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EDN 2nd Annual Design Contest winners announced

Two advanced A/D concepts provide high performance

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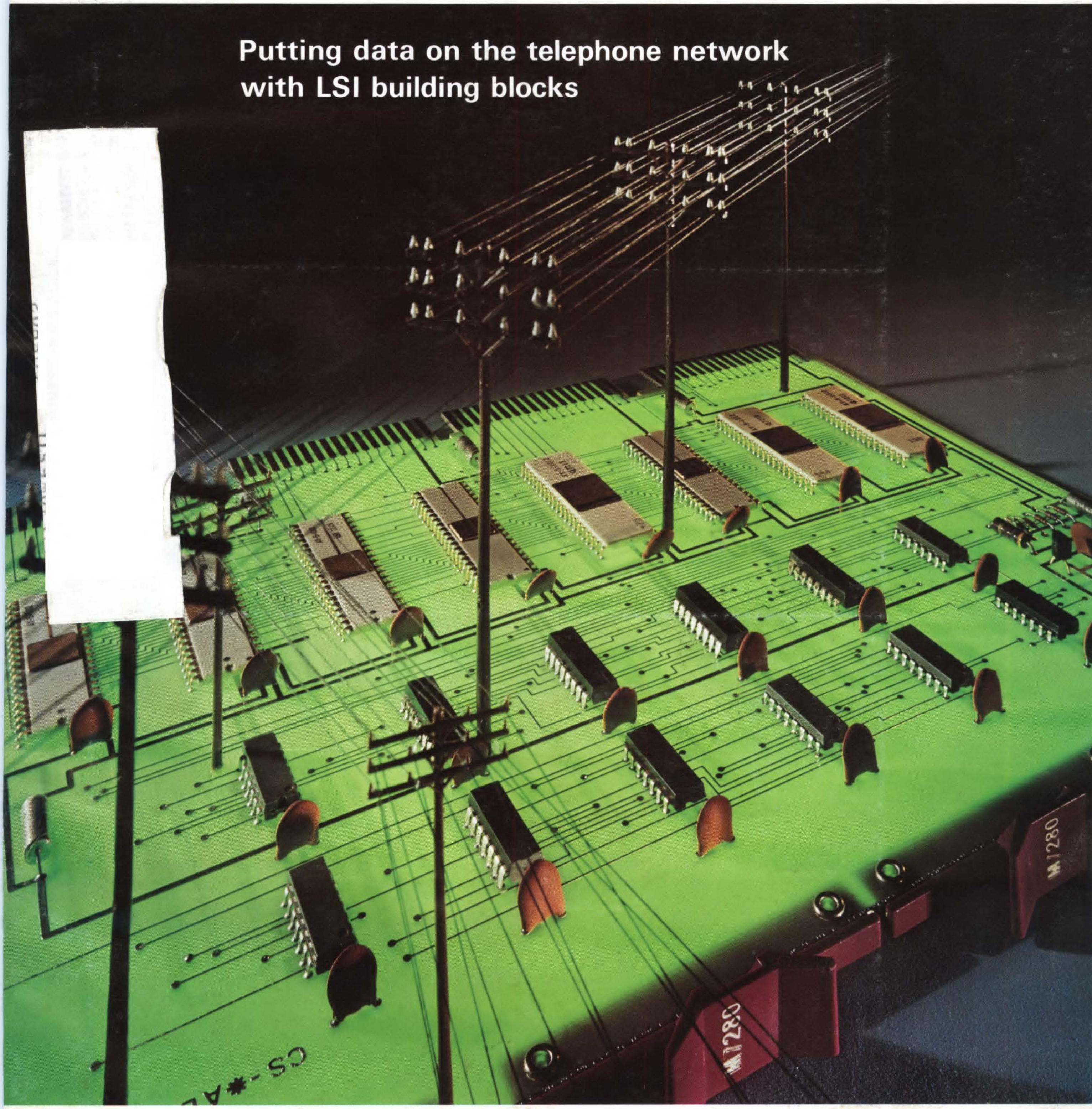

A CAHNERS PUBLICATION

JUNE 5, 1973


Acopian
MODEL TD15-40
OP-AMP DUAL POWER SUPPLY
+V +S COM -S -V AC AC GND

JUNE 5, 1973
VOLUME 18, NUMBER 11

EDN with EEE
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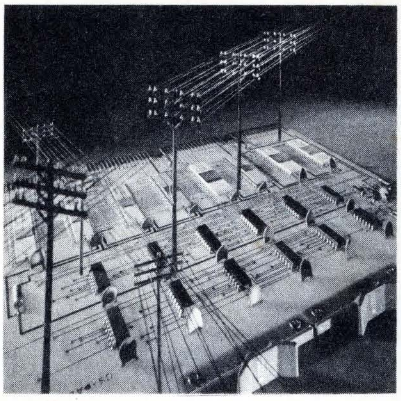

COVER

The eight LSI "UARTs" on this Digital Equipment Corp. I/O board allow DEC's PDP-11 computer to service eight telephone data conversations. The 40-pin UARTs are a mixture of Western Digital and General Instrument devices. DEC uses multiples of this board to handle up to 40 simultaneous conversations, enough to load all the phone lines superimposed on the board. To learn more about the value of LSI like the UARTs in data communications, turn to pg. 30.

DESIGN NEWS

DESIGN FEATURES

PROGRESS IN PRODUCTS

DESIGN PRODUCTS

DESIGN DEPARTMENTS

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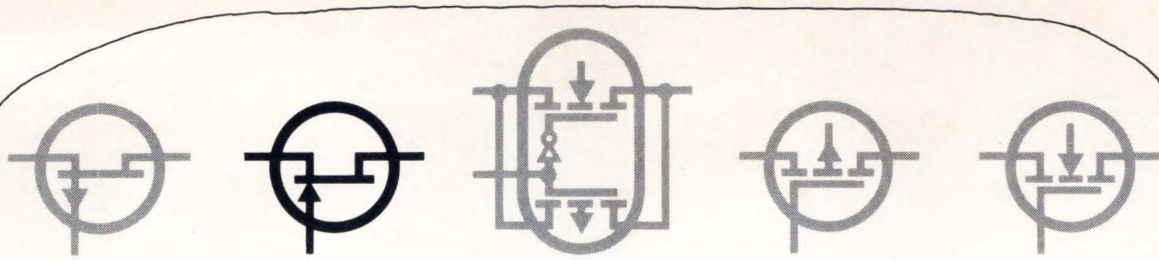

P-channel J FET | N-channel J FET | CMOS FETs | P-channel MOS FET | N-channel MOS FET

Since 1962, Siliconix has evolved FET technology and applied it to a complete line of singles, duals, arrays, and ICs. So what's new?

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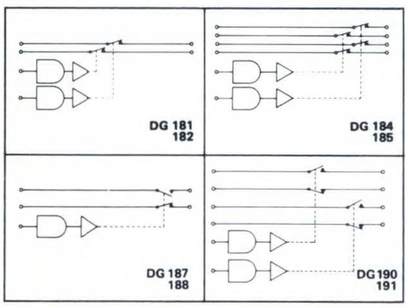
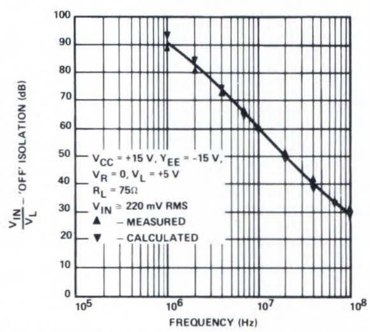
- 60 dB OFF isolation at 10 MHz with 75 Ω load
- t_{on} and t_{off} = 150 ns typical
- 1 nA max (100 pA typical) leakage from signal channel in either ON or OFF state.



DG181-DG191 Functional Diagrams



Switch OFF Isolation vs Frequency—DG181

The key to this exceptional performance is the Siliconix concept of monolithic driver design, with careful attention to critical details such as low driver output impedance. DG181-DG191 driver (switch OFF) resistance to ground is only 200Ω, providing good a-c by-pass on the FET switch gate. Contrast this with other driver circuits with impedances as high as 26 MΩ, which adversely affect isolation characteristics.

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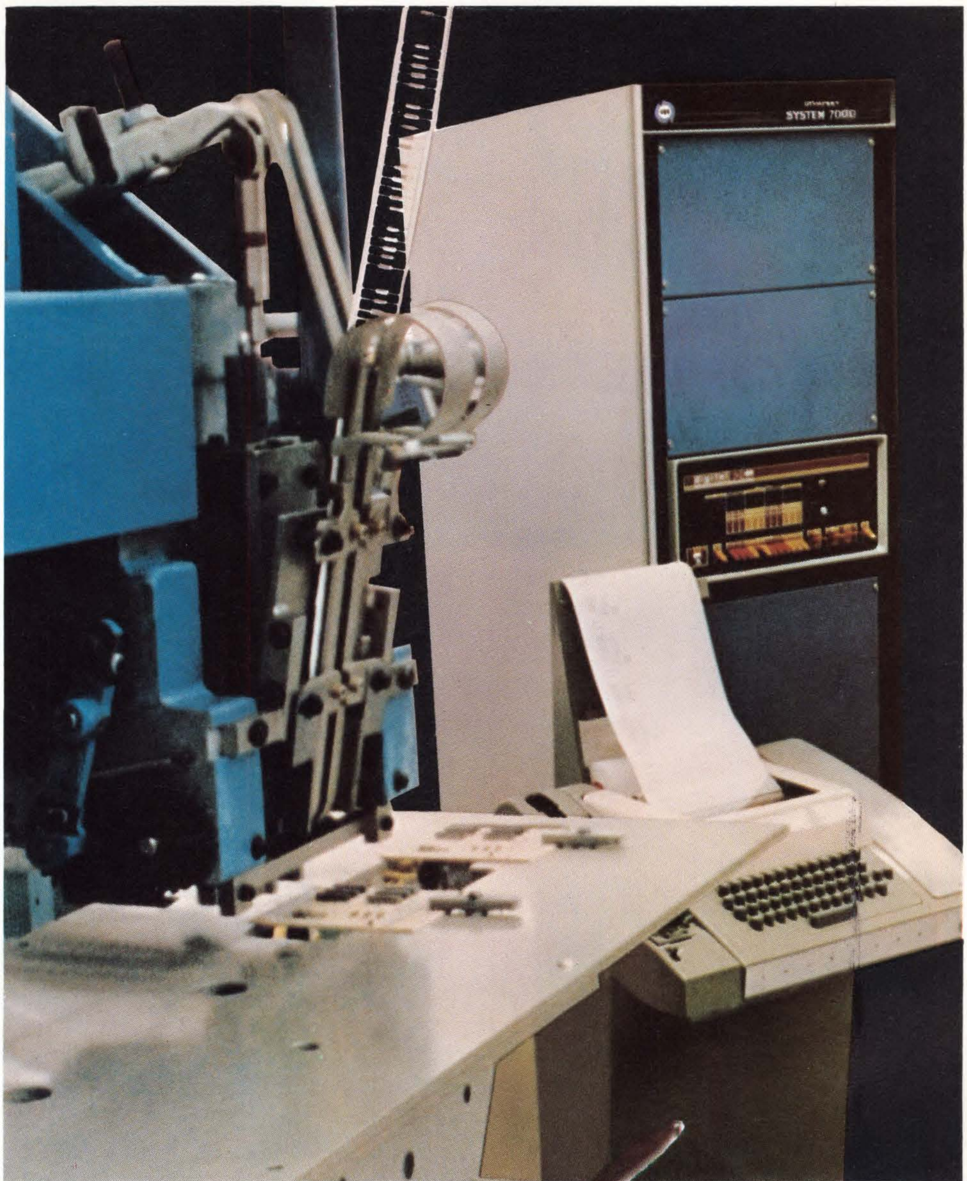
Circle No. 4

Chairman of the boards.



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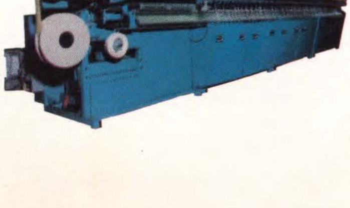

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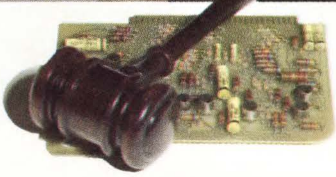

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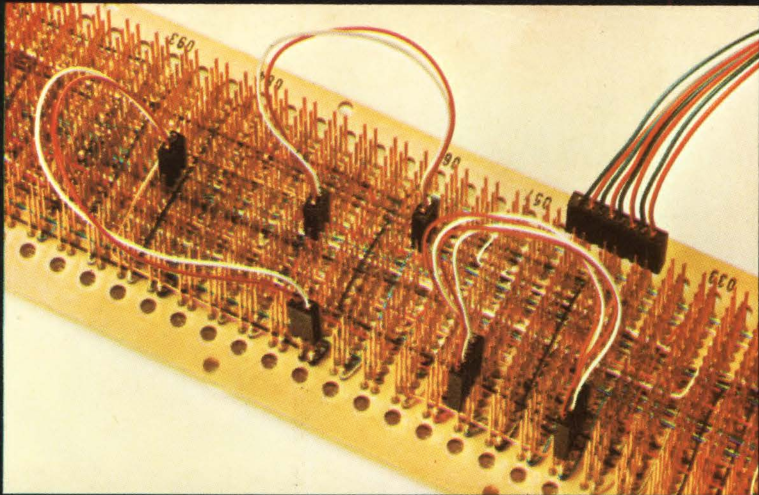
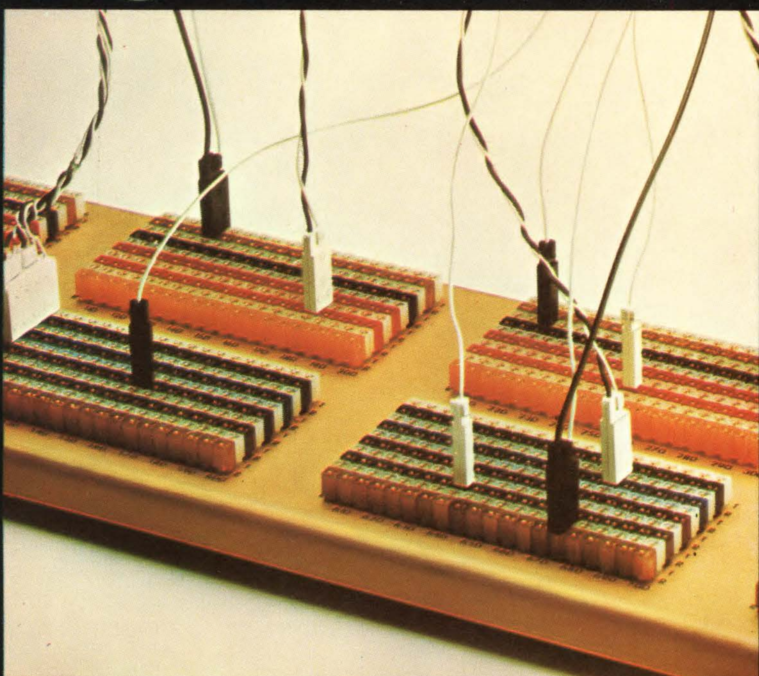
The Productivity People

Circle No. 5

# of interconnections.



level 3 Low cost strip connectors (above) are used as jumpers in back plane wiring. Intermates with .025″ square or round posts. ■ Circuit Concentration Bay (below) consists of wire wrappable panels that are five times as compact as the telephone distribution frames they replace.



level 4 Modular Integral Connector concept lets you make your own pin & socket connector to fit your needs. Five contact sizes, thousands of combinations. Sufficient components for six connectors in handy MIC-KIT. Design and assemble your own prototypes.

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Circle No. 22

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You're in a race. A race to provide the best performance, price, delivery and reliability for your customers. Not just now... but from now on. TI's 3-ns 54S/74S Schottky TTL can help you get out front. And stay there.

TI introduced 54/74 TTL in 1965 and 54S/74S Schottky in 1970... and 54/74 logic has become the most popular, fastest growing, most second-sourced logic form. It has set the standards for the industry.

Since it is fully compatible with conventional TTL, TI's Schottky can be used selectively to improve system performance. Economically. Combine this with the broadest and fastest growing choice of functions and you can see that a decision to design now with Schottky TTL could be vital in your product planning.

With constant demand for higher performance at lower costs, the trend is toward increased use of Schottky TTL... up to 90% in many new designs.

For your new designs (or upgrading existing ones) TI's Schottky offers an unmatched combination of performance, choice, volume availability, low cost, design simplicity, versatility, reliability and complexity. Consider these advantages:

- **Broadest choice of functions.** No one has introduced and delivered more Schottky circuit functions than TI. Check the list at right. Newest circuits are starred, and more are coming soon... including higher complexity MSI functions.
- **Volume production.** TI has been building Schottky TTL in production quantities for more than three years. The results are high volume capability, good yields and lower costs for you.
- **Proven reliability.** The same built-in reliability found in all TI 54/74 ICs has been proven for TI Schottky through extensive factory testing and field experience.
- **Full temperature and package choice.** TI Schottky is available in both industrial and military temperature ranges, and in plastic or ceramic DIPs and ceramic flat packs.

Series 54S/74S Schottky MSI Circuits

SN54S/74S174	Hex D-type storage register, 110MHz
SN54S/74S175	Quad D-type storage register, 110MHz
SN54S/74S194	4-bit bi-directional shift register, 105 MHz
SN54S/74S195	4-bit parallel-access shift register, 105 MHz
*SN54S/74S85	4-bit magnitude comparator
SN54S/74S86	Quad Exclusive-OR
SN54S/74S135	Quad Exclusive-OR/NOR
SN54S/74S181	4-bit ALU and function generator
SN54S/74S182	Carry look-ahead for SN54S/74S181
*SN54S/74S280	9-bit odd/even parity generator/checker
SN54S/74S151	8 to 1-line multiplexer
SN54S/74S251	8 to 1-line multiplexer, 3-state output
SN54S/74S157	Quad 2 to 1-line multiplexer
SN54S/74S257	Quad 2 to 1-line multiplexer, 3-state output
SN54S/74S158	Quad 2 to 1-line multiplexer
SN54S/74S258	Quad 2 to 1-line multiplexer, 3-state output
SN54S/74S153	Dual 4 to 1-line multiplexer
SN54S/74S138	3-8-line decoder/demultiplexer
SN54S/74S139	Dual 2 to 4-line decoder/demultiplexer
*SN54S/74S124	Voltage controlled oscillator (VCO)

Series 54S/74S Schottky SSI Circuits

SN54S/74S00	Quad 2-input NAND gate
*SN54S/74S02	Quad 2-input NOR gate
SN54S/74S03	Quad 2-input NAND gate, o.c. output
SN54S/74S04	Hex inverter
SN54S/74S05	Hex inverter, o.c. output
SN54S/74S10	Triple 3-input NAND gate
SN54S/74S11	Triple 3-input AND gate
SN54S/74S15	Triple 3-input AND gate, o.c. output
SN54S/74S20	Dual 4-input NAND gate
SN54S/74S22	Dual 4-input NAND gate, o.c. output
*SN54S/74S30	8-input NAND gate
SN54S/74S40	Dual 4-input NAND buffer
*SN54S/74S51	Dual 2-wide, 2-input AND-OR-INVERT gate
SN54S/74S64	4-2-3-2-input AND-OR-INVERT gate
SN54S/74S65	4-2-3-2-input AND-OR-INVERT gate, o.c. output
SN54S/74S74	Dual D-type flip-flop (110MHz), preset, clear
SN54S/74S112	Dual J-K flip-flop (125 MHz), preset, clear
SN54S/74S113	Dual J-K flip-flop (125 MHz), preset
SN54S/74S114	Dual J-K flip-flop (125 MHz), common clock, clear
*SN54S/74S132	Quad 2-input NAND Schmitt trigger
SN54S/74S133	13-input NAND gate
SN54S/74S134	12-input NAND gate, 3-state output
SN54S/74S140	Dual 4-input NAND 50-ohm line driver
*SN54S/74S260	Dual 5-input NOR gate

*Recent introductions

For new 54S/74S applications report, Bulletin CA-176, write on company letterhead to Texas Instruments Incorporated, P.O. Box 5012, M/S 308, Dallas, Texas 75222.

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Circle No. 7

What's an engineer worth

We were once accused in a rather irate letter-to-the-editor of "hobnobbing with the moguls of industry, who (as the writer said) at that very time were exploiting the working engineer". The letter took us rather by surprise, since not only wouldn't we recognize a mogul if we fell over one, but also because our basic editorial philosophy is to provide a useful service to the engineer.

What motivated that letter we don't recall exactly, but it undoubtedly arose from something we said concerning engineering salaries or job security. These are touchy areas, affecting as they do not only life-style, but ego as well.

For example, what is an engineer really worth? There are hard, objective ways to answer this, and there are subjective and sometimes emotional ways.

Shouldn't his 4, 6 or maybe 7 years of tough schooling play a role; or his ability to come up with novel or unusual designs; or maybe his 15 years with the company? In themselves, they should not, being mainly factors in his individual development as an engineer.

What really counts in assessing worth is how well the individual helps his organization achieve its goals. His schooling, experience and inherent ability are important to him, but it's how they're used that really counts.

At this point some readers will have turned purple with rage, particularly those who suffered through periods of unemployment in recent years. Even now during prosperous times there are some companies, either misguided or unscrupulous, who reportedly use devious methods to replace older engineers with younger, lower priced people.

These things not withstanding, though, the fact remains that an engineer's worth to an organization is based on his contribution, without regard to how much plumbers make or how much schooling was required.

Getting a company to recognize how much its engineers are really worth, unfortunately, is a different matter. Many, including the most successful ones, do. But others do not, and end up with mediocre or unmotivated engineers, or extensive engineering turnover.

Over the long haul, all companies become either victims or beneficiaries of that old expression, "you get what you pay for". And in the case of engineers, companies either are or are not paying for engineering help in achieving their goals—nothing else.

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		0.25 AMP	0.8 AMP	4.0 AMP					8.0 AMP	12 AMP	16 AMP
		Case 28 Style 8	Case 29 TO-92 Style 10	Plastic Case 77-02 Style 2			Plastic Case 90-04 Style 1		Case 90-04 Style 1	Case 221-02 TO-220 AB Style 1	
V_{DRM} V_{RRM} BLOCKING VOLTAGE (DC OR PEAK) VOLTS	15 V	MCR051	MCR101	—	—	—	—	—	—	—	—
	25 V	—	—	—	—	—	—	—	MCR3000-1	—	—
	30 V	MCR052	MCR102 2N5060	2N6236	MCR106-1	MCR107-1	MCR406-1	MCR407-1	—	—	—
	50 V	—	—	2N6237	—	—	—	—	2N4441 MCR3000-2	2N6394	2N6400
	60 V	MCR053	MCR103 2N5061	—	MCR106-2	MCR107-2	MCR406-2	MCR407-2	—	—	—
	100 V	MCR054	MCR104 2N5062	2N6238	MCR106-3	MCR107-3	MCR406-3	MCR407-3	MCR3000-3	2N6395	2N6401
	150 V	—	MCR115 2N5063	—	—	—	—	—	—	—	—
	200 V	—	MCR120 2N5064	2N6239	MCR106-4	MCR107-4	MCR406-4	MCR407-4	2N4442 MCR3000-4	2N6396	2N6402
	250 V	—	—	—	—	—	—	—	—	—	—
	300 V	—	—	—	MCR106-5	MCR107-5	—	—	MCR3000-5	—	—
	400 V	—	—	2N6240	MCR106-6	MCR107-6	—	—	2N4443 MCR3000-6	2N6397	2N6403
	500 V	—	—	—	MCR106-7	MCR107-7	—	—	MCR3000-7	—	—
	600 V	—	—	2N6241	MCR106-8	—	—	—	2N4444 MCR3000-8	2N6398	2N6404
	800 V	—	—	—	—	—	—	—	—	2N6399	2N6405

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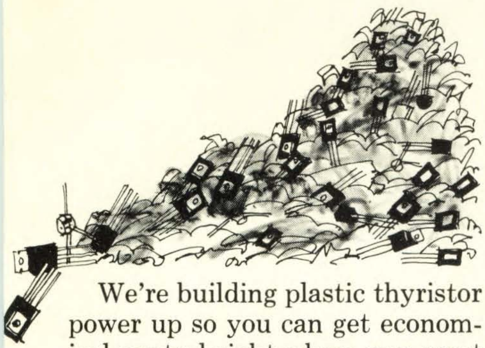

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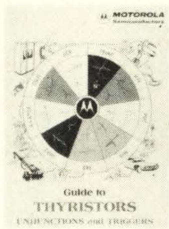
Use the reader service number to get your copy of our new "Guide To Thyristors." It contains selection and application guides, talks about definitions, symbols, technology and terminology, provides a complete cross reference and lists prices of all Motorola thyristors: SCR, triac, unijunction or trigger; plastic *or* metal.



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TRIACs		ON-STATE (RMS) CURRENT											
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		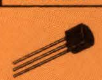											
		Case 29-02 TO-92 Style 12			Case 77 Style 5			Case 221-02 TO-220 AB Style 2		Case 90 Style 4		Case 221-02 TO-220 AB Style 2	
V_{DRM} V_{RRM} BLOCKING VOLTAGE (DC OR PEAK) VOLTS	25 V	—	—	—	2N6068	2N6068A	2N6068B	—	—	MAC11-1	MAC10-1	—	—
	30 V	MAC92-1 MAC92A-1*	MAC93-1 MAC93A-1*	MAC94-1 MAC94A-1*	—	—	—	—	—	—	—	—	—
	50 V	—	—	—	2N6069	2N6069A	2N6069B	—	—	MAC11-2	MAC10-2	—	—
	60 V	MAC92-2 MAC92A-2*	MAC93-2 MAC93A-2*	MAC94-2 MAC94A-2*	—	—	—	—	—	—	—	—	—
	100 V	MAC92-3 MAC92A-3*	MAC93-3 MAC93A-3*	MAC94-3 MAC94A-3*	2N6070	2N6070A	2N6070B	—	—	MAC11-3	MAC10-3	—	—
	200 V	MAC92-4 MAC92A-4*	MAC93-4 MAC93A-4*	MAC94-4 MAC94A-4*	2N6071	2N6071A	2N6071B	2N6342	2N6346	2N6154 MAC11-4	2N6151 MAC10-4	2N6342A	2N6346A
	300 V	MAC92-5 MAC92A-5*	—	—	2N6072	2N6072A	2N6072B	—	—	MAC11-5	MAC10-5	—	—
	400 V	MAC92-6 MAC92A-6*	—	—	2N6073	2N6073A	2N6073B	2N6343	2N6347	2N6155 MAC11-6	2N6152 MAC10-6	2N6343A	2N6347A
	500 V	—	—	—	2N6074	2N6074A	2N6074B	—	—	MAC11-7	MAC10-7	—	—
	600 V	—	—	—	2N6075	2N6075A	2N6075B	2N6344	2N6348	2N6156 MAC11-8	2N6153 MAC10-8	2N6344A	2N6348A
*Denotes A Version	800 V	—	—	—	—	—	—	2N6345	2N6349	—	—	2N6345A	2N6349A

Circle No. 30

For reliability, we stick to the basics.

You're looking at a cut-a-way of one of our least expensive lighted pushbuttons. The Series 4.

Inside, you can see what also makes it one of our most reliable: a precision SM snap-action basic switch. The time-proven SM assures you of mechanical and electrical dependability throughout the long life of the Series 4.

See those two mounting clips? They allow you to snap the Series 4 into the front of your panel. In seconds. Notice too, that the terminals are quick connect for ease of wiring.

Relamping is just as fast and simple. Pull out the display screen and the lamp is automatically extracted. The display screens themselves are bright, vivid rectangles of color that do wonders for the front of your panel.

Something we can't show here are all our options: low energy (1 amp, 125 VAC max.) and power load (5 or 10 amp, 250 VAC max.) all UL listed, bezel and barrier housings, matching indicators and a wide variety of display techniques.

For the complete list of options, contact your MICRO SWITCH Branch Office or Authorized Distributor (Yellow Pages, "Switches, Electric"). They're reliable, too. You'll see.

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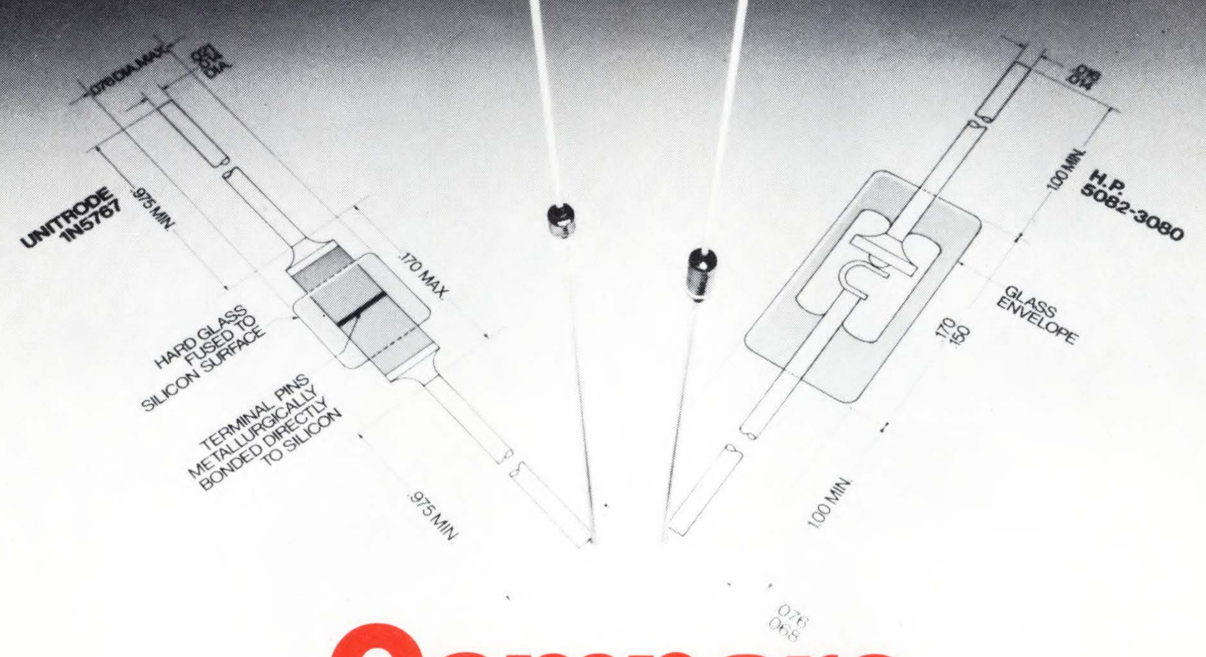
Shown 2½ times actual size.

MICRO SWITCH products are available worldwide through Honeywell International.

Circle No. 11

C-LINE PIN DIODES



Compare Unitrode's 1N5767 with H.P.'s 5082-3080

The 1N5767 is HP's EIA Registration of the 5082-3080. Both Unitrode and HP meet the same specs. Both are competitively priced. The difference is in how they're made. Unitrode's fused-in-glass process results in a monolithic structure with the lowest possible thermal and series resistance available. The silicon chip is metallurgically bonded directly to the terminal pins and a hard glass sleeve is then fused to the pins. The result is unmatched peak and average power dissipation. And the normal parasitic inductance and capacitance is far less than in conventional diodes with straps, springs, whiskers, or ceramic packages. Unitrode's 1N5767 can withstand thermal cycling from −195°C to +300°C and it exceeds all military environmental specs for shock, vibration, acceleration, moisture resistance and solderability. They're ideal for use in general purpose PIN diode applications such as CATV attenuators and switches and simple series switches for transceivers, radar, etc. As to HP's diode construction, we think it only fair that they should tell you about it.

For samples, call Howard Kaepplein at (617) 926-0404 collect, Unitrode Corporation, Dept. No.11 Z , 580 Pleasant St., Watertown, Mass. 02172. For the name of your local Unitrode distributor or representative, dial (800) 645-9200 toll free, or in New York State (516) 294-0990 collect.

ELECTRICAL SPECIFICATIONS (25°C)

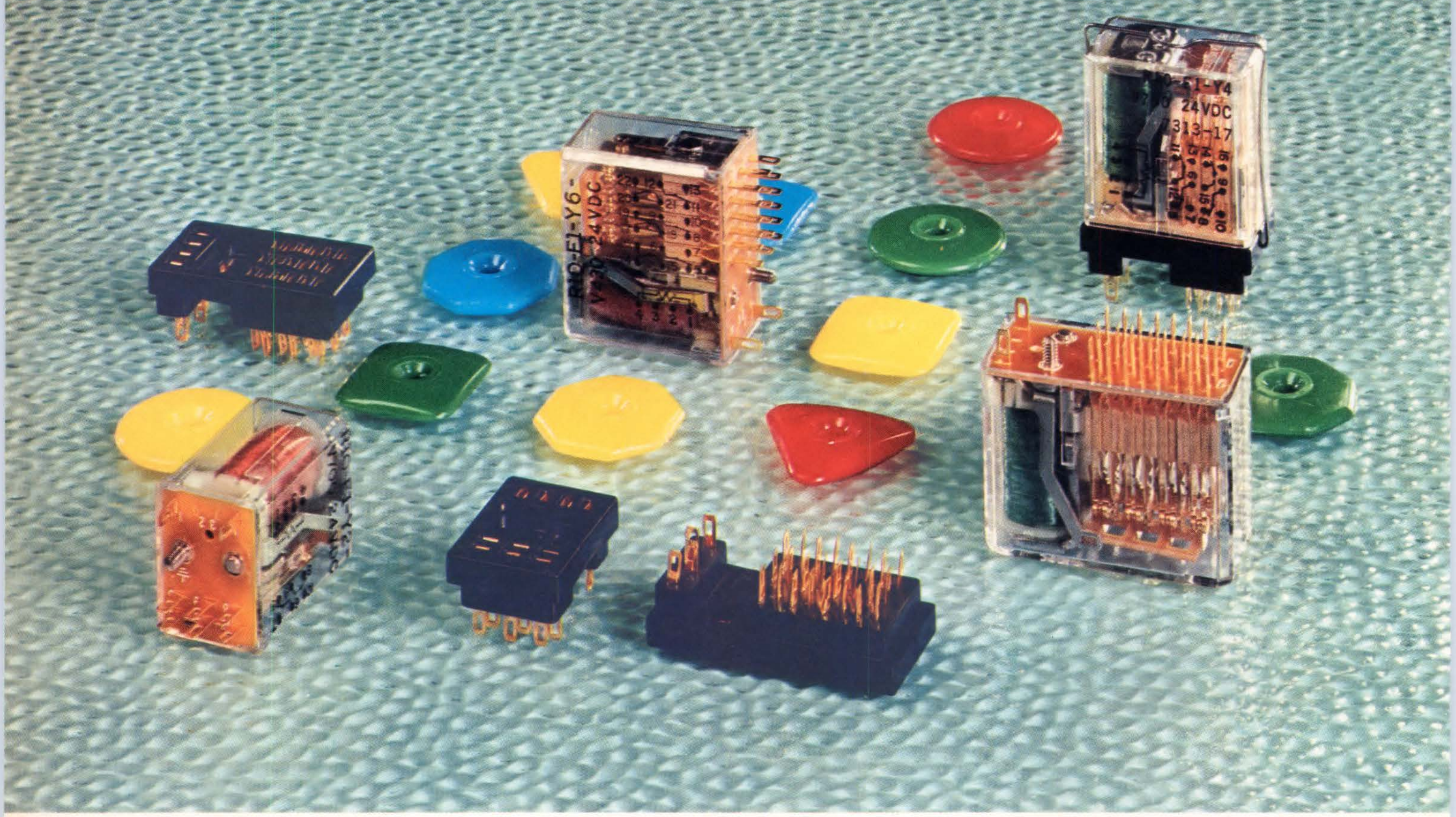
Unitrode Series	C_T Total Capacitance 50V, 1MHz pF	RF Resistance @10μA, 100MHz Ω	RF Resistance @20mA, 100MHz Ω	RF Resistance @100mA, 100MHz Ω
1N5767	0.4 max.	1000 min. 3000 typ.	8 max. 4 typ.	2.5 max. 1.5 typ.

See EEM Section 4800 and EBG Semiconductors Section for more complete product listing.

UNITRODE quality takes the worry out of paying less.

Circle No. 12

P&B's compact R10 relays help you solve more application problems than with any other relay.



Relays shown actual size.

Our R10 relay series offers designers a whole family of AC and DC industrial relays that combine extraordinary versatility of application, the reliability of telephone-type relays, plus small size (less than a cubic inch). They are widely used in copiers, computer peripherals, business machines, and precision instruments.

These relays have so many options that each model may literally be designed by you to meet your particular needs. This single family of relays, with many common mechanical dimensions and mounting techniques, cover the whole range of switching loads from dry circuit to 10 amperes, 28 VDC, 120 VAC. There are terminal styles for octal plug, solder, or pc board mounting. And, sockets multiply design options even more.

R10 relays can be ordered with Form A, B, C and D contacts and up to 8 Form C. Recognized by Underwriters Laboratories under file 42810. R10 relays have a continuous power dissipation of 2.2 watts maximum. Standard sensitivity is 125 miliwatts per pole (more sensitive units available on special order). Electrical life ranges from 100,000 to 100 million operations.

For complete information on R10 industrial relays, call your local P&B Representative. Or, call or write Potter & Brumfield Division AMF Incorporated, Princeton, Indiana 47670. Telephone 812 385 5251.

FREE PUZZLE*

Arrange the pieces so that no color or shape is duplicated in any row, column, or either diagonal. As an engineer, you should solve this puzzle in 27 minutes.

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

*"Bali-Buttons". © Behavioral Sciences, Inc.

Solving switching problems is what we're all about.

AMF

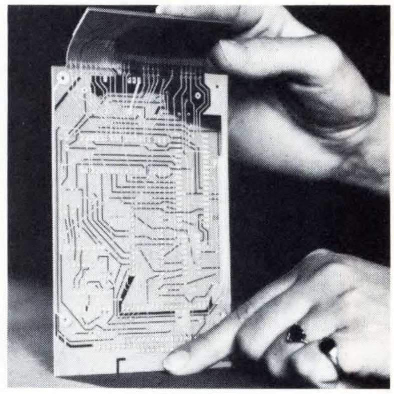
Potter & Brumfield

Circle No. 13

Sanders Flexprint® Circuitry is working, working, working.

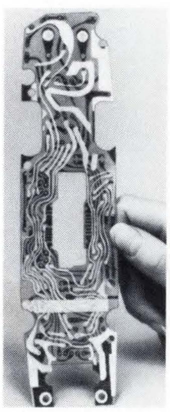
1. Complete recovery — for a New England manufacturer of process control equipment. The wire-bundle for a pull-out component assembly tended to bunch up when moved back and forth, with wire tangling and breaks resulting. Sanders Flexprint® cable was used instead. Laminated with specific dielectrics, it had the abrasion resistance and lasting spring-back-recovery qualities needed to solve the problem.

1



2

3. Inner space probe — for a major communications supplier in the South-Atlantic area. A pushbutton telephone with touch "dialing" in the handset had to contain all interconnect circuitry, reliably, inside its slim silhouette for rapid assembly and easy quality-control inspection in mass production — and make it rugged enough to take rough handling. Sanders Flexmax* circuitry met every requirement — eliminated all hand wiring and cut costs as well.



3

2. Bending over backwards — for a West Coast maker of semiconductors. A new hand calculator's circuitry had to withstand 270-degree bending in order to fit a compact housing, without breakage. Sanders' double-layer Flexmax* circuitry, with hardboard backers for component support was used; thereby the entire circuit could be flow-soldered in one pass with significant labor savings. By replacing conventional wiring, the stress problem was solved; the minimum space requirement was met; and 44 connections were eliminated — increasing reliability.

SA

SANDERS ASSOCIATES, INC.
FLEXPRINT DIVISION

Call your nearby Sanders rep, or write Sanders Flexprint Division, Grenier Field, Manchester, New Hampshire 03103

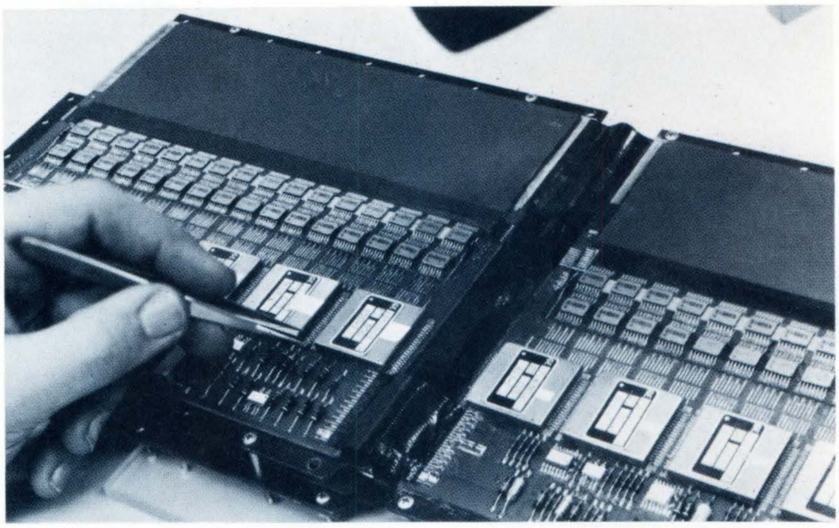
* TM Sanders Associates, Inc.

Circle No. 14

Lamp filament material shrinks computer memory and cuts power

Strands of magnetically coated tungsten wire about the diameter of a human hair are being fabricated by General Electric aerospace engineers into smaller and more versatile computer memories for guiding supersonic aircraft and distant space probes with greater control.

Based on a wire-electroplating technique developed at the GE Research and Development Center, the new memory array is four times smaller and lighter than conventional plated-wire memories, packs four times more information and requires only one-half the power.



A 4k by 25-bit plated-tungsten wire memory array shown at the back of the pc board is stacked with another like array to form a complete 8k × 25-bit memory. The new memory array is four times smaller and lighter than conventional plated wire memories and consumes only one-half the power.

The new computer memories—based on plated tungsten wire—will be produced by the Aerospace Electronic Systems Department (AESD) of GE's Aircraft Equipment Division, Utica, NY, for use in military, aerospace, and industrial-control applications.

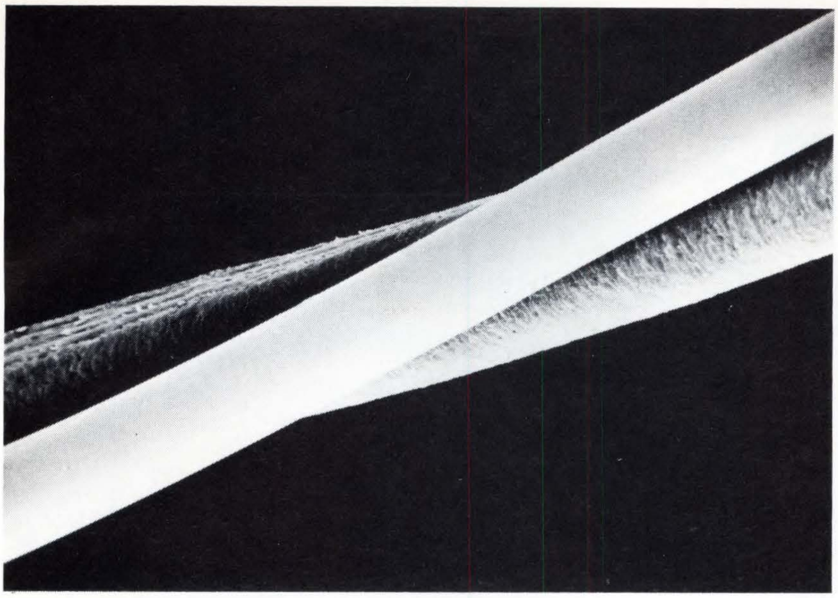
The dramatic reduction in size and power requirements of the new memory, plus its boost in data-storage capacity, is achieved through use of magnetic plating on a tungsten wire only half the diameter of conventional beryllium-copper strands. Tungsten is stiffer, stronger and easier to handle than beryllium-copper.

Moreover, the smaller tungsten wire permits the use of thinner coatings of magnetic film. It is this combination of thinner wire and thinner film that gives the new memory a greater capacity, with less power needed for operation.

Plated wires are preferred as main memories in aerospace and industrial-control applications because of their small size, higher speeds, low power requirements, reliability, long life, nondestructive readout, and nonvolatility (stored information is not affected by power interruptions). By contrast, core and semiconductor memories are preferred for use in general-purpose commercial computers because of cost considerations.

Diameter of the tungsten wire is 0.0025 in. Although plated wire using beryllium-copper is available in the smaller size, GE scientists say tungsten substrates result in greater production yields—better than 90 percent—and lower manufacturing costs. Average yield for the industry is about 60 percent.

GE's new wire-processing technique is an automated, continuous operation involving six basic steps: cleaning, copper plating, coating with an ultrathin magnetic film, annealing, testing, and cutting to desired lengths. It was developed over a six-year period at the GE Research and Development Center by a team of scientists and engineers headed by Dr. Fred E. Luborsky and including William D. Barber, Dr. Arthur



A scanning electron-microscope view of the magnetically coated tungsten wire (at 500X) gives a good perspective of the wire size (2.5 mils), when compared with a human hair in the background.

C.M. Chen and Richard 0. McCary.

According to Dr. Luborsky, tungsten was selected as the substrate for the smaller-diameter wire memory because of the need for a stiffer wire. The company has had long experience with this metal, stretching back over 65 years when GE produced the first ductile tungsten man had ever seen. It still is at the heart of the billions of incandescent lamps made each year.

The thin magnetic film used to coat the wire, called Permalloy, is less than half the thickness of that covering conventional plated wires, measuring about 4000 Angstroms. (The thickness of ordinary facial tissue is about 500,000 Angstroms.) This extremely thin coat permits the use of less current. Thus, drive requirements are reduced by some 50 percent.

Dr. Luborsky describes testing of the wire as "an essential key to success" of the final memory. It is done on-line under a rigid set of conditions for both quality and expected performance. Additional testing is then done off-line to evaluate such things as operating margins, stress sensitivity and aging.

During assembly, the tungsten wire is threaded through plastic tunnels to form memory arrays, which are mounted on boards to form memory planes. These planes are then stacked to form any memory size desired.

Each 2-mil wire memory plane contains 3000 wire intersections or memory sites per square inch. Each sense line is spaced on 10-mil centers; each word strap on 30-mil centers.

8k-word by 25-bit memories are presently being built by AESD. They measure 9 × 6-1/2 inches × 3/4 inch high and weigh four pounds. Average required operating power is six watts. Minimum life expectancy ranges from 10 to 20 years.—*RF*

New display technique presents data in 4-dimensional patterns

Developed to present organized digital data in a combined digital/analog form for rapid visual inspection, a new display technique provides a simple, relatively inexpensive shortcut to extracting the macro-information content of large fields of interrelated numerical data. The technique could lead to the reduction or elimination of thousands of man-hours now spent in data review and analysis.

Known as Direct Digital Graphics, it employs a specially developed group of 16 optically weighted numerical characters called the Opti-Font (**Fig. 1**). The Opti-Font extends from 0 to 15, and each character is clearly readable as an individual number. At the same time, each is weighted more heavily than the one before it in terms of coverage on the printed page. Thus, while individual datum point values are represented in the display by recognizable characters, value differentials throughout a field of data form meaningful graphic patterns which can be immediately recognized and interpreted by the viewer.

A fourth dimension of information display is provided by a range of 4 distinct levels of printing intensity, ranging from light gray to full black. These may be used to display a separate parameter, or may be combined with the 16 Opti-Font weightings to provide a total of 64 graphic-display levels for 6-bit presentation (**Fig. 2**).

The Opti-Font display is generated from raw digital data by a

Fig. 1—Basic to the Direct Digital Graphics technique is the Opti-Font (left), a proprietary group of 16 optically weighted characters. Generated by the Digicoder, the characters literally create "pictures by the numbers", thus presenting digital data in graphic form. Characters are composed of dots on a 4 × 5 matrix. Shown to the right is the Model D2 Digicoder, an inexpensive processor/controller that accepts raw digital data and produces a D/A output for easily-read, hard-copy display by a facsimile or high-speed electrostatic printer. It can be operated either on-line or off-line from magnetic or paper tape.

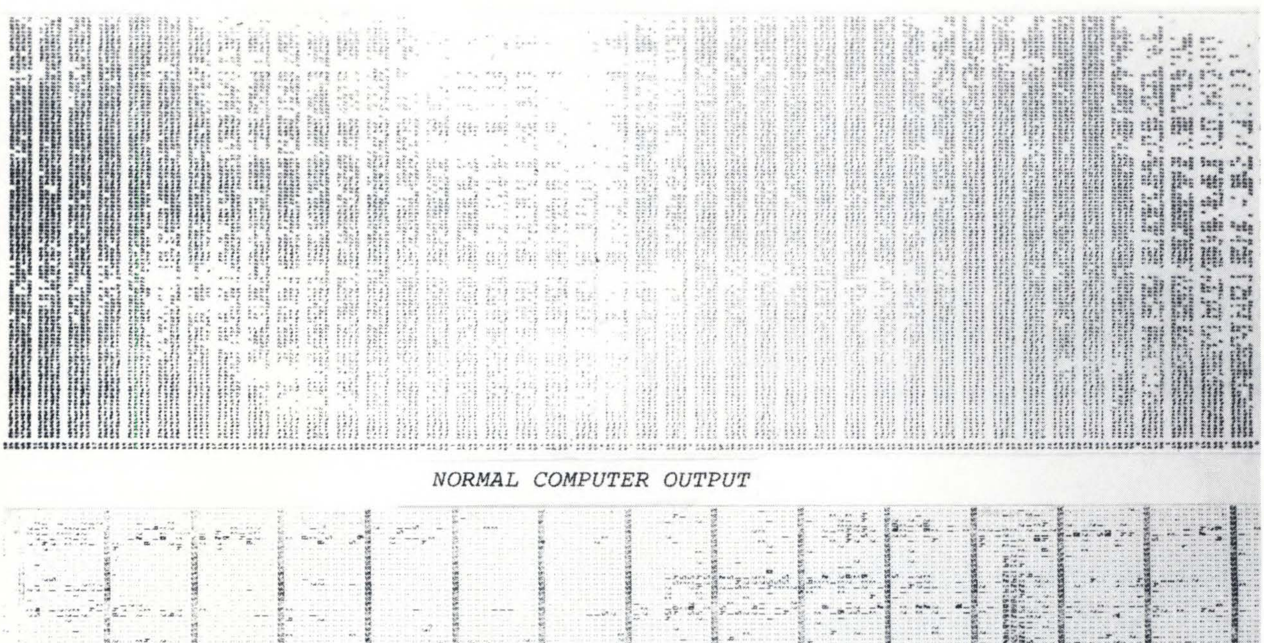


Fig. 2—Normal computer output (top), reduced to approximately 1/5 of original size, reveals little or no information on visual inspection. The same data (bottom) presented by the Digicoder in Opti-Font characters and using pattern enhancement reduced to approximately 3/4 of original size, reveals readily-distinguishable informational patterns, yet retains absolute quantitative data. Pattern enhancement, a Digicoder feature, eliminates most background noise and accentuates meaningful information.

special processor/controller called a "Digicoder". Used in conjunction with a printer, this instrument is all that is needed to present data from monitoring or test instruments, from a computer, or from tape storage, in graphic D/A form.

It is estimated that considerably over 90% of all the numerical data generated today by instruments and data processors is never used, simply because there are not enough man-hours available to cope with the increasing flood of information. The Digicoder system, unlike complex computer-graphics systems available today, is said to be capable of presenting quantities of data, either on-line or off-line, for quick visual scanning and evaluation, while retaining the full information content needed when more rigorous analysis is required.

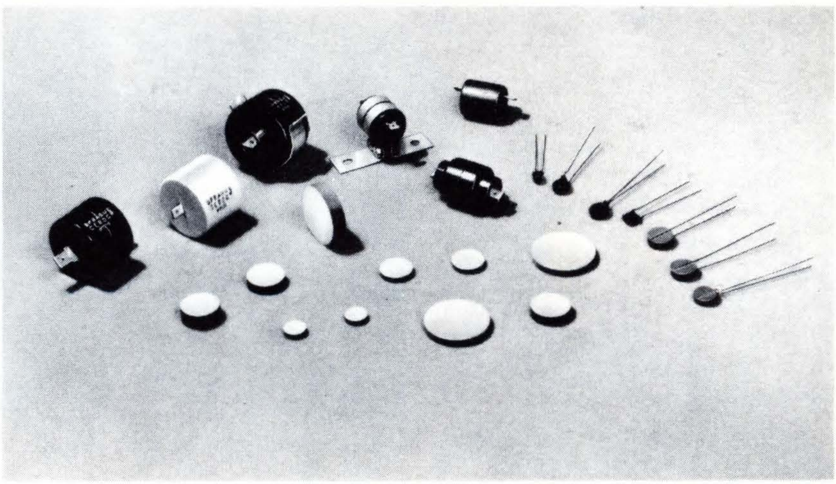
The basic concept of an optically weighted number series was developed by the Lowell Technological Institute Research Foundation in the course of their research. Digicom, Inc., of Chelmsford, MA, the Digicoder's developer, utilized that concept in producing several systems designed to handle one specific scientific application.

Among the broad range of potential industrial, business and scientific applications that can make use of Direct Digital Graphics are: the testing of complex electronic systems; strain-gage monitoring; component testing; space-data analysis; graphic representation of business computer outputs; schlieren analysis; terrain measurement and contour plotting; and microdensitometry and spectroscopy.

Digicoder systems are available for on-line applications, or with an integral tape transport, for off-line use. With a high-speed electrostatic printer, the system can print out up to 2300 cps. Facsimile printers can be used for remote monitoring over ordinary telephone lines. A Digicoder can handle up to 256 separate input channels and can print data at a rate of 128 or 256 characters/line. It includes a standard 5120 × 6-bit memory buffer. A broad range of data-formatting options is available. System prices range from a basic $1994 to $30,000.—*RA*

New ceramics can be used as control or switching elements

A new group of ceramic materials employing barium titanate and controlled additives has been developed by the Sprague Electric Co. for use in contactless switching and temperature-sensing applications. Some of the new Sprague Ceroc™ electroceramic devices have the capability of controlling currents as great as 15A at 400V.



The new positive temperature coefficient resistors (PTCR) can be used for a variety of contactless-switching and temperature-sensing applications. They vary from tiny, leadless discs to high-current devices molded in plastic housings with quick-connect terminals.

The new Sprague Ceroc components are an extension of the company's work in electronic ceramics. The Ceroc switching devices are basically positive temperature coefficient resistors (PTCR) with the special property of switching suddenly from a very low resistance to a very high resistance when the PTCR passes its so-called "Curie point". This may be anywhere from 25 to 125°C and is an inherent characteristic of the specific ceramic composition used.

The Ceroc devices can be made to function either through changes in ambient temperature or by means of superheating—when sufficiently high current is placed through the PTCR. The superheating passage of current causes internal temperature to rise and the resistance then to shift steeply to a predetermined value based on the material composition. Ceroc devices are bistable and remain in the high-resistance state once switched, as long as voltage is applied, so that the thermoresistor maintains its temperature at or above its Curie point. The time required to heat a PTCR element, and thus lower the current passing through it, is a function of the mass of both the PTCR and of the terminal mass connected to it, as well as of the local ambient temperature. The high-temperature steady-state resistance of a self-heated Ceroc control element is a function of the applied voltage and the amount of heat which is conducted away from it; however, it maintains heat balance since the current flowing through it changes as the operating temperature changes.

Temperature-sensing functions are achieved by: (1) measuring the resistance change of the device with very little power applied, and (2) by the heat loss from the PTCR. Most sensing functions use the latter method.

Generally, a Ceroc PTCR can be used in both low-power and high-power applications. Low-power use includes temperature sensing, liquid-level sensing and air and liquid-flow measuring. Some low-power applications include automotive fuel-injection control, headlight time delay, fuel-level meter readings, telephone and communciation current limiters and over-temperature sensing for motors, transformers and control circuitry, plus thermal modulation in both major and traffic - type appliances.

High-power applications include temperature-stable heaters, large-current time-delay motor-start switches, current limiters and television degaussing, as well as single-phase motor switches and phase-shifters and heaters for bi metals and bellows.

In the high-power mode, Ceroc thermoresistors maintain themselves at a constant temperature, as determined by the Curie temperature of the devices. Hence, they make excellent constant-temperature heaters with a rapid heat-up time. They are ideally suited as drivers in thermal amplifiers.

Sprague can supply heaters capable of operation from supply voltages as high as 240V with physical diameters up to 1.2 in.—*RF*

Study results should yield better laser trimmed thin-film resistors

Thanks to recent studies by Western Electric engineers, lasers can now be used to trim precision thin-film resistors with stabilities, yields and economies equal to or greater than those obtainable by anodization.

The studies—aimed at predicting stabilities of laser machined thin-film circuits—will make it possible to improve the design of such circuits and minimize drift during their lifetime.

Better stabilities can be achieved with laser-trimmed thin-film resistors thanks to a Western Electric study. Here, a thin-film circuit is readied for active trimming via a Nd:YAG laser.

Laser trimming is particularly suited to trimming completely assembled circuits with resistors requiring better than one-half percent accuracy.

Anodization, on the other hand, is better suited to bulk trimming of multicircuit substrates where subsequent tuning or individual circuit trimming is not required. Since the many circuits on a single substrate can be anodized simultaneously, the trim time for each resistor is very short.

However, once the substrate has been separated into individual circuits and additional trimming or functional tuning is required, the use of anodization can present some problems. The most significant of these is the parasitic capacitance introduced by the anodizing electrolyte which makes the monitoring of a circuit function, while trimming the resistor, virtually impossible.

Laser trimming does not have this disadvantage. What's more, it is a clean operation and a fast one, due to recent advances in beam-positioning systems. In fact, the only stumbling blocks to its use in production have been the knowledge that improper laser trimming can lead to greater instability than anodization, and the lack of knowledge of what constitutes proper laser trimming.

How, for example, is stability affected by laser power? Or by resistor geometry? Or by the extent of resistance changed with laser machining? And, finally, how does the performance of ideally lazed thin-film circuits compare with that of anodized circuits?

To answer these questions, the Western Electric group fabricated sputtered tantalum-nitride resistors similar to those actually used in Bell System thin-film circuits, and machined them with a Nd:YAG laser, Q-switched at 3000 pulses per second. A numerically controlled table moved resistors beneath the focused laser beam at a constant speed of 20mm/sec, resulting in a pulse overlap of 70 percent at a focused power of about 10^7 W/cm^2. Stability of the machined resistors was then measured by determining the percent change in resistance as a function of time for resistors held at 150°C.

Based on the considerable amount of data collected, some of the conclusions reached were that laser-trimmed resistor stability varies directly with the machined line width, and inversely with line length, as well as with laser power. Resistors machined with high power age twice as much as those machined at low power.

Stability is also a function of the laser beam's focus. Units machined with a well-focused beam are more stable than resistors trimmed with a defocused beam.—*RF*

Automatic test equipment: users report on interface problems

Approximately 150 engineers and scientists gathered at a recent ATE (automatic test equipment) seminar in Saddle Brook, NJ, to hear expert user panelists discuss ATE problems and solutions and to exchanage ideas. From the comments overheard, it was obvious that, while ATE systems have made impressive technological and economic gains, much remains to be solved in the areas of electronic as well as human interfacing.

The seminar was sponsored by Instrumentation Engineering of Franklin Lakes, NJ, a manufacturer of automatic test-equipment systems.

It was forecast at the seminar that ATE testing will become the dominant testing method by 1980 in spite of the initially high costs ATE systems command ($50,000 and up). This will happen for three reasons:

1. Most modern stimulus have some remote-programming capability.
2. More and more instrument houses are getting into the business of automatic testing.
3. IC devices are getting more and more complex, thus requiring sophisticated test systems for faster and more accurate testing and for lower costs.

Interfacing is a problem

One reason why small companies have not been too keen on ATE systems has not been the initially high cost of such systems, but their lack of commitment to a philosophy of ATE. That's how Jim McCarthy, Instrumentation Engineering's

vice president for software development put it. This same opinion was expressed by another seminar observer who cautioned that companies had better start thinking of ATE now, or they won't be able to compete effectively in their respective fields, given the added complexities future devices will have. "It usually takes a few months to debug any ATE system, so future planning is very important," he said.

"Any ATE purchaser is not going to be 100% right in his choice of a system" says Charles Harding of ITT's STL Div. in England, one of the seminar's panelists. "If the system is flexible and accommodates changes in technology, then the user will not have to spend too much more in time and money to reach his final requirements. Only experience will make a user choose his system closer to the mark" he said. Mr. Harding is in charge of coordinating ATE systems for all of ITT's groups.

One thing a user company should be careful of not doing is to ignore the importance of its ATE system's software development. This requires careful interfacing with the ATE manufacturer. Software program and truth-table developments should be coordinated and worked out at the manufacturer's plant before the system's delivery, to eliminate future system downtime.

"It behooves a company to let the design engineer who is going to use the ATE system write both the test program and truth tables," explained Larry Simmons of Xerox Corp., another panelist.

One factor that has not received too much attention is that of discipline. "Many engineers will simply not change their ways of doing things, at least not overnight," explained panelist Fred Pfifferling of RCA's Astro Electronics Div. "Manufacturing engineers may still believe their testing methods are better than the ATE's."

He suggested that one way of alleviating this problem is to give the manufacturing engineer a stronger voice during the purchase phase of the system and provide him with better rapport with the design engineer.

Looking down the road

One trend that ATE systems have been taking and is expected to continue growing is the capability of doing both analog and digital testing.

Panelist Phil Jackson, Instrumentation Engineering's vice president for engineering, forecast that more sophisticated digital testing is the future trend, where multiple levels of logic families all could be tested simultaneously.

"Fault isolation is one new challenge for ATE systems, particularly with high-complexity ICs," he explained. "More and more emphasis will be placed on precise fault isolation and location."

He explained that one approach is to use less expensive system substations so the main station will not be tied up for too long a period of time.

Jackson also predicted a future battle between turnkey ATE and off-the-shelf component, do-it-yourself systems, where the latter will suffer from expensive software developments. He conceded that they probably would be satisfactory for simple testing applications.

According to RCA's Fred Pfifferling, the big money savings in ATE is not in testing but in diagnosis. Future systems should have diagnosis capabilities as well he related. "The fact is, we have a shortage of skilled technicians who can do complex diagnosis of devices, and we must rely on ATE systems to do this," was the way he put it.—*RA*

Communication circuits: Putting data on the telephone network

Robert H. Cushman, Special Features Editor

Ma Bell's vast existing telephone network is going to be put to much heavier use by digital systems designers. The forcing function for this expanded use will come from the following three facts:

1. There are thousands upon thousands of large, powerful central-computer installations with ever-growing computing power and data banks.
2. Most of the data needed by these central computers comes from scattered locations that are beyond the distances that privately constructed lines can serve.
3. There exists, now, a worldwide network of phone lines that go between all the central-computer installations and scattered data sources.

Put these three elements together and you can see why data communications is right now said, even by Ma Bell herself, to be the fastest-growing part of the biggest business in the world.

It is ridiculous to continue sending pieces of typed paper through the slow mails to the computer site—data in a form that still has to be keypunched before it can be understood by the computer. It is also ridiculous to keep hauling reels of magnetic tape about in trucks from one computer site to another.

But there is always that tendency for the engineer, steeped in the wonders of solid-state, to overlook the existing telephone network, and mentally jump to some more attractive technical solution, like laser or microwave links. These wideband solutions will undoubtedly be the answer some day, but for the foreseeable future, there is nothing like those two wires by which Ma Bell (and her many rich and politically powerful relatives) can connect practically all civilized points of the world to each other.

Everything is wrong with these two wires for digital-data transmission, but it is better for data to crawl along Ma Bell's wires (getting an occasional boost from Ma Bell's microwave links on long-distance hops) than to wait for the mails or trucks. Just remember, it has taken nearly 100 years to string all those wires and bury all those cables, and it will take at least another ten years before they are bypassed by something better. Even when the new carriers such as DATRAN and MCI are in operation, most digital data will still have to go through local telephone lines to reach these high-performance links.

Therefore, the question is: how does the digital designer make the most of Ma Bell's throwback to the 19th century? The answer is: by making use of the recently introduced PMOS LSI and associated linear bipolar ICs designed for the purpose—like the UARTs and FIFOs we will be discussing in this article. With these sophisticated LSI components, you can go a long way towards making Ma Bell's anachronism "emulate" a half-way decent data link.

Setting basic system guidelines

In **Fig. 1,** we zero in on about the most basic sort of data-communication link imaginable—a remote typewriter to the left (location-A) and the central computer site to the right (location-B). The two phone wires that unite the locations are in the middle.

The PMOS/LSI devices that we will be concentrating on are the UARTs (Universal Asynchronous Receiver/Transmitter) at each end of the line that convert the data at each terminal into the proper serial form for transmission over the phone lines, and the FIFOs (First-In, First-Out) that buffer the different data rates at critical points in the system.

We will also touch briefly upon some of the linear bipolar ICs that help the designer convert the signal level and waveforms to properly interface with the phone line and other communication equipment. These are the IC phase locked loops used for generating and detecting the tones sent over the phone lines and the TTL to RS-232C signal converters.

Our system has quite conservative perfor-

mance—just 150 and 1200 baud rates—and it falls quite a bit short of the high-performance 9600 baud (and higher) rates that the next generation of synchronous versions of UARTs and adaptive digital LSI modems will give designers. But we want to show what can be done very economically today. Most of the LSI and IC building blocks shown can be purchased for well under $10 in quantity.

UARTs do a lot

The UART or Universal Asynchronous Receiver/Transmitter is a beautiful example of how a much needed communications function can be shrunk inside a 40-pin DIP and be "given away" for practically nothing—UARTs are selling for just $8 in quantity. Before the UART came along, the function was either done in an inflexible way with hardwired TTL or in a time- and memory-consuming way with software in a minicomputer.

The original UART was developed by a small Long Island MOS house, Solid State Data Sciences, that promptly folded before it made significant deliveries. One of Data Sciences' customers was Digital Equipment Corp., the well-heeled mini-maker of Maynard, MA. Vincent Bastian, a design manager with DEC's data-communications group said: "We liked the UART the minute we saw it, for it met the specifications we had already set forth for the function. It was just what we needed to unload our front-end processor minis that were being tied up by having to perform the function themselves. But it seemed that no sooner had we gotten our hands on a few parts when our supplier shut his doors."

"We scurried around hoping to interest other MOS houses and even paid several of them to start working on the UART. The design was essentially that conceived by Data Sciences but with the inclusion of internal pull-up and pull-down resistors at the TLL interfaces and the ability to kill parity on all code lengths, not just 5 bits."

Thanks to DEC's persistance, there are now at least a half-dozen MOS houses making UARTs... General Instrument, Texas Instruments, Western Digital, Standard Microsystems, American Micro-Systems and Signetics. It really looks like the UART may live up to EDN's prediction for it when we ran its announcement back in our Nov. 1, '71 issue: "The 709 of custom MOS."

As for DEC's use of the part, you only have to turn to this issue's cover to see how DEC is loading up communication I/O boards with them.

Fig. 1 shows how UARTs can take over a large percentage of the job of transmitting data serially over phone lines. The lone remote terminal at the left side (one of several) is shown transmitting into a central-computer station at the right side. Only the sending half of UART-A at the remote terminal and the receiving half of UART-B at the central station are shown in detail. The pin numbers on UART-A at the remote terminal will be followed by the letter "A" and likewise the pins of UART-B at the central site will be followed by the letter "B" in the text to prevent confusion in the following explanation of the data-flow steps in transmitting from A to B.

Now the first thing needed for these two UARTs to be able to talk to each other is they be referenced to the same clock rate. A separate clock at each location must feed each UART with a frequency that is 16 times the desired line-transmission rate, or baud rate as it is called in asynchronous telecommunications.

A low-speed 150-cps baud rate is selected for the transmission from A to B because A is only servicing a manual keyboard, and 150 baud is adequate to keep up with any typist. Therefore, the clock pulses into pin 40A and pin 17B will be $16 \times 150 = 2400$ Hz. These clocks are usually crystal controlled, but clocks with only 1% accuracy could be used. Note that separate clock inputs are used for the sending and receiving halves of these UARTs so that it is possible, as shown, to have a different clock rate (1200 baud) coming back from B to A.

Before any transmission, both the UARTs must have had their master resets (pins 21A and 21B)

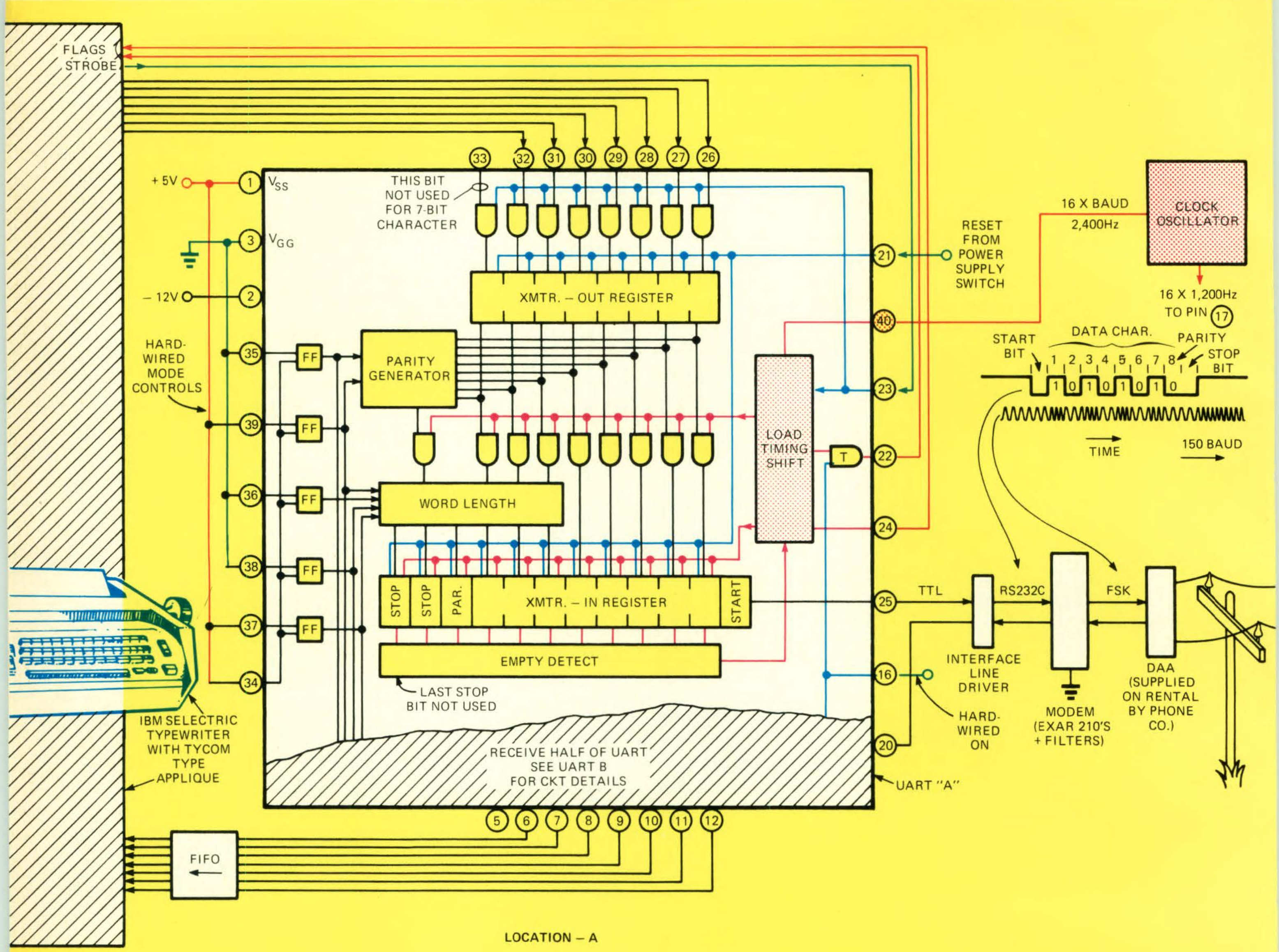


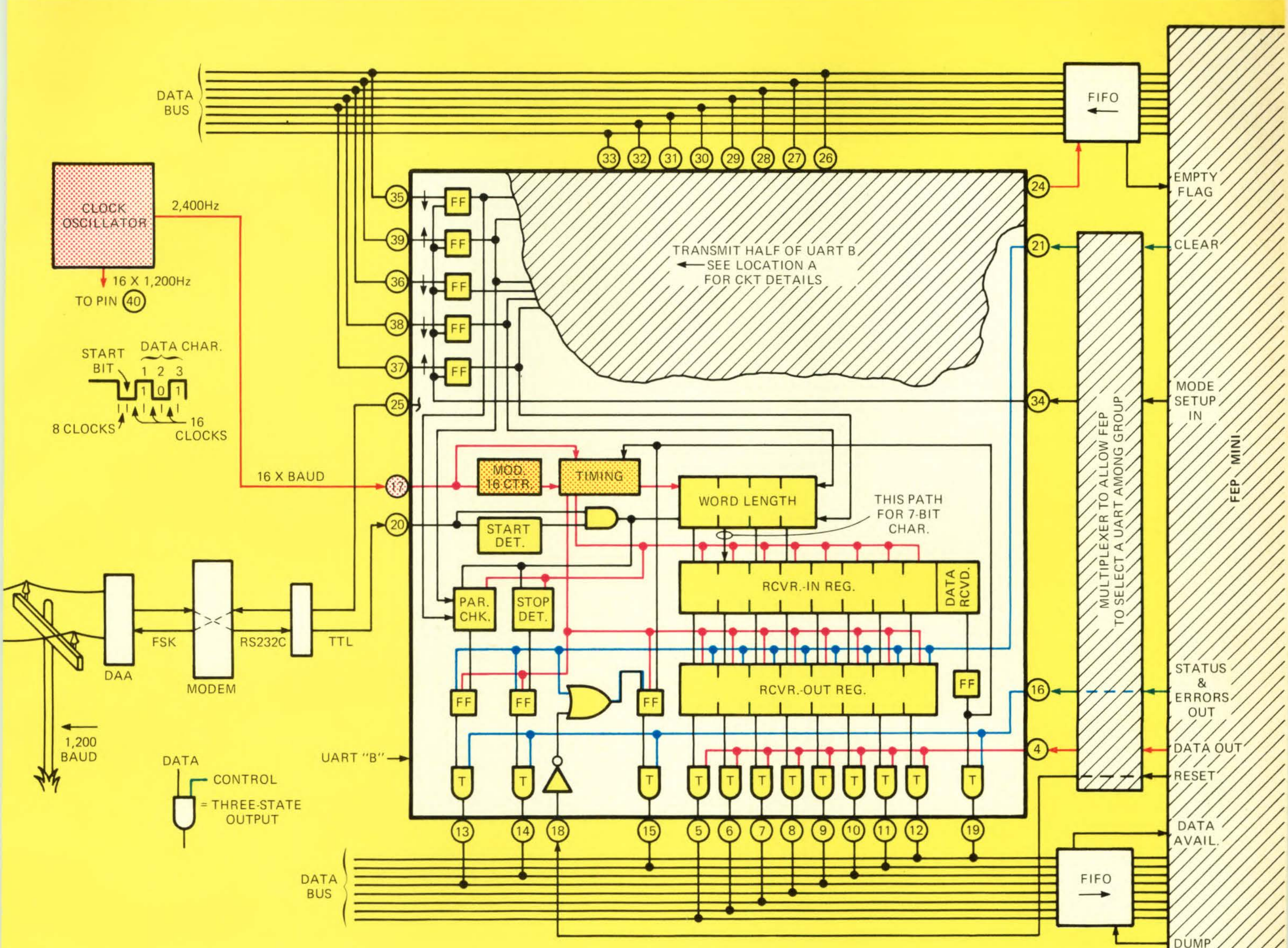
Fig. 1—Complete low-performance data communication system can be implemented at a low parts cost by taking advantage of the many special-purpose PMOS LSI and bipolar ICs now available as standard, multi-sourced products. The UARTs (Universal Asynchronous Receiver/Transmitters) featured here are outstanding examples of how large-scale integration can solve communication problems. Terminal-A to the left is an office typewriter that, by virtue of an applique, can also serve as a data terminal. Terminal-B to the right is a central computer site where a minicomputer serves as the FEP (front-end processor) for a large host computer.

pulsed so that all their internal flip-flops and registers will have been cleared to a known state. Often the equipment designers will provide external circuitry that accomplished this automatically upon power up.

Before a particular transmission, the two UARTs should be put in the same character-format modes. Say that it's decided that the message from A to B will have the full 7-bit ASCII character plus parity, and that even, rather than odd, parity will be used. Further, it is decided that just one stop-bit will be added to the end of the character to be able to pack more data into the given baud rate.

Pins 35A and 35B must be put to logic ZERO to "enable" the internal parity logic; pins 39A and 39B must be both put to logic ONE to make this parity even; pins 36A and 36B must be put to logic ZERO to cause the single stop-bit to be added and, finally, pins 37A and 37B must be put to ZERO to obtain the 7-bit data character. Then, to enter these commands into the UART internal control flip-flops, pins 34A and 34B must be pulsed.

Note that these control pins apply to both halves of the UART; both transmit and receive. Therefore, since they share the same mode controls, both halves must be operating in the same data format, even though they may be going at different clock rates. Otherwise, these controls make the UARTs obviously quite flexible and are



LOCATION – B

one of the reasons that the UARTs deserve to be called "universal".

For the remote terminal, A, all these setups, including the strobe-in input from pin 34, can be accomplished by hard-wiring or by manual switches. The small DIP-type pc mounted switch gangs are a handy way of programming these when they won't be changed too often.

For the central site, B, these mode-control set-ups would probably be put under computer control, as indicated. For example, the communications-control minicomputer—an FEP or "front-end processor" as they are called—can very nicely set up different operating modes, via software programming, for each of perhaps hundreds of terminals it might want to talk to. (This would be particularly desirable for a central processor that never knew what type of terminal it might be asked to dial-up next over the switched telephone network.) Having all the UART commands strobed in by pin 34 and then held internally by flip-flops inside the UART, means the FEP can quickly get these commands into the UART and then forget about them until they need to be changed again. The FEP doesn't have to tie up any of its own I/O in holding these commands for the UART, as was said to be necessary on some previous TTL implementations of this UART function. Also, as shown, the UART mode-control commands can be bussed in by the same lines that the FEP sends data in to the UART.

Sending the data

The actual transmission of data will occur any time the operator hits a key on the keyboard at A. When a key is depressed, the keyboard transducers and logic will deliver the associated ASCII character code (it could be IBM Selectric code, or any other code, as far as the UART and the communication link is concerned, for they are "transparent" to the code used) to the first seven

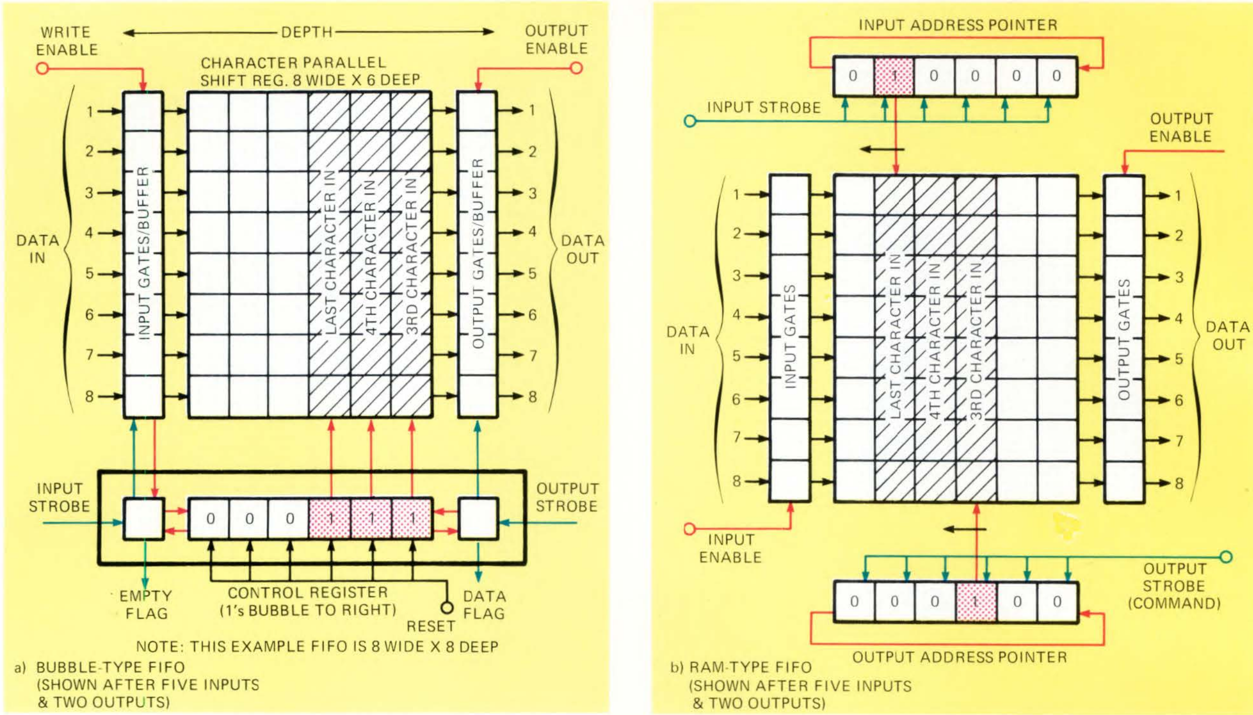


Fig. 2—FIFO (First-In, First-Out) buffer memories are mechanized on two principles: the bubble-through **(a)** and the RAM-plus pointer **(b).** The bubble-through types depend on a special "control" register so constructed that ONEs will always move right towards output until they come up against other ONEs. The RAM types depend upon a single ONEs in two shift registers to point to relative memory locations. See text for more complete descriptions of the operation of both types.

of the UART inputs, pins 26A to 32A, inclusive. Pin 32A is not used in our application example.

At the same time the key is hit, or perhaps a millisecond or so afterwards to allow the outputs to settle, there should be some additional logic in the keyboard to produce a pulse on pin 23A to strobe the data in. The data is now in UART-A's first register—the transmitting holding register.

At this point, UART-A takes over. Stepped by the clock, it almost immediately parallel shifts the data down to UART-A's second register—the transmitting shift register. Then UART-A starts clocking the data out on pin 25A on every 16th clock pulse. In the process of transferring the data between the two registers and shifting it out, UART-A executes the formatting commands that were previously set up on pins 35A to 39A, and computes and adds the proper parity bit. It also precedes the bits with a start-bit and follows them with a stop-bit. It knows how many shift pulses to apply to get the full 10-bit assembly on the line.

As the UART is double buffered, it could receive a second keystroke input right after the first. This second data character would come into the holding register and wait until the first word was completely shifted out of the second register. However, the UART then could not take care of a third rapid keystroke in a row. It is unlikely, however, that any average human operator could go faster than the 15-Hz rate at which the characters are being removed. But to provide an indication of this situation, the UART provides a flag-out or feedback status on pin 22A, which, when low, warns that both registers are full and that the UART can't accept more data.

The path between output pin 25A and input pin 20B of the receiving UART can be as short as a pair of wires down the hall, or as long and tortuous as a dial-up call across the continent. The TTL level output from 25A will typically get boosted to the standard RS-232C interface levels, go into a modem where it will be converted into FSK (frequency-shift or 2-tone transmissions), go out through the telephone network and finally back through modem demodulation and RS-232C-to-TTL reconversion and then into input pin 20B.

We will touch upon the circuits available for some of these intermediate points later on. We somewhat sketchily show an Exar 210 phase locked loop being used for these modem functions at each end. The actual coupling to the line could be either hard wired or via an acoustical coupler at these modest frequencies. But if hard wired, a phone company "DAA" (data access arrangement) should be used for legal operation.

Receiving the data

The receiving UART, B, continually looks at the TTL level it is being presented on pin 20B. Whenever this level goes from ONE to ZERO, UART-B releases an internal counter that is excited by the 16X baud clock rate on pin 17B.

When this counter reaches 8, which nominally places the center of the incoming bit cell at 20B, UART-B again looks at the level on 20B. If the TTL level is still ZERO, UART-B assumes that a valid start-bit has been received—not a noise pulse—and begins to count in 16 clock increments to go from center to center of the incoming bit cells. (In some designs, the UART demands that a ZERO remain on 20B during all eight counts after the start-bit transition has occurred.)

Each time the count of 16 indicates that the center of a bit cell has been reached, UART-B applies a shift pulse to its input register, and the data on 20B at that time is captured and sent down the register. In this way, all seven data bits are loaded into the shift register. Note that the receiving section of the UART is constructed so that the character length command previously set up via pins 27B and 38B gate the serial word coming in on 20B to the right point in the register, insuring that the character will end up all the way to the right.

As the data is being shifted in, the quality of the data is being monitored by the error detection circuits, according to the previously set up mode control criteria. The parity is being checked by tallying the data bits, plus the parity error flag flip-flop (leading to pin 13B) is set. The presence of the stop bit is checked by looking at the center of the cell that follows the parity bit, and if this is not ONE, the framing error flag flip-flop (leading to pin 14B) is set.

When the data is shifted all the way down the register, the register-full situation will be detected and this will cause the information in the shift register to automatically be transferred in parallel to the output holding register, and at the same time (or just slightly after) set the data-available flag flip-flop (leading to pin 19B). This, of course, tells the outside world that a message element has been received and is ready to be strobed out.

The FEP at the central site will be scanning to see when 19B is logic ONE. The FEP must put an interrogation pulse—a logic ONE—on pin 16B in order to see if "data available" is being flagged on 19B, and then it must put a logic ONE on pin 4B to read that data out of the holding register.

It is now becoming very common to have one high-speed minicomputer FEP servicing up to 20 of these UARTs in parallel on a common bus. The outputs, as indicated on the drawing, are 3-state, which means that when they are not gated ON, they present high impedances to all the supply rails. The FEP sequentially queries these UARTs by hitting their respective 16 pins one after the other. If the FEP finds one of the UARTs has data available—a ONE on pin 19—the FEP has several choices. The FEP can, of course, just read the data out by hitting that UART's pin 4. But suppose the FEP sees by the error flags (also activated when 16 is hit) that there is something wrong with the data. In that case, the FEP might be programmed not to read the data out but, instead, ask for a retransmission (in our **Fig. 1** example, the FEP might make the request for retransmission by sending a message back to terminal A via the transmitting side of UART-B and the receiving side of UART-A).

In any event, the FEP must remove data from the UART-B before the next character is shifted all the way into the first register. The UART is constructed so that new data is written into the holding register over the old. Also, it is left up to the FEP or other external devices to provide the reset for the "data available" flip-flop driving pin 19B. The FEP must put a pulse on pin 18B to do this. If it doesn't provide this reset, the overrun flag flip-flop driving pin 15B will be set. This latter, however, is an optional bit of handshaking etiquette between the FEP and UART and in some cases is ignored.

FIFOs: elastic communications buffers

The PMOS FIFO (first-in, first-out) buffer memory got a "who-needs-it?" response from many communication systems designers when the FIFOs in LSI first started coming out about a year ago. But many of these same designers are now quite enthusiastic about the value of FIFOs. They've had a chance to see what some of the first devices like the AMI "semi-FIFO" S1709 and the Fairchild "full FIFO" 3341 will do.

At present, Texas Instruments, Signetics, Western Digital and SMI are in the throes of delivering new PMOS FIFOs. Most of these are in 28-pin DIPs. Mostek has a nice deep FIFO, but it is, for the present, a proprietary device owned by the customer that paid for its development. This rash of FIFO sources indicates that the FIFO, like the UART, will become a staple building block for digital communication equipment. However, the FIFO, unlike the UART, has not settled down into one standard form.

The reason for the FIFO's sudden popularity is simple; it provides an elastic interface between the widely-varying and often unpredictable data rates found in real-world communications systems. You will recall that one of the shortcomings of the UART is that it only has two stages of buffering at each end. If these two stages become filled up faster with data characters than the UART can send the data on, the additional data will either get rejected or thrown away. FIFOs which have from 13 to 64 stages of buffering—and are cascadable to greater depths—can be put ahead of and behind UARTs to rectify the situation. As

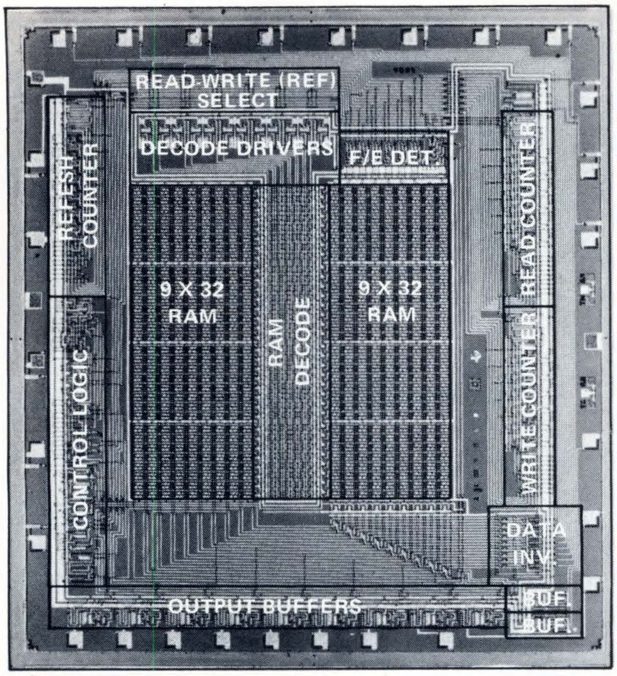


Fig. 3—Chip photo of a FIFO is labelled with the functional regions. TI designer Don Redwine said that this represents rather conservative geometry as it was initially laid out several years ago—a fact which Redwine believes accounts for the chip's good behavior in operation. *(Texas Instruments, Inc.)*

shown in **Fig. 1,** a FIFO can be used in path A to B to accumulate a whole block of slow asynchronous data from a 150 baud line, and then spurt it out synchronously at rates up to 1 MHz (depending on the make of FIFO) into the FEP computer. As also shown in **Fig. 1** in path B to A, a FIFO can be used to accumulate a whole line of characters for a printer, to be ready as a continuous stream after the carriage return.

What makes the FIFO different from ordinary serial buffers is that the FIFO immediately and automatically moves any data it receives as far down towards the exit as it can. The FIFO electronically implements that familiar human behavioral phenomenon, the "FCFS" (first-come, first served) waiting line. Humans entering a waiting line, as in front of a ticket window, will automatically move up as far as they can, right behind the person who got there before them. Each time a person at the window is served and leaves, the whole line moves up a notch. There is no delay or wasted line space as there would be if people did not move up. There is also a "fair" sequence of service.

Bubble-through FIFOs

The earlier PMOS FIFOs, like the Fairchild 3341, use a bubble-through mechanism (**Fig. 2a**). As the data character is strobed (in parallel), a marker bit—a ONE— is created at the start of a control shift register (shown at the bottom of the FIFO diagram in **Fig. 2a**). This control register is designed so that it will automatically 'bubble" ONEs down the register to the right towards the exit end. The ONE being bubbled will carry all the parallel bits of its associated data character in the shift register above along with it. (Just think of the whole vertical column of data bits above the marker bit in **Fig. 2a** moving along to the right with marker bit.) The cells of the control register are designed so that a ONE in any cell will be constantly looking to its right, and if it sees there is a ZERO in the next cell, the ONE will move into it. But when it sees another ONE in the next cell to the right, it will stop. The rightwards bubbling will automatically stop when a marker bit gets to the right end of the control register (otherwise data would "fall out" and be lost). The data characters above will therefore automatically queue up behind each other, waiting their turn to be strobed out. The strobe-out signal will, of course, come from some following equipment when that equipment is ready to receive the data.

The Western Digital FIFO also appears to be built on this principle, but (see Table) it is a full 9 bits wide, while the earlier Fairchild is only 4 bits wide. But as a tradeoff—possibly to make room for the width—the Western Digital FIFO is only 40 bits long while the Fairchild one is 64 bits long.

A shortcoming of FIFOs mechanized on the "bubble-through" principle for higher-speed applications is that bubbling down a long register takes a fair amount of time. There is a propagation delay associated with each "stop-look-move." The long Fairchild FIFO needs 32 μsec to bubble a character all the way down through a previously empty FIFO. The shorter Western Digital FIFO specifications cite a 20-μsec maximum ripple time, even though the data rate can be as high as 1 MHz. To look at the situation in reverse, it will take the same 32 and 20 μsecs for an "emptiness" indication to shift back to the beginning of a full FIFO upon the exit of a character.

RAM-plus-pointer FIFOs

A number of the FIFOs currently being introduced are mechanized on the RAM (random-access-memory) principle, with the FIFO behavior being achieved through address manipulation. The Texas Instruments TMS 4024 and the Signetics 2535 use this approach. The value of the RAM organization is that the "fall-through" time is reduced to the time to change the addresses, which, as it involves far fewer propagation delays, can be as short as a couple of microseconds.

The operation of these RAM-type FIFOs is also easy to explain on the block-diagram level, though they too are said to be tricky to realize in LSI. TI designer, Don Redwine, compared his design with its 576 bits of memory to a 1k RAM like the 1103, with respect to PMOS sophistication (chip photo, **Fig. 3**).

As shown in **Fig. 2b,** which is a generalized diagram applicable approximately to both the TI and the Signetics devices, the data characters are stored as vertical slots in the RAM that are addressed from above by the input address "pointer", and from below by the output address "pointer". The pointers are ONE bits in shift registers that otherwise contain only ZERO. These shift registers only shift left, and at their left-most end are looped back around to their right end.

Initially, when the FIFO has been initialized via the RESET or CLEAR input, both pointers will be at their right-most positions. (Incidentally, it is not always necessary to clear the data cells in any of these FIFOs; only the marker bits and the pointers must be cleared and reset.)

In this condition, the READ output command will be inhibited (either by built-in internal logic as in the case of the TI unit, or by user supplied external logic using the flag warning supplied in the case of the Signetics unit); the FIFO should not be read because it is empty. Then suppose an "upstream" equipment presents a data character on the input lines and gives the FIFO the strobe signal that enters this data. The first data character will be entered at the right-most position of the RAM because that is where the input address pointer is pointing. At the end of this WRITE cycle, the input address will automatically shift one to the left, where it will be properly pointing at the next empty space in the waiting line. Meanwhile, the output address pointer will still be pointing at the last right-most slot in the RAM. If a WRITE command strobes the FIFO output, this just entered data character will be read out. If a WRITE command from some "downstream" equipment is ready to accept a data character from the FIFO and strobes the FIFO's READ command, the just entered data character will be read out. Then the output pointer will move one to the left.

What happens if the whole RAM gets filled up with entries and there have been no readouts? The upper pointer will have moved all the way to the left, and the lower pointer will still be to the right. Then the housekeeping logic will have to put up an "FIFO-full" flag and further data entries will have to be locked out. But then, say, some room is opened up by some data readouts. The lower pointer will accordingly move to the left, and the upper pointer will loop or circulate around to the right hand of the upper register, and so new data will start to be read in again to the now-empty right-hand side of the RAM. But meanwhile, the lower pointer will remember where the first-in data is (middle of the RAM).

Table: FIFO Characteristics

Supplier	Part No.	Width	Depth	Operating Mode	Speed
Fairchild	3341	4	64	bubble	
AMI	S1709	8	13		
	to be announced	8?9?	32?		
Signetics	2535	8	32	RAM	1 MHz
Texas Instruments	TMS 4024	9	64	RAM	250 kHz
Mostek	–	–	(long)	–	
Western Digital	FR1502E	9	40	bubble	1 MHz

The operation is a lot like that of a rotating magnetic drum memory, except that in this case, the drum (RAM) stands still and the read/write heads (pointers) move.

The Signetics FIFO adds an extra register to keep tally of the relative "fullness" of the RAM. This is an UP/DOWN (U/D) counter that counts UP when the upper pointer moves, signifying a character has been entered, and DOWN when the lower pointer moves, signifying that data has been removed. Thus, no matter how many thousands of times the data has wrapped or "rotated" around the RAM locations during the course of normal FIFO operation, the count in this UP/DOWN counter will represent the distance between the two pointers or the number of RAM slots filled with data.

Because of pin limitations, Signetics only brings out the U/D counter pins that show when their FIFO is 1/4 and 1/2 full, from which the user can, of course, externally decode the 3/4-full situation.

There are some additional differences between the TI and Signetics FIFOs. The TI unit, unlike most of the other FIFOs to date, employs a dynamic RAM and so needs two clock phases and a refresh cycle. Designer Don Redwine said this should not trouble the user since the clock can be a simple free-running TTL multivibrator, running at 500 kHz or less, and that the refresh operation is taken care of automatically on the chip, with minimum interference to the regular asynchronous behavior of the FIFO. Possibly because it is dynamic, the TI FIFO is considerably longer and slightly wider than the Signetics unit, but still contained within a reasonably sized 187 × 196-mil chip (**Fig. 3**).

The Signetics unit, on the other hand, has a serial-to-parallel conversion tacked onto its input and a parallel-to-serial conversion tacked onto its output. Joe Kroeger, Signetics application engineer, says this was done to make the part even more "universal." But at the time this was being written, Signetics was experiencing some "routine" start-up delays in producing their FIFO.

How wide? How deep?

The width of a FIFO determines how many bits can be in the data characters it handles. Fairchild's 3341 is just 4 bits wide, and while that was all right for BCD, it falls short of what is needed to handle standard ASCII of 7 bits plus parity. But now there appears to be a growing desire to have 9-bit characters. It seems that some users want to use forms of "extended ASCII", or they are working with data from large computer environments where the magtapes typically carry nine tracks (8 data bits plus parity). You will note (see comparison table) that some of the FIFOs can (like the UARTs) handle 9 bits, while others can only handle 8. Some of those with just the capacity for 8 bits have told us that they wish they had the full 9 bits for the additional "universality" that it would give them.

The depth needed in a FIFO depends on such factors as expected message block sizes and differences in input and output data rates. For example, Neil Hazelwood, one of the designers at ICP, the Dallas cassette terminal manufacturer, says he is using a FIFO to provide the slack to allow him to bring the cassette up to speed. He is using one of the early AMI 13-bit deep FIFOs and finds that he can, moreover, servo the cassette speed to keep the FIFO at about half fullness.

Another FIFO user, Vincent Bastiani, engineering manager of the communications equipment design group at Digital Equipment Corp., says DEC is using a number of the Fairchild 64-bit FIFOs in parallel after the multiplexer that selects data from the eight UARTs (see cover photo) for their FEP. Obviously, it would, in an application like this, be nice to have enough FIFO depth to take care of data bursts between FEP scans.

Most of the FIFOs are designed to be easily expandable in both width and depth, just like regular LSI memories. They have the command inputs and flag outputs to shake hands with themselves as well as with other upstream and downstream equipment. However, the market economics always favor the product that can do the job in one package.

Other ICs help designers

The other ICs shown in **Fig. 1** help the designer to implement the modem function and to convert back and forth between TTL and standard EIA RS-232C levels. These bipolar ICs really perform two services for the designer in a hurry. First, because of their small size and low cost, they help the designer bury communication functions inside terminal equipment, often making for a lower-cost, more attractive product for the end user. Second, because of tailored specifications and the application notes supporting these products, the designer is guided towards meeting the accepted standards in communications. The value of this guidance can be appreciated from **Fig. 1** where it is seen that the elements of communications system are hemmed in by FCC regulations on the telephone lines on one side, and de facto product interface standards on the other.

The phase locked loop ICs convert the logic ONE and ZERO levels to two audio tones that can be transmitted through the telephone lines, and then (with different external components) reconvert these tones back into logic ZEROs and ONEs. Exar, Signetics, Plessey and Harris are among the suppliers that make suitable IC PLLs for this application.

The application notes that Exar puts out for its 210 PLL gives specific advice for implementing this FSK (frequency-shift keying) function. Alan Grebene of Exar says that the two 210s will replace about two-thirds of the circuitry usually used in one of these low-speed modems. The only additional elements needed are a simple low-pass filter at the transmitter output to meet the FCC requirements (which are particularly directed at preventing energy into the 2600-Hz signalling band used by the phone company) and perhaps a 4-pole filter at the input off the line to remove phone-line noise. This filter can be of the active type, inexpensively achieved with a quad IC op amp, Grebene says. He estimates that the total parts cost for the modem would be about $20-30, which is 10-15% the cost of an OEM modem card.

The 210 happens to come with RS-232C-compatible outputs, but even if it did not, the designer can obtain DIPs costing less than $2 that carry dual drivers and quad receivers that will match TTL to this standard communications equipment interface. The Texas Instruments SN150/154 pair and the Motorola MC1488/89 are examples. The EIA 232C interface signal is archaic; it is a single ended line that uses large amounts of hysteresis on the receiver to overcome noise... rather than the balanced line using differential amplifiers found in most of today's computer interconnection lines. But right or wrong, it has become the popular standard. These ICs are pre-engineered to meet all the voltage, short circuit, etc. stipulations of the EIA RS 232C document. □

Acknowledgement: *The application literature on the Western Digital UART provided helpful guidance in developing* **Fig. 1.**

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Circle No. 9

Today's hardest design decision: An overview of custom CMOS/LSI

If you don't go custom, competitors may beat your price. If you do, they may beat you to market. You'd better make the right choice!

Bill Furlow, Associate Editor

We don't plan to tell you how to design a custom CMOS chip in this article. There wouldn't be room in ten such articles for that. Neither do we plan to tell you whether you should design a custom chip or use standard devices. Nobody can take that burden off your back.

What the heck are we going to tell you, then? First and foremost, we're going to try to place into perspective the rapidly-changing criteria that effect your decision, to help you get a feel for the practicality of custom CMOS. We will also try to plot some of the future trends in custom CMOS. The ground rules change almost weekly, but there are some landmarks that you can use for reference.

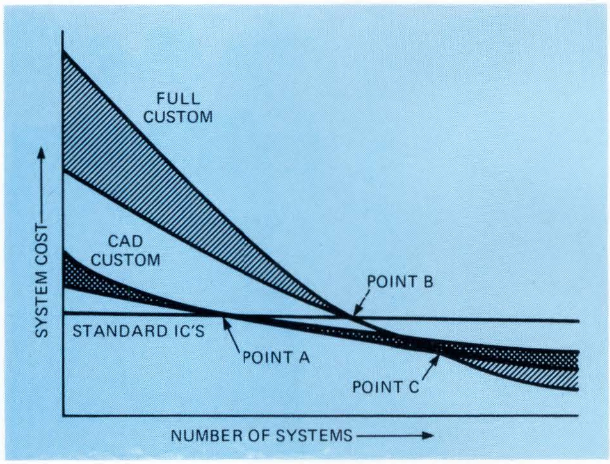

Fig. 2—Cost comparison of LSI and SSI systems is shown by their volume vs cost curves. Point "A" is typically 5000 to 20,000 systems per year, point "C" somewhere between 20,000 and 100,000 systems per year.

When is custom attractive?

Price, size and power are probably the three factors that will most often make you look to a custom chip. These factors, along with schedules, and that all important variable—quantity, will have an important bearing on your decision, but how do you weight each factor? Some products are so size dependent that they wouldn't even be possible without an LSI chip. CMOS wristwatch circuits like the one shown in **Fig. 1** is one example of such a product. We will look at another design, a pocket pager, where size is also a major factor, later in this article.

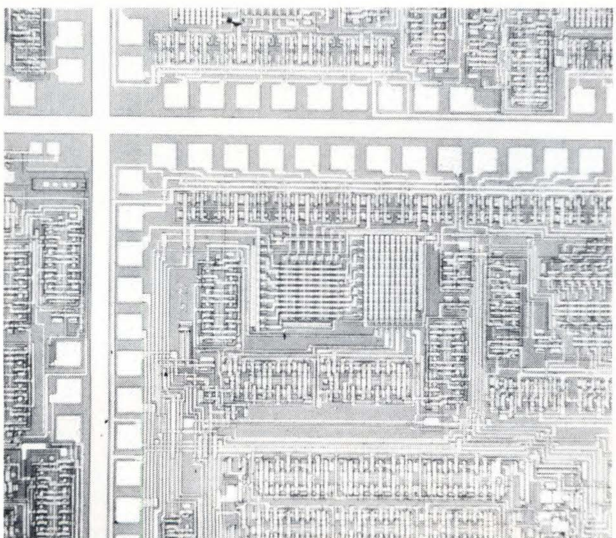

Fig. 1—CMOS/LSI watch circuits, like the one shown here from Micro Power Systems, represent a commercial application that was impossible before LSI. Micro Power's 2-layer metallization techniques have reduced the size of this chip even more.

If size doesn't force you to LSI, and it generally doesn't, then cost usually becomes the deciding factor. As you can see from the chart in **Fig. 2,** given to us by Dick Galloway of Motorola, the systems cost of a standard IC design remains nearly constant, regardless of volume. This occurs despite the reduced cost of components achieved in volume purchasing because the semiconductor content of an average system is only fifteen percent. A large part of the remaining cost is assembly labor, and LSI can provide dramatic reductions in that area.

The crossover points in **Fig. 2** vary a great deal

Table 1

After winning a contract to design 4500 subsystems with stringent requirements for high noise immunity and low power consumption, a manufacturer, whom we cannot name here, initially chose to implement the subsystem design with standard 4000-Series CMOS logic. While the prototype worked fine, the cost for producing the 4500 subsystems with the standard devices was estimated to be much higher than originally planned. Following is a cost analysis based on the prototype implementation:

DEVICE TYPE	QTY./ SYSTEM	COST/ SYSTEM
4001AD/QUAD-2 GATE	8	
4023AD/TRIPLE-3 GATE	3	
4009AD/HEX BUFFER & INVERTER	2	
4027AD/DUAL JK, SET/RESET	4	
4029AD/PRESETABLE UP-DOWN COUNTER	4	
TOTALS	21	$59.50
LSI CIRCUIT	1	$24.00

For building just the prototype, the cost of the 21 devices in ceramic DIPs was about $214. This cost was substantially reduced to about $59.50 as the result of competitive bidding on the mixed production quantity of 94,500 devices. Thus the estimated cost for building 4500 subsystems totaled approximately $267,750.

Feeling that the estimated device cost was still too high—even with the production-quantity discount—the manufacturer was prompted to evaluate a custom LSI approach. He learned that the 21 devices required for each subsystem could be replaced by a single LSI circuit, measuring 110 mils by 120 mils and assembled in a ceramic DIP, for a one-time development/tooling charge of $35,000 plus an average piece-part cost of $24. The total cost for producing the 4500 LSI devices would therefore be $143,000—which amounts to $124,750 less than the cost for the standard 4000-Series devices.

By taking the custom LSI approach, a further savings was gained in the cost of the printed circuit board. Instead of using the $22.50 multi-layer pc board required for the standard devices, a $5.40 two-sided pc board could be used with the LSI devices. This resulted in an additional $76,950 savings — thereby bringing the total savings on device and pc board costs to $201,700.

Although it's easy to justify the custom LSI approach simply on the reduced cost of the devices and pc boards, there are additional savings which make the custom LSI approach even more attractive. For example, the use of the standard 4000-Series requires additional handling, testing and storage of some 90,000 devices. Moreover, some 1,500,000 leads would have to be soldered. Because the LSI equivalent results in only 190,000 leads to be soldered, it shrinks assembly cost even further—while adding the bonus of better reliability because of fewer interconnections.

depending on logic complexity, device yield and a lot of other variables. Just to show you what ballpark we're in, though, the crossover at point "A" is generally felt to occur at 5000 to 20,000 devices per year. We are talking about computer-aided design (CAD) LSI here, and CAD is less efficient in its use of silicon area than manual layout is. Estimates given us seem to indicate that CAD is about twenty percent less efficient. This could be as little as ten percent in the case of highly-organized logic such as a long shift register. It can also run as high as fifty to one hundred percent in the case of complex random logic. On the other hand, the initial outlay for a CAD chip is significantly less, and for speed of design CAD wins hands down. You trade initial cost for sustained cost.

The crossover point for CAD and manual-layout designs, point "C" in **Fig. 2,** is between 20,000 and 100,000 chips per year.

Table I is a case history and cost analysis given to us by Micro Power Systems; it should help you analyze your own systems costs.

Makers are overlooked

Just because you've estimated the point at which LSI becomes economically feasible for you, don't think you've discovered the volume at which the semiconductor manufacturers are going to be interested. The semiconductor houses are having a big year, and business that they would have grabbed in 1970 doesn't move them at all now.

Development cost for design seems to be typically $15,000 to $30,000. Now that's the amount you can expect to pay the manufacturer between the time you come to him with firm logic requirements and the time he delivers the first prototype units. That doesn't include engineering and support time at your company. What's more,

TABLE II—Time required for custom CMOS design	
LOGIC SIMULATION AND PARTITIONING	2 WEEKS
CIRCUIT LAYOUT AND SIMULATION	4 WEEKS
PLACEMENT, ROUTING, CHIP LAYOUT	2 WEEKS
COMPUTER AIDED ARTWORK GENERATION	2 WEEKS
MASK FABRICATION	3 WEEKS
TEST PROGRAM GENERATION (USUALLY DONE IN PARALLEL WITH ABOVE ITEMS)	2-9 WEEKS
PROTOTYPE WAFER FABRICATION	4 WEEKS
WAFER PROBE	1 WEEK
ASSEMBLY	1 WEEK
ENGINEERING EVALUATION AND CHARACTERIZATION	1 WEEK
TYPICAL TIME TO PROTOTYPE UNITS	20 WEEKS

that amount of money is only a fraction of what the manufacturers expect in a production order. Many of them have confided to us that they will not accept business which will not run over $100,000 per year in production. Some even want a guaranteed three-year production run. One marketing type admitted it would probably take a cool half-million dollars to get a custom project into his production facilities this year.

Don't be disheartened; makers are expanding their facilities as rapidly as possible, and new manufacturers should begin to arrive on the scene shortly. For right now, though, remember that the larger the manufacturers, the larger the project he is interested in. Make an accurate estimate of your project and approach the corresponding-sized manufacturer.

What is practical?

Walt Kalin of Solid State Scientific points out that gate counts, while useful, can be a deceptive way to measure chip size. Two custom circuits developed by his company illustrate this point. The first is a dual 128-stage shift register employing over 2500 devices on a chip 133 by 115 mils. On the other hand, a custom pattern decoder—a random-logic array—contains 950 devices on a 130 by 145 mil chip.

Walt points out, and others we've talked to concur, that a 100 by 100 mil chip is a very economical size to produce. Chips still practical for commercial production can go over 160 mils. If you were willing to pay for it, much larger sizes are possible, but don't expect yields to be anything but dismal at very large chip sizes. Chip size (and thereby rejections and costs) can be kept low by refraining from specifying overdesigned output buffers, special resistive and capacitive elements or extraneous test circuitry.

How long will it take?

The data in **Table II** happens to have come from Walt Kalin, but it correlates very closely with information we've been given by most other manufacturers. This is for a CAD layout. Changes during development can seriously effect your schedule. You should do everything in your power to have firm requirements drawn up before you begin. On the other hand, you should establish some sort of reporting procedure with the manufacturer so that you are aware of his progress also.

One thing that doesn't show in **Table II** is error or design oversight. This is not at all uncommon and will cost you at least two to four weeks of schedule. The only way to handle this is to do everything you possibly can to insure that the prototype units will be perfect, and then schedule one month for the corrections. If you don't need that month, you're fat—but don't ever count on perfect prototypes.

After you've tested the prototypes and given your approval, you're about 14 to 16 weeks from initial production deliveries. Those are average numbers, and in some cases it will now be considerably longer.

A case history

To check what we'd been told by the manufacturers, we went to an experienced CMOS/LSI designer. Sevier Sabin works at Martin Marietta's Orlando, Florida division. He was responsible for the development of Martin's HICAP pager, shown in **Fig. 3** and marketed through several Bell System companies as the "Bellboy". It's shown full size, so those of you who have had some experience with pocket pager can appreciate the size reductions that were accomplished. But the size alone doesn't begin to cover the advances that were made with this unit. A far cry from the tone modulated systems which used to use vibrating reeds, and later the op-amp active-filter units, for tone demodulation; Martin's HICAP uses pulse-code addressing. Up to 60,000 separate addresses can be serviced on a single frequency, and they already have schemes for expanding that if it's ever required. The custom device at the bottom (by Harris Semiconductor) is a programmable-address module. It's in a custom 17-pin DIP (to avoid reverse installation) and can be removed and replaced by merely opening the cover and unplugging it. It recognizes two separate address codes, and the pagers give forth with two distinct audible tones. This permits the user to have two different numbers for whatever purpose he may need them. For example, a doctor "beeped" on the golf course would know immediately whether he should call his office or his hospital.

To cap off all of these features, the pager contains over 2000 transistors and is powered by a standard AA cell. Clearly, this design would not have been possible without custom CMOS/LSI.

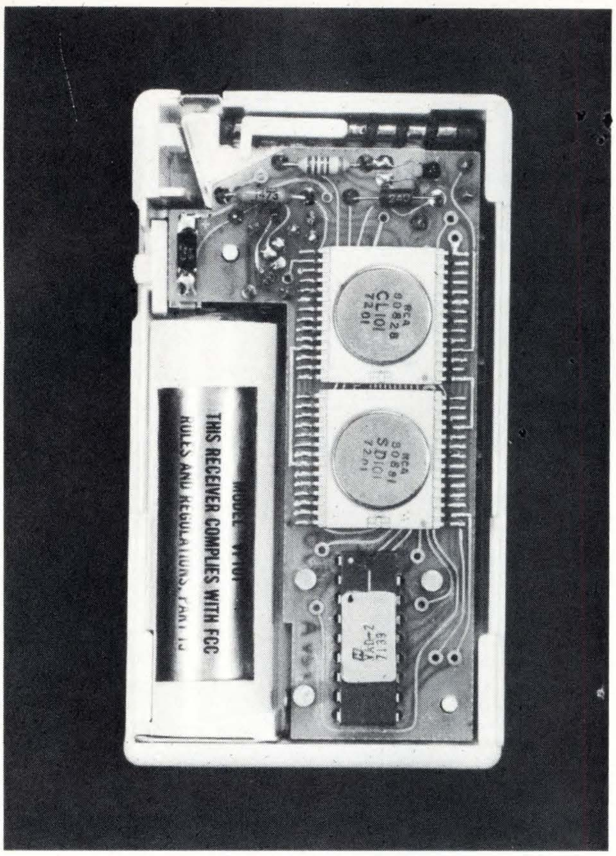

Fig. 3—Two custom CMOS/LSI devices (ceramic DIPs) made possible dramatic size reduction of this Martin Marietta pocket pager—shown full size here. CMOS also permitted powering the pager from a single AA size battery.

Here are some of the highlights of a discussion we had with Sevier:

Would you give us some idea of how you approached this design?

"Yes. I first did a complete system design which included extensive computer simulation to determine my exact logic requirements.

"I then made two breadboards—one implementing the required logic with standard CMOS 4000 Series DIPs, and the other 4000 Series bare chips mounted in hybrid circuits. The hybrid version gave me a production sized model. Both worked. I then wrote a very detailed spec which I presented to RCA for their evaluation. In this spec I defined logic in detail, that is, a flip-flop here, a gate here, etc.—but not in geometries or layout. I then requested a breadboard from them.

I wanted to play it safe, so I chose a vendor who had standard devices and processes so that I could build all of these systems breadboards. With a vendor who had no standard devices, I wouldn't have been able to make these comparisons; I would have had to take a lot more on faith.

I should say that today I have a lot more faith than I did two and a half years ago."

Would you say there are any problems in breadboarding with 4000 Series devices first?

"Yes! With standard devices you're using NAND and NOR gates for everything. The manufacturer won't necessarily use NANDs or NORs in custom LSI. If an AND function is needed, they'll build an AND. So there will be slight differences which could actually get you into trouble.

A more significant thing is that the standard packages are set up to drive specified, relatively large loads. Power consumption will, of course, be larger because LSI is tailored for minimum-size devices for the particular drive requirements.

Next, when you go to hybrids, you'll find that the speed of the logic changes radically because the stray capacitance is down. If you don't account for this in your logic design, you can encounter race conditions. This can also happen when you go to LSI. You must rely on the vendor's design engineer to help you avoid this.

I have a lot more confidence in CAD today; I don't think that breadboards are required."

What about second sources?

"My guess is that the manufacturing processes vary enough from vendor to vendor that you'll have trouble applying masks and the design rules, that is, line sizes and spaces and device geometries, from one vendor to another. This might not be true with simple devices, but the more complex your design is, the less likely you'll be to find a second-source vendor who can use your original masks.

Martin owns the masks; we write our contracts that way, and we were given the name of a qualified second source. We haven't used them yet. Besides those two, any other vendor would most likely say that they couldn't guess yields and wouldn't guarantee anything.

I would probably then end up in a second design effort."

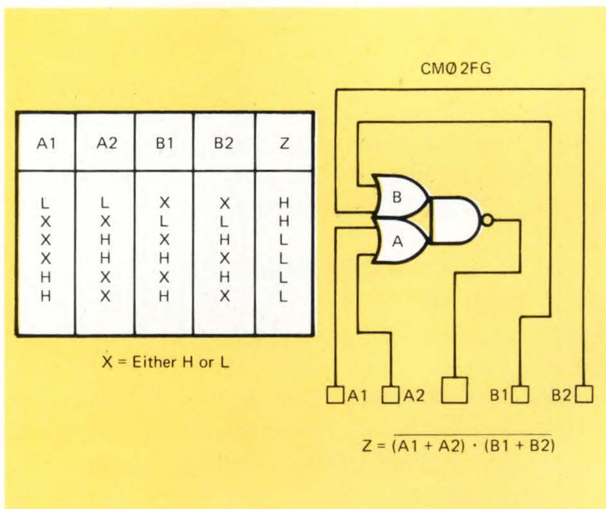

Fig. 4—Typical cell from a CAD "cell library" permits designer to choose and place logic functions on an LSI chip in much the same manner he would choose and place DIPs on a pc card.

Fig. 5—Digitizing a chip cell plot at Motorola's Localogic center feeds cell location, metallization and chip-pad locations to key punch. Control cards are then used for generating fabrication masks.

Do you have any more comments for the designer?

"Just this: On a chip in the neighborhood of 150 by 150 mils there is a high probability of error. Probably fifty to ninety percent of the time there will be some sort of error that won't show up until wafer probe.

You know, you're playing with thousands of lines on the mask. You only need one of them to be wrong and the product is no good. I would guess that it usually takes a month, maybe longer, to correct this. It could take a lot longer if you have a real foul up, but that doesn't happen very often."

A look at a CAD facility

To get a better feel for CAD design of CMOS/LSI, we visited Motorola's Localogic™ Eastern Design Center, in Lexington, Mass. Al Sheng, engineering manager for the center gave us a run-down on how the Localogic™ center functioned and how it differed from other design centers.

Motorola's Polycell system reduces LSI design to an exercise not much more involved than designing with standard logic blocks and designing a pc board for that system. The Polycell library contains 33 standard CMOS functions already developed and fully characterized by Motorola. An example of one of these cells is shown in **Fig. 4.** A full set of design, simulation, checking, artwork generation and test programs reduce LSI design to its very rudiments. Designs at the Localogic center average about 200 gates in complexity, and Motorola likes to limit the chip size to about 160 by 160 mils.

The cell-library concept, of course, isn't exclusive to Motorola; most CAD facilities use a similar set up. RCA, in fact, will begin a network of remote-design centers of their own this summer. Eventually there should be a CAD/LSI design facility in every major engineering center in the country.

But how easy is it for a designer to learn CAD/LSI design? Using their cell library as a basis, and covering PMOS (both metal- and silicon-gate) and CMOS (metal-gate, only) the Localogic design center offers a one week course that they report can make LSI designers out of most engineers. The course consists of 20 hours covering MOS technology, Polycell design and simulation, and 20 hours of layout and graphics. There is homework and a substantial amount of preparatory reading. The course takes you all the way through the design cycle, including the digitizing of the chip layout, as shown in **Fig. 5,** to the end of the design work. Cost of the course for 6 designers from one company is $2600. Motorola is beginning to offer mixed classes (that is, 6 engineers from different companies) at a tuition of $500 per person. This course represents the easiest way to learn LSI design, but it's only representative. Other companies offer design courses, too, and you should contact those that are conveniently situated.

Some tips for success

Walt Kalin, of SSS, offers these pointers for your first time through a custom LSI design:

When specifying CMOS integrated circuits, the following items should be clearly defined:

- Circuit schematic and/or logic diagram
- Power supply voltage range
- Power consumption (static and dynamic)
- Circuit speed including propagation delays, transition times and maximum clocking rates
- Number of pins and packaging constraints
- Output impedance characteristics
- Minimum/maximum input logic levels
- Known race conditions in prototype or engineering breadboard
- Operating temperature range
- Special testing requirements

The above specifications are well worth establishing in the design-engineering phase before going to the IC manufacturer. Where a CMOS system is concerned, there is a sufficient variety of standard logic and memory functions available to fully breadboard the system and work out a meaningful set of specifications. As mentioned earlier, however, system speed and power-

Need more information?

Since custom CMOS is a very individual area, we have not assigned reader service numbers. You'll get better information by contacting the companies directly.

American Micro Systems, Inc.
3800 Homestead
Santa Clara, CA 95051
Phone(408)246-0300

Analog Devices
(Analog circuits only)
3100 Alfred
Santa Clara, CA 95050
Phone(408)249-2111

Harris Semiconductor
P.O. Box 883
Melbourne, FL 32901
Phone(305)727-5430

Hughes Aircraft Co.
500 Superior Ave.
Newport Beach, CA 92663
Phone(714)548-0671

Intersil, Inc.
10900 N. Tantau Ave.
Cupertino, CA 95014
Phone(408)257-5450

Micro Power Systems, Inc.
3100 Alfred
Santa Clara, CA 95050
Phone(408)247-5350

Mostek Corp.
1215 W. Crosby Rd.
Carrollton, TX 75006
Phone(214)242-0444

Motorola Semiconductor Products Div.
P.O. Box 2953
Phoenix, AZ 85036
Phone(602)244-6900

Motorola Localogic Center
2 Militia Dr.
Lexington, MA 02173
Phone(617)861-1350

National Semiconductor
2900 Semiconductor Dr.
Santa Clara, CA 95051
Phone(408)732-5000

RCA/Solid State Div.
Rte. 202
Somerville, NJ 08876
Phone(201)722-3200

Rockwell International
Microelectronics Co.
3430 Mira Loma Ave.
Anaheim, CA 92803
Phone(714)632-8111

Solid State Scientific, Inc.
Montgomeryville Industrial Center
Montgomeryville, PA 18936
Phone(215)855-8400

Solitron Devices, Inc.
8808 Balboa Ave.
San Diego, CA 92123
Phone(714)278-8780

Texas Instruments, Inc.
MOS Dept. 12201 Southwest Freeway
P.O. Box 1443, MS 640
Houston, TX 77001
Phone(713) 494-5115

dissipation characteristics will be somewhat enhanced when integrated onto a single chip.

Above and beyond good engineering practice, there are certain other intangibles which govern the probability of success in a custom IC design. A visit to the IC manufacturer is well worthwhile. There the design, processing, test and QC facilities can be personally evaluated. There should be good rapport established between system-design engineers and the IC project engineer so that written specifications and design tradeoffs work out to the mutual satisfaction of both parties.

Some IC manufacturers will balk at the following requests, but there's no harm in asking for them. Ask for device design and layout rules. Ask for process parameter specifications such as device thresholds, junction breakdown voltages, device gains—not theoretical figures, but actual in-process measured data. The reason is twofold. First, the process quality can be evaluated. But more importantly, data from manufacturer to manufacturer can be compared to determine whether alternate or multiple sourcing is feasible. □

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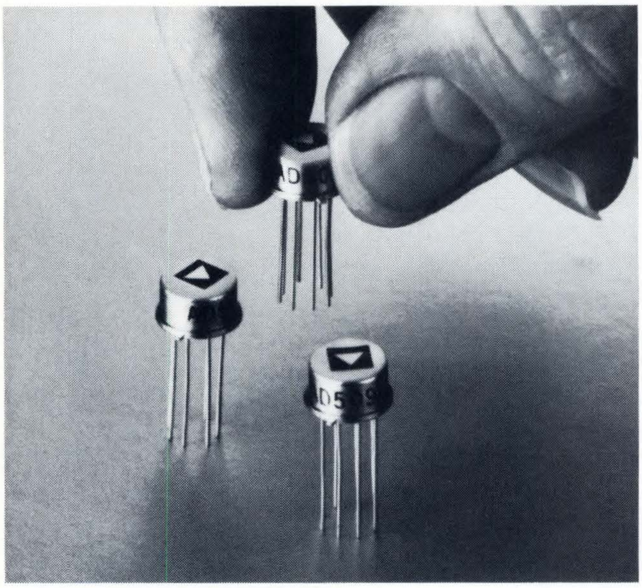

Let's face it. Most of the fast, wideband IC op amps on the market require excessive external compensation for stability, sacrifice DC performance to increase speed, and just plain cost too much.

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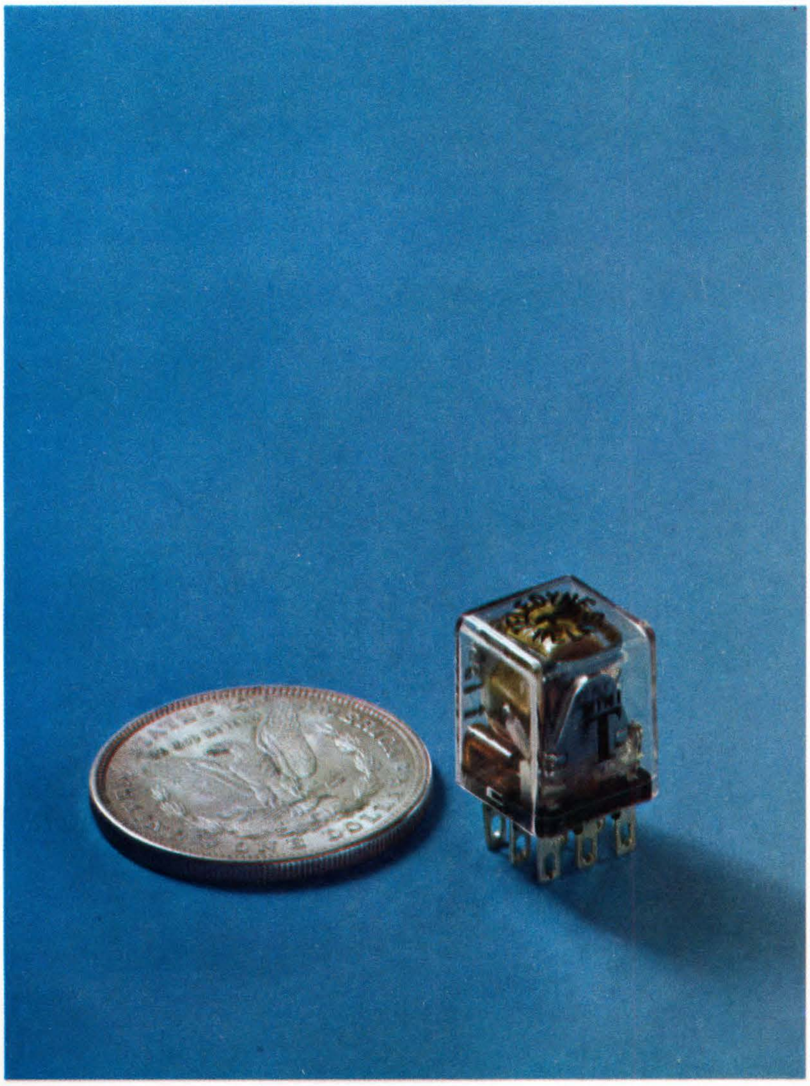

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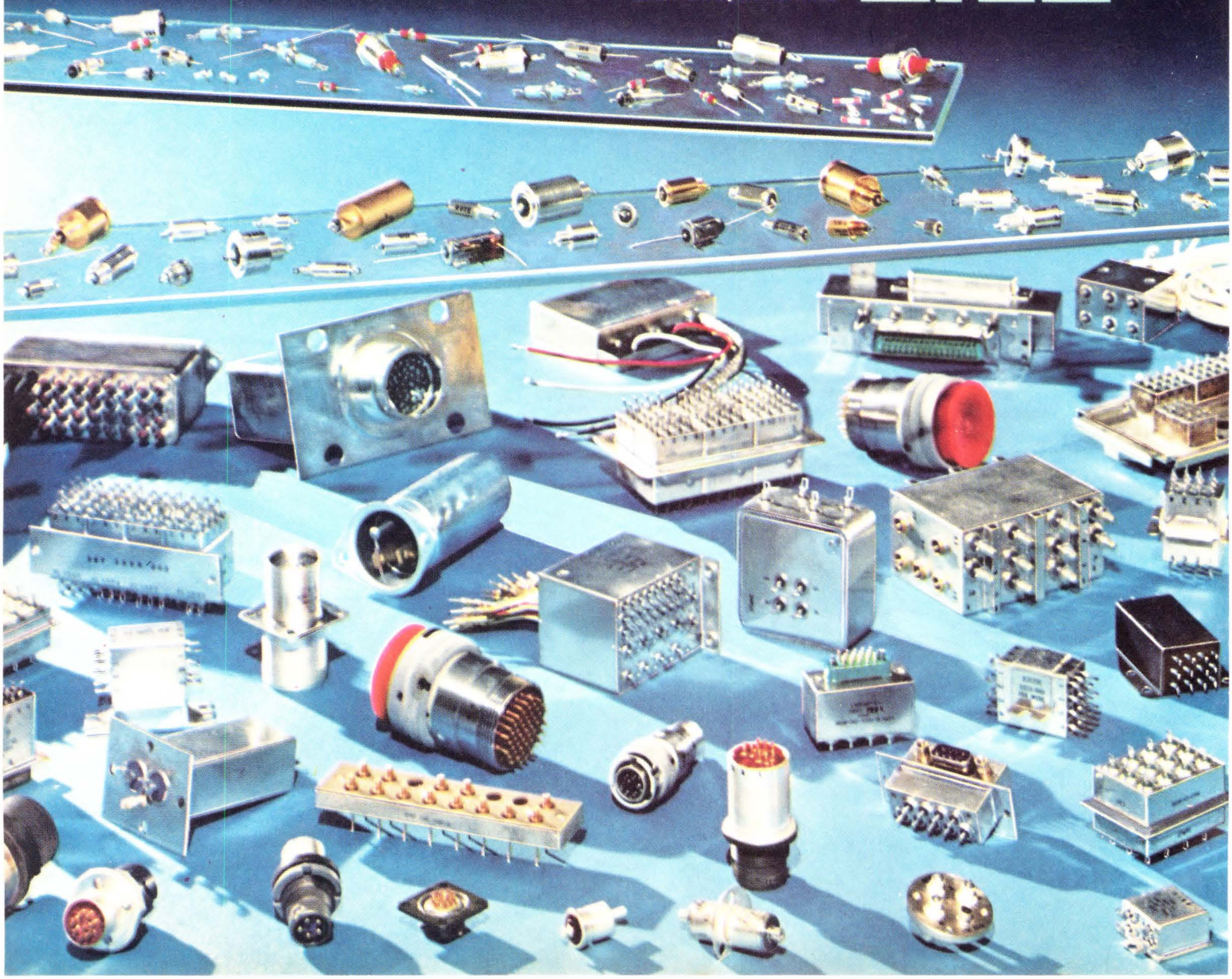

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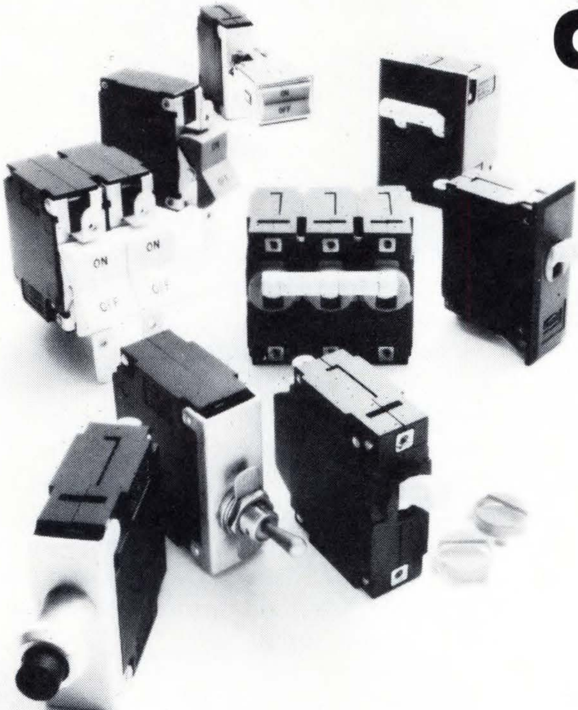

A word to those of you who've been considering our hydraulic-magnetic breakers only in terms of reduced component and service costs—your customers may like the way they look on your equipment.

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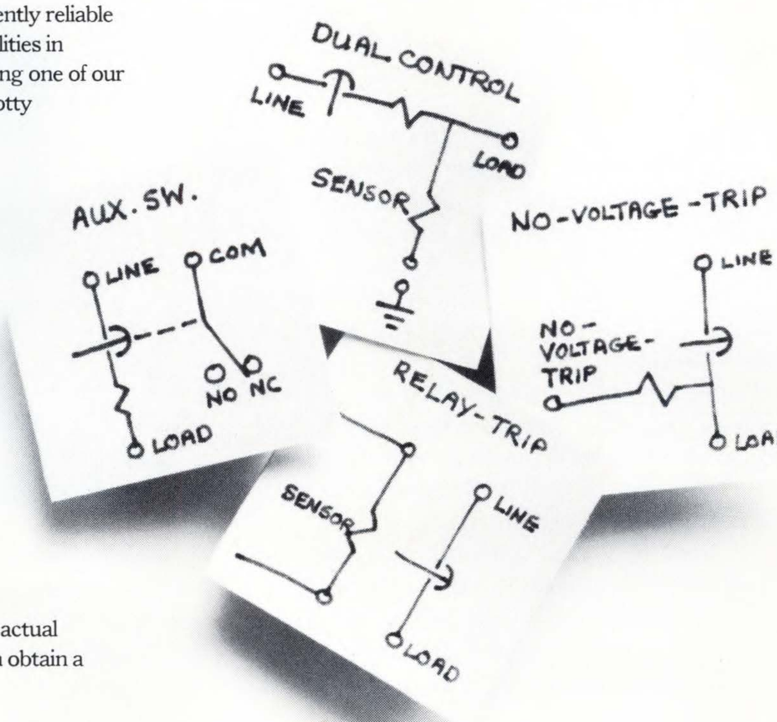
Our new Bulletin J-3333 gives a thorough airing to many such ideas based on actual applications of these internal circuits. You can obtain a copy by writing to Heinemann Electric Co., 2626 Brunswick Pike, Trenton, N.J. 08602.



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Circle No. 20

Circle No. 21

Texas engineer wins 1st prize in EDN's 1973 Creative Design Contest

An engineer from Texas, Edward Erwin, is the grand prize winner in EDN's 1973 Creative Design Contest. His entry, a digital calendar and display, wins for him the 1st prize of $1000.

To Ed Erwin, the 10 runners up—each of whom receives a Hewlett-Packard Model 35 Calculator—and the many other readers who submitted entries in this year's contest, we give our sincere thanks.

This year the category into which the greatest number of entries fell was "in-the-home" uses of electronics. These ranged from relatively simple burglar alarms to elaborate systems that monitored everything from the condition of the furnace filter to water on the basement floor. One even monitored all outside weather conditions and reported the measurements at a central location within the home.

Another popular category was the digital measurement and display of time. Entries for the timing of model-car races, official road rallies and the taking of birth control pills were received. As with last year's contest, many electronic games were also received.

One thing that stood out this year was the catchy and very descriptive names that many designers gave their entries. Names such as "The Pizzazziest Automatic Garage Door in Your Neighborhood," "The Hunters Hailer," and "The Automatic Integrated Drinking Equipment (abbreviated AIDE)" were almost the rule rather than the exception. This proves, at least to us, that engineers are more promotional minded than many people think.

EDN would like very much to present the complete entries of all the contest winners, including schematics and circuit descriptions. Due to the extensive nature of many of them,

The Winner

This year's happy winner, Edward Erwin, is an engineer with Western Electric Co. in Dallas. Ed is involved in the design and fabrication of custom test equipment used for production testing of apparatus built at the Dallas plant. The test equipment is usually computer controlled and generally one-of-a-kind.

Prior to joining Western Electric, Ed was with General Electrodynamics designing video cameras, and before that with the Microwave Division of Collins Radio. He received his BSEE from A & M University.

Ed lives in Dallas with his wife and two daughters, Jeannie Kay and Stephanie Lynn. In his spare time, he keeps busy at his two hobbies: home electronics and antique cars. He is currently restoring a 1931 Ford Model A coupe.

Home electronic projects have included a stereo system of his own design, a digital clock, a television camera and a tune-up dwell-tachometer. Currently, Ed is building a 32-track stereo unit on a quadraphonic reel-to-reel tape recorder.

All the winners

Grand prize

Edward A. Erwin Design Engineer Western Electric Co.	Digital calendar and display

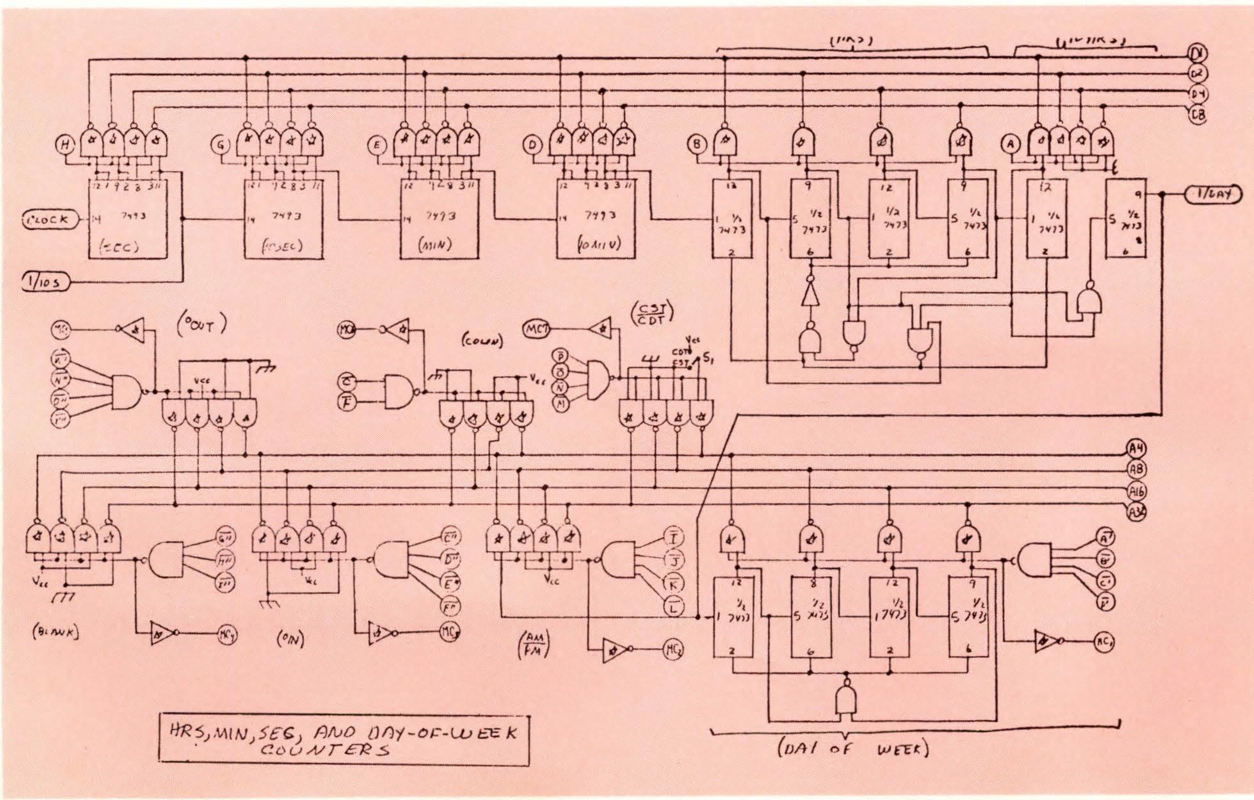
Runners up

Ralph E. Bell Senior Engineer Bendix Aerospace	Instant pulse beat counter
Terry Benson Senior Engineer Digital Products	Five-tac-toe—a game of semi-skill
Charles H. Briggs Instrumentation Engineer General Electric Co.	Analog function generator
David B. Brown Member, Technical Staff Bell Laboratories	Receiver selection system for space diversity FM reception
Sam Butt Group Leader Asto Communication Lab.	Precision mini W-L-T instrument
David B. Hallock Engineer Collins Radio	Car finder system
Donald J. Propp Electrical Product Engr. Ohio Medical Products	A look at the American home—1980
Gary Reininga Engineer Itel	Electronic calendar and birth control pill computer
Steve Sarns Consulting Engineer	A bio-feedback EEG synthesizer
Waller M. Scott Project Engineer NuTone Co.	Remote environmental data center

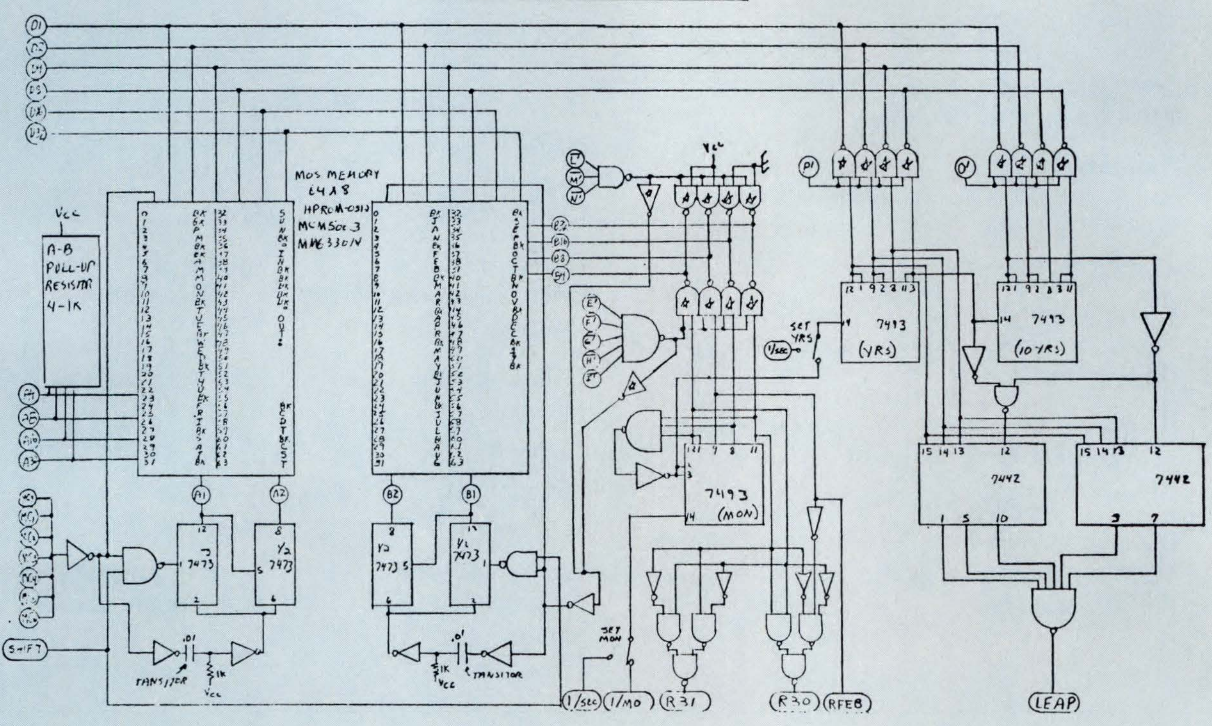
though, this is impossible. However, in addition to the material presented here, we will attempt at a future date to publish abbreviated, but useful, versions of most of them.

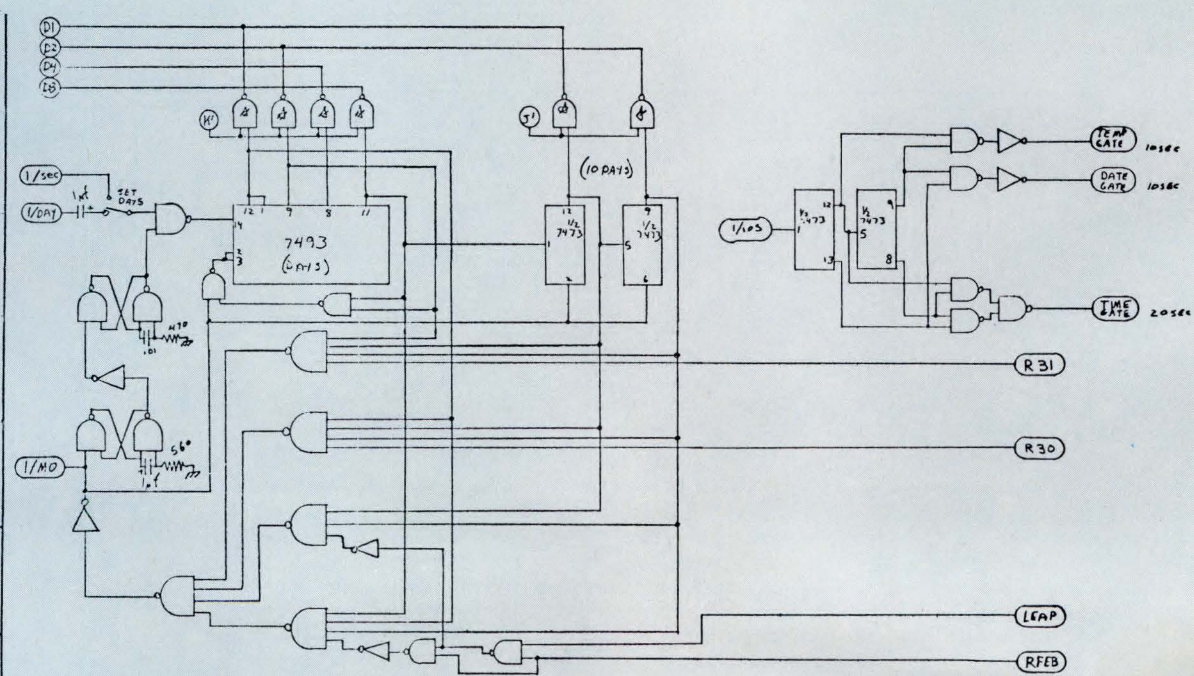
The winning entry

The digital calendar and display device is a completely self contained unit that displays the time of day, the calendar date, day of the week

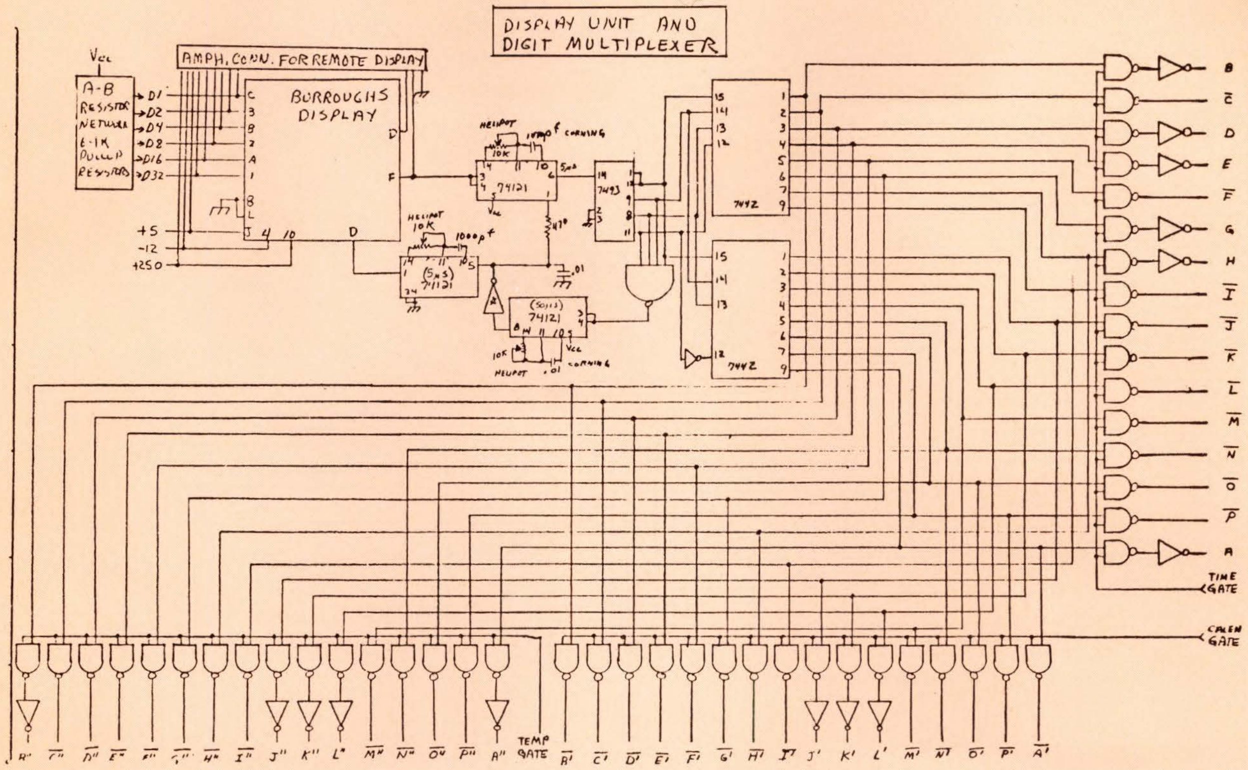


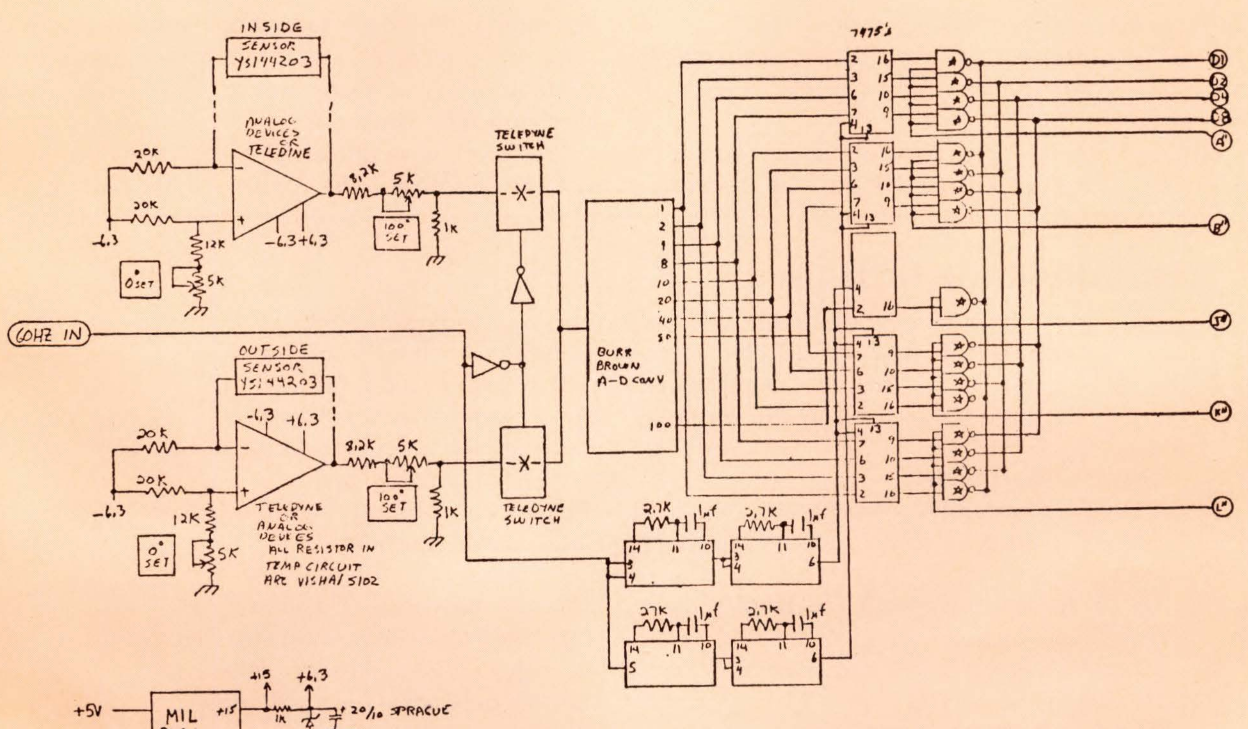
MONTHS & YEARS COUNTER



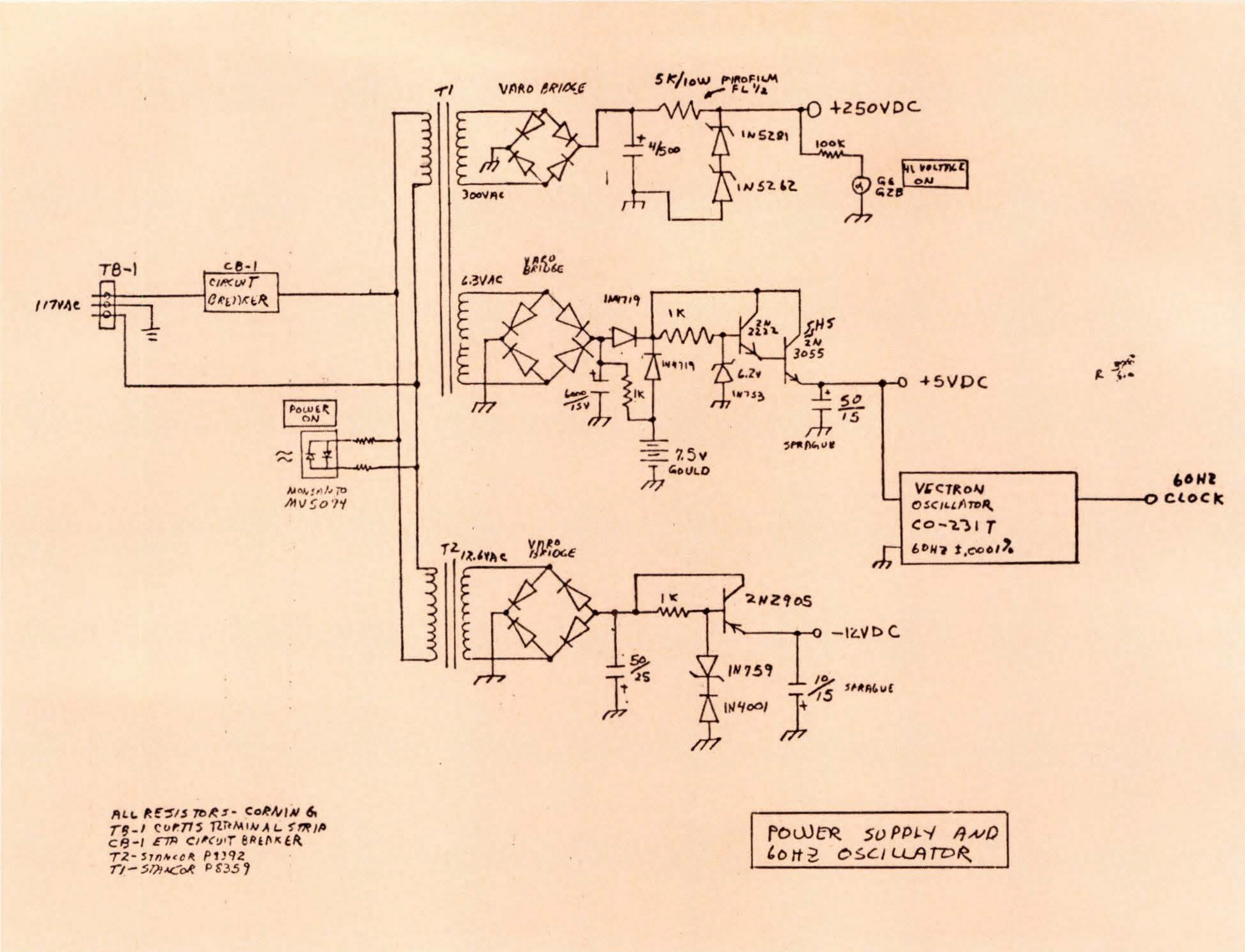


MESSAGE MULTIPLEXER AND DAY-OF-MONTH COUNTER





DUAL STATION DIGITAL TEMPERATURE CIRCUITRY



and the inside and outside temperature.

Internal batteries are used to provide redundant power for the counting circuits in case of power failure.

Display messages occur in successive time intervals. Time is displayed for 20 seconds, followed by the day of the week and the calendar date for 10 seconds, and finally inside and outside temperature are displayed for 10 seconds. Then the sequence starts over.

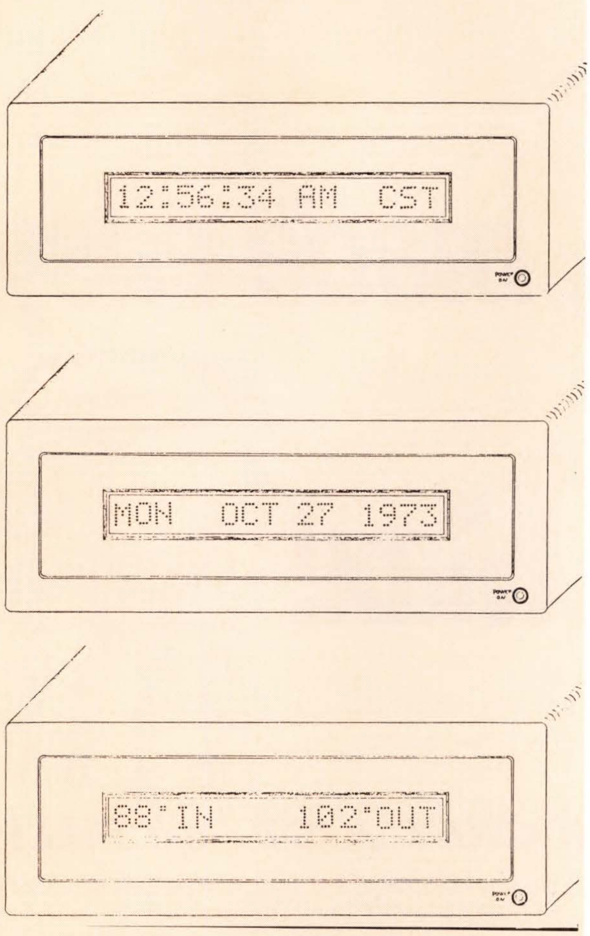
Provision is made on the rear panel for two remote displays. The switches for setting the

Advertised products used

One of the criteria for judging the contest was the number of products advertised in the Jan. 5 issue of EDN that were used in the design. Here are those used by the winning entry.

Display—Burroughs
ROMS—Monolithic Memories
Circuit protector—ETA Products of America
Dc-to-dc converter—MIL Electronics
Switches—McGill
Rectifiers—Varo Semiconductor
IC packaging—EECO
Terminal blocks—Curtis
Sockets—Cambion
Indicators—Monsanto
Clock oscillator—Vectron Labs.
Lamps—General Electric
Connector—Amphenol
A/D converter—Burr-Brown
D/A converter—Burr-Brown
Analog switches—Teledyne Crystalonics
Trimmers—Beckman
Resistors—Corning
Capacitors—Corning
Capacitors—Electrocube
Resistor networks—Pyrofilm
Tantalum capacitors—Tansitor Electronics
Resistors—Vishay Resistor Products
Pull-up networks—Allen-Bradley
Linear IC—Analog Devices
Dc-to-dc converter—Semiconductor Circuits

TYPICAL DISPLAY MESSAGES



various display messages are also on the rear panel.

Standard-time or daylight-time indication is switch selectable at the rear panel. In addition, the two temperature probes can be placed at any location by the user.

The calendar uses primarily TTL logic, except for two MOS memory units that provide storage for repeated messages. All power voltages are regulated for line fluctuations from 90-130V ac, with total power consumption being about 12W. The back-up battery logic supply will last about 2 hours, and can be recharged in 24 hours by the internal-charging circuit.

BCD outputs of any or all data can be supplied on the "data-output" connector on the rear panel. This data is TTL compatible.

The unit can be packaged in a case 10 in. wide x 3 in. high x 9 in. deep. Estimated hardware costs are about $300. □

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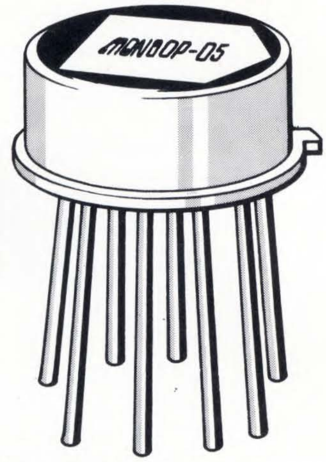

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High-speed, high-resolution A/D converters: here's how

Two advanced concepts, VAROM and "sampling-on-the-fly", are combined to avoid many limitations of conventional designs.

David Benima and **James R. Barger,** RCA

High-speed, high-resolution A/D conversion forms the bridge between the analog world of sensor data, video and audio communications and radar signals, and the fast, powerful world of the digital computer. The computer can now apply a measure of sophistication and flexibility to the processing of analog information far beyond what can be achieved with analog tools alone.

In studying the possibilities and limitations of the wideband, high-resolution A/D conversion process, several advanced concepts have evolved. Two of these, the VAROM concept, and the related innovation of "sampling-on-the-fly" will be discussed.

Conventional conversion techniques

In conventional A/D converter systems, the analog voltage is first measured, and the measurement result is then used to generate a digital output. In the VAROM system (voltage-addressable read-only memory), all the possible digital outputs are already present and stored in a read-only memory. The conversion process then consists of using the analog voltage to select the address that contains the proper digital output.

"Sampling-on-the-fly" refers to the measurement of an electrical signal while it is changing, in contrast to the conventional method of first converting the signal to be digitized to dc and then performing the measurement on the latter.

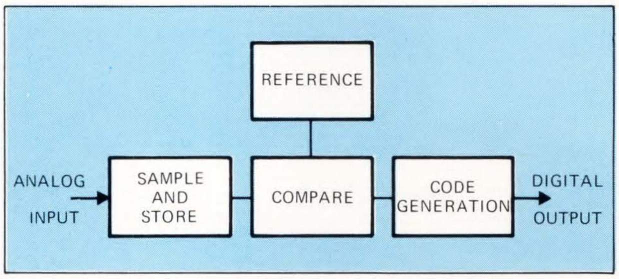


Fig. 1—The most elementary A/D conversion process makes use of a sample-and-hold circuit, a comparator and a code generator. In practice, few converter systems are quite this simple.

A closer look at some aspects of the conventional A/D conversion process is necessary to appreciate the significance of these two new concepts. **Fig. 1** is a simple flow chart of the elementary conversion process. Few systems are quite this simple. Usually, the conversion takes place in two or more steps, as shown in **Fig. 2**. Step conversion involves the added complication of a conversion back to analog form followed by a subtraction. The additional complication is generally more than offset by a reduction in the converter hardware, however.

At substantially higher conversion speeds, the

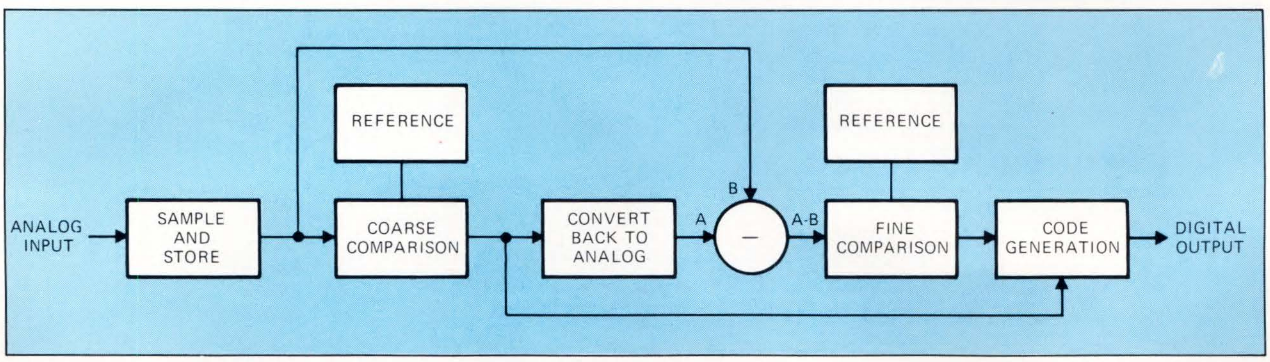


Fig. 2—A/D conversion flowchart using two steps involves the added complication of a conversion back to analog form, followed by a subtraction. The additional complication is generally more than offset, however, by a reduction in the A/D converter's hardware.

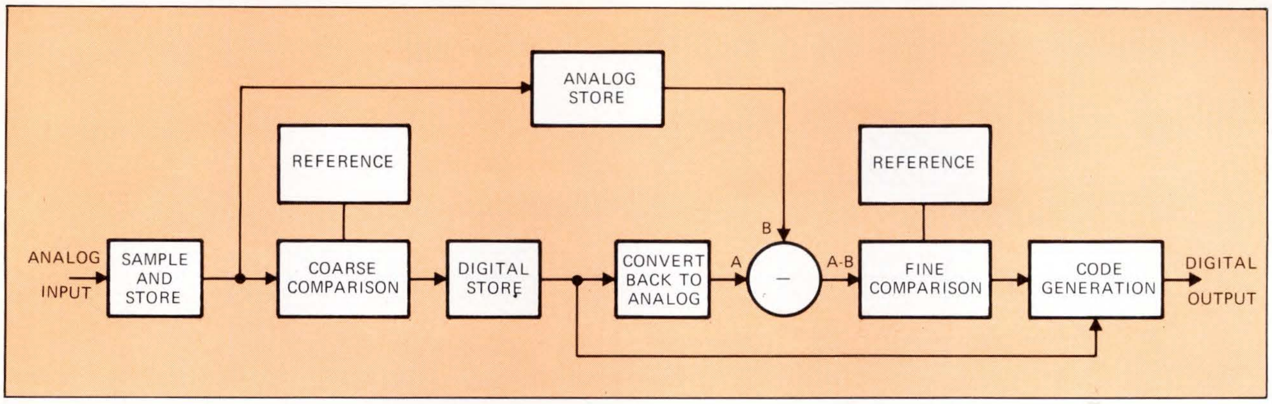


Fig. 3—For high conversion rates, 2-step conversion with overlapping operations is used. All systems with conversion rates of 20 MS/sec (20 megasamples per second) or higher use this approach.

difference between 1-step and multi-step systems becomes significant. When the conversion rate increases, the time available for each conversion shrinks, and it becomes impossible to carry out the entire multi-step conversion process in one conversion period (the time needed between two successive samplings). In that case, consecutive conversions must be overlapping.

A flow chart for a conversion process with overlapping conversion is shown in **Fig. 3.** All 2-step conversion systems with conversion rates of 20 MS/sec (20 megasamples per second) and higher are of the general type shown in **Fig. 3.**

Limitations of conventional techniques

By referring to the flow chart of **Fig. 3,** one can easily identify the weaknesses of the 2-step conversion process when high-conversion rates, required for handling high-frequency signals, are encountered. The D/A conversion and the second analog store are sources of considerable error, particularly at high speeds. However, the largest source of error is from the very first circuit operation of sample-and-hold. In fact, any sample-and-hold operation is subject to a so-called "tracking" error. This error is due to fundamental electrical laws and simply cannot be eliminated by improved design.

The "tracking" error can become prohibitively large at higher speeds. The exact magnitude of the error depends on the history of the signal. For a 50-MHz sine-wave signal, the error will vary between ±11% for example.

Fig. 4 shows the general model for a sample-and-hold circuit. Waveforms associated with the operation of such a circuit are shown in **Fig. 5.** Note that the switch in **Fig. 5** opens and closes periodically. When the switch is closed, the holding capacitor, C, charges toward the analog input signal and follows or "tracks" the signal. When the switch opens, the capacitor retains the voltage as it was at that instant. It is this unchanging voltage that is measured in the conversion process.

The unavoidable series resistance, R, in any realizable switch, in conjunction with the holding capacitor, creates a time constant RC which slows the tracking of the signal by the capacitor, and results in a lag which is of the order RC(dV/dt), where RC is typically 1 nsec. The result is a large tracking error when dV/dt is large, as is the case for wideband signals.

The VAROM concept

The sample-and-hold tracking error can be eliminated only by removing the capacitor—that is by not immobilizing the signal, but rather by measuring the signal while it is changing. This technique rules out the use of any 2-step process and poses the problem of measuring a signal accurately while it is changing at an exceedingly fast rate. **Fig. 6** illustrated how this can be accomplished using strobed comparators in a VAROM configuration.

The operation is remarkably straightforward. Each of the 2^n subranges which together make up the total signal range is served by a comparator. **Fig. 6** shows three comparators of a column which contains 2^n comparators. The output of each comparator can be frozen in its instantaneous

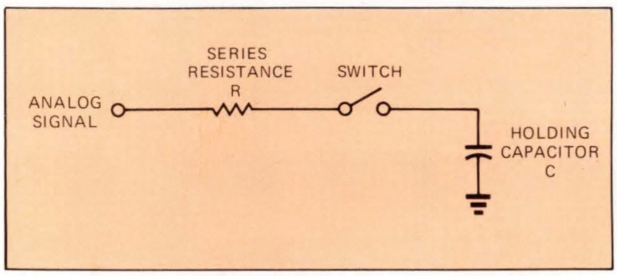


Fig. 4—A sample-and-hold circuit in A/D conversion systems can be represented by this equivalent circuit. The circuit's unavoidable series resistance, R, in conjunction with the holding capacitor, C, creates a time constant RC which slows the tracking of the signal by the capacitor and results in a lag which is of the order of RC(dV/dt). This tracking error gets larger for wider-bandwidth signals.

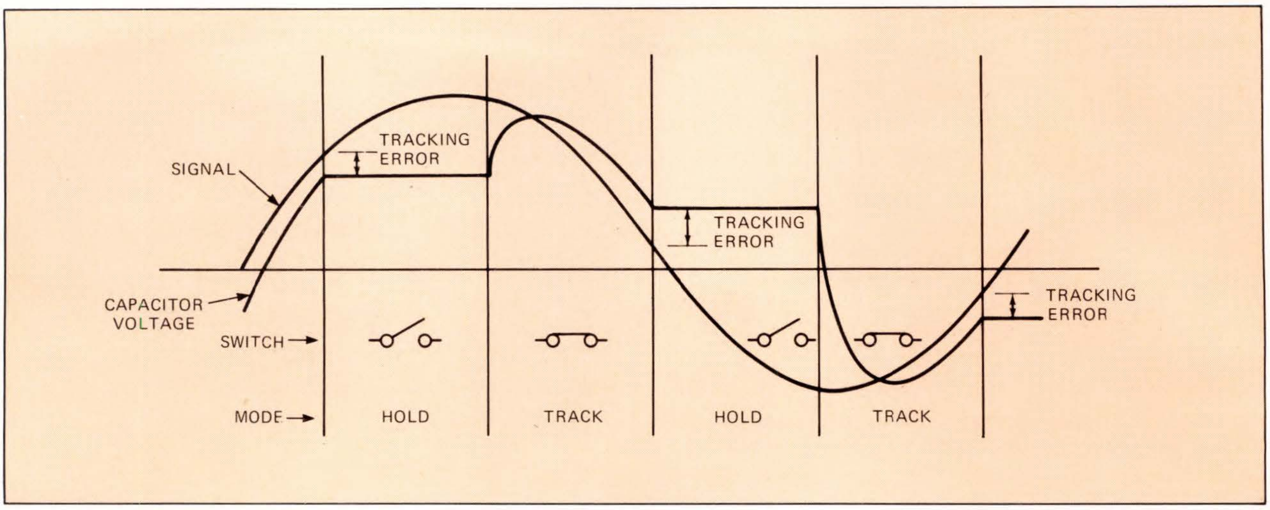


Fig. 5—Tracking errors can result in a sample-and-hold circuit due to the time lag in the holding capacitor's response. This tracking error is of a fundamental nature and cannot be reduced beyond a certain limit.

state by means of a strobe. If, at the time of strobing, the signal value is between reference level n and reference level n+1, the comparator outputs will be such that only gate n has a high output. This high output selects word n from the read-only memory (ROM), and this word contains the proper output code for a voltage with a value between reference level n and n+1.

Sampling-on-the-fly concept

As simple as it is, the combination of the VAROM concept and the sampling-on-the-fly approach affords a much higher speed and much higher resolution conversion, in principle, than any of the conventional multi-step sample-and-hold systems.

While avoiding many of the problems inherent in previous systems, the new approach is not a cure-all, but rather has its own peculiar difficulties. These new difficulties are expected to yield

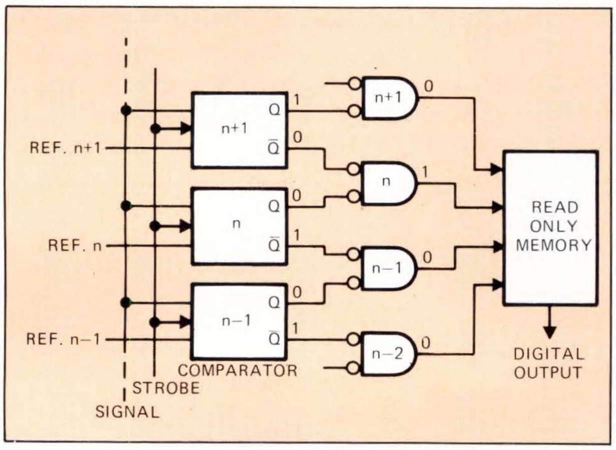


Fig. 6—Sample-and-hold circuit tracking errors can be eliminated by using strobed comparators in a VAROM (voltage-addressable read-only memory) configuration. Shown is a section of VAROM with the "sampling-on-the-fly" principle (for a signal value between reference levels n and n+1). This technique of measuring a signal while it is changing eliminates the inherent weaknesses of the 2-step conversion process.

to technical improvements. The tracking error and other faults in conventional sample-and-hold systems are of a fundamental nature and are irreducible beyond a certain limit.

The most serious problem of the sampling-on-the-fly concept is the spread in strobing times of the comparators (of which there are 2^n for an n-bit converter). This spread gives rise to a so-called "aperture" error, which is a fluctuation in the time of sampling. Such a fluctuation detracts from the resolution of the converter and the effect is more severe as higher frequencies are being processed.

It can be shown that beyond certain levels of resolution and speed, special alignment procedures are needed to ensure that strobing times fall within a sufficiently narrow range. The refinement of these procedures is one area that is currently under investigation.

The VAROM concept tends to compare unfavorably with conventional sample-and-hold systems in power consumption and in the number of components used. The basic simplicity of the VAROM structure, however, allows packaging economies which can offset its higher component count.

Modular packaging allows for expansion

Both the VAROM and the sampling-on-the-fly principles are embodied in a 30-MS/sec, 7-bit/S (30 megasamples per second, 7 bits per sample) A/D converter built at RCA's ATL (Advanced Technology Laboratories) as shown in **Fig. 8.** The converter's block diagram is shown in **Fig.7.** A practical way had to be found to interconnect the converter's 128-word ROM and comparator logic.

Fig. 8 shows the elegant solution of this problem, an SOS (silicon-on-sapphire) ROM[1] measuring 55 × 58 mils and containing only 8 word lines which are coded with a fixed pattern.

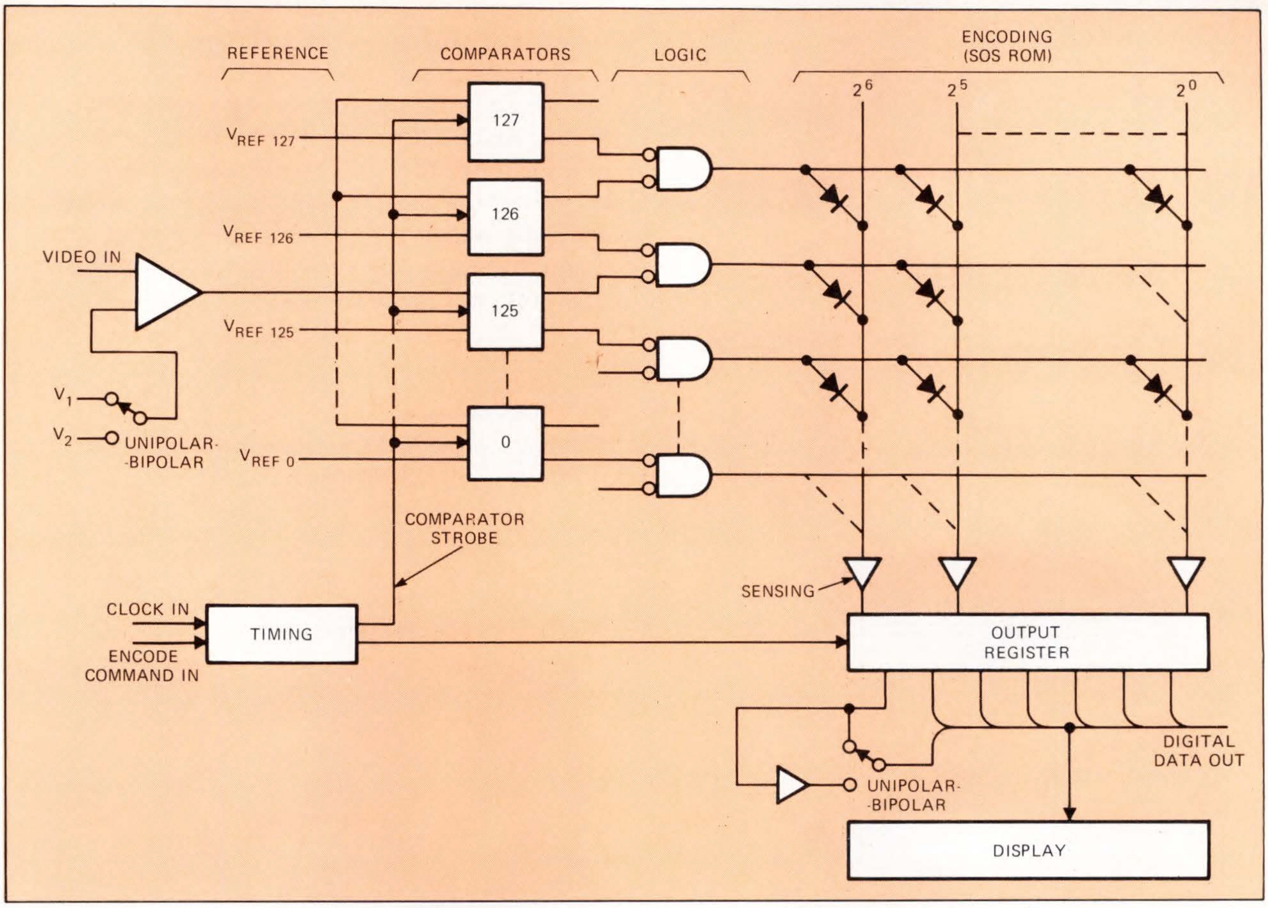


Fig. 7—This 30-MS/sec, 7-bit/S (30 megasamples per second, 7 bits per sample) A/D converter circuit block diagram embodies the latest conversion advancements of VAROM and "sampling-on-the-fly".

This chip is mounted on a thick-film substrate which also contains 8 comparators (4 Motorola MC1650 chips) and 8 logic gates (2 Motorola MC1663 chips). The substrate[2] is mounted in a 30-lead beryllium-oxide package measuring 0.8 × 1 in. This package constitutes almost a complete 3-bit A/D converter. Eight of these packages are mounted on a pc board, and two of these boards comprise the bulk of the 7-bit converter.

It is interesting to note that all the packages are completely identical, including the one for the SOS ROM. The 128 different output codes are derived from the one fixed code produced within the 3-bit packages by discretionary wiring.

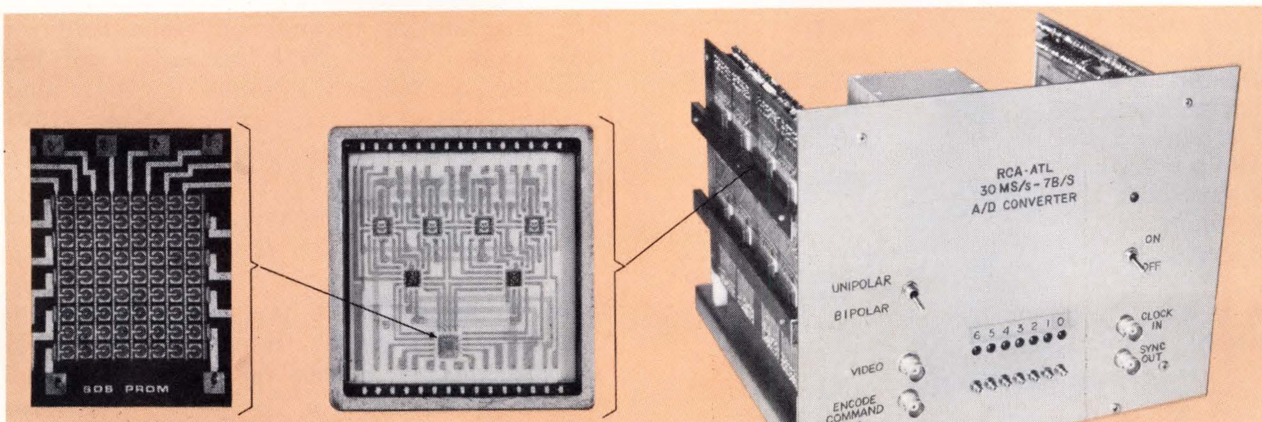


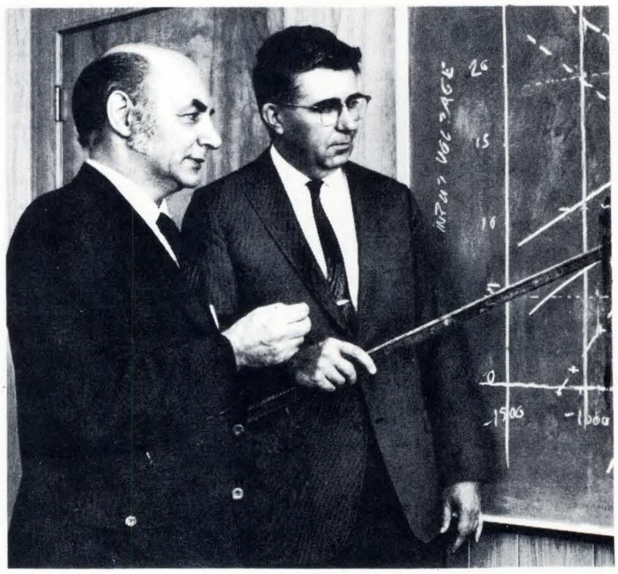
Fig. 8—The complete 30-MS/sec, 7-bit/S A/D converter built by RCA's ATL (Advanced Technology Laboratories) uses the VAROM and "sampling-on-the-fly" concepts (right). The converter measures 8 × 9 × 7 in. and dissipates 50W. At left is the converter's 3-bit hybrid chip (shown 3.5X actual size). The center photograph is that of the SOS (silicon-on-sapphire) 128-word ROM chip (shown 36X actual size of 55 × 58 mils) used in the converter.

This highly modular packaging concept is well suited for expansion. In fact, the 3-bit modules used in the present converter and the pc boards on which they mount, contain redundant elements which allow them to be used without any modification for a 512-comparator, 9-bit converter. Future designs are aimed at increasing the sampling rate to 100 MS/sec, and the resolution to 8 and 10 bits, while reducing the power dissipation and package size. □

References

1. Produced by the RCA Laboratories, Princeton, NJ.
2. Made by MET, Somerville, NJ.

Authors' biographies



David Benima (left) received his BEE from the Delft Institute of Technology, Netherlands in 1954. From 1954 to 1959 he worked for the University of Toronto Computing Center and Remington Rand Univac. He then joined RCA's Information Systems Div., going on to the Signal Processing Laboratory of ATL where he is working on logic and memory techniques for high-speed A/D conversion.

James R. Barger (right) received his BEE from Ohio State Univ. in 1952, from which time he has been with RCA. In 1966 he joined the Signal Processing Laboratory of ATL where he has since contributed to circuit designs for speech-recognition systems and an Automatic Magnetic Anomaly Detection (AMD) unit. Mr. Barger is a member of IEEE and has been awarded two patents.

Stan Harris of Analog Devices speaks out on the real world of the 741

Engineers may treat 741 op amps as interchangeable, off-the-shelf, standard items. They do so at their own risk.

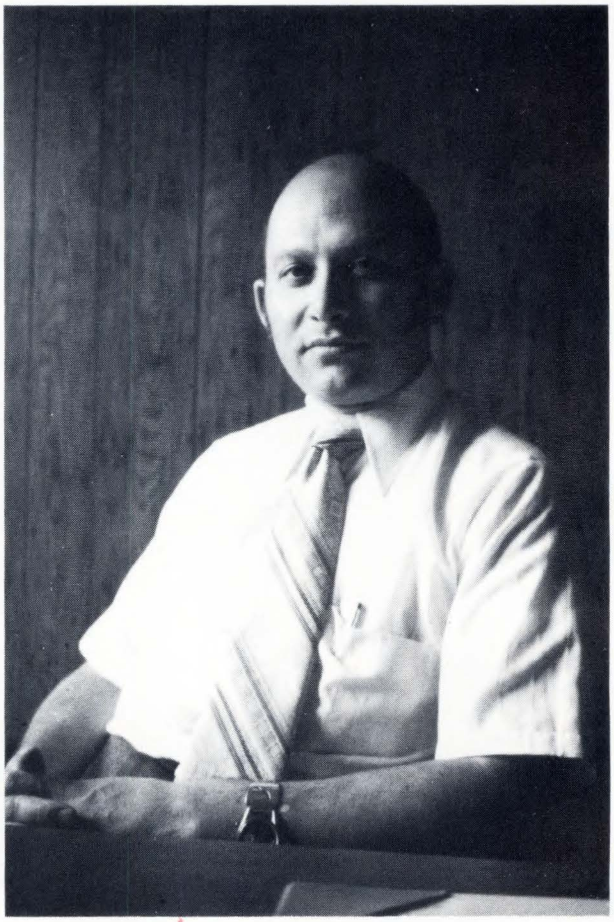
All you 741 users.....You take it pretty much for granted, don't you...that a 741 is a 741 is a 741, and pretty much the same from all the suppliers—get the cheapest price you can...and use 'em in places where you used to use transistors. Right? ....Not quite!

Let's quickly trace the history of the 741 (and throw in a few observations and facts that might help illuminate the way). Its origin is buried somewhere in the new-product files at Fairchild, but it isn't inconceivable that the 741 may have started as a case of one-upmanship. Remember...upstart National was challenging Fairchild in linear ICs and had announced the 101 series as a second-generation replacement for the Fairchild 709. How to respond? Let's see....the 101's I_b, I_{os}, V_{os}, Gain, CMRR specs are all pretty good...nothing there. Got it! The 709 uses three external compensating components; the 101 uses one. We won't use any...voilà—the 741, and we don't even have to improve specs.

Sharp product marketing or one-upmanship? In a competitive situation, maybe they're one and the same. Anyway, it really doesn't matter.

The 741 rapidly became the most popular IC op amp around (although the 101A series—successor to the 101—isn't far behind). Time passes...the first alternate source...and the second... third... fourth in rapid succession, until now there are...how many suppliers? Fifteen? Twenty?

Curious thing about all those 741 suppliers. Some of them make a pretty good 741; some of them make a pretty bad 741; and some don't make a 741 at all. This conclusion isn't just a qualitative feel...there's hard engineering data to back it up. We can distinctly remember one of our own engineers prefacing the results of his evaluation of a competitive 741 with..."It's a good op amp, and if I were still designing systems, I might even use it. But it sure isn't a 741".



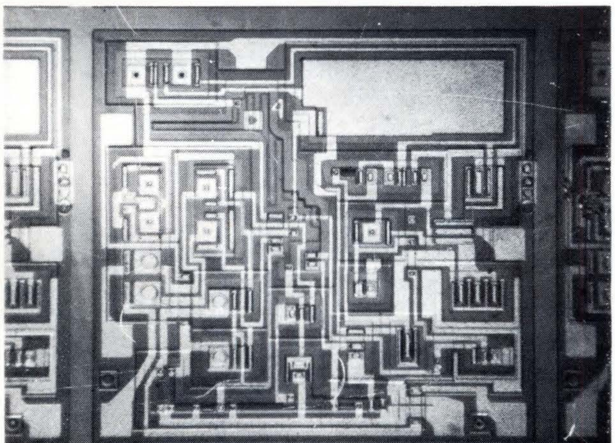
Call it product improvement, lack of manufacturing control, or just IC design license, but there are enough processing and design variations around to strongly suggest a policy of Caveat Emptor on your next "standard" 741.

For instance...Noise. And by noise we mean popcorn noise; the erratic jump of bias current between two levels at random intervals. There are several manufacturers, big and small, whose 741s have a pretty low percentage of popcorn noise units. On the other hand, there are about an equal number, also big and small, who supply lots of 741s with popcorn noise whose scope traces run as high as 150 μV(p-p) with 100 kΩ source resistance (150 μV/100 kΩ = 1.5 nA). Now noise is a phenomenon that is process oriented and varies from lot to lot...but, in general, the manufacturers who supply low noise 741s are always pretty good, and those who don't, aren't.

Then there's ac performance. Of late, we've seen several claims about so-called "fast" 741s. It turns out, if you look a little deeper, that it all involves the thickness of the compensating capacitor's oxide layer (dielectric). The thicker the oxide, the fewer the pF's, and the faster the 741. Nothing magical, or perhaps even by intent, because a number of manufacturers make 741s that slew at greater than 0.5V/μsec...which is up in the "fast" area. We've seen one 741 with a slew rate well above 1.0V/μsec and a 2.0 MHz bandwidth. There's not much publicity about it though. The phase margin is thin enough to make it oscillation-prone.

And then there's V_{os} drift. Even though it's not specified on the 741 and 741C data sheets, $\Delta V_{os}/\Delta T$ has got to be of interest to most knowledgeable users. Unfortunately, the practice of nonspecification, perhaps justifiable from a competitive price standpoint, deprives users of a highly desirable spec. However regrettable, it is an economic necessity: if you don't have a max $\Delta V_{os}/\Delta T$ spec, you don't have to reject a 40 μV/°C unit for not meeting a 20 μV/°C limit.

The dilemma for the good guys is: if you have a process that can usually be depended upon to produce a large proportion of $<$10 μV/°C units, how do you give your customers the benefit of the better specs, still remain price competitive, and maintain some protection against poor yield days. Needless to say, it can be done. As is the case with noise, some manufacturers supply 741s with good V_{os} drift characteristics, which means tight distribution below 20 μV/°C. (And then there are those whose 741s drift up to 40 μV/°C with alarming regularity.) Those with the good devices...and the confidence to go with them...offer versions of the 741 with a max. drift spec, at a price that is warranted by the benefits of not only a $\Delta V_{os}/\Delta T$ spec, but usually other significantly improved parameter guarantees.



And here it is, the ever-present 741 op amp. You can't tell what you're getting from a microphotograph, either.

A last word on V_{os} and $\Delta V_{os}/\Delta T$. If the 741 had a simple differential pair as its input stage, then V_{os} trimming would tend to improve the V_{os} drift performance (by about 3.3 μV/°C/mV_{os}). But the 741 has six transistors and two resistors in its front end, which make things complex enough so that the above relationship doesn't necessarily hold, and further that the artificial unbalancing that you do when you trim the V_{os} may considerably increase the V_{os} drift. On the other hand, it may improve it . . . but remember, Mr. Murphy once wrote a law which said '..................' A reasonable solution is to use a 741 that is guaranteed to have low initial V_{os} (say 0.5 to 1.0 mV), because then the 3.3 μV/°C/mV_{os} relationship may more closely approximate the real situation, and less V_{os} to trim means less $\Delta V_{os}/\Delta T$ will be induced.

Back to history. The laws of supply, demand, market elasticity, and all that being what they are, the average selling price of the 741 dropped... from $10 to $5 to $1 to $0.60.

Those of us who work for profit-making organizations are generally aware of such things as average selling price (A), manufacturing cost (M), and profit margin (P). If A goes down pretty rapidly (as in the case of the 741), then M must go down equally fast to keep P where it's supposed to be. Sometimes, to keep M coming down, a highly motivated production manager might find it necessary to omit certain manufacturing-cost items, such as 100% testing, or relax the test-limit guard bands, or loosen the AQL at outgoing Q.C. Don't scoff...it happens!

If production efficiencies that are normally realized by moving up the learning curve don't occur, then corner-cutting is sometimes the only way to keep the profit margins reasonable. Which may help to explain why, as the price of the 741 has decreased, so has its quality, as indicated by increased lot rejection at the user's incoming Q.C. and more field failures in his systems. (An ethical comment here. By no means is this all the fault of the IC manufacturer. Remember, it takes two to create a purchase, and there can be a relatively fine line between cost-conscious buying and the lowest-price-always-gets-the-order attitude that fuels price wars. But then, that's ethics...not op amps.)

	CHARACTERISTIC	SHOULD BE/SHOULD HAVE
(1)	Offset Voltage Drift: 0 to +70°C; −55 to +125°C	$< 20\mu V/°C$; $< 30\mu V/°C$
(2)	Offset Voltage Null Range	10 to 35mV
(3)	Offset Voltage Nulling	(a) minimal degradation of gain (b) minimal induced change in offset voltage drift
(4)	Short Circuit Current	15 to 40mA; able to withstand shorts to ground or either supply voltage
(5)	Voltage Noise (0.1Hz to 10Hz)	$< 3\mu V$(p-p); < 3% exhibit popcorn noise
(6)	Gain @ +25°C: $R_L = 2k\Omega$, $V_{out} = -10V$	20k min (741C); 50k min (741) (Most all 741s meet their min gain spec swinging high positive output voltages; some do not at high negative output voltages.)
(7)	Dynamic	(a) able to drive 1000pF without oscillating (b) small signal bandwidth of 1.0MHz ±20% (c) slew rate of $0.5/\mu sec$ ±50% (d) reasonably glitch-free step response

741, 741C esoteric characteristic check list. A proper evaluation of a 741 (or any device, for that matter) should start with a confirmation that the device meets its published minimum and maximum specifications. Beyond that, the evaluation enters the less well-defined area of general-operating characteristics. As an aid to the daring engineer who wishes to delve into performance not specified on the 741 data sheet, this guide (by no means complete) is presented. While devices that do not meet these requirements may still be perfectly usable 741s, they should not be considered as favorably as those that do.

Because the cost of lower quality is far more than a few pennies per unit, the smart user no longer buys 741s on price alone, but considers variations of the 741 that are a cut (or several cuts) above the average in performance, pays a somewhat higher-than-rock-bottom price, and gets the better reliability permitted by a reasonable profit margin.

Several IC manufacturers offer versions of the 741 that...because of a higher average selling price...can profitably maintain high quality standards. And the considerably higher accuracy provided by these circuits allows the user to update his system's performance at the same time.

Where does this all lead?

To a sober realization that many design engineers, component engineers and buyers tend to regard their use of a 741 as one regards breathing, or the ticking of a clock. That is, they don't pay much attention at all...until breathing gets difficult, or the clock stops...until the old reliable 741 they were so familiar with is no longer reliable or even very familiar...or their apparent cost saving due to the 741 price war isn't really a saving. Nor will they pay attention until finally the new supplier's 741 doesn't act as it should and they decide that their new design could use a little more accuracy than the "standard" 741 gives.

So...all you sober, industrious, and intelligent designers...shop around, but look hard—for a 741 may not be a 741 may not be a 741 may not be... □

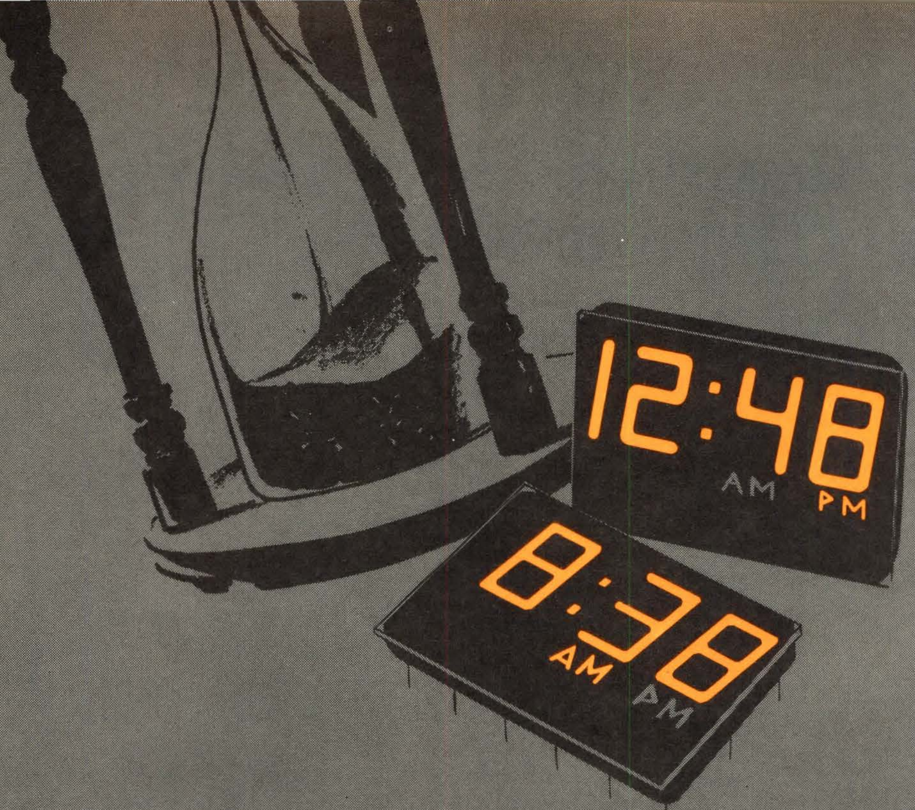
Who is Stan Harris?

Stan Harris is the Microcircuits Marketing Manager for Analog Devices Inc., a position he has held for the past three years. He is responsible for directing Analog's marketing of linear ICs.

Mr. Harris was previously employed by Computer Microtechnology as Eastern Regional Sales Manager for one year and by Transitron for four years as West Coast Sales Manager and Marketing Manager for Integrated Circuits.

He graduated from Cornell Univ. in 1956 and received his BEE. In 1963 he received his MBA from Northeastern Univ.

A native of Mattapan, MA, he presently lives in Lexington, MA with his wife, two children and a dog. When he's not thinking about ICs he's a Little League baseball manager, amateur photographer and art collector.



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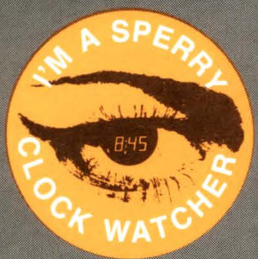

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Get better price/performance from electrical contacts

Don't choose contacts blindly. Familiarize yourself with the various contact materials and construction methods and become a wiser specifier.

J. Porter Duell, Jr., Deringer Manufacturing Co.

To many engineers, electrical contacts are much like personal health: not thought about very much until they fail. And when such failures occur, all too often it is found that the contacts were not the optimum type for that particular application.

How, then, do you choose the best contacts for a given application? Data such as that given in **Tables 1** and **2** is extremely useful, but is by no means the last word. Since the choice involves not only materials and design, but also manufacturing processes as well, it is obvious that the contact manufacturer is the best source of complete information. The user himself, though, can substantially reduce his contact problems by becoming familiar with the ways in which materials and design affect contact performance.

Silver is used most

Fine silver is the most extensively used contact material. It has the highest electrical and thermal conductivity of any metal, is corrosion resistant and can be readily fabricated into a variety of contact shapes. If the contact application requires a light closing force and low contact resistance, fine silver is ideal.

Silver is recommended for sensitive contacts under light or medium pressure. As long as current and voltage are not excessive, it will operate satisfactorily for long periods. When circuits are closed, silver will carry reasonably high-current loads without excessive heating because of its high electrical conductivity. In addition, its high thermal conductivity will dissipate circuit arc energy without excessive temperature increase or detrimental effect on the silver contact.

On the negative side, silver has a low-melting point, is soft, and under certain conditions may pit and transfer. A sulphide surface will also form in sulphurous atmospheres, causing high contact surface resistance. Combining silver with metals such as cadmium, copper, nickel, palladium, zinc, manganese, platinum, iron, etc., will overcome these disadvantages, and may even enhance some inherent characteristics.

For example, coin silver (10% copper) is used for applications requiring harder material, and is less expensive than fine silver. A light oxide film sometimes forms on this alloy, so a higher closing force must be used to break it down. Electrical and thermal conductivity are lower than for fine silver, but still high enough for high-current carrying capacity and good heat dissipation.

In many applications, silver and its alloys—including silver-cadmium alloy—have been replaced with silver-cadmium oxide. The result is higher current capacity without any increase in size or, conversely, retention of the same rating with a reduction in size. Silver-cadmium oxide combines silver's high conductivity with cadmium's resistance to arc erosion. Its ability to resist sticking or welding is better than that of fine silver and many other silver alloys, even though its melting point is the same as that of fine silver.

Generally, as the percentage of silver in a material decreases, contact force should be increased. With silver-cadmium oxide, the contact pressure required is considerably lower than for many silver alloys, but slightly higher than for fine silver.

Besides the above mentioned advantages, plus lower cost, silver-cadmium oxide increases the contact current rating up to 200% and in some cases more, and will withstand high contact temperatures. Low contact resistance can be maintained even after long use and many operations. Silver-cadmium oxide is available in a composition range, by weight, of up to 16.8%, and thickness can be controlled to meet service requirements of each application.

Platinum is highly reliable

When absolute reliability is essential, particularly for extremely-sensitive low-voltage applications, platinum and its alloys are generally used. This metal has a high melting point (3217°F), high corrosion resistance and good resistance to sticking and arc erosion.

Pure platinum is relatively soft, so it is often alloyed with irridium to improve wear resistance. Other alloys used in varying percentages are osmium, palladium, rhodium and ruthenium. Because of platinum's low electrical conductivity, it is ideal for applications where low voltage, low level and dry-circuit loads, and light contact pressure are required.

Besides its other advantages, platinum maintains initial contact resistance throughout contact life under extreme environmental conditions. Typical uses are in aircraft gauges and instruments, alarms, auto clocks and gauges, electrical instruments and meters, medical apparatus, relays and sensitive controls.

Palladium is similar to platinum

Another metal, palladium, resists corrosion and oxidation almost as well as platinum. It is suited to applications calling for low currents switched at relatively low voltages. A slightly higher contact pressure should be used than for platinum to overcome a tendency to tarnish in moist atmosphere and to oxide at high temperatures.

Palladium is the most economical, practical contact material for many applications since it has the lowest specific gravity and the lowest cost among platinum-group metals. It resists inductive loads and has excellent non-sticking characteristics. When alloyed with copper, nickel, platinum, ruthenium or silver, palladium improves hardness, reduces welding and increases service life. Palladium alloys are very similar to platinum alloys and a thorough comparison between both is mandatory to obtain optimum results.

Gold is oxide-free

Similar in characteristics to platinum, including corrosion resistance, is gold. It is oxide and sulphide free and requires relatively low contact pressures or closing forces. Its softness, however, does result in high mechanical wear. Improved hardness and tensile strength as well as higher melting point, are achieved by alloying gold with copper, irridium, palladium, platinum or silver. Chemical inertness is maintained even when alloyed.

Although gold alloys are lower in cost, somewhat higher contact pressures are required than with pure gold. Contacts made from gold and its alloys are most frequently used in low-current and voltage systems, such as sound circuits, sliding contacts and sensitive relays.

Tungsten and molybdenum are strong

Tungsten is stronger, harder and heavier than any other pure metal. It has high resistance to arc erosion, corrosion and pitting. In addition, it has low vapor pressure, is free from sticking or

Table 1 – Contact material applications*

	Reference Material Number Order of Preference (see Table 2)			
Aircraft:				
Instruments	8	7	4	3
Relays – light	18	26	38	20
medium	38	40	41	42
heavy	50	42	40	41
Appliances:				
Can openers	18	29	28	26
Clothes washers and dryers	18	38	26	28
Coffee makers	18	38	41	54
Irons	18	38	40	56
Ranges	18	22	38	42
Refrigerators	18	40	38	44
Toasters	18			
Automotive:				
Circuit breakers	38	42	29	35
Directional signals	38	53	29	26
Horn rings	18	26	29	53
Ignition	60	62		
Seat switches	29	38	26	41
Stoplight switches	29	26	18	36
Voltage regulators	29	26	60	41
Window switches	29	38	26	41
Burglar & Fire Alarms	13	1	4	10
Circuit Breakers:				
Air	51	49	47	48
Controls:				
Elevator	18	26	38	40
Lighting	18	38	17	35
Motor	18	38	42	35
Lift Trucks	38	41	42	50
Relays:				
Dry circuit	1	13	6	9
Light duty	18	58	22	26
Medium duty	35	38	40	42
Heavy duty	51	47	48	42
Telephone	13	4	3	2
Switches:				
Light duty	18	28	21	22
Medium duty	38	37	56	35
Heavy duty	42	41	40	38
Rotary	43	44	46	26
Wall	18	26	29	54
Telephone:				
Jacks	59	17	7	9
Relays	13	4	3	2
Thermostats	18	19	24	12
Toys	63	28	29	18
Traffic Signals	18	26	38	31
Vending Machines	26	29	18	38

*These materials have been used in the typical applications listed above, and are recommended for initial design and testing in similar applications.

welding, and has a very high melting point of 6170°F. Tungsten also provides good strength at high temperature in protected atmospheres and is slow wearing, even in heavy duty applications.

One problem with tungsten is oxide formation. However, its extreme hardness and strength often make it possible to use high closing forces or a wiping action to break through the oxide and reduce contact resistance. Tungsten is frequently combined with silver, copper and/or carbide to add high electrical conductivity to its high arc resistance.

Molybdenum is similar to tungsten in characteristics, but lower in density and melting point. It is used in applications involving lower electrical

Table 2 – Contact material characteristics

Reference Material Number (see Table 1 for applications)	Composition % by Weight	Electrical Conductivity % IACS	Melting Point °F
Gold And Gold Alloys			
1	99.9 min Au	77	1945
2	75 Au, 25 Ag	16	1885
3	72 Au, 26.2 Ag, 1.8 Ni	14	1870
4	69 Au, 25 Ag, 6 Pt	10	1885
5	50 Au, 50 Ag	45	1830
Platinum Metals And Alloys			
6	99.9 min Pt	15	3215
7	95 Pt, 5 Ir	9	3220
8	90 Pt, 10 Ir	7	3250
9	85 Pt, 15 Ir	6	3270
10	80 Pt, 20 Ir	5	3299
11	95 Pt, 5 Ru	5	3227
12	89 Pt, 11 Ru	4	3260
13	99.9 min Pd	16	2825
14	95 Pd, 5 Ru	8	2900
15	90 Pd, 10 Ru	6	3000
16	72 Pd, 26 Ag, 2 Ni	4	2520
17	60 Pd, 40 Ag	4	2440
Fine Silver			
18	99.95 Min Ag	105	1761
Silver Platinum and Silver Palladium Alloys			
19	97 Ag, 3 Pt	48	1800
20	99 Ag, 1 Pd	79	1762
21	97 Ag, 3 Pd	58	1790
22	90 Ag, 10 Pd	30	1830
23	75 Ag, 25 Pd	14	2030
24	60 Ag, 40 Pd	21	2240
Silver Copper Alloys			
25	92.5 AG, 7.5 Cu	88	1510
26	90 Ag, 10 Cu	88	1500
27	72 Ag, 28 Cu	84	1437
28	50 Ag, 50 Cu	75	1607
29	75 Ag, 24.5 Cu, 0.5 Ni	75	1441
Silver Nickel			
	Ag Ni		
30	95 5	95	
31	90 10	87	
32	85 15	80	
Silver Cadmium Alloys			
33	95 Ag, 5 Cd	60	1720
34	90 Ag, 10 Cd	47	1670
35	85 Ag, 15 Cd	35	1620
36	77 Ag, 22.6 Cd, 0.4 Ni	31	1560
Silver Cadmium Oxide Materials			
	Ag CdO		
37	95 5	84	
38	90 10	75	
39	90 10	74	
40	86.5 13.5	68	
41	85 15	65	
42	83.2 16.8	61	
Silver Graphite Materials			
	Ag C		
43	99.75 0.25	94	
44	99.5 0.5	90	
45	93 7	50	
46	90 10	40	
Silver Refractory Materials			
47	50 Ag, 50 W	60	
48	35 Ag, 65 W	50	
49	65 Ag, 35 WC	58	
50	50 Ag, 50 WC	48	
51	40 Ag, 60 WC	43	
52	35 Ag, 65 Mo	45	
Miscellaneous Semirefractory Materials			
53	Ag, MgO, N10	70	
54	90 Ag, 10 Fe	90	
55	99.7 Ag, 0.3 CaO	100	
56	90 Ag, 10 W	92	
Miscellaneous Silver Alloys			
57	Ag, Hg	100	1760
58	90 Ag, 10 Au	48	1780
59	75 Ag, 25 Zn	40	1300
Miscellaneous Materials			
60	Tungsten	31	6170
61	Molybdenum	33	
62	Equiaxed tungsten	31	6170
63	OFHC copper	100	1981

loads than can be carried by tungsten, but requiring more wear resistance than is provided with silver. Being half as heavy as tungsten, molybdenum is used where tungsten's higher density may be mechanically objectionable.

Both molybdenum and tungsten are also used in low-voltage, inductive circuits where little arcing is present.

Manufacturing processes vary

Contacts are made from solid or composite materials in one of four basic types: shank, weld, screw and stamping. The type selected reflects the assembly method used in subsequent operations. And since billions of contacts are assembled each year, the simplification of assembly is essential in any design. Thus, contacts are generally designed to mate a flat face against a radius. To eliminate any later need for part orientation, spherical rather than cylindrical radii are normally used.

Solid contacts can be produced from wire on cold-heading equipment, from rod on screw machines, from strip on punch presses, and through use of powder metallurgy. These homogeneous pieces are also used as "carrier" components in composite design contacts that are made up of two or more different materials bonded metallurgically.

Composite contacts require longer manufacturing cycles and broader tolerances than solids. But when the cost of silver, silver alloys and other precious metals is considered, a composite may be the best design to offset these rising costs, and still obtain completely satisfactory performance.

Several different methods can be used to join the dissimilar materials used to produce composite contacts. One of the most common is brazing. The brazing methods—torch, furnace, resistance—are defined according to the equipment used to generate the required heat.

A direct-bonding process is also used where silver and some of its alloys are melted directly on backing material to produce a composite contact. While this melting operation is very fast and inexpensive, it cannot be used for all material combinations.

Some contacts cannot be fabricated by alloying methods because of incompatible melting points or nonsolubility. But they can be manufactured through powder metallurgy. Powder metals are thoroughly mixed, hopper-fed into dies in a powder press and then compacted. An atmospherically controlled furnace similar to a brazing furnace then sinters them.

This process produces individual materials or contacts that can be rolled, drawn and machined for later use in contact production and assembly.

Contact reliability and the long shelf-life demanded by modern, complex electrical circuitry calls for electroplating. Gold plating will protect contacts from sulphides and other contaminating substances and is used in many dry-circuit applications or where contacts are not used for long periods. Other precious metals often used for plating are rhodium, palladium, platinum and their alloys.

Plating is a compromise between cost and reliability and can present some inherent difficulties, such as blistering, nonuniformity, peeling, porous plating, scaling or thickness variations. A "gold-treatment" process that overcomes these disadvantages is available. In addition, contacts so treated are much lower in cost. The process is used in low-level applications requiring the corrosion-resistant properties of gold. In many applications fine silver and silver alloy subjected to the gold treatment can satisfactorily replace palladium, platinum or gold alloy contacts. □

Author's biography

J. Porter Duell, Jr. is executive vice president of Deringer Mfgr. Co., where he has been employed for over 22 years. Mr. Duell is involved in managing and directing the company's manufacturing operations. He attended the Univ. of Illinois and Northwestern Univ.

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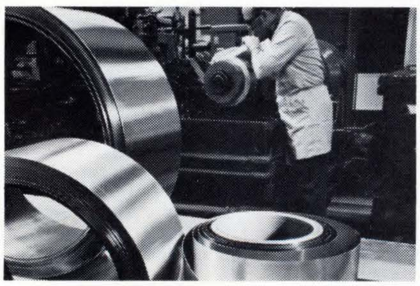

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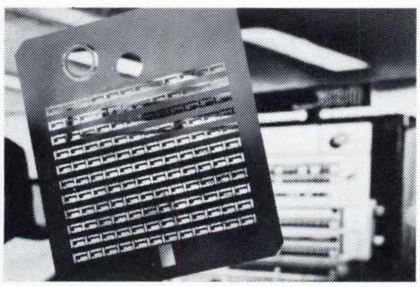

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The impact of bulk alloys on resistor technology

This technology adds another dimension to traditional discrete precision resistor specs used for high-performance applications.

Anthony Troianello and **Dennis E. Wheatley,** Vishay Resistor Products

The electronics industry has evolved at a remarkable rate over the past decade. New techniques and advances have shrunk equipment size and have brought pressures to bear on discrete-component manufacturers for components that approach the ideal in performance.

Although overall system performance is improved by upgrading each component or subsystem, performance of the worst component still determines total system performance. Each component comes to the system with built-in tradeoffs that limit overall performance in such areas as stability, frequency response and noise.

In the discrete resistor industry, advances have been made in wirewound, carbon-composition, cermet and thin-metal film resistors, with each offering various tradeoffs in performance per unit cost. One significant breakthrough in resistor technology is the use of a Bulk-Metal™ film alloy on a glass or ceramic substrate.

Let us briefly review the present resistor state of the art, outlining the advantages and disadvantages of various types. Particularly important to our understanding of resistor performances are the interlinked effects of thermal and mechanical forces on resistor electrical characteristics which will be explored and are summarized in **Table 1.**

Stresses, whether mechanical or thermal, cause a resistor to change its electrical parameters. If such aspects as shape, length, or diameter are changed by mechanical or other means, the electrical parameters are also changed as can be observed by the fundamental equation:

$$R = \frac{\rho L}{A}$$

where:

R = resistance value
ρ = material resistivity
L = resistor length
A = resistor area

When current passes through a resistor element, heat is generated, and the thermal reaction causes mechanical changes by expansion or contraction in each of the materials involved in the component. Ambient temperature conditions have the same effect. The ideal resistor element would, therefore, be required to undergo no mechanical change during manufacturing, and the process would eliminate the need to compensate for the effects of heat or stress during use.

Wirewound resistors

The wirewound resistor is usually made by winding resistance wire of a specific diameter around a core or card. Different wire diameters, lengths and alloys provide the desired resistance.

The precision of wirewound resistors can be as high as ±0.005%. Temperature coefficient of resistance (the amount of resistance change with each degree Centigrade change in temperature) can also be as little as 5 ppm/°C, but generally is in the region of 15 to 25 ppm/°C. Thermal noise is low and tracking to ±2 ppm/°C over a limited temperature range is possible.

Important manufacturing factors that affect wirewound resistor properties are:

(1) The winding of wire around a core deforms the wire. The wire is wound under tension that can elongate it and create alteration in the wire diameter. Each turn of wire has one surface under compression as it is formed to the shape of the card or core on which it is being applied; at the same time its other surfaces are under tension. Plastic deformations—as compared with elastic or recoverable deformations—are irreversible; the change is permanent.

Permanent mechanical changes, which happen randomly and in unpredictable ways, cause equally random and unpredictable changes in the electrical parameters of the wire. The result is that

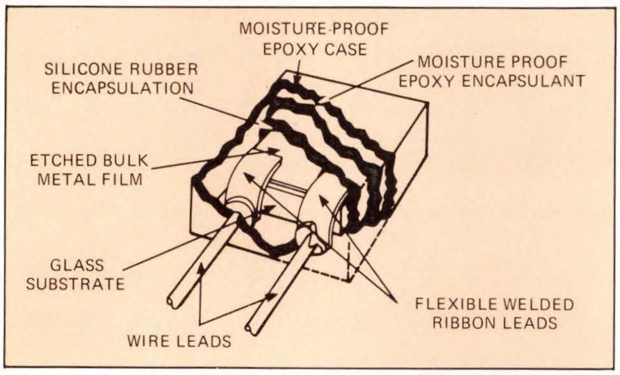

Fig. 1—Typical bulk-metal film resistor construction. Flexible ribbon-type leads are welded to the resistive element, and wire leads are then welded to the ribbons, effectively isolating the resistive element from any mechanical stresses that could be transmitted during mounting or shock conditions.

resistance elements emerging from the winding stage can have highly variable electrical-performance characteristics. Some of the resistors will be excellent, some good, some fair and some poor.

(2) Because of their coiled-wire construction, wirewound resistors are inductors, and proximity of the turns creates intercoil capacitance. Compensation winding techniques are often introduced to minimize the inductance, but this increases cost. Due to the inductance and capacitance inherent in the design, wirewound resistors have poor high-frequency characteristics, particularly above 50 kHz.

(3) It's difficult to make two wirewound resistors that accurately track each other over a specified temperature range when they are of the same nominal resistance value, and especially so when their values are not the same. The reason for this disparity is that a 1-kΩ resistor is made with a different diameter, length, and possibly

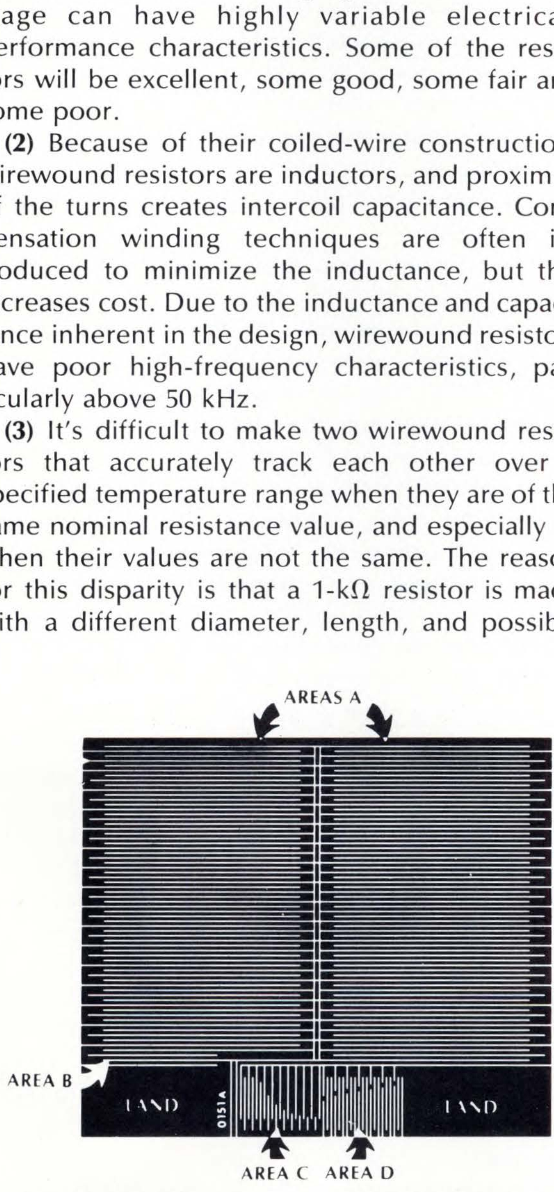

Fig. 2—Close-up of a bulk-metal film resistor chip shows a typical resistance pattern with precise conducting lines and spacings. The film pattern for a given chip is determined by the resistance range.

alloy of wire than, for example, a 100-kΩ resistor. Moreover, the core sizes and turns per inch are different—again, mechanical properties affect electrical properties. The tracking ability becomes extremely important in high-precision circuitry.

(4) Traditional wirewound manufacturing methods do not isolate the resistive element from the various stresses arising out of handling, packaging, insertion pressures and lead forming, for example. Here, one must consider tension applied to, say, axial leads—usually on mounting, and pressure on the package exerted by mechanically induced forces. Both can change the resistance, either with or without power applied.

(5) Over long periods of time, the wound element tends to change physically as the wire attempts to regain its original shape.

Carbon-element resistors

Carbon-composition resistors represent one of the more widely applied resistor types in volume of usage. They are quite low in cost and are used mainly in nonprecision applications. They find wide acceptance in such equipment as radio, television, hi-fi amplifiers and consumer oriented electronics and communication equipment, particularly where low cost is of major significance.

While they possess good frequency response, carbon-composition resistors have other characteristics that prevent their use in precision applications. Accuracy is in the range of ±5 to ±20% and tolerances are about 1% at best. The temperature coefficient of deposited carbons can be held through selection to 500 ppm/°C, but carbon composition, slug or filament, give coefficients only as good as ±2000 to ±8000 ppm/°C. Deposited carbon resistors can be selected to provide ±50 ppm/°C tracking. Shelf-life stabilities are about 2 to 5% of resistance value (20,000 to 50,000 ppm/year) and noise is appreciable, particularly in the filament type.

Deposited thin-metal film resistors

In thin-film resistors, deposition of the film onto the substrate is evenly controlled across the face of the element and, to a degree, from resistor to resistor. The blank resistor element is usually adjusted by two stages of "spiralling", either on the outside or inside diameter of the unit. The primary step approaches the desired resistance value, and the secondary phase attempts to achieve the final value. "Spiralling-in" techniques—especially in the secondary phase and with the complication of the termination-connection operation—are still unable to produce a resistance accuracy better than ±0.1%. The nature of the manufacturing process is such that temperature coefficients of resistance better

CHARACTERISTICS OF DIFFERENT TYPES OF RESISTORS*

	Tempco in ppm/°C -55°C-+125°C	Tolerance in %	Load Life Stability in %	Shelf Stability in %	Mil-Std 202 Moisture Resistance in %	Noise in dB/decade
Bulk metal film	±3	±0.005	±0.03	±0.0025	±0.03	-50
Wirewound	±15	±0.005	±0.075	±0.02	±0.25	-35
Evaporated metal film	±50	±0.1	±1.5	±0.1	±0.5	-20
Cermet	±100	±0.1	±1.0	±0.1	±0.5	+20
Carbon film	-200	±1.0	±5.0	±2.0	±5.0	+20
Carbon Composition	-5000	±5.0	±20.0	±5.0	±15.0	+30

* Typical — Non Hermetically sealed, no special conditioning.

than ±25 ppm/°C are extremely difficult to produce. Moreover, the temperature coefficient changes of any two resistors fall randomly into the 50 ppm/°C span of the product.

As in most other resistor types, the environment resistance and load-life changes shown by thin-film resistors cumulatively add up to, and exceed, their initial tolerances. Thus, resistance changes can reach ±1 to ±2% regardless of whether the initial resistor tolerance was ±0.1 or ±1%. When changes amounting to ±2% occur, then a total design tolerance of 6% would have to be considered in a circuit employing ±1% units, or 4.2% for ±0.1% units. This degree of instability has prohibited the use of evaporated metal-film resistors as direct replacements for precision wirewound types.

Various and complex factors contribute to the instability of thin - film resistors such as lattice distortion, discontinuous aggregate formations, occlusion of gas at crystal interfaces, oxidation of the film to form oxide semiconductors and mechanical strains. The principle virtue of thin-film type resistors, however, is that they can be used in high-speed applications with fairly good precision and stability, and where price is a consideration.

Because thin-film resistors are deposited on substrates and require fewer external connections, their overall reliability is also enhanced.

Bulk-Metal film resistors

Bulk-metal film techniques on glass substrates produce a combination of highly desirable and previously unattainable resistor specifications. This offers reproducible performance characteristics of the following order:

- Standard temperature coefficients of 1 ppm/°C (0.0001%) over 0 to +60°C for values above 100Ω
- Absolute tolerances of ±0.005% (down to ±0.001%)
- Tracking between resistors of 0.5 ppm/°C over 0 to +60°C
- Rise times of 1 nsec with no ringing
- Standard shelf stabilities of 25 ppm/year (down to 5 ppm/year)
- Inductance of 0.08 μH max.
- Capacitance of 1/2 pF max.
- Noise that is nonmeasurable on a Quantech Model 315 instrument

Fig. 1 shows a typical bulk-metal film resistor construction.

The specifications now available bring high stability and reliability to systems performance, and compromises between accuracy, stability and speed are not necessary. The design and processing is unlike that of any other resistor and arises out of an analysis of the problems associated with the state-of-the-art limitations.

To acquire a precise resistance value, the basic bulk-metal chip is calibrated by cutting across built-in "shorting bars". To increase the resistance in known increments, areas **A, B, C** and **D (Fig. 2)** are cut and represent increasingly finer adjustment areas. Because the chips are so small (0.255 × 0.223 in.), the trimming operation needs to be precise and is thus done under magnification.

Standard temperature coefficients of ±1 ppm/°C over the range between 0-60°C are derived from the properties of the alloy and its match with the substrate. The coefficient of expansion of the metal alloy used is positive, and the metal tends to expand under increasing temperature, while that of the substrate used is also positive but less than the alloy. Therefore, when the two are combined and are subjected to rising temperatures, the alloy's expansion is inhibited somewhat due to the substrate's lower coefficient of expansion. As a result, the alloy is actually compressed slightly by the restraining influence of the glass substrate.

The compression of the alloy creates a negative temperature coefficient within the alloy, while on the other hand, the unrestricted alloy would have a positive temperature coefficient of resistance.

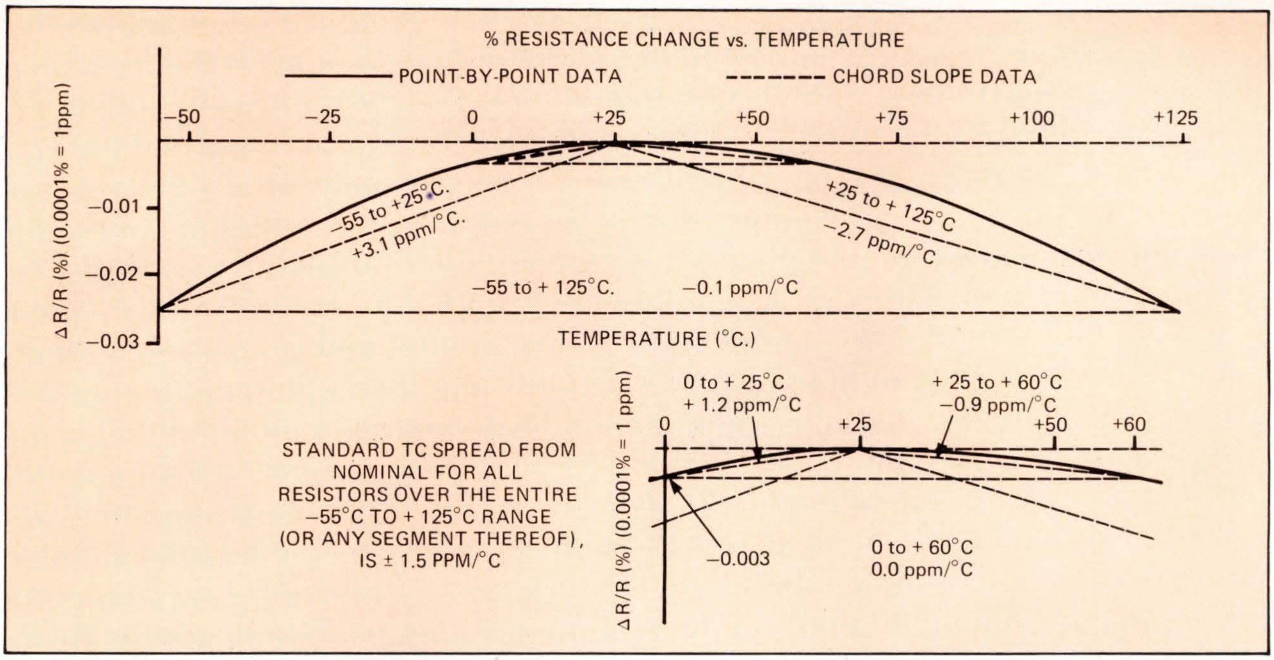

Fig. 3—Overall bulk-metal film resistor TC curve from -55°C to +125°C, along with the details of the 0 to +60°C part of the curve. The maximum in the TC curve (TC centering) is reproducibly set at +25°C. The result is that the lowest TC is obtained in the most useful region for normal operation.

The positive and negative components thus set up in the resistance element are virtually equal. The resultant overall temperature coefficient is a bell shaped curve **(Fig. 3),** centered at +25°C, with a nominal chord slope of +3.1 ppm/°C in the range between −55°C and +25°C, and −2.7 ppm/°C from +25°C to +125°C. All resistors above 100Ω will be within 1.5 ppm/°C of this curve, regardless of the time of manufacture.

The planar design with parallel patterned element layouts compensates for inductance effects; maximum total inductance of the resistor is 0.08 μH. Capacitive effects are 0.5 pF max. A 1 kΩ resistor has a settling time of less than 1 nsec up to 100 MHz. Rise time depends on resistance value, but higher and lower values are only slightly slower than mid-range values. Absence of ringing is especially important in high-speed switching as in, for example, computer conversion ladder networks.

The dc resistance of 1 kΩ bulk-metal film resistor compared with its ac resistance at 100 MHz can be expressed as follows:

$$\frac{\text{ac Resistance}}{\text{dc Resistance}} = 1.001$$

You can make your own resistors

An in-plant facility is possible for those who need precision resistors for breadboarding prototypes and for final circuit trimming. By using some basic equipment, the user can calibrate a resistor element to the exact value needed and can perform the final encapsulation procedures that are identical to those used at Vishay. Therefore, by stocking a small number of uncalibrated resistor chips, one can make any desired value and tolerance needed.

Because the complete resistor can be produced in less than 48 hours (including curing), the in-plant facility can be a solution to delays usually experienced in ordering small quantities of precision resistors.

How much performance?

Naturally, not every engineer needs an entire high-performance package for his circuitry. Resistors with much poorer specifications can be used satisfactorily in many applications, so the question of need is divided into five basic categories:

1 Existing applications that can be upgraded by relying on the *total* performance package of bulk-metal films.
2 Existing applications that require *one,* or more, but not necessarily all of the bulk-metal film performance parameters.
3 State-of-the-art circuitry that can only be developed now because of the availability of improved specs for precision resistors.
4 Purposeful over-specifying of resistors to allow for future upgrading.
5 Cost savings by having the circuit accuracy maintained by the resistors rather than by the active devices, which would greatly increase cost for only slightly better levels of performance.

In group (2), for example, the need for a single parameter must be weighed with the economics of the whole package. It could cost less to use a resistor with superior overall performance specifications because the need for compensating circuitry (and the cost of the associated components plus their assembly), may be eliminated. Another question that might be posed is: "Would using an improved resistor performance for upgrading equipment performance enhance market acceptance of the equipment?" □

Author's biographies

Anthony Troianello is a senior applications engineer with Vishay where he is responsible for technical coordination and training, specification negotiations, and quotation supervision activities. He has been with Vishay for 3-1/2 years and prior to that worked at Mepco, Inc. Mr. Troianello holds a BSEE degree from Marquette Univ.

Dennis E. Wheatley is Vishay's international marketing manager promoting world wide resistor sales. A year ago, he was the marketing and general sales manager for the Plessey Group and ITT Cannon in England. Mr. Wheatley holds a National Diploma of Electrical Engineering from Rutherford College of Technology, New Castle, England, and a higher National Certificate of Electrical Engineering.

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Circle No. 63

Positive feedback "idealizes" small transformers

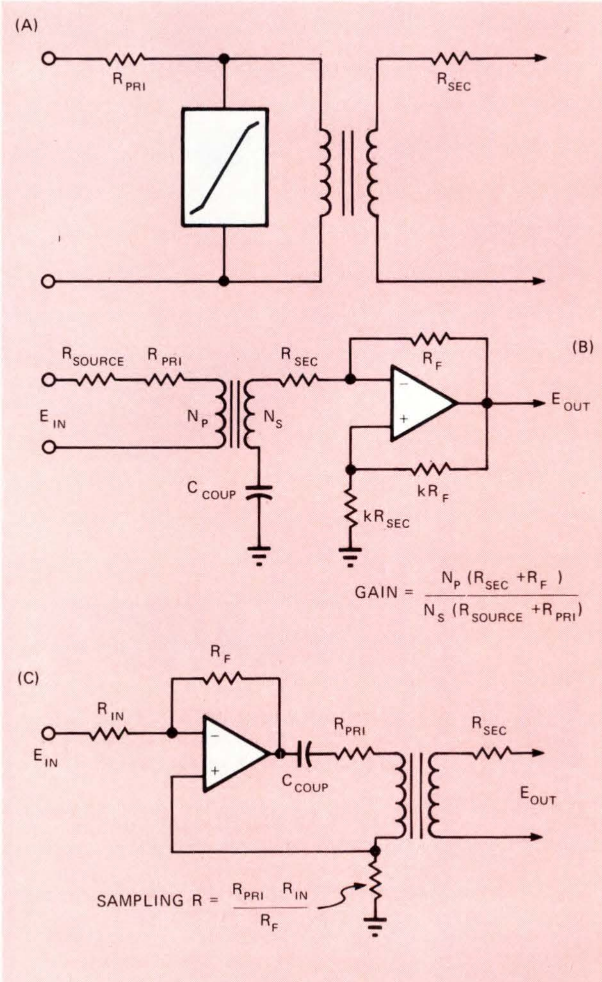
Leland Van Allen
Penril Data Comm., Rockville, MD

The presence of resistance in the windings of small audio transformers leads to distortion and loss of amplitude response, especially at low frequencies. This is because some of the input voltage is lost in the winding resistance because of current flow that is not due to secondary loading.

The transformer may be represented by the equivalent circuit "A" where an ideal transformer is shown with its series resistances separated, and with a non-linear shunt impedance connected across its primary.

Now, for the input transformer case, ideal performance can be achieved simply by operating the transformer with its secondary winding short circuited (as a current transformer). But in order to do this, the secondary winding must "look" into a negative resistance equal to the secondary winding resistance. Circuit "B" shows an easy way to make this happen. The positive feedback causes a virtual short-circuit to be placed across the secondary of the "ideal" transformer, with the result that there can be no exciting current or core losses since there is no signal voltage impressed on the windings. The primary winding resistance, then, just becomes a part of the input resistance. The coupling capacitor, the reactance of which is made small compared to R_{sec} at the lowest frequency of interest, is needed to prevent the now "zero" resistance secondary winding from shorting out the stabilizing dc feedback around the op amp.

In circuit "C" which illustrates the output transformer case, positive current feedback is used to create a negative resistance at the amplifier output, just sufficient to cancel the primary winding resistance (and the current sampling resistance). Thus the signal applied to the "ideal" primary is a replica of the input waveform, with its distortion removed, and the non-linear shunt impedance doesn't matter. Here the secondary winding resistance becomes a part of the output resistance. Again the coupling capacitor is needed for dc reasons as mentioned above. □



Idealized transformer, circuit "A", unfortunately contains a nonlinear shunt across the primary in real life. This effect can be overcome with the simple op amp designs shown for idealizing transformer inputs in circuit "B" and outputs in circuit "C".

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51025	100	45	2.5	5	9.7
51054	1.0	60	25	100	0.37
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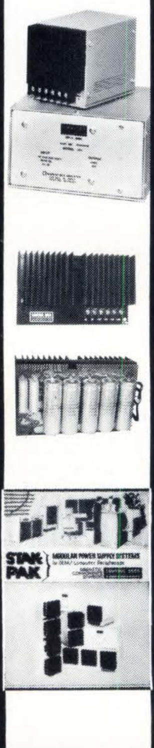

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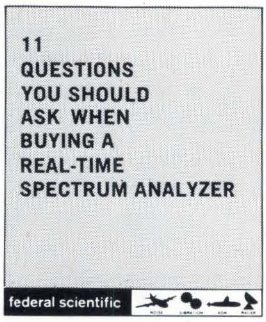

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Circle No. 35

FET stabilizes sine-wave oscillator

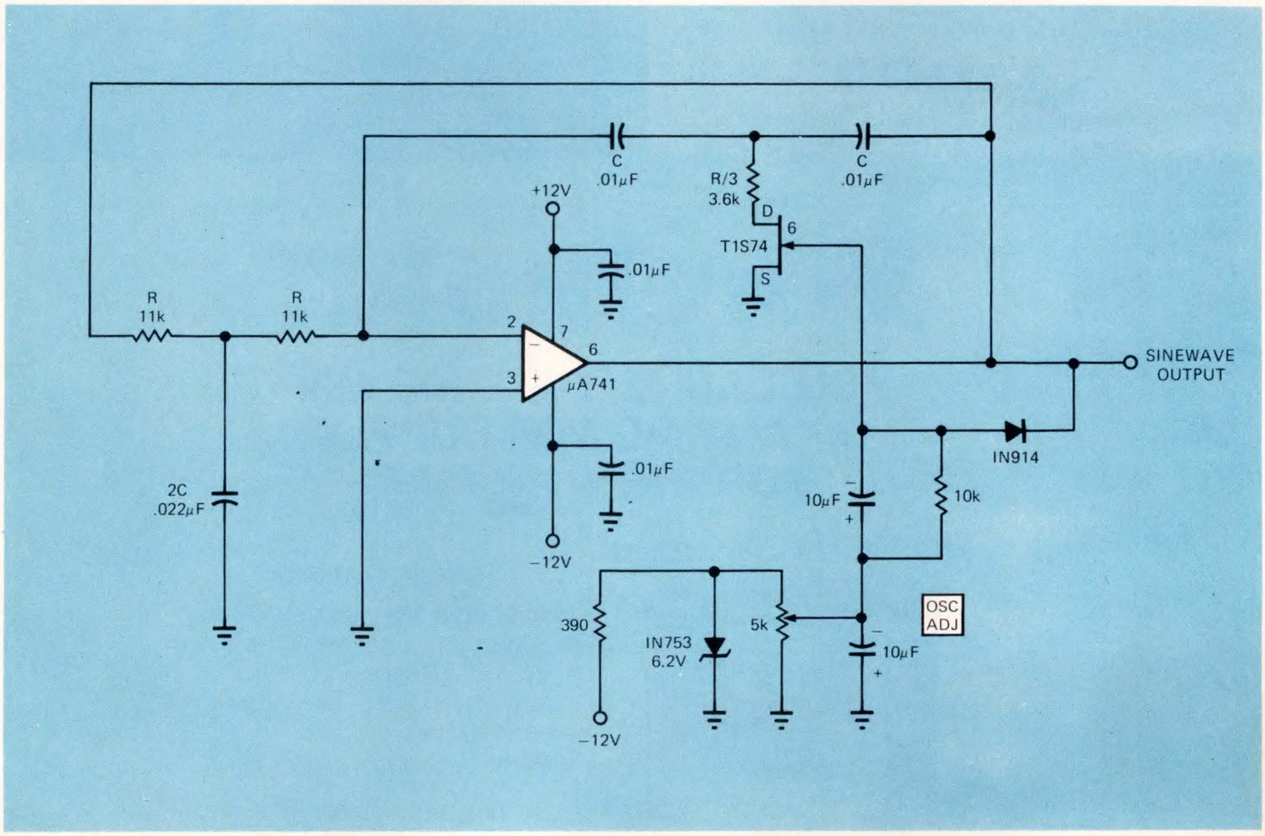
Frederick Macli
Goldmark Communications, Stamford, CT

This FET stabilized sine-wave oscillator consists of a peak detector and a FET, operated in the voltage variable-resistance mode, added to the standard double-integration circuit with regenerative feedback. In the standard configuration, the resistor, R/3, and the FET are replaced by a potentiometer such that the sum of the two resistances is equal to R/2. The pot is then adjusted until oscillation is barely sustained. That configuration, however, is highly susceptible to power supply and temperature variation. The improved version of the circuit peak detects the sine-wave output to provide a dc voltage to control the resistance of the FET, thereby automatically adjusting the condition for oscillation and improving stability. The peak detector is referenced to an adjustable dc voltage to allow for variation in FET resistance from unit to unit. This also provides a dc bias point for the feedback loop.

For the component values shown in the diagram, this circuit provides a 10V p-p, 1460-Hz sine wave into a 500Ω load with power supply voltage ranges of 8 to 18V without any variation in output amplitude or frequency. Over a temperature range of +10 to +65°C, the circuit varies less than 1.5% in frequency and 6% in amplitude. Under all conditions the second harmonic was 25 dB below the fundamental.

The circuit can be modified and extended to other frequencies of operation. □

To Vote For This Circuit
Circle 151



Voltage controlled resistance FET replaces the potentiometer in this otherwise classic oscillator to provide improved stability.

Multiplexers synthesize Boolean expressions

John R. Tracy
Litton Systems, Van Nuys, CA

The implementation with gates of complex Boolean expressions of many variables can result in designs having significant chip counts, even when minimized. An 8-input multiplexer MSI function, found in most logic lines, can often be used to efficiently implement such expressions. This is accomplished by mapping the desired

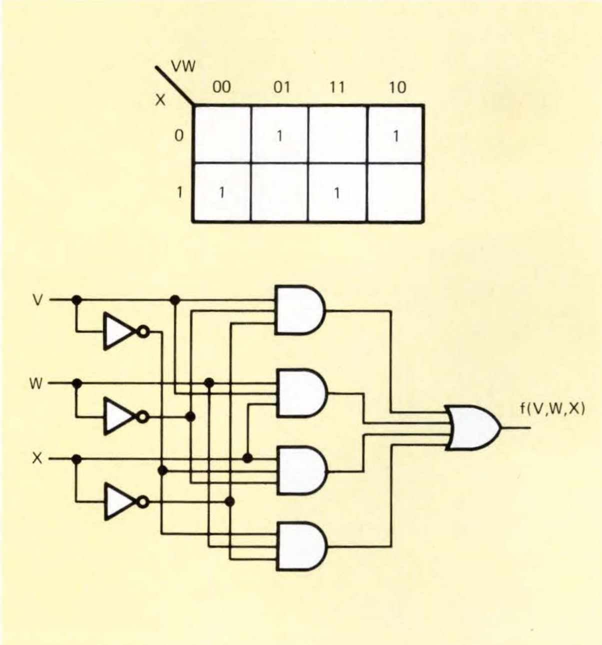


Fig. 1—Karnaugh map of Eq. 1 shows that no minimization is possible. Therefore the minimum circuit to perform the function of **Eq. 1** will require 3 inverters, 4-AND gates and 1-OR gate.

function onto the data-channel inputs of the device and using the selector inputs for the variables of the expression. A simple example of this method is illustrated by the implementation of the function defined by the disjunctive normal expression:

$$f(V,W,X) = V\bar{W}\bar{X} + VWX + \bar{V}\bar{W}X + \bar{V}W\bar{X} \quad \textbf{(Eq. 1)}$$

The Karnaugh map in **Fig. 1** indicates that no minimization is possible, and the resulting minimum AND-OR implementation is shown.

To implement this function using an 8-input multiplexer, the channels representing ONEs of the function are hardwired HIGH, and the channels representing ZEROs are hardwired LOW.

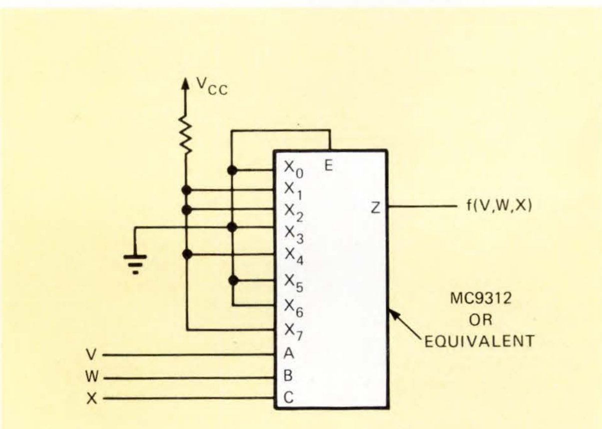


Fig. 2—A single multiplexer solution to Eq. 1 hardwires input channels to HIGH or LOW states and uses the V, W and X functions as channel-select commands.

The variables are applied to the channel-select inputs. The resulting circuit configuration is shown in **Fig. 2**.

Expansion to expressions of a larger number of variables can be accomplished by the parallel connection of more than one multiplexer chip, dynamically remapping the channel inputs as a function of the additional expression variables, or a combination of both. To illustrate this expansion capability, the following expression in 5 variables is considered:

$$f(V,W,X,Y,Z) = V\bar{W}\bar{X}\bar{Y}\bar{Z} + VWX\bar{Y}Z + VW\bar{X}Y\bar{Z} + \bar{V}\bar{W}XY\bar{Z} + \bar{V}WXYZ + \bar{V}\bar{W}\bar{X}YZ + V\bar{W}XY\bar{Z} + V\bar{W}\bar{X}YZ + \bar{V}WX\bar{Y}\bar{Z} + \bar{V}\bar{W}\bar{X}\bar{Y}\bar{Z} + \bar{V}W\bar{X}\bar{Y}Z + VWX\bar{Y}\bar{Z} \quad \textbf{(Eq. 2)}$$

The Karnaugh map in **Fig. 3** indicates that the only minimization possible is the combination of the two terms $VWX\bar{Y}\bar{Z}$ and $VWX\bar{Y}Z$ into a single term VWXY. The gate implementation is not shown here, but it's very complex.

To implement this function, two 8-input multiplexers will be used. Variables V, W, and X will drive the selector inputs, Y will be used for a chip selection bit, and W will be used to dynamically map certain channel inputs. The mapping of the function onto the inputs is made by visual inspection of the Karnaugh map of the truth table. The channel inputs representing partial products

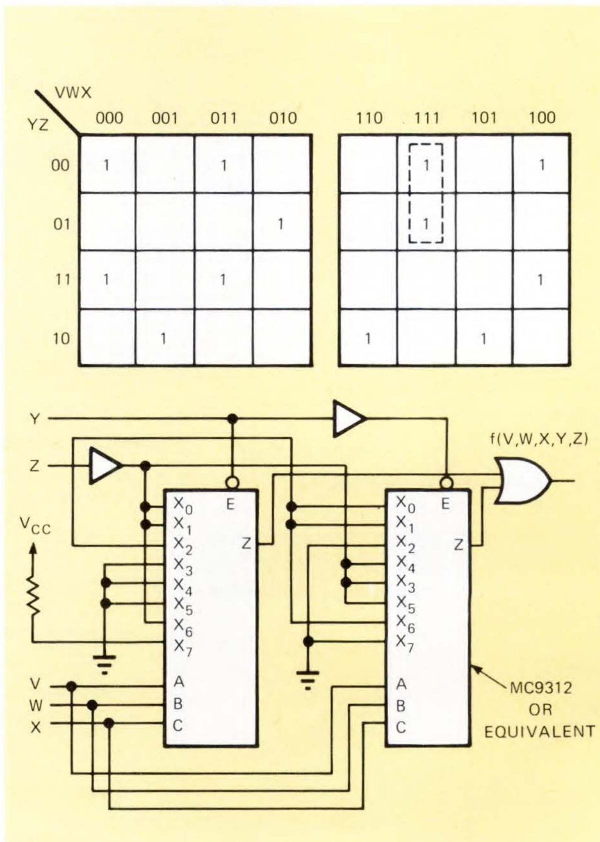
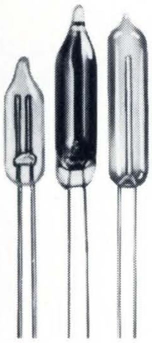


Fig. 3—Solution to a 5-variable function, as given in **Eq. 2** and mapped above, shows only slight minimization potential, yet can be solved using 2 multiplexer circuits.

MULTIPLE CHOICE



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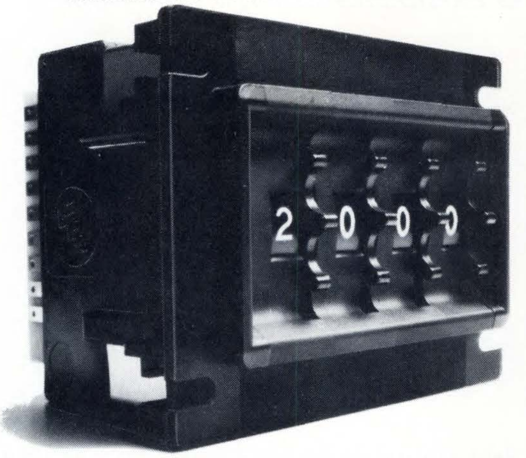

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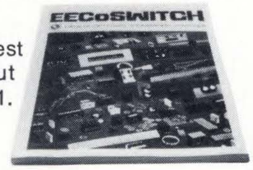

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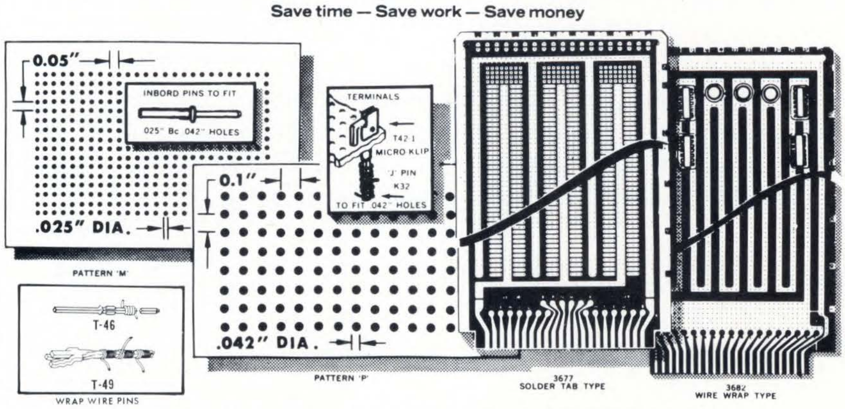

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of the variables V, W, X, and Y that are invariant with respect to the variable Z are hardwired as described in the example above. Those channel inputs that represent partial products of V, W, X and Y that are a function of the variable Z have that function applied. In the case of one dynamic mapping variable, the function can only be Z or $\bar{Z}$. The circuit is also shown in **Fig. 3.** □

To Vote For This Circuit
Circle 152

Optical sensor has built-in hysteresis

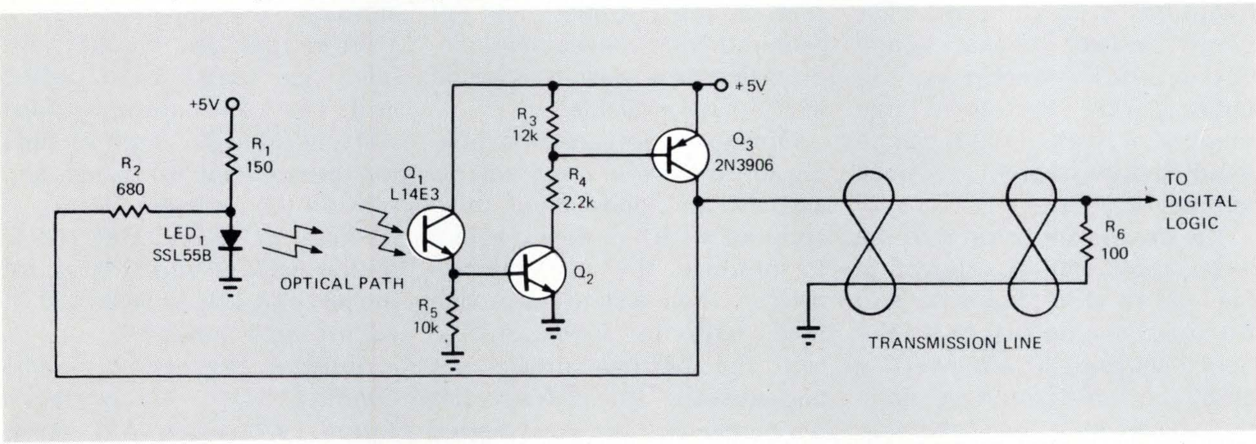
David C. Hoffman
Industrial Nucleonics Corp., Columbus, OH

It is often difficult for an optical sensor with a digital output to operate at zero speed as well as high speeds and still have suitable rise times to drive digital logic. This is especially true when the logic device is at the other end of a transmission line. This sensor has built-in optical hysteresis so that it does provide digital outputs at low, and even zero-operating speeds.

When the optical path from D_1 to Q_1 is completely obscured, Q_1, and also Q_2 and Q_3, are OFF. The output is pulled LOW by R_6. As more light passes between D_1 and Q_1, Q_2 and Q_3 begin to turn ON. The rising collector of Q_3 adds more current through R_2 to D_1. This gives Q_1 more light and drives Q_3 into saturation.

As the light dims, Q_1 begins to turn OFF, and as the output falls, the extra current is cut off turning Q_3 OFF. Because of this hysteresis, there is no constant light level where the circuit will oscillate. The circuit has been tested at 4-kHz operation and is speed-limited at about 20 kHz. □

To Vote For This Circuit
Circle 153



Simple optical sensor has good rise times for driving digital logic, regardless of the speed or rep rate of the monitored event.

Readers have voted:

Robert J. Wincensten winner of the November 1st Savings Bond Award. His winning circuit is "Absolute value circuit uses only five parts". Mr. Wincensten is with King Radio Corp., Overland Park, KS.

Mahendra J. Shah winner of the January 5th, 1973 Savings Bond Award. His winning circuit is "Wide-range pulse generator uses single IC". Mr. Shah is with the Space Science and Engineering Center at the Univ. of Wisconsin, Madison, WI.

Bjorn Brandstedt winner of the December 15th Savings Bond Award. His winning circuit is "Digital interlocking switch is inexpensive to build". Mr. Brandstedt is with McDonnell-Douglas Corp., St. Louis, MO.

IC drivers offer a systems approach for multiplexed high-voltage displays

PROGRESS IN MICROELECTRONICS

Although they weren't the first on the market with high-voltage driver ICs, you have to give Sprague's Semiconductor Division extra points for their well thought-out approach. When used together for display driving, their 480- and 490-Series drivers can eliminate discrete semiconductors altogether. Coupled with standard 200-Series resistor networks and 904-Series RC networks, the entire driving chore for a large number of readout digits can be handled by an impressively small number of DIPs.

The drivers are tailored to the exact requirements, shown in **Fig. 2** of the Sperry- and Burroughs-type displays. The Series 480 and 481 are inverting amplifiers which interface directly between MOS logic levels (up to 30V) and high-voltage levels (up to 130V). They are intended for application as cathode (segment) drivers and can sink up to 5 mA. Turn-on time varies with output load and voltage but will usually be about 5 μsec.

The 480 contains five drivers in a 14-pin DIP, and the 481 has seven drivers in a 16-pin DIP. Multiplexing 7-segment numerals requires only a single 481, while a pair of 480s could drive numerals, decimal points, a minus sign and an overflow indicator—the ordinary calculator readout. A 480 and a 481 together could give you the ability to drive commas, available on most displays, or the centered "one" (9-segment) displays that many designers would like to have available.

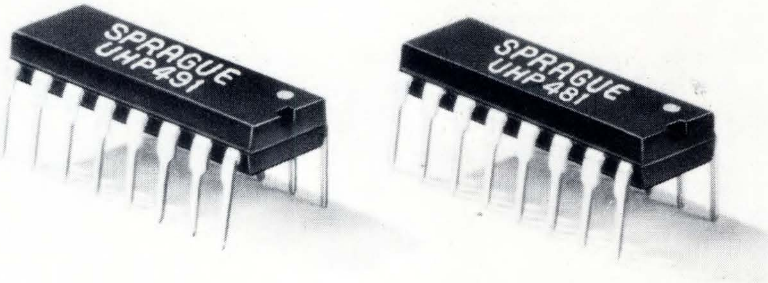


Fig. 1—High-voltage display drivers of the 480 and 490 Series offer designers a systemized approach and flexibility not previously available in IC drivers.

Obviously, Sprague was looking ahead to these requirements and also to alphanumeric-drive applications when they decided to produce the two cathode drivers. Their systems approach holds with the anode drivers, too. The 490 (five drivers per package) and 491 (six drivers per package) give you a great degree of flexibility in applications, although it's apparent that a 4-driver package would have been very useful, too. The 490 and 491 can handle output voltages up to 80V. Turn-on time for these circuits is 3 μsec, and turn-off time is 5 μsec.

Prices in plastic DIPs (UHP prefix) are $2.65 and $2.90 ea. for the 480 and 481; $2.06 and $2.31 ea. for the 490 and 491.

Sprague Electric Co., Semiconductor Div., 115 Northeast Cutoff, Worcester, MA 01606. Phone(617)853-5000. **150**

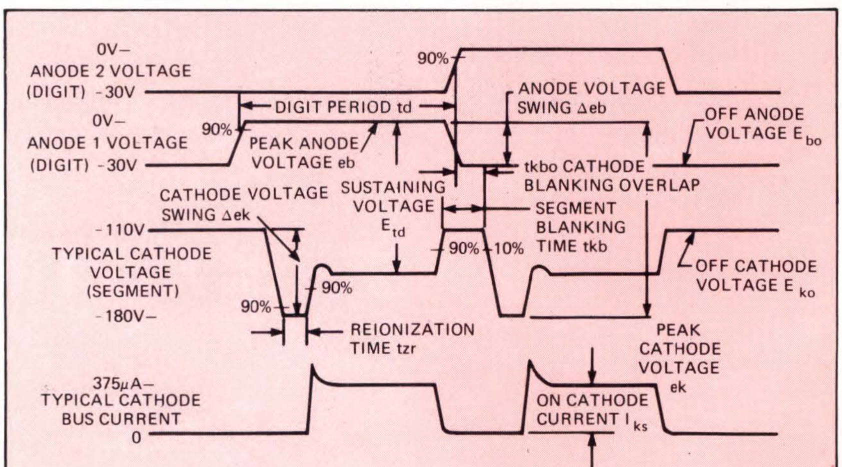


Fig. 2—High-voltage readout drive waveforms for multiplexed operation have been beyond the capability of IC drivers until very recently.

Four-quadrant multiplying D/A converter minimizes spiking and feedthrough

PROGRESS IN PACKAGED CIRCUITS

One problem that plagues users of multiplying D/A converters when applying them to CRTs in display systems is the occurance of spikes in the display when the ac signal crosses zero (**Fig. 1**). This happens when the ac reference is applied to the converter's input and the digital input is all zeros.

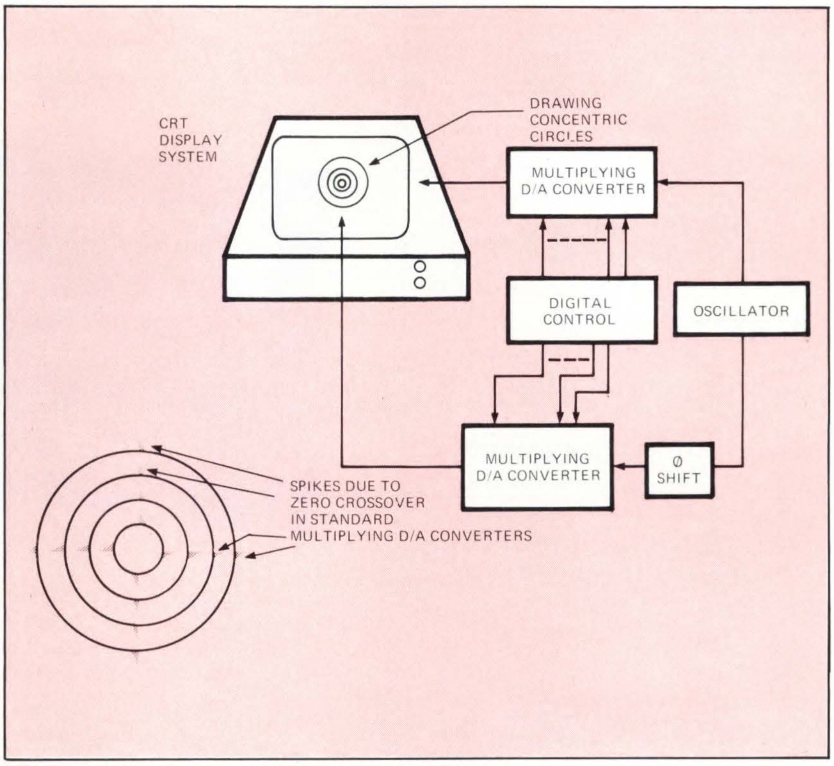


Fig. 1—Multiplying D/A converters used for CRT displays (right) generally suffer from the appearance of spikes on the CRT screen caused by the ac reference crossing zero. The CRT's concentric circles (left) show the effects of this zero-crossover spiking as smudged lines.

The DAC316 converter eliminates all this. It uses a proprietary switch that is said to be superior in eliminating display spikes over standard techniques that are used to control multiplying D/A converter-bit switches (**Fig. 2**), and has excellent low feedthrough of ±0.05% at 20 kHz.

The 4-quadrant unit features an output settling time of 2 μsec to 0.05% of its final value (and for a 20V reference change), and an accuracy vs temperature rating of 30 ppm/°C.

Available in straight binary or 2's complement input codings, the DAC316 unit comes in 10-, 11- and 12-bit resolution versions with reference input ranges of ±10V and linearities of ±1/2 LSB. The converters have output voltage ranges of ±10V (±5V for 2's complement coding) and output currents of 10 mA with 1Ω output impedances.

Additional specifications include a 3-dB bandwidth of 1.5 MHz (600-kHz full-power bandwidth), 20V/μsec slew rate and input impedance of 10 kΩ. The units are DTL/TTL compatible and operate over the temperature range of 0 to +70°C.

Each encapsulated module measures 2 × 3 × 0.4 in. and is fully repairable at the factory. Each operates from ±15V at 30 mA.

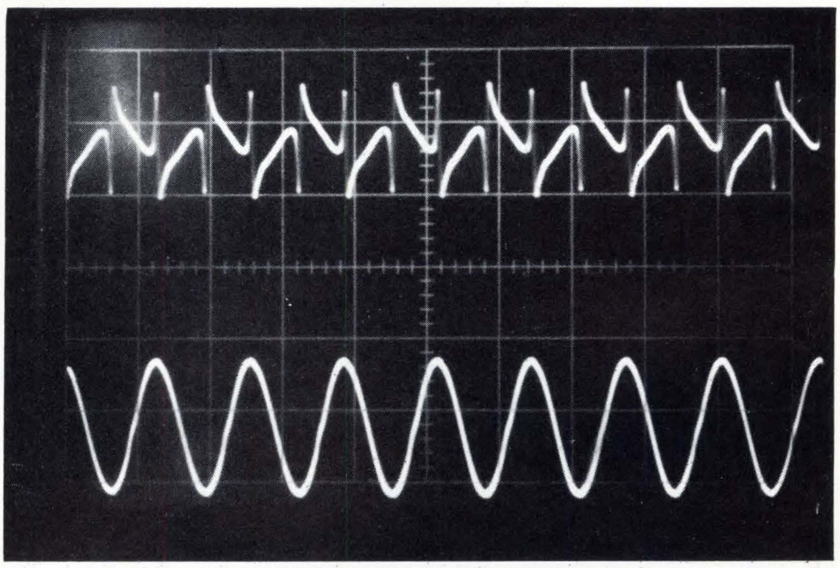


Fig. 2—The DAC316-12 4-quadrant multiplying D/A converter (bottom) is in its normal multiplying mode optimized for minimum zero-crossover spiking. Note the elimination of the spikes found commonly in standard multiplying converters (top). The reference frequency is 100 kHz and the vertical-scale calibration is 50 mV/div.

Prices are as follows: 10-bit binary DAC316-10 ($125); 11-bit binary DAC316-11 ($150); 12-bit binary DAC316-12 ($175); and 3-decade BCD DAC316-3-BCD ($125).

Hybrid Systems Corp., 87 Second Ave., Burlington, MA 01803. Phone(617)272-1522. **151**

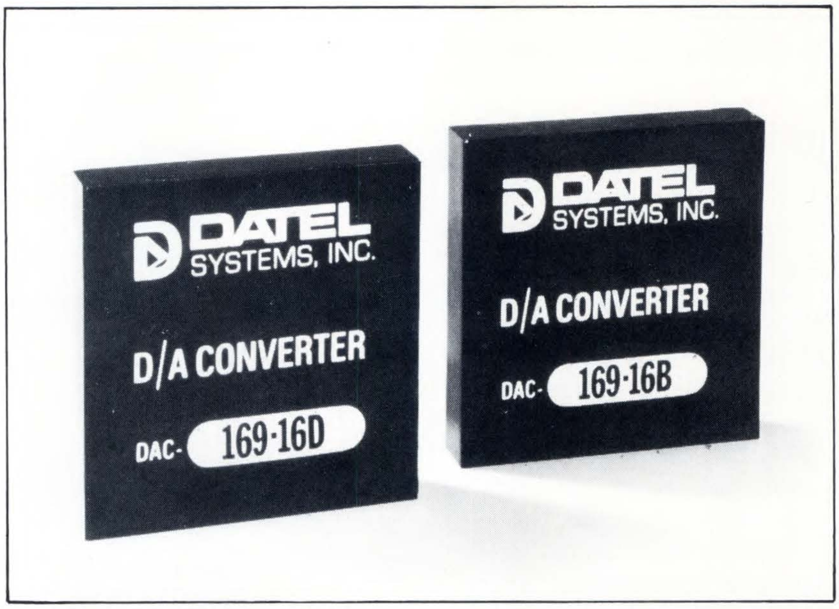
16-bit resolution D/A converters cost only $89

PROGRESS IN PACKAGED CIRCUITS

For applications requiring moderate performances, the DAC-169 16-bit D/A converter with 14-bit linearity can't be beat. Its low single-unit price of $89 ($78 in 100 quantities and $65 in 1000 lots) comes close to that of many 12-bit units on the market, considering its fast update rate of 5 MHz.

The unit offers output settling times of 750 nsec for current-output versions and 30 μsec for voltage-output models, both to 0.005% of full scale. The $89 price includes either voltage or current output configurations, and an internal reference source with a TC of ±0.0005%/°C.

Two types are available: the DAC-169-16B straight-binary unit and the DAC-169-16D 4-digit BCD unit with user-selectable (by pin strapping) voltage outputs of 0 to +10V, 0 to −10V, and ±5V at 5 mA and current outputs of 0 to +2 mA and ±1 mA for straight-binary versions. BCD units can have voltage-selectable outputs of 0 to +10V and 0 to −10V, and a current output of 0 to +1.25 mA.



At $89 in single quantities, this 16-bit resolution D/A converter pair (14-bit linearity) rivals many 12-bit units on the market. Available in straight-binary and BCD versions, the converters feature 5-MHz update rates and are available in either current-output (750-nsec settling times) or voltage output (30-μsec settling times) models.

Both units (binary and BCD) have a maximum voltage compliance of 1.0V for a full-scale current output. All inputs are TTL/DTL compatible. To compensate for long-term drifts, offset and gain adjustments are provided. Linearity TC is specified as ±0.0005%/°C and gain TC is ±10 ppm/°C (current-output units). Longterm stability is ±0.005%/year.

Each converter module measures a mere 2 × 2 × 0.375 in. and is rated to operate over a temperature range of 0 to +70°C. Power requirements are +15V dc at 25 mA and −15V dc at 25 mA.

Datel Systems, Inc., 1020 Turnpike St., Canton, MA 02021. Phone(617)828-6395. **152**

Logic analyzer instrument adds a new dimension for viewing complex digital signals

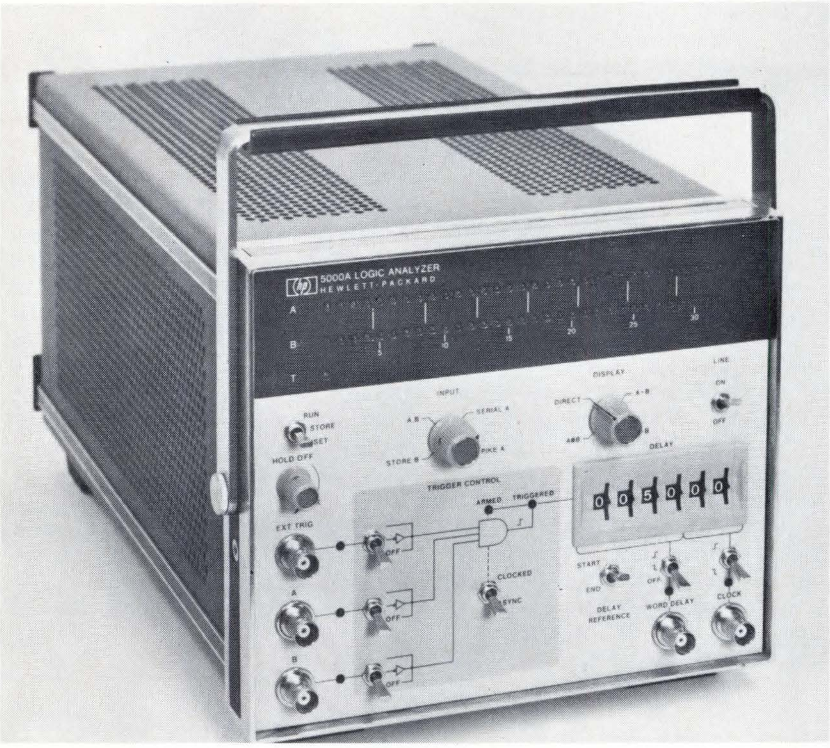
PROGRESS IN INSTRUMENTATION

Utilizing two rows of 32 LED indicators, Hewlett-Packard's Model 5000A allows a designer to capture, store and display any part of a digital logic data stream at up to 10 Mbits/sec for quick and easy interpretation.

On a row of 32 LEDs, the instrument shows the logic states during any 32 successive clock intervals. The LEDs turn on for HIGH states and off for LOW states, producing understandable data language statements.

The user can easily choose just which 32 bits in the data stream are to be frozen for analysis. For example, should he want the sequence beginning at the 109,501st clock interval after a trigger, he simply dials in the number. The 32-bit display "window" can be moved in time to any part of the data stream.

The 5000A can also do something that is quite different from any other instrument. It can look backward in time, before the trigger, to show causes as well as effects.



Total analysis of logic timing is what this instrument allows a designer to do in seconds. The 5000A logic analyzer is compatible with all digital logic families. It uses two rows of 32 LED indicators to capture, store and display any part of a digital logic data stream at rates up to 10 Mbits/sec.

And just in case no pulses are being received or the input cable or probe is not making contact, individual LED indicators are situated at the channel A and B inputs and at "clock", "word delay" and "ext. trigger" inputs to pinpoint the fault. Two other LEDs annunciate arming and triggering functions.

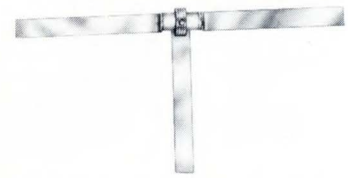
This new digital "scope" is compatible with all digital families: TTL, ECL, RTL, HTL, MOS and even CMOS with no logic-level or loading problems. The input logic threshold level is variable over a range of ±1.4V. Input impedance is 1 MΩ shunted by 25 pF. All inputs are compatible with standard divider probes which yield input impedances of 10 MΩ shunted by 25 pF. This extends the threshold-level range to ±14V.

The digital logic being analyzed is used for triggering, either into channel A or B inputs, or through the external-trigger input. Or the trigger word can be any HIGH-LOW combination at two or three of these inputs. In this way a fault condition on more than one input could be made to trigger a display.

Because the display is always divided into clock cycles digitally, there is no need to devote a data channel to the clock waveform. The 5000A's display shows successive logic states in clock cycles, precisely the information needed for comparison with truth table timing diagrams. Dividing the information digitally into clock cycles also removes problems arising from jitter in the data stream.

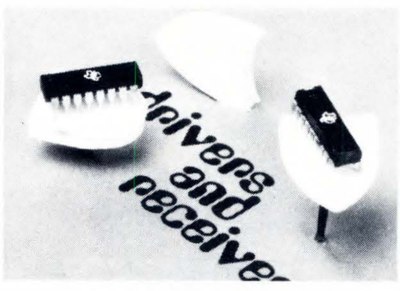
Price for the 5000A is $1900. A variety of probes, $50 each, is available to augment the 5000A.

Hewlett-Packard Co., 1501 Page Mill Rd., Palo Alto, CA 94304. Phone(415)493-1501. **153**



BACK-TO-BACK CAPACITOR TUNING DIODES OFFER LOW PROFILE. In the GC1702EE Series, two varactors are common-cathode connected and have ribbon leads readily adaptable for pc board mounting. The center lead is welded to the common base of the two diodes. Prior to assembly diodes are individually tested for Q(@4V) in excess of 1200. If desired, the diode pairs can be matched for capacitance to ±1% prior to assembly. The low-loss ceramic packages have inductance of less than 0.5 nH and package capacitance of 0.15 pF. Voltage breakdown capability is 120 V. MSI Electronics Inc., 3432 57th St., Woodside, NY 11377. Phone(212)672-6500. **251**

POWER TRANSISTORS ARE RADIATION-HARDENED. Developmental types TA8007, TA8007B, TA8100 and TA8100B are designed for aerospace applications in which they might be subjected to extreme neutron and gamma-ray exposure. These devices are rated for operation in radiation environments having neutron fluence levels to 1×10^{14} neutrons/cm^2, and are intended for service in 5 to 10A high-frequency power inverters. All types employ a flat, cylindrical package. Prices (in 100 unit quantities) are: TA8007—$75; TA8007B—$85; TA8100—$75; TA8100B—$85. RCA Solid State Div., Route 202, Somerville, NJ 08876. Phone(201)722-3200. **252**

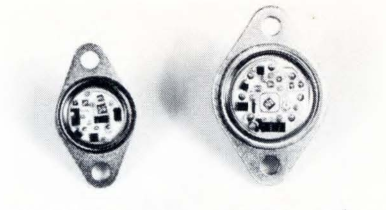


FOUR DUAL-LINE DRIVERS AND RECEIVERS have been added to the TI line of computer-system interface circuits. The SN75121 and SN75123 are plug-in replacements for the 8T13 and 8T23, respectively. The triple-line receivers, the SN75122 and SN75124, are replacements for the 8T14 and 8T24. All are TTL compatible. The SN75121 driver and SN75122 triple-line receiver are designed for coaxial cable, strip line or twisted-pair transmission lines with impedances of 50 to 500Ω. The emitter-follower outputs on the SN75121 enable 2 or more drivers to drive the same line. Texas Instruments Inc., P.O. Box 5012, Dallas, TX 75222. Phone(214)238-2011. **253**

ALTERNATE SOURCE FOR SCHOTTKY TTL MSI. Transitron has added 5 MSI circuits for data selection, multiplexing and carry generator applications. These Schottky-diode clamped TTL ICs are available for both military and industrial temperature ranges. The new circuits include: T54/74S151 8-input Data Selector/Multiplexer; T54/74S153 Dual 4-Line to 1-Line Data Selector/Multiplexer; T54/74S157 Quad 2-Line to 1-Line Data Selector/Multiplexer; T54/74S158 Quad 2-Line to 1-Line Data Selector/Multiplexer and T54/74S182 Look Ahead Carry Generator. Transitron Electronic Corp., 168 Albion St., Wakefield, MA 01880. Phone(617)245-4500. **254**

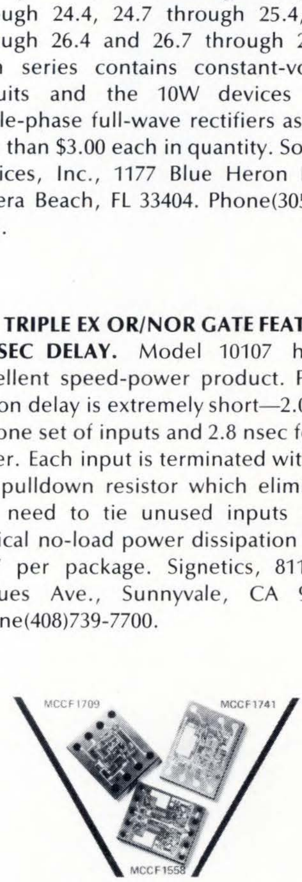
QUAD OP AMPS ARE SIMILAR TO 741s. The 4136 costs approximately 1/2 as much as four 741s and comes in a standard 14-pin dual in-line package. It has 2 stages of voltage gain and a class AB complementary emitter-follower output stage. Input is biased by a constant-current source (500 mA max.) that provides single ended differential voltage gain and a convenient node for internal frequency compensation using a small capacitor. A PNP input configuration makes it well suited for low-noise signal processing. Raytheon Semiconductor, 350 Ellis St., Mountain View, CA 94040. Phone(415)968-9211. **255**

ECL BUS DRIVER/RECEIVER PAIR PROVIDE INTERFACE to logic busses which operate on TTL or IBM-type logic voltage levels. The driver accepts ECL 10k logic levels, (HIGH −0.900V, LOW −1.750V, typical) and yields selectable outputs: TTL levels (HIGH >+2.5V, LOW <+0.5V); or IBM-type levels (HIGH >+3.11V, LOW <+0.15V). The MC10128 outputs may be disconnected from the bus by means of a tri-state "Disable" input. The quad bus receiver, MC10129, accepts TTL or IBM-type bus logic levels, and outputs at ECL 10k logic levels. A hysteresis control is included. Motorola, Inc., Semiconductor Products Div., Box 20924, Phoenix, AZ 85036. Phone(602)273-6900. **256**

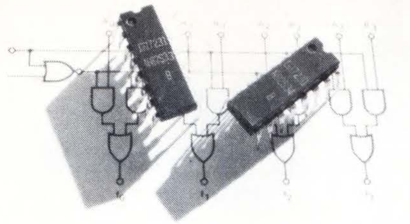


5 W AND 10 W HYBRID POWER REGULATORS. The SDR 120-12 through 27 series has 5W power dissipation and the units are in a 2-lead TO-66 case. The SDR 119-12 through 27 series has 10W power dissipation and the units are in a 7-lead TO-3 case. Fixed output voltages for both series are 11.9 through 12.3, 13.9 through 14.3, 17.8 through 18.3, 23.8 through 24.4, 24.7 through 25.4, 25.7 through 26.4 and 26.7 through 27.4V. Each series contains constant-voltage circuits and the 10W devices have single-phase full-wave rectifiers as well. Less than $3.00 each in quantity. Solitron Devices, Inc., 1177 Blue Heron Blvd., Riviera Beach, FL 33404. Phone(305)848-4311. **257**

ECL TRIPLE EX OR/NOR GATE FEATURES 2 nSEC DELAY. Model 10107 has an excellent speed-power product. Propagation delay is extremely short—2.0 nsec for one set of inputs and 2.8 nsec for the other. Each input is terminated with a 50 kΩ pulldown resistor which eliminates the need to tie unused inputs LOW. Typical no-load power dissipation is 115 mW per package. Signetics, 811 East Arques Ave., Sunnyvale, CA 94086. Phone(408)739-7700.



LINEAR FLIP CHIPS. Motorola has just introduced its first linear flip chips, op amps MCCF1709, MCCF1741 and MCCF1558/MCCF1458. The MCCF1558 is a dual op amp of the 1741 type, and the MCCF1458 represents the relaxed specification of the prime-grade device. The chips can be simultaneously attached by using a single reflow solder operation; further, they eliminate the need to subject the entire hybrid assembly to possibly-damaging die bonding temperatures encountered with conventional chips. Technical Information Center, Motorola, Inc., Semiconductor Products Div., P.O. Box 20924, Phoenix, AZ 85036. Phone(602)273-6900. **259**



TTL MULTIPLEXERS ARE FOR RAPID DATA SELECTION. Models 82S33 and 82S34 Schottky-clamped multiplexers are 2-input, 4-bit digital multiplexers designed for general purpose data-selection applications. The 82S33 features noninverting data paths, and the 82S34 features inverting data paths. The 82S34 has open-collector outputs which permit direct wiring to other open-collector outputs. As many as 40 4-bit words can be multiplexed by using 20 82S34s in the WIRED-AND mode. In lots of 100 encapsulated plastic DIP packages cost \$4.28 each. Letterhead or phone requests only. Signetics, 811 East Arques Ave., Sunnyvale, CA 94086. Phone(408)739-7700.

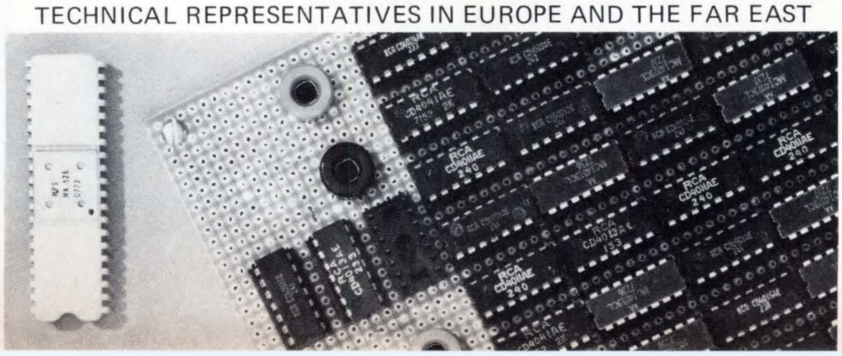
BUS TRANSCEIVERS FOR HIGH-SPEED PARTYLINE OPERATIONS have drive capabilities higher than any similar circuit on the market. The Am26S12 and Am26S12A transceivers, built with Schottky clamped transistors, offer driver current-sinking capability of 100 mA at a max. of 0.8V. The high current-sink capability of the drivers coupled with the high input impedance of the receivers enables as many as 200 devices to be connected onto a 100Ω double-terminated bus line. Delay through the receiver from bus to data output is 26 nsec maximum, and through the driver from data input to bus 15 nsec maximum. Advanced Micro Devices, Inc., 901 Thompson Place, Sunnyvale, CA 94086. Phone(408)732-2400. **261**

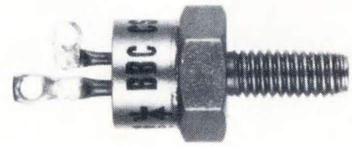
THREE RF TRANSISTORS FOR VHF aircraft transmitters feature 6W (min.) output at 118 MHz. RCA 40975, 40976 and 40977 are especially intended for use in VHF AM transmitters operating from a 12.5V supply. Types 40975 and 40976 are supplied in TO-39 package; the 40977 output unit features emitter-ballasting resistors, together with a low thermal-resistance stripline package (RCA HF-44) that makes it particularly rugged and reliable. Prices in 100-unit quantities, are \$1.15 for the 40975; \$1.80 for the 40976; \$6.60 for 40977. RCA Solid State Div., Box 3200, Somerville, NJ 08876. Phone(201)722-3200. **262**

Circle No. 46

HYBRID OP AMP FEATURES HIGH SLEW RATE. Halex Model HX0032 is a high-speed, FET-input operational amplifier. Bandwidth to 70 MHz; slew rate to 500 V/μsec; and JFET input impedance of $10^{12}\Omega$. The high-speed, high-impedance performance characteristics of HX0032 lend themselves to use in D/A summing amplifiers, sample and hold circuits, integrators and video amplifiers. Model HX0032, \$40.00 each in 100-piece lots; Model HX0032C, \$18.00 each in 100-piece lots. Delivery: 2-3 weeks. Halex, Inc., 3500 West Torrance Blvd., Torrance, CA 90509. Phone(213)772-4461. **263**

OPTICAL DETECTOR / AMPLIFIERS BOAST GOOD SENSITIVITY. A new UDT PHOTOPS Series of optical detector/amplifier combinations are intended as replacements for photomultiplier tubes. These high-gain, low-noise, high-speed devices are available with large ($1 cm^2$) sensing area and FET circuitry. Sensitivity is as low as 10^{-12}W with bandwidths to 10 MHz. PHOTOPS are available from stock and are priced from \$67 to \$195. United Detector Technology, Inc., 1732 21st St., Santa Monica, CA 90404. Phone(213)829-3357. **264**

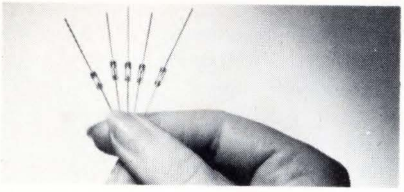




INVERTER SCR BOASTS TURN-OFF OF 12 μSEC. The 25A rms inverter SCR, Model CS 4.9, features fast turn-off, permitting the use of small inexpensive commutating components in circuits for motor-control and battery-charger, applications. The device, available to 600V, offers standard reapplied di/dt of 200 A/μsec. Data is provided for high-frequency applications. 200V prices start at $3.49 each in lots of 100 pcs. Brown Boveri Corp., 1460 Livingston Ave., North Brunswick, NJ 08902. Phone(201)932-6066. **265**

2-PACKAGE, 4-BIT TTL MULTIPLIER HAS TRI-STATE OUTPUTS. National's DM7875/DM8875 multiplier is packaged as "A" and "B" circuits, each a standard 16-pin package. Both multiplier and multiplicand are applied inputs of each package. The outputs of each package give the 8-bit product in parallel. A gated 2-input strobe controls the Tri-State outputs on each package. The multiplier is available in either molded epoxy or ceramic dual inline packages with military (DM7875A&B) or commercial specs (DM8875A&B). Unit prices in 100-up quantities are $32.00 in the military "J" package and $15.50 in the commercial Epoxy B package. Letterhead and phone requests only. National Semiconductor Corp., 2900 Semiconductor Dr., Santa Clara, CA 95051. Phone(408)732-5000.

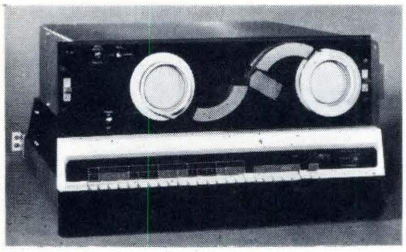
MOS/LSI STATIC SHIFT REGISTERS IDEAL FOR PUNCHED-CARD applications centered around the 96-column punch card such as keypunch, key-to-tape and key-to-disc systems. A single device can be used to store a whole tier of a 96 column card. Both devices, designated the TMS3122 and TMS3123, have a single low-capacitance clock which can be driven directly by TTL ICs. Max speed is 2 MHz. Offered in either a plastic (NC suffix) or ceramic (JC suffix) dual-in-line package, prices in 100-999-piece quantities are $8.80 each for the TMS3122JC and TMS3123JC and $6.60 each for the TMS3122NC and the TMS3123NC. Texas Instruments Inc., Inquiry Answering Service, P.O. Box 5012, M/S 308, Dallas, TX 75222. Phone(214)238-2011. **267**



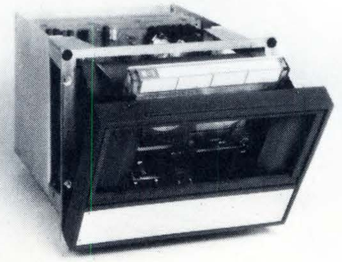
PIN DIODES FEATURE LOW INSERTION LOSSES. A series of glass packaged silicon PIN diodes designed for applications requiring low insertion loss and high isolation are available with breakdown voltages of 50, 100, 200, or 500V. A wide variety of performance characteristics may be obtained with the VSD-300 series, including: junction capacitances ranging from 0.05 to 0.75 pF and series resistances from 0.3 to 2.0Ω. Typical minority carrier lifetime ratings for VSD-300 diodes are between 5.0 and 350.0 nsec. They will withstand operating temperatures from −65 to +150°C. Varian, Solid State East, Salem Rd., Beverly, MA 01915. Phone(617)922-6000.
268

MICROTRANSMITTER PROVIDES 250 mW AT 27 MHz. The LP2001 is usable as an AM or pulse modulated transmitter at frequencies up to 150 MHz with an external crystal controlling its oscillator. The IC also includes a transformerless modulator, buffer stages, and a self-biased output stage which drives an external LC antenna-matching network. A preamp is provided for low-level modulation inputs, as well as internal power supply regulation. A latching power supply switch permits zero standby alarm application. The circuit operates from a single +3 to +15V power supply. The LP2001 is priced at $18.75 in quantities of 100. Lithic Systems, Inc., P.O. Box 478 Saratoga, CA 95070. Phone(408)867-5600.
269

COMPLETE 4-DIGIT UP/DOWN COUNTING AND DECODING accomplished with only two MOS LSI devices. The M003 is 4-decade, synchronous up/down counter arranged as 2 subsystems, each comprising 2 decades. Each subsystem has inputs for a single-phase clock reset to 0 and to 9, and up/down control, all common to both decades. The M004 is a 4-digit multiplexer/decoder storing the content of the counter through a single control line, and continuously decoding it to 10 decimal outputs. The combination of these 2 LSI devices provides a 4-figure counter with necessary decoding. SGS-ATES Semiconductor Corp., 435 Newtonville Ave., Newtonville, MA 02160. Phone(617)969-1610.
270



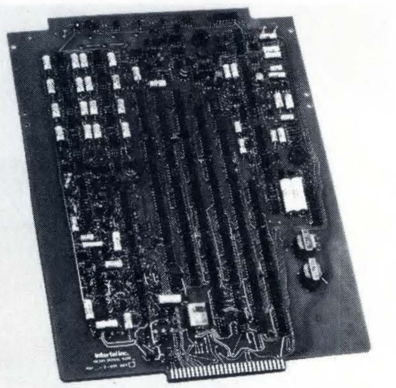
DIRECT-ACCESS MASS MEMORY FOR MINIS. The system, Model CO-500DA, is delivered plug compatible with the PDP-11 including unibus cable. Included with the system is a LINC tape loader, utility software and a keyboard executive. Data transfer between the PDP-11 and LINC tape is via direct memory access. Transfer rate is 8400 bytes/sec and storage capacity is 335,000 bytes/drive. Up to 15 additional drives may be added to the master unit. $4500. Computer Operations, Inc., 10774 Tucker St., Beltsville, MD 20705. Phone(301)937-5377. **204**



DRIVE PROVIDES RELIABLE DATA INTERCHANGE. The DCD-3 drive, intended for the OEM market, conforms to the proposed ANSI standards for 1/4-in. cartridge devices. It was designed for the Scotch brand DC 300A data cartridge. Available with 1-, 2- or 4-track, read-while-write heads, the drive has such standard features as 1600 bpi recording density, 48k bps transfer rate, 30 ips bi-directional read/write speed and 90 ips bi-directional shuttle speed. $330. 3M Co., P.O. Box 33600, St. Paul, MN 55133. Phone(612)733-2925. **205**

CARD CONVERTS PARALLEL TO SERIAL FORMAT. The universal asynchronous receive/transmit (UART) card provides universal interface to all devices compatible with EIA Standard RS232C. UART renders the 9000 Series photoelectric punched-tape readers capable of interface with user terminals and other peripheral devices requiring serially-formated data transmission. It also enables these tape readers to interface with, or directly replace, serial I-O terminals in printers, modems, minicomputers and some telecommunications equipment. $250. Electronic Engineering Co. of California, 1441 E. Chesnut Ave., Santa Ana, CA 92701. Phone(714)547-5651. **206**

INTELLIGENT TERMINALS HAVE 7k BYTES OF MEMORY. The memory option for Model 340 communication terminals allows more extensive use of terminal application language (T.A.L.), enabling users to write sophisticated editing programs for storage and execution from the terminal's memory. The combination of the memory option and the flexible programming capabilities of T.A.L. provides users with improved editing and validation of data at branch offices or other remote locations. Sycor, Inc., 100 Phoenix Dr., Ann Arbor, MI 48104. Phone(313)971-0900. **207**



201B-TYPE MODEM AVAILABLE ON pc CARD. Model 2010 which provides fully Bell 201B compatible operation at 2400 bps, features automatic fast sync, new sync, clear-to-send delay, carrier detect, external/internal transmitter timing and MARK hold on receive data when carrier is lost. It achieves an error rate of less than 1 bit in 10^6 at a signal-to-noise ratio of 15 dB on unconditioned lines with 20° p-p phase jitter at a rate from 0 to 180 Hz. $1040. Intertel Inc., 6 Vine Brook Park, Burlington, MA 01803. Phone(617)273-0950. **208**

PATCH MODULES CONNECT TERMINALS TO COMM. EQUIPMENT. The 8502-02 is connected in series between the data terminal equipment (DTE) and the data communication equipment (DCE). Signal cables from the DTE and the DCE plug into the back of the module through standard EIA RS232 connectors. A front-panel switch allows selection of either the patch mode or the normal mode. In normal mode, the DTE and DCE rear-panel connectors are bussed together. In the patch mode, the DTE and DCE connection is broken and each side of the break is available on front-panel connectors for channel-to-channel patching. International Data Sciences, Inc., 100 Nashua St., Providence, RI 02904. Phone(401)272-5100. **209**

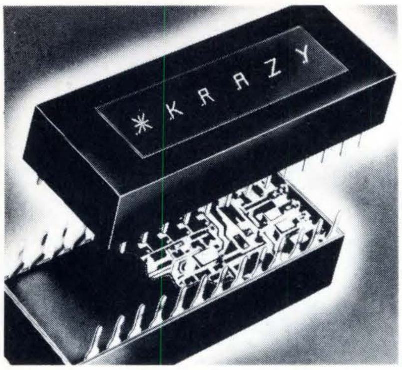
INDUSTRIAL MINICOMPUTER SYSTEM UNDER $20,000. This data acquisition and control system integrates a high-level language with an industrial computer system. The IDACS 8/C is made of 3 major elements: the PDP-8/F minicomputer CPU, industrial interface, and a high-level industrial BASIC software system that allows the user to define his process in BASIC language. The heart of the system is the PDP-8/F, with 8k of read/write core memory, power-fail detection with auto-restart, dual-drive magnetic tape unit with ROM bootstrap loader, and a real-time crystal clock. The industrial interface provides a noise-immune bus with multiplexing capability. Digital Equipment Corp., Maynard, MA 01754. Phone(617)897-5111. **210**

TERMINALS PROVIDE INEXPENSIVE SOURCE-DATA ACQUISITION. The terminal combines an optical card reader with advanced CMOS ICs to read punched cards or badges in a stationary condition. When the card/badge is inserted into the terminal, the data on the card is read and is transmitted serially on 2 wires along with variable data and semi-fixed data entered through optional numeric keyboard and thumbwheel switches. Other options include time-of-day display, 12-digit LED displays, ACK-NACK reply, RS232-C interfacing and precoded validity check on the card. From $1800. Panasonic, Matsushita Electric Corp. of America, Pan Am Building, 200 Park Ave., New York, NY 10017. Phone(212)973-5700. **211**

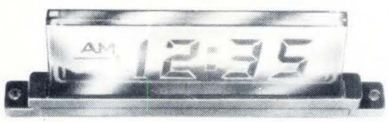
120 cps DATA TERMINAL OFFERS LOW PRICE. The EDT 33 MSR, an integrated package of Teletype Model 33 and a 120 cps magnetic-tape cassette buffer, transmits and receives data at line speeds of 30 or 120 cps asynchronously. The buffer interfaces with a customer-supplied Bell System 103 modem or 202 series data set or equivalent. It will be offered in 2 configurations: automatic send and receive (ASR) and keyboard send and receive (KSR). Excluding the modem, pricing for the EDT 33 MSR is as follows: for the KSR model, $108 a month on a 1-year lease; for ASR, $121. Western Union Data Services Co., 16 McKee Dr., Mahwah, NJ 07430. Phone(201)529-1170. **212**

3330-TYPE DISC OFFERED FOR 360/50s. The 360/50 user no longer has to step up to the more expensive IBM System 370 model 145 for the advantages of rotational-position sensing, command retry and data capacity. The 7830-2/7330-2 subsystem may be shared between any combination of IBM 360/50 and up and 370 computers. When used with the 360/65 and up or 370 the 7330-2 will operate at the lower data-rate speed of 625 kB, but will retain complete data compatibility across the mixed systems. ITEL Corp., 1 Embarcadero Center, San Francisco, CA 94111. Phone(415)989-4220. **213**

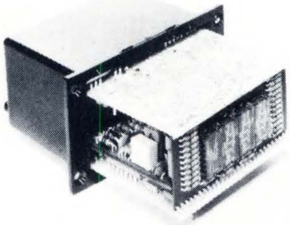
"U-PROGRAM" THIS 128 × 24 PROM-COMPATIBLE CROM. One of the prime features of the field-alterable CROM is the flexibility it gives the user in making changes in data content without additional charges. That is, any discrete bit in the storage array can be reprogrammed repeatedly within seconds as required by the user—even while the system is operating. The basic storage array is gold plated and has index throughout so that the bits are easily located. The advantages of this system over semiconductor PROM is that it permits programming mistakes since the user can change his errors for zero cost. $162. Integrated Memories, Inc., 260 Fordham Rd., Wilmington, MA 01887. Phone(617)658-5073. **214**



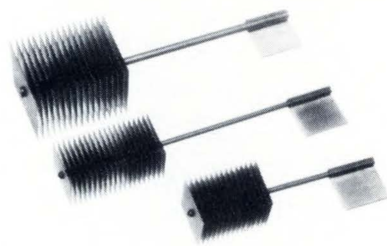
ALPHANUMERIC LED DISPLAY HAS STORAGE AND DRIVE CIRCUITS. By employing a single serial data-input line, system wiring complexity is simplified. This 14-segment continuous-line device provides superior character definition. Visually-objectionable dots and dashes are eliminated. The monolithic approach also offers the inherent reliability lacking in dot-matrix discrete devices. The 6 character readout is available from stock. Custom devices may be fabricated to provide additional LED characters. American Electronic Labs., Inc., P.O. Box 552, Lansdale, PA 19446. Phone(215)822-2929. **215**



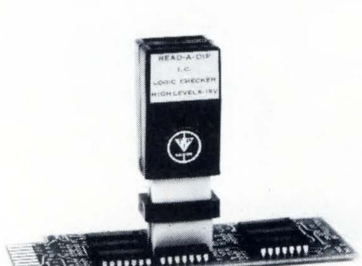
Pc CONNECTORS FOR LIQUID CRYSTALS. The Series 6100 features single-side design and is available with 31 contacts. A choice of terminal options includes solder lug, thru hole and 2 sizes of dip solder. Standard molding is glass-fiber-filled diallyl phthalate Type GDI-30 per MIL - P - 19833 specifications. Contact material is phosphor bronze, gold plated over copper underplate. Continental Connector Corp., 34-63 56th St., Woodside, NY 11377. Phone(212)899-4422. **216**



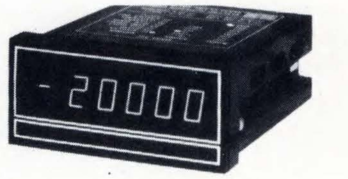
DPM SELLS FOR $99 IN SINGLE QUANTITY. Model DM-2000 3-1/2-digit LED panel meter contains a true differential input. Both inputs and the analog common can sustain up to ±2 common-mode volts with respect to the digital output common. Other features include a choice of input range (±1.999 mV or 1.999 VFS), a common-mode rejection ratio of 70 dB at 60 Hz, input bias current of 20 nA and input impedance of 100 MΩ plus automatic polarity. Accuracy is ±0.05% and resolution is 100 μV. Input settling time is 50 μsec and up to 200 readings can be made asynchronously or synchronously. Datel Systems, Inc., 1020 Turnpike St., Canton, MA 02021. Phone(617)828-6395. **217**



HEAT PIPES PROVIDE BETTER HEAT TRANSFER. They have the ability to transport heat over 100 times better than solid metals. The heat pipe allows the designer to position heat-generating components for optimum electrical performance, then place the heatsink at some convenient remote point. The inherent thermal conductance of heat pipes allows them to spread "hot spots", causes several components to operate at the same temperature, transfers heat great distances with almost no thermal drop and makes conventional heat dissipators more efficient by reducing their thermal gradients. These heat pipes are supplied in tubular, finned, flat and variable-conductance types. Jermyn, 712 Montgomery St., San Francisco, CA 94111. Phone(415)362-7431. **218**

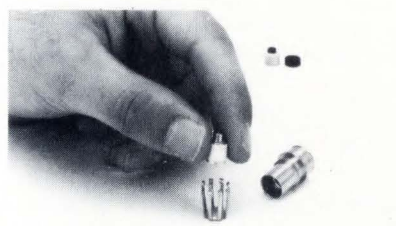


CHIP-POWERED LOGIC CHECKER HANDLES 14/16-PIN DIPs. READ-A-DIP is V_{cc} and Gnd. seeking automatically. It tests gates of TTL or DTL having 14 or 16 pins, and such ICs as flip-flops, counters, shift registers, decoders and adders. The LED readout indicates high, low and pulsing states of each pin. $125. Micro Electronic Systems Inc., 8 Kevin Dr., Danbury, CT 06810. Phone(203)746-2525. **219**

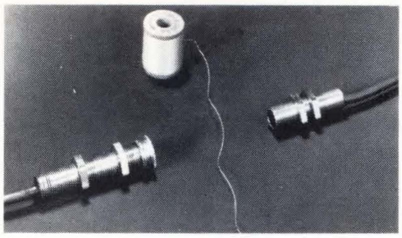


4-1/2-DIGIT PANEL METER FEATURES SPERRY PLANAR DISPLAY. Model 385 is designed for high-accuracy electronic weighing, temperature measurement and photo-chemical applications. Options include bipolar, ratio, wide-range zero offset, analog output, differential input, resistance and current measurements. Every unit receives a 96-hr. burn-in at 60°C and has a 2-year warranty. About $199. Electro-Numerics Corp., 2961 Corvin Dr., Santa Clara, CA 95051. Phone(408)738-1840. **241**

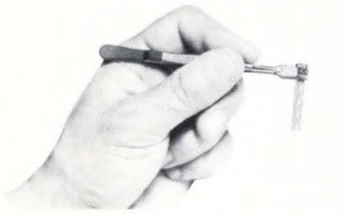
AXIAL FAN IS ONLY 1-IN. THICK, 4-1/2 IN. SQ. Series 760 Model 98XH provides air flow rate of 75 cfm with static pressures up to 0.370 in. H_2O. Both 50/60 Hz and 400 Hz versions are available. Operating temperatures are −48 to +158°F (50/60 Hz), with 10,000 hrs. guaranteed minimum life expectancy. Fans have double-shielded, greased-for-life ball bearings. $21.45. Amphenol Sales Div., 2875 S. 25th Ave., Broadview, IL 60153. Phone(312)345-4260. **242**



SURGE ARRESTOR PROTECTS EQUIPMENT FROM OVERLOADS. A gas-tube unit with ceramic enclosure, the new arrestor has widespread applications in the fields of telephony, radio transmission and microwave devices of all kinds. It is suitable for use on lines up to 175V dc. To install, the old disc carbons are removed and one of the new units is dropped into place. The Model EL242S ceramic gas-tube surge arrestor will pass up to 100 times as many surges as carbon-type units without decrease in efficiency. $1. Electrons Co., 65 Passaic Ave., Fairfield, NJ 07006. Phone (201) 227-3830. **243**



IR LED PHOTOELECTRIC CONTROL DETECTS SMALL OBJECTS. Though designed primarily for invisible transmitted beam operation, the ST1 7060-series OPTOSWITCH™ also performs well as a proximity or retro-reflective sensor. Range is up to 8 ft. The controls have been field proven for many precision sensing, counting and actuating applications. Typical production uses include counting 0.020-in. dia. drills passing on a conveyor, maintaining a liquid level to ±0.005-in. tolerance and detecting the presence or absence of a 1/16-in. thick tabbed lock washer in an assembly. $155 complete with control electronics. Scientific Technology Inc., 1157 San Antonio Rd., Mt. View, CA 94040. Phone(415)965-0910. **244**



MIL-T-27 AUDIO PLUG-IN TRANSFORMERS ARE 1/4 IN. SQ. The PICO-F Series is offered with primary and secondary impedance of 5Ω to 30 kΩ and response of ±3 dB from 400 Hz to 250 kHz. They handle 100 mW at 1 kHz and meet thermal shock to MIL-STD-202D. (Inductors to 10H.) Pico Electronics, 316 W. 1st St., Mt. Vernon, NY 10550. Phone(914)699-5514. **245**

INDICATOR FEATURES MANUAL RESET. Series L21603/01 fault indicator was developed to monitor the performance of electrical or electronic circuits. It provides a visual warning of trouble when operation falls outside of design parameters. When the circuit is functioning normally, a window on the front of the indicator presents an all-black appearance. When a fault occurs, the window trips to a contrasting black and white design. The fault indicator responds to a nominal pulse width of 50 msec. North American Philips Controls Corp., Cheshire, CT 06410. Phone(203)272-0301. **246**

INCLINOMETERS MEASURE TILT TO 0.0003°. Series 701 inclinometers use a newly-discovered force-balance principle. They are made specifically for control, by changes in inclination, in all industrial, commercial, military, oceanographic, and aircraft applications where cost and performance considerations are paramount. They provide an electrical output proportional to the angle of inclination from 0.0003 to 90°. Single units are $250 each. Columbia Research Labs., Inc., Woodlyn, PA 19094. Phone(215)532-9464. **247**

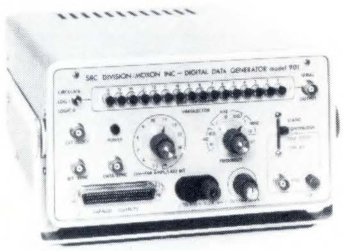
MERCURY WETTED RELAY IS RATED FOR 25 MILLION OPERATIONS. Series LC2R is housed in a hermetically sealed metal capsule. Loads to 1A at 24V dc or 0.1A at 200V dc permit rated life. Contact resistance is less than 0.05Ω and varies less than 0.002Ω over life. Operate time is less than 2.5 msec. The LC2R is available in a SPST form "A" nonlatching model with coil voltages of 5, 12 and 24V dc standard. Under $4 in production quantities. Fifth Dimension Inc., Box 483, Princeton, NJ 08450. Phone (609)924-5990. **248**

26-RANGE 5 1/2-DIGIT MULTIMETER IS LOW PRICED. Model 7205 has lead compensation for resistance measurements, ac response to 1 MHz and in-line in-plane Sperry display. Ranges include 5 for dc voltage (to 1 μV resolution and with 1000V protection on all ranges), 5 for ac voltage with 500V protection and 1 MHz response, 6 for resistance and 10 for dc and ac current to 1.3A. CMR and NMR are greater than 140 dB and 60 dB respectively. $995. Systron-Donner, Instruments Div., 10 Systron Dr., Concord, CA 94518. Phone(415)682-6161. **185**

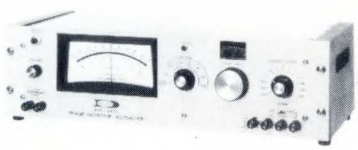
PORTABLE 14-LB SCOPE OFFERS 10 MHz AND DELAYED SWEEP. The dual-channel 2100G has dc-to-10 MHz bandwidth, sensitivity of 10 mV/div, sweep speed of 50 nsec/div, 8×10 div display with 6.5 kV accelerating potential and delayed sweep capability. Included are full auto triggering single sweep capability and verniers on vertical and time-base controls. Field proven MTBF exceeds 5000 hours. $1195, complete with tilt handle, front cover and a vinyl rain jacket. Dumont Oscilloscope Labs., Inc., 40 Fairfield Pl., W. Caldwell, NJ 07006. Phone(201)575-8666. **186**

COMPUTING TACHOMETER READS FROM 0.1 TO 99,999 RPM. By using an extremely accurate low-frequency counter with 5-digit preset, Model 284 can normalize ac-coupled inputs to give a direct RPM readout to 3-place accuracy. RPM is computed instantly, even with only two input pulses. $1275. Time Systems Corp., 1130 W. Evelyn Ave., Sunnyvale, CA 94086. Phone(408)736-0840. **187**

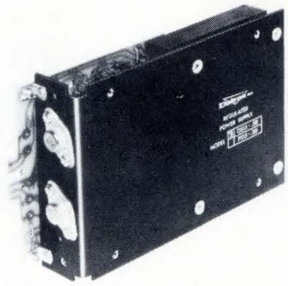
AUTOMATED TEST SYSTEM HAS LOW PROGRAMMING COSTS. LOCOST-106 can be operated by a laboratory technician. The control system's calculator has capability equivalent to a 10k - 12k minicomputer. This is coupled with a data terminal, high-speed thermal printer and 32,000-word programming cassette memory. Programming costs are 80 to 90% lower than for conventional computer-controlled systems. Overall costs range from $25,000 to over $100,000. Julie Research Lab., Inc., 211 W. 61st St., New York, NY 10023. Phone(212)245-2727. **188**



DIGITAL DATA GENERATOR IS VERSATILE. Model 901 combines many instruments required for breadboard testing of digital circuits into one package, and provides both 16-bit serial output and dynamic "hard wired" parallel outputs plus 3 power-supply outputs for logic excitation. It features 16-pushbutton selection of logic "0"s and "1"s in either serial or parallel, with output levels adjustable from 0 to ±15V over the dc to 15 MHz frequency range. $995. Moxon Inc., SRC Div., 2222 Michelson Dr., Irvine, CA 92664. Phone(714)833-2000. **189**



PHASE-SENSITIVE VOLTMETER HAS SELF TEST. Model 244 measures total voltage, in-phase and quadrature voltages and phase angle. Phase-sensitive voltmeter operation is at any prespecified frequency between 50 Hz and 15 KHz. Full-scale sensitivity ranges from 300 μV to 300V. There is a dc output for driving an external DVM. A built-in phase shift standard lets the user monitor phase angle accuracy. $800. Dytronics Co., Inc., 4800 Evanswood Dr., Columbus, OH 43229. Phone(614)885-3303. **190**

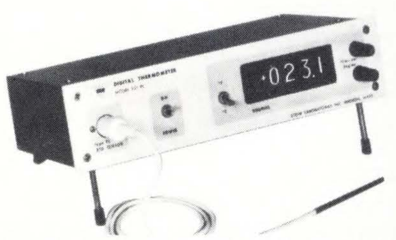


DUAL-OUTPUT SUPPLIES HAVE IC REGULATION. Model PSQ15-.4D, with two completely independent isolated outputs adjustable from 5 to 15V delivers up to 0.4A. Outputs can also be used in parallel, in series, or in master-slave tracking. Specifications are 0.01% regulation, 500 μV pard. High performance ICs, hermetically-sealed power components and socketed power transistors are used. $95. Deltron, Inc., Wissahickon Ave., North Wales, PA 19454. Phone(215)699-9261. **191**

ECONOMY VOLTAGE REFERENCES GIVE ±0.01% ACCURACY. Model E-10-D provides a voltage output between zero and ±11V dc in 100 μV steps. Output current is 50 mA—short-circuit and overload protected. The Model E-100-E provides two ranges: ±10V and ±100 mV, plus 10% overrange in both cases. Output current is 50 mA at 10V with an output impedance of 50 mΩ. Model E-10-D, $450; Model E-100-E, $525. Electronic Development Corp., 11 Hamlin St., Boston, MA 02127. Phone(617)268-9696. **192**

DIGITAL ELECTROMETER (DMM) CAN BE AUTOMATED. Model 616 measures voltage, current, resistance, and charge with extremely high input impedance. Sensitivities are 10 μV/digit to 200V, 10^{-16}A/digit to 200 mA, resistance as high as $2 \times 10^{14}\Omega$ and 10^{-15} coulombs. CMR is greater than 140 dB. An optional digital output/control permits the unit to be fully interfaceable and controllable by automatic measuring systems. $995, plus $595 for the option. Keithley Instruments Inc., 28775 Aurora Rd., Cleveland, OH 44139. Phone(216)248-0400. **193**

ELECTRO-OPTICAL TRACKER IS COMPACT, PORTABLE. General-purpose solid-state Model 501 consists of a control unit and optical head, which together weigh 22 lbs. It operates from either 117V ac or 12V dc at 15 VA. Displacement range covered can be from 0.002 in. to infinity, depending on the optical lens system selected (a range of interchangeable lenses is available). Response time is dc to 25,000 Hz. An accessory velocity-accleration unit (Model 575) converts the displacement signal to velocity and acceleration signals simultaneously, so that all three are continuously available. Optron Div., Universal Technology, Inc., 30 Hazel Terrace, Woodbridge, CT 06525. Phone(203)389-5384. **194**



DIGITAL THERMOMETER SWITCHES FOR °F OR °C. Model 921 PL allows continuous or intermittent operation monitoring over the temperature range of −85 to +200°C (−121 to +392°F), with accuracy and stability of ±0.2% of reading ±0.15° over the full range. A linear calibrated analog output of 10.00 mV per degree, is provided, as is a computer-compatible TTL-level BCD output. $595. Stow Lab., Inc., Kane Industrial Dr., Hudson, MA 01749. Phone(617)562-9347. **195**

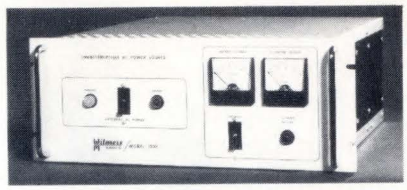
2.5 NSEC RISE-TIME PULSE GENERATOR HANDLES TTL/ECL WORK. The PM5771, an advanced version of the Philips PM5770, has rise and fall time improved to 2.5 nsec to permit tests of ECL components at rated conditions. Internally-triggered pulse repetition time is selectable in 9 ranges from 1 Hz to 100 MHz, with continuous adjustment between ranges. Output amplitude is continuously adjustable from 80 mV to 5V from 50Ω source resistance, and to 10V as an open-circuit current source. Pulse width and delay are both continuously variable in 8 ranges from 5 nsec to 100 msec. Duty cycle can approach 100% when using the inverted pulse output, limited only by the minimum pulse duration of 5 nsec. Test & Measuring Instruments Inc., 224 Duffy Ave., Hicksville, NY 11802. Phone(516)433-8800. **196**

Circle No. 54

LINE SCAN SYSTEM HAS UP TO 512 PHOTODIODES. The first all solid-state non-contact measuring system with this resolution, the system consists of the LC600 line-scan camera and RS600 series controller. It is designed for the precise measurement of size, position or gap, and the automatic inspection of mass-produced parts. The controller provides supply voltages for the camera and presents a digital display of the object dimension being scanned. It also provides for setting high and low limits, has BCD output, can provide feedback for closed-loop process control and can be programmed to recognize a desired pattern. Complete systems from $2150, cameras from $1200. Reticon Corp., 450 E. Middlefield Rd., Mt. View, CA 94040. Phone(415)964-6800. **197**

BATCH COUNTER GIVES ENGINEERING-UNIT READOUT. Model H603A's 5-digit display counts switch closures, pulses, ac inputs or voltage transitions. Adjustable scaling permits direct engineering-unit readout. Input levels as low as 10 mV rms and frequencies up to 50 kHz are accepted. Five thumbwheel switches preset a batch count, and when the displayed count reaches this setting, a lamp and a relay both operate. $450. Howell Instruments, Inc. 3479 W. Vickery Blvd., Forth Worth, TX 76107. Phone(817)336-7411. **198**

FFT PROCESSOR OPERATES LIKE AN INSTRUMENT. Series OF-400 Analyzer is a universal digital signal analysis system for real-time viewing of changing functions—a complete instrument with all signal conditioning and display calibration built-in. Features include high speed of 68,000 samples/sec throughout, and high resolution with a 2048 transform size and extra-sharp input anti-aliasing filtering. It offers high dynamic range, ease of use, display flexibility with two simultaneous display outputs and frequency coverage to 100 KHz. Federal Scientific Corp., 615 W. 131st St., New York, NY 10027. Phone(212)286-4400. **199**



UNINTERRUPTIBLE AC POWER HAS NO SWITCHOVER. Containing its own built-in batteries, battery charger and dc-to-ac inverter, Model 1202 ensures absolute continuity of frequency-stable 60-Hz 115V ac sine wave voltage to critical loads. With commercial ac power present, it supplies an output of 250V continuously, and will continue to supply it for a minimum of 10 minutes when no ac input is present. The 1202 UPS is well-protected against overloads, short circuits and most user errors. $975. Wilmore Electronics Co., Inc., P.O. Box 2973, W. Durham Sta. Durham, NC 27705. Phone(919)489-3318. **200**

DATA LOGGER EMPLOYS CONSTANT-CURRENT OUTPUT CIRCUIT. The DL 1200 Digilogger converts 10 digits of parallel 1248 BCD data to serial 8-level (11-bit) ASCII code suitable for driving teletypewriters and other ASCII devices. Digilogger inputs are strobed and loaded into a buffer memory within 100 nsec of a log command, eliminating the need to hold input data constant for scanning. $875. Nationwide Electronic Systems, 7N662 Rte. 53, Itasca, IL 60143. Phone(312)773-0370. **201**

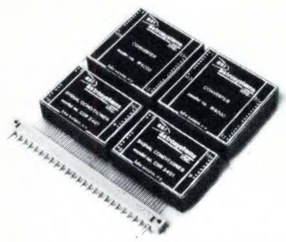
STEPPING-MOTOR DRIVER PROVIDES 20,000 STEPS/SEC. The compact Model 8082 runs from 115V/230V, 50/60 Hz source and delivers an adjustable current of 0.5 to 2.5A/phase to motors up to 240 oz-in. of torque. The unit includes a complete stepping-motor translator with integral power supply, and can drive any 4-phase stepping motor within its current rating. Summit Engineering Corp., 2311 S. 7th Ave., Bozeman, MT 59715. Phone(406)587-0636. **202**

INFRARED THERMOMETER MEASURES TO 0°C. The SL200's long-wavelength detector overcomes previous low-temperature limitations. Typical temperature ranges are 50 to 500°F and 100 to 1000°F. Temperature scales are linear, and analog or digital meters offer 1° resolution in either F or C. Featured are through-the-lens sighting with adjustable rear focusing, narrow field of view and 0.1 sec response time. Raytek, 1277 Terra Belle Ave., Mountain View, CA 94040. Phone(415)961-1650. **203**

TINY 4-DECADE BCD D/A CONVERTER COSTS ONLY $69 IN SINGLES. The DAC328-4-BCD converter measures 2 × 2 × 0.4 in. and is compatible with TTL/DTL inputs. It features ±0.01% linearity, 1-μsec settling time, accuracy vs temperature of 30 ppm/°C, and an operating temperature range of 0 to +70°C. The current-output unit has 1.25V compliance and comes with an internal reference. The unit uses thin-film resistors and hermetically sealed components. It is powered from ±15V dc. Hybrid Systems Corp., 87 Second Ave., Burlington, MA 01803. Phone(617)272-1522. **170**

MULTIPLYING D/As HAVE HIGH FEEDTHROUGHS/SETTLING TIMES. Models 4028 and 4029 8- and 10-bit units, respectively, feature guaranteed −60dB feedthroughs at 10 kHz and settling times of 3 μsec to 1/2 LSB. The external-reference signal may vary from −10 to +10V at up to 80 kHz and may be any waveform. Both units are rated to operate over 0 to +70°C. Each measures 2 × 2 × 0.4 in. The 8-bit 4028 costs $179 and the 10-bit 4029 costs $229, in single quantities. Teledyne Philbrick, Allied Drive at Rte 128, Dedham, MA 02026. Phone(617)329-1600. **171**

INTEGRATED POWER SWITCHES HANDLE UP TO 200A. The TIXH807, TIXH808 and TIXH809 are housed in conduction-cooled aluminum cases measuring 7 × 3.5 × 1.6 in. They feature turn-off times of 0.5 μsec, operate from dc to 10 kHz and can be driven by DTL or TTL ICs. They are rated at 150A @ 100V; 200A@ 100V; and 60A@400V, respectively. Each unit contains two switches which may be connected together for a single push-pull output, or separately as two independent switches. From $785 for single units to $450 in 1000-piece quantities. Texas Instruments Inc., Box 5012, Dallas, TX 75222. Phone(214)238-2011. **172**

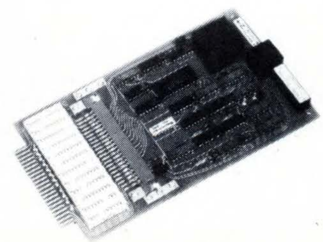


DUAL-SPEED SYNCHRO CONVERTERS PROVIDE 18-BIT RESOLUTION. These dual-speed (coarse and fine) units are available to convert 1:8, 1:16, 1:32, 1:36 and 1:64 speed inputs to a single combined digital output. Outputs are either in natural binary (BAMS) or BCD with binary resolutions from 11 to 18 bits and BCD resolution to 0.01°. Accuracy in all cases is ±1 LSB. Inputs can be accommodated at standard signal levels of 11.8V/400 Hz, 90V/400 Hz or 90V/60 Hz. Digital outputs are held in an internal register for ease in interfacing and are DTL/TTL compatible. Astrosystems, Inc., 6 Nevada Dr., Lake Success, NY 11040. Phone(516)328-1600. **173**

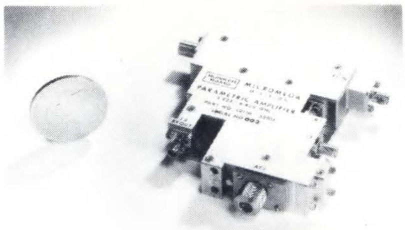
HYBRID D/A CONVERTERS MEET MIL 883 REQUIREMENTS. The four converter devices are packaged in DIP-compatible plastic shells. Available off-the-shelf are 2-digit BCD converters with or without a self-contained output op amp (types UHM-309 and UHM-308, respectively), and 3-digit BCD multiplying (bipolar) converters either with or without the self-contained output op amp (types UHM-332 and UHM-333, respectively). Conversion times are: 5 μsec (UHM-309), 2 μsec (UHM-308) and 15 μsec (UHM-332 and UHM-333). Sprague Electric Co., 115 Northeast Cutoff, Worcester, MA 01606. Phone(617)853-5000. **174**

HIGH-INPUT-IMPEDANCE VOLTAGE COMPARATOR HAS 0.5-nA BIAS. Model 33 operates from a single-ended power supply of +10 to +18V dc and has a 100-μsec response time. Its input range extends from 0 to +5V dc, inverting and noninverting, and input overload is up to +100V dc. Other features include positive switching by built-in hysteresis, a built-in 6.2V dc reference source, and an operating temperature range of 0 to +75°C. The unit comes in a potted module measuring 2.35 × 2.125 × 0.75 in. $45. Pioneer Instrumentation, 4800 E. 131st St., Cleveland, OH 44105. Phone(216)587-3600. **175**

IC LOG AMP WITHSTANDS SEVERE ENVIRONMENTS. The 120-MHz Model ICLT120 amplifier meets the thermal shock requirements of MIL-STD-331 and has 50,000 hours MTBF. This device meets all electrical parameters over the temperature range of −30 to +71°C, 100g shock, 50g acceleration, and thermal shock of a 100°C change in 5 minutes. Center frequency is 120 MHz, bandwidth is 50 MHz and dynamic range is 60 dB. The logging accuracy is ±1 dB and propagation delay is 25 nsec. $995. RHG Electronics Laboratory, Inc., 161 E. Industry Ct., Deer Park, NY 11729. Phone(516)242-1100. **176**



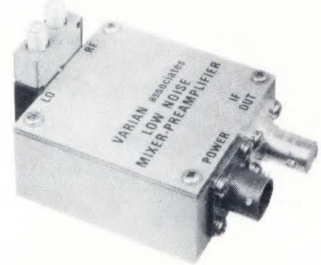
AUTOMATIC TELEPHONE DIALERS COME ON pc BOARDS. Both the pulse Model 4201 and tone Model 4202 dialers on pc boards are activated either by a pushbutton or contact closure. The action is the automatic dialing of up to 40 addresses made of 7, 8, 10 or 11 digits. Optional features such as automatic line seizure, re-dial, multiple-address capability and dial-tone detector can be ordered integrally with the pc board or as add-ons when needed. Each flat dialer card measures 7-1/2 × 4-1/2 × 3/4 in. and dissipates only 300 mA at 5V dc. OPT Industries, Inc., 300 Red School La., Phillipsburg, NJ 08865. Phone(201)454-2600. **177**



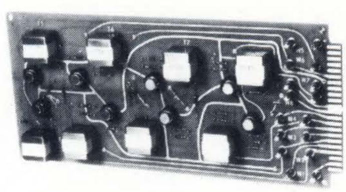
LOW-NOISE C-BAND PARAMETRIC AMPLIFIERS WEIGH ONLY 12 OZ. Developed for potential use in free-world communications satellites, the 7.5-in.^{3} units feature a 5.9-to-6.4-GHz instantaneous bandwidth and a 140°K uncooled noise temperature. Typical gain (one stage) is 15 dB and gain ripple over bandwidth is ±0.20 dB. The units incorporate Micromega-built Gunn-effect pump oscillators, and are completely solid-state. They are available with or without chamberless temperature stabilization, and may also be supplied with built-in voltage regulators and power supplies to drive the pump source. Micromega Div./Bunker Ramo Corp., 12575 Beatrice St., Los Angeles, CA 90066. Phone(213)391-7137. **178**

CUSTOMIZED SOLID-STATE RELAYS AVAILABLE OFF-THE-SHELF. A choice of a combination of parameters such as the type of control, control voltage, load voltage, load current and packaging, is available in over 60 types of relays. Units are available with 3 different types of control: contact closure, all solid state and hybrid (reed relay). Control voltages range from 2 to 30V dc. Load voltage ranges from 6 to 48V in dc units and 50 to 140V and 100 to 240V in ac units. Load currents range from 0.01A up to 15A. Grayhill, Inc., 555 Hillgrove Ave., La Grange, IL 60525. Phone(312)354-1040. **179**

2-TO 4-GHz AMPLIFIERS PROVIDE 4.5-dB NOISE FIGURE. These amplifiers, designated WJ-5004-200, also provide +10 dBm power output at the 1-dB compression point and 25-dB small-signal gain, both guaranteed specifications. Size is 1.3 × 2.3 × 2.9 in. with a 115V ac integral power supply. The overall design of these solid-state amplifiers is consistent with the general requirements of MIL-E-16400 and MIL-E-5400, Class 2. Modular construction adds to their reliability under adverse operating conditions. Delivery is 60 to 90 days. Watkins-Johnson, 3333 Hillview Ave., Palo Alto, CA 94304. Phone(415)493-4141. **180**



MIXER PREAMPS HAVE LOW NOISE AND HIGH POWER. The KC-7A Series of L through Ku-band coaxial mixer preamplifiers combine noise figures of 7.5 dB in L and S bands with power outputs of +10 dBm at 1-dB compressions. Noise figures for C and X-band units are 8.0 dB; and for Ku band it is 8.5 dB. Minimum rf to i-f gain is 20 dB for all models. Separate units to cover each of the bands between L and X are available with 3-dB bandwidths of 10, 20 or 40 MHz and i-f of 30, 50, 60 or 70 MHz. $525. Varian, Solid State East, Salem Rd., Beverly, MA 01915. Phone(617)922-6000. **181**



AMPLIFIER SIMPLIFIES PHONE CONFERENCE BRIDGING. Replacing 8 amplifiers and a resistance bridge with a single unit, the QAB-44 4-way, 4-wire amplifier bridge can be used to interconnect any number of audio channels. The active bridge is available in 4 arrangements that can be interconnected to form larger configurations with many ports and a variety of gain requirements. It is contained on 4-1/2-×-10-in. pc card and provides 600Ω termination at each of its 4 ports. The device will operate over a temperature range of 0 to +70°C and can provide gain up to 30 dB. Quindar Electronics, Inc., 60 Fadem Rd., Springfield, NJ 07081. Phone(201)379-7400. **182**

DOUBLE-BALANCED MIXER SPANS 0.5 TO 1350 MHz. Broadband Model FP-CDB-145 double-balanced mixer is not only a wideband device, but also exhibits 1 to 2 dB less conversion loss than earlier designs across its entire frequency spectrum. It features a typical conversion loss at 1000 MHz of 7 dB, and at 500 MHz of 6.5 dB. The mixer has dimensions of 3/8 × 1/2 × 1/8 in. and is small-quantity priced at $29 each. Olektron Corp., 6 Chase Ave., Dudley, MA 01570. Phone(617)943-7440. **184**

FDM TRANSCEIVER USES ONL\ 1-1/2 × 5 × 4-3/4 IN. Model 5380 interfaces digitally with EIA, CCITT, TTL/DTL, or Teletype lines for full- or half-duplex operation. It consists of an FSK transmitter and receiver in one double-deck module. Bandpass filters provide for min. adjacent-channel rejection of 40 dB for channels with a bandwidth of 85 Hz or greater. Channel density ranges from 1 channel at 600 baud each to 24 channels at 75 baud each. From $233. RFL Industries, Inc., Powerville Rd., Boonton, NJ 07005. Phone(201)334-3100. **183**

APPLICATION NOTES

TESTING AND MATERIALS BOOK: "Direct-Current Magnetic Hysteresigraphs" covers the present state of the art of d-c recording hysteresigraphs. Five papers describe approaches to the problem and successful solutions. An appendix lists manufacturers. Papers are abstracted and key-word indexed. 62 pgs., soft cover, 6 × 9, $6. Available from ASTM, 1916 Race St., Philadelphia, PA 19103. **271**

CASSETTE DATA LOGGER. Electrical and mechanical specifications, performance data and application data on a battery operated data logging system are listed in this 16-pg. brochure. Applications include oceanography, pollution monitoring, meteorology, seismology and other remote data logging requirements. Datel Systems, Inc., 1020 Turnpike St., Canton, MA 02021. **272**

LF GAIN/PHASE APP NOTE. This 26-pg. booklet, App. Note 157, bridges the gap between theoretical analysis and practical measurements. It contains a number of applications that represent measurement solutions. The last section discusses instruments presently available, and a chart summarizes significant alternatives. INQUIRIES MANAGER, Hewlett-Packard Co., 1501 Page Mill Rd., Palo Alto, CA 94304. **273**

BROADBAND PUSH PULL RF AMPLIFIERS. Application note AN-6126 discusses 60 and 100W broadband (225 to 400 MHz) amplifiers using RCA 2N6105 vhf/uhf power transistors. The design and performance of a basic single-stage push-pull amplifier and the use of combined pairs of this basic circuit to obtain higher output power levels are explained. An improved version of the basic push-pull circuit is also described. The note contains schematic diagrams, performance characteristics, and photographs. RCA Solid State Div., Box 3200, Somerville, NJ 08876. **274**

SURFACE MEASUREMENT GUIDE. A compact brochure "New Dimensions in Measurement" outlines the parameters of precision electronic-mechanical measurement. It covers equipment to measure roundness, surface-texture and dimensions. Measurement is achieved by electro-mechanical tracers or probes. Perthen Div., Ehreneich Photo-Optical Industries, 623 Stewart Ave., Garden City, NY 11530. **275**

SIGNALITE APPLICATION NEWS. An external periodical is available free to engineers and technicians. The latest issue tells how a TV receiver can benefit from having a neon-lamp switch in its oscillator drive. It is liberally illustrated with circuit diagrams and oscilloscope traces. Signalite, 1933 Heck Ave., Neptune, NJ 07753. **276**

A GUIDE TO SOLID STATE MOTOR SPEED CONTROLS provides many application options. The full range of controls for industrial, commercial and consumer products is catalogued in this 4-pg. guide. The comprehensive chart indicates the motor types to be controlled, then briefly details the ratings, dimensions, mounting, features, options and typical applications for the firm's 13 series of motor controls. KB Electronics, Inc., 5803 Foster Ave., Brooklyn, NY 11234. **277**

MICROCIRCUIT DESIGN HANDBOOK. This fully illustrated publication offers complete sections on microcircuit applications, designing by plan, production and product reliability. A major portion of the handbook, totaling 15 pages, is devoted to designing by plan. Among design considerations discussed are definitions of current performance and packaging requirements, and evaluations of component power dissipation, density and compatibility. Drawings, charts and tables supplement text material in each topic area. Beckman Instruments, Inc., 2500 Harbor Blvd., Fullerton, CA 92634. **278**

SOLENOIDS...LAMINATED & C FRAME. This 12-pg. booklet discusses the proper selection of solenoids for specific applications as well as the construction of various solenoid designs. The introductory section reviews the 6 major criteria for solenoid selection, including determining required force, duty cycle, stroke length and design of operating linkage. Controls Co. of America, 9655 Soreng Ave., Schiller Park, IL 60176. **279**

RAM TECHNOLOGY ANALYZED. This 6-pg. monograph helps engineers select random access read/write memory technologies. It describes all current MOS and bipolar RAM technologies, performance, cost and manufacturing methods. Advanced Memory Systems, Inc., 1276 Hammerwood Ave., Sunnyvale, CA 94086. **280**

SQUARE WAVER/MODULATOR NOTE provides information for the applications of AEL's FSW-05 for externally modulating standard signal generators and other signal sources in the 40-to-500-MHz frequency range, and for constructing automatic level-control loops, remote controlled attenuators, SPST, SPDT switches and phase detectors. Diagrams describe each application. American Electronic Laboratories, Inc., Box 552, Lansdale, PA 19446. **281**

SEMICONDUCTOR FUSE HANDBOOK. The extensive work—over 100 pgs. long, with numerous graphs, ratings, tables and circuit diagrams—is entitled "Semiconductor Fuse Applications Handbook." The work is divided into four chapters, on fast acting fuses, fuse characteristics, coordinating fuses with semiconductors, and applications. Copies of the handbook, HB-50, are available only by writing on company letterhead. International Rectifier Corp., Semiconductor Div., 233 Kansas St., El Segundo, CA 90245.

ANALOG AND DIGITAL I/O EQUIPMENT. A 32-pg. catalog details standard real-time peripheral devices which interface any popular minicomputer to a user process. Illustrated are wide-range analog-input systems, low-level systems, high-level systems, D/A converters, sample-hold amplifiers, and digital I/O modules. Computer Products, Box 23849, Ft. Lauderdale, FL 33307. **283**

SUPERCONDUCTING DEVICES. Technical Bulletins TB-141 and 261 describe the features and performance of a line of superconducting solenoids and a precision laboratory superconducting magnet system. All solenoids and systems described are wound with multi-filament superconducting wire. Magnetic Corp. of America, 179 Bear Hill Rd., Waltham, MA 02154. **284**

60-pg. CAPACITOR/RESISTOR/NETWORK CATALOG. Design guide EPD GDG-1 gives physical specifications in both English and metric units. Performance specs and curves, Corning's statistical design-tolerance concept and 100,000-hr. load-life test data are included. A.F. Donnelly, Corning Glass Works, Corning, NY 14830. **285**

"RATCHET-LESS" COUNTERS. An 8-pg. bulletin on the RG Series impulse counters lists some 116 models. There are three basic sizes, with 3, 4, 5, 6 or 8 digits in each. They operate at 10, 25, 35, or 60 counts/sec, depending on the design; on dc or ac, and can be specified with manual or electrical reset, or both. Sodeco, 4 Westchester Plaza, Elmsford, NY 10523. **286**

WIRE TESTER BULLETIN. A 4-pg. bulletin describes and illustrates the Siemens VD 36 wire tester used for quickly and inexpensively finding and identifying a particular wire in a mass of wires. Applications and mode of operation, as well as technical data are included. Siemens Corp., Scientific Instruments Div., 186 Wood Ave. South, Iselin, NJ 08830. **287**

L-C FILTERS CATALOG. Catalog #12F presents a wide range of custom-built precision L-C filters. Introduced are sharpest cut-off lowpass and highpass filters supplied in Tchebycheff and elliptical designs, with frequency ranges available from 400 Hz to 50 MHz. The 12-pg. catalog includes complete specifications, graphs and a glossary of filter terms. Allen Avionics, Inc., 224 E. 2nd St., Mineola, NY 11501. **288**

rf MODULAR AMPLIFIERS that plug-in into existing circuitry are the subject of a bulletin. Designated as the Optimax AH-56 Series, these low-cost, wideband units have a frequency range of 5 to 300 MHz and are designed for use in receiver front ends; i-f amplifiers; agc amplifiers; isolation amplifiers; and CATV applications. Optimax, Inc., Box 105, Advance Lane, Colmar, PA 18915. **289**

PLATFORM PACKAGES for microelectronic-circuit applications are described in this 12-pg. bulletin, PF2/73. Featured are 32 metal cases drawn to actual size to facilitate matching to actual substrate. Sizes and styles of covers are also detailed. Tekform Products Co., 2770 Coronado Ave., Anaheim, CA 92806. **290**

LOW-FREQUENCY QUARTZ CRYSTAL OSCILLATORS are outlined in a 4-pg. brochure. Technical characteristics, typical specifications and dimensional data for TO-5 and flatpack devices is given. The brochure also provides graphs, schematics and formulas explaining the mechanical and electrical properties of quartz crystals. Statek Corp., 1233 Alvarez Ave., Orange, CA 92668. **291**

Dc/dc POWER SUPPLY CATALOG. 32-pg. Catalog 733 for 1973 lists over 1200 models with single, dual, triple, and quadruple outputs up to 20W. There are regulated, unregulated, special-purpose, and general-purpose versions. A selector index helps locate a standard model for a particular application. MIL Electronics Inc., 176 Walker St., Lowell, MA 01854. **292**

SOLID-STATE CHOPPER CATALOG describes a line of isolated microchoppers, field-effect, basic, 60-Hz, 400-Hz, high frequency, high-voltage and vibrator choppers. All units in the 32-pg. catalog utilize a miniaturized, ruggedized design and are recommended for military and industrial applications. Solid State Electronics Corp., 15321 Rayen St., Sepulveda, CA 91343. **293**

SYNCHRO/RESOLVER DATA FILE. Instrumentation for testing and simulating synchro/resolver systems and components to absolute accuracies of 2 sec of arc, is described in Astrosystems new 8-pg. Data File #105. It contains features, specifications and operating information for Synchro/Resolver Standards and Bridges. Astrosystems, Inc., 6 Nevada Dr., Lake Success, NY 11040. **294**

TEST PROGRAM FOR ICs. A 20-pg. Program Library identifies available test programs that have been generated for the Computest (Microdyne) bench-top series of IC testers. It lists popular linear and digital ICs along with associated MSI and special devices. Computest Corp., 3 Computer Dr., Cherry Hill, NJ 08002. **295**

TECHNICAL BULLETIN AIDS SILICONE FLUID SELECTION. Properties and potential end-use benefits of 14 silicone fluids are listed in 12-pg. bulletin 22-053. Specialized and general-purpose fluids are detailed in terms of inherent, engineering and application characteristics. Tables simplify the selection. Dow Corning Corp., Midland, MI 48640. **296**

CIRCUIT BREAKER BULLETIN INCLUDES TEST DATA. Bulletin HE-3504 gives technical details and Mil-spec compliance data on Series HE ruggedized, subminiature hydraulic-magnetic circuit breakers. Time-delay curves, applications and dimensional data are given for all models. 12 pgs. Heinemann Electric Co., 127 Magnetic Dr., Trenton, NJ 08602. **297**

MINICOMPUTER BULLETIN. This is a 12-pg. product bulletin on the Model 85 minicomputer. The new series processor features microprogramming techniques in the form of user-alterable, Dynamic Control Store (DCS). The 16-bit computer is built around an interleaved MOS/LSI solid-state 16-kB memory, providing 270 nsec average main-memory, providing 270 nsec average main-memory cycle time. Interdata, Inc., 2 Crescent Pl., Oceanport, NJ 07757. **298**

MULTI-TERMINAL GRAPHIC-DISPLAY SYSTEM. The anagraph display system uses digital TV techniques to bring low-cost computer graphics to management information, computer aided design and command and control systems. In an 8-pg. brochure, typical graphic displays are pictured in full color, as is the system. The applications, hardware and software capabilities are detailed. Data Disc, 686 W. Maude Ave., Sunnyvale, CA 94086. **299**

CURES FOR "BROWN-OUTS". Devices to combat both dropouts and ac line and load noise are described in a 28-pg. catalog. Specs and prices cover models with ratings to 5000VA and with noise suppression as high as 400:1. Also included are lab models, a 1ϕ to 3ϕ converter, frequency converters, and other power products. Tele-Dynamics/Wanlass, Div. of AMBAC Industries, 525 Virginia Dr., Fort Washington, PA 19034. **300**

MINIATURE BRUSHLESS dc MOTORS. Detailed descriptions of the Siemens Type 1AD31 brushless dc motors are contained in a 4-pg. bulletin. Continuous torque rating is up to 1.7 oz. in., and these motors are especially suitable as drives for the Philips cassette and 3M data cartridge. The bulletin outlines features, applications, specifications, performance and principle of operation. Siemens Corp., Power Equipment Div., 186 Wood Ave., South, Iselin, NJ 08830. **165**

MICROWAVE COMPONENTS AND APPLICATIONS are shown in a 252-pg. catalog. Described in detail are double-balanced mixers, 0° and 180° power dividers/combiners, 0°-180° and 90° hybrids, amplifiers, directional couplers, impedance-matching transformers, frequency doublers, standing-wave-ratio bridges and attenuators. Anzac Electronics, 39 Green St., Waltham MA 02154. **166**

COUNT MONITOR/SCANNERS. An 8-pg. brochure describes solid-state Models 515 and 516 that contain all necessary circuitry to gather traffic engineering and maintenance data from PBX, PABX and small central offices. Both feature a 400 double buffered 4-digit storage register and a 24-hr. clock. Write on company letterhead to Alston Div., Conrac Corp., 1724 S. Mountain Ave., Duarte, CA 91010.

SUBMINIATURE SWITCHES FOR pc BOARDS. The 4-pg. bulletin (72B) describes subminiature toggle and pushbutton switches for pc board applications. These switches, ideal for subchassis checkout, interlock circuits and field service, are designed for solder pin insertion into 1/16-, 3/32- and 1/8-in. pc boards. Control Switch, Inc., 1420 Delmar Dr., Folcroft, PA 19032. **167**

signals and noise

Interfacing CMOS isn't that easy

Dear Sir:

I would like to take small exception to part of your fine article in the February 5 EDN "Interfacing CMOS With Other Logic And Display Devices". In the section "Driving High Threshold Logic" you state "A standard CMOS gate will drive one HTL load". True, in the high state, but not in the low state. MC 660 series HTL requires 1.2 mA in the low state, and 300 series Hi NIL requires 2.1 mA. A "typical" value for CMOS sink current may be this high, but good design practice dictates staying within the published maximum limit, which is 0.5 mA for any manufacturer's standard CMOS gate. CMOS buffers are generally required to interface to bipolar logic.

CMOS certainly has many advantages and will be the answer to a host of design problems. But it also has disadvantages, such as interfacing, which must be taken into account by the design engineer.

Regards,
Michael I. Wier
Product Marketing Engineer
ITT Semiconductors

The ten commandments of electrical safety

Although these rules submitted by Hospital Safety Testing Labs, Inc., Stoughton, MA, are aimed at hospital labs, most could just as well apply in any electronics lab. They are thus presented for the edification of all. —*Ed.*

1. Beware of the lightning that lurketh in an uncharged condenser lest it cause thee to bounce upon thy buttocks in a most embarrassing manner.
2. Cause thou the switch that supplieth large quantities of juice to be opened and thusly tagged, that thy days may be long in this earthly vale of tears.
3. Prove to thyself that all circuits that radiateth, and upon which thee worketh, are grounded and thusly tagged, lest they lift thee to a radio frequency potential and causeth thee to make like a radiator too.
4. Tarry thou not amongst these fools that engage in intentional shocks for they are not long for this world and are surely unbelievers.
5. Take care that thou useth the proper method when thou takest the measures of high-voltage circuits too, that thou dost not incinerate both thee and thy test meter, for verily, though thou has no company property number and can be easily surveyed, the test meter has one and, as a consequence, bringeth much woe unto a purchasing agent.
6. Take care that thou tamperest not with interlocks and safety devices, for this incurreth the wrath of the chief electrician and bringeth the fury of the engineers on his head.
7. Work thou not on energized equipment for if thou doest so, thy friends will surely be buying beers for thy widow and consoling her in certain ways not generally acceptable to thee.
8. Verily, verily I say unto thee, never service equipment alone, for electrical cooking is a slow process and thou might sizzle in thy own fat upon a hot circuit for hours on end before thy maker sees fit to end thy misery and drag thee into his fold.
9. Trifle thee not with radioactive tubes and substances lest thou commence to glow in the dark like a lightning bug, and thy wife be frustrated and have not further use for thee except for thy wages.
10. Commit thou to memory all the words of the prophets which are written down in thy Bible which is the National Electrical Code, and giveth out with the straight dope and consoleth thee when thou hast suffered a ream job by the chief electrician.

"Author unknown"

World's smallest capacitor?

This was the claim in our April 5 product section and was backed up by dimensions of 0.80 × 0.04 in. From the number of letters received by the manufacturer, Tensor Electronics, Inc., San Diego, CA, you obviously read the product section quite closely. But please stop the funny letters. The true dimensions are 0.080 × 0.040 in. for the ceramic capacitors whose capacitance range is 0.5 pF to 15,000 pF at 10, 15 or 25V.
ED.

"IT'S A LANGUAGE YOU CAN'T USE IN FRONT OF KIDS!"

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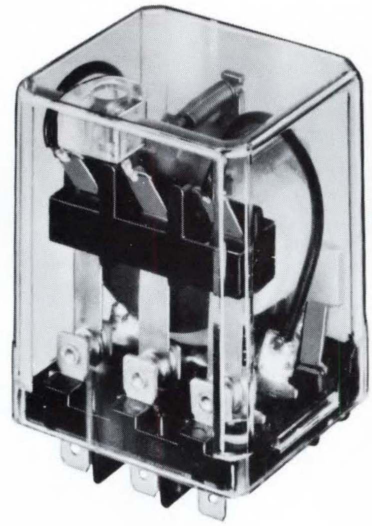

MAGNECRAFT'S NEW CLASS 388
GENERAL PURPOSE RELAY

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

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

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

FREE!

DESIGNER'S CATALOG

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

See Us at WESCON, Booth 2400

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