problem must be solved anyway and a setback for the SST means a corresponding setback for the ecology program. The SST program should have been approved on the condition that the ecology conditions could be met. This would then stimulate the ecology program and not stunt its development.

Although the administration in Washington includes engineers and scientists, this does not mean that engineers and scientists in industry are being adequately represented. Since even the administration's power is limited, a separate driving force is necessary.

Solution

In order for the engineers and scientists to protect their interests, an effective lobby should be set up in Washington at the earliest possible date. If every engineer paid an annual due of say one dollar (a mere pittance to protect their ten to twenty thousand/year income) a small group representing the engineers and scientists could be maintained.

Jack Wiens, Chf. Eng.
Mountain View, CA

KTI Is Alive and Well—

and Out from Under Chapter XI

Last December we published an article that detailed some of the incredible facets of how a young active-filter company—KTI—fell into financial difficulties and finally filed for bankruptcy and began operating under Chapter XI.

Because of our association with KTI during those hard times, it was especially gratifying to hear from Hal Tenney, KTI president, that the situation has been turned around, that KTI has extricated itself from the restrictions of Chapter XI and that shipments for the first quarter 1971 exceeded the sum of the three previous quarters.

Congratulations, KTI!

About 'Tables Speed Design of Low Pass Active Filters'

(March 15 EDN)

This article evoked a letter from Russell Kincaid of Sanders Associates Inc., Nashua, N. H., in which he commented (in part) as follows:

"I notice that the low Q sections are listed first in the Butterworth table, and the high Q sections first in the Chebychev tables. In constructing the filters it is always best, due to the gain of the high Q sections, to put the low Q sections first to avoid clipping."

Mr. Al Nasser, in his answer to the letter, said: "Your point that the low Q sections should precede the high Q ones is well taken." He also noted that there were two errors present in the article as it appeared: 1) **Eq. 1** should have read $E_0 = E_i/\{\quad\}$. 2) In **Eq. 9**, C4 and C5 should have read C1 and C2.

A final comment by Mr. Al Nasser: "Another point worth mentioning is the practical limitation imposed on the cutoff frequency by using off-the-shelf ICs. For instance, with the μA 741 it is limited to 10 kHz or less because of the finite gain-bandwidth product and the output impedance of the amplifier."

"Is that really you, Doctor Bagley?"

'Information, Please'

I would like some information— is there an LSI chip that does multi-decade counting? I need five decades but don't know what is available in LSI.

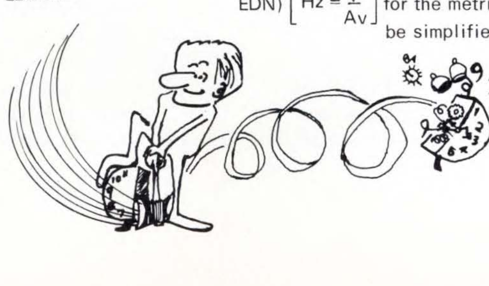
E. F. Rutschmann, STE
General Dynamics
1306 Marshalldale
Arlington, TX 76013

Time Cut in Half

Gentlemen:

The equation submitted by reader Burns (March 1, EDN) $\left[Hz = \frac{1}{Av} \right]$ for the metric unit of time should be simplified further:

Avis = No. 2
Therefore: Hz = 1/2



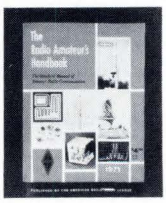
Henry Hofheimer
Eltek Corp.

Advanced Electronic Instruments And Their Use

Sol D. Prensky; Hayden Book Co., Inc., New York, N.Y., 1970, 208 pages; $6.95 (paper), $9.50 (cloth).

This is a useful reference book that should find its way into the libraries of laboratories and companies who cannot afford the luxury of their own specialized instrumentation and calibration staff. It covers most sophisticated, general-purpose laboratory instruments like scopes, various types of multimeters, recording instruments, sensors and transducers, etc., both from theory of operation to limits and advantages of one type of instrument over another. Also very important are the discussions on standardization and calibration procedures. This book makes no attempt to be all things to all people but indirectly serves that purpose by providing a good reference bibliography for instruments not covered. For more information about this book, circle R.S. No. **375**

The Radio Amateur's Handbook



Headquarters Staff, American Radio Relay League, Newington, CT 06111; 1971 – 48th Edition; 688 Pages (6-1/2 by 9-1/2 inch); paper; $4.50.

Too well known to need an introduction after 47 previous editions, this latest version has been added to, revised and expanded. The Semiconductor, SSB and Measurements chapters have been rewritten to bring them more in line with the current state of the art.

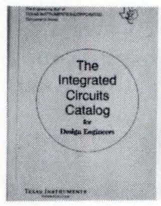
For constructors, several new projects have been added – among them solid-state transceivers, receiving accessories and antennas. Also added are new solid-state receivers and transmitters, and new VHF transmitting equipment.

Sharp clear illustrations along with nongloss paper make readability unusually good. It would be difficult to imagine a more useful practical radio handbook. Circle R.S. No. **376**

COS/MOS Manual

Basic principles of COS/MOS integrated circuit design and application are described in "RCA COS/MOS Integrated Circuits Manual". It covers RCA's 3 to 15V devices, as well as traditional 6 to 15V devices. Prepared for equipment designers, it is also valuable to educators, students, radio amateurs and hobbyists. Price is $2.50 a copy from RCA Commercial Engineering, Harrison, N J 07029, or circle R.S. No. **377**

The Integrated Circuits Catalog For Design Engineers



Integrated Circuits Catalog, Texas Instruments Incorporated; 1616 pages; $4.95.

Complete IC data-sheet information supplemented by application hints and diagrams are contained in a huge new publication from TI. Subjects covered include Schottky TTL, high-speed TTL, standard TTL, low-power TTL, MOS, ECL, DTL, high-noise-immunity logic, radiation-hardened circuits, hybrid circuits, systems interface circuits, linear circuits, and the MACH IV high-reliability procurement system.

The information is indexed by number and circuit function; cross-reference guides are also included in this hard-cover new volume. For a copy, send a check or money order to Texas Instruments Incorporated, MS84N, Dallas, TX 75222.

NSF Surveys R&D

National Patterns of R&D Resources, 1953-71 – Funds and manpower in the United States. National Science Foundation, Washington, D. C., Dec. 1970; 8 by 10; 38 pages; $0.50 from Supt. of Documents, U.S. Government Printing Office.

Total R&D expenditures should reach $27.8 billion in 1971, a 2.7% share of GNP. This report traces, with text and graphs, the rise of R&D funding, its relation to the economy and the relationship of Federal to industrial funding in several technological areas. It also reflects the erosion of inflation and projects growth rates to 1980. Circle R.S. No. **378**

Also Worth Noting

"Handbook of Universal Active Filter Use" provides general application data on the use of active filters and tables for design of Butterworth highpass and lowpass filters, Bessels, Chebyshevs, elliptic function filters, Gaussian highpass and lowpass and Legendre filters. Graphs are included that give magnitude, phase and group-delay characteristics of five types. Cost: $1.95 from Kinetic Technology Inc., (KTI), Santa Clara, CA 95050, or circle R.S. No. **379**

"Standards for Trimming Potentiometers", new industry standard for wirewound and nonwirewound pots, is organized into two parts: terms and definitions, and inspection and test procedures. Variable Resistive Components Institute; $3. Circle R.S. No. **380**

"Personnel Testing and Equal Employment Opportunity" summarizes research papers on "one of the most complex issues faced by the Equal Employment Opportunity Commission". It includes guidelines on employee selection. Forty-eight pages, $0.55 from Supt. of Documents, U.S. Government Printing Office, Washington, D C 20402. R.S. No. **381**

"Impact of Changes in Federal Science Funding Patterns on Academic Institutions, 1968-70" surveys 104 institutions, details changes when funding bases shift, in 76 pages. Costs $0.75 from Supt. of Documents, U.S. Government Printing Office, Washington, D. C. 20402. Circle R.S. No. **382**

Standard symbols for electrical and electronics diagrams contained in IEEE No. 315, ANSI Y32.2-1971 supplant those in the 1967 edition. Many symbols have been revised and some 200 new ones have been added. All are enlarged 50%. Class designation letters, formerly in ANSI Y32.16, are now found in Y32.2. Adopted for mandatory use by DoD, the new standard is priced at $11.50 postpaid from Institute of Electrical and Electronics Engineers, 345 E. 47th St., New York, NY 10017. Circle R.S. No. **383**

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Application Notes

"Small Computer Automated Testing Facilities" is a four-page bulletin that describes how automation can aid in testing of concepts as well as devices in a number of areas. How communications and other electronic equipments will function in a variety of environments is included. Computer Sciences Corp., 9841 Airport Blvd., Los Angeles, CA 90045. **350**

"Applications Memos" is the title of this 400-page handbook that includes an introduction to digital logic and discusses digital considerations by family, decoding and steering, counters, shift registers and memories, interface and display elements, linear considerations, timing circuits and parallel data handling. Signetics Corp., 811 E. Arques Ave., Sunnyvale, CA 94086. **353**

A new linear power transistor for high-frequency single-sideband equipment is the subject of this 12-page application note. AN-4591 discusses the advantages of SSB operation, some basic transistor characteristics and trade-offs, and describes the new unit. A linear amplifier that provides 150W PEP over the 2- to 30-MHz range is included. RCA Commercial Engineering, Harrison, N J 07029. **356**

Insulation resistance testing with megohmmeters is described in this 34-page handbook. The handy, pocket-sized booklet, Manual 17456, is available from Associated Research, Inc., 3777 W. Belmont Ave., Chicago, IL 60618. **351**

Hybrid 50W power audio amplifiers are the subject of this 24-page application note that describes the uses and performance of these high-power audio amplifiers. Airpax Electronics, Box 8488, Fort Lauderdale, FL 33310. **354**

"Designing with Analog Gates" is the title of this eight-page note that covers ac and dc swing, interfacing with TTL and the use of referral resistors. Teledyne Semiconductor, 1300 Terra Bella Ave., Mountain View, CA 94040. **357**

"On the Frequency Analysis of Mechanical Shocks and Single Impulses" is a 32-page technical review that discusses how with modern instrumentation it is possible to perform a Fourier transform on a signal and analyze it in the frequency domain. B & K Instruments, Inc., 5111 W. 164th St., Cleveland, OH 44142. **352**

"Monolithic Integrated Circuits for Stereo Processing" is the title of this 8-page app note that discusses how to replace a number of functions common to FM stereo receivers with ICs. Engineering Bulletin 27109-1 is available from Sprague Electric Co., North Adams, MA 01247. **355**

"Swept Frequency Measurements" is a four-page application note that illustrates several useful techniques for using function generators that are available today to make swept frequency measurements. It is available from Clarke-Hess Communication Research Corp., 43 W. 16th St., New York, NY 10011. **358**

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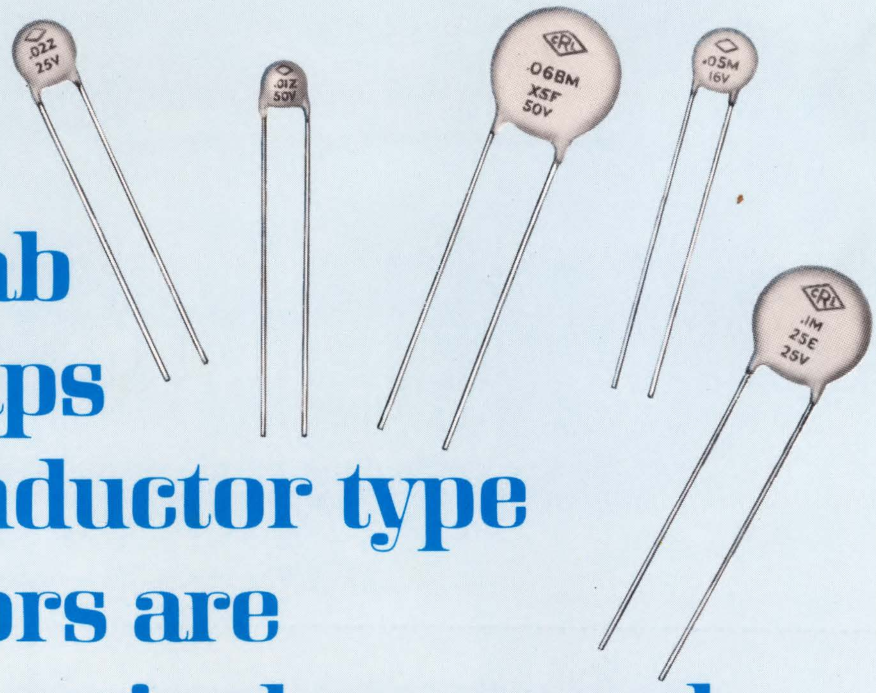

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.290	.02	5.0	.015	65.0	.01	1000
.390	.033	3.0	.022	45.0	.015	1000
.405	.05	2.0	.033	30.0	—	—
.485	—	—	.05	20.0	.022	1000
.515	.068	1.5	—	—	.033	1000
.590	0.1	1.0	.068	15.0	.047	1000
.690	0.15	0.65	0.1	10.0	.05	1000
.760	—	—	—	—	.068	1000
.820	0.2	0.5	0.15	6.5	—	—
.920	0.3	0.33	0.2	5.0	0.1	1000

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