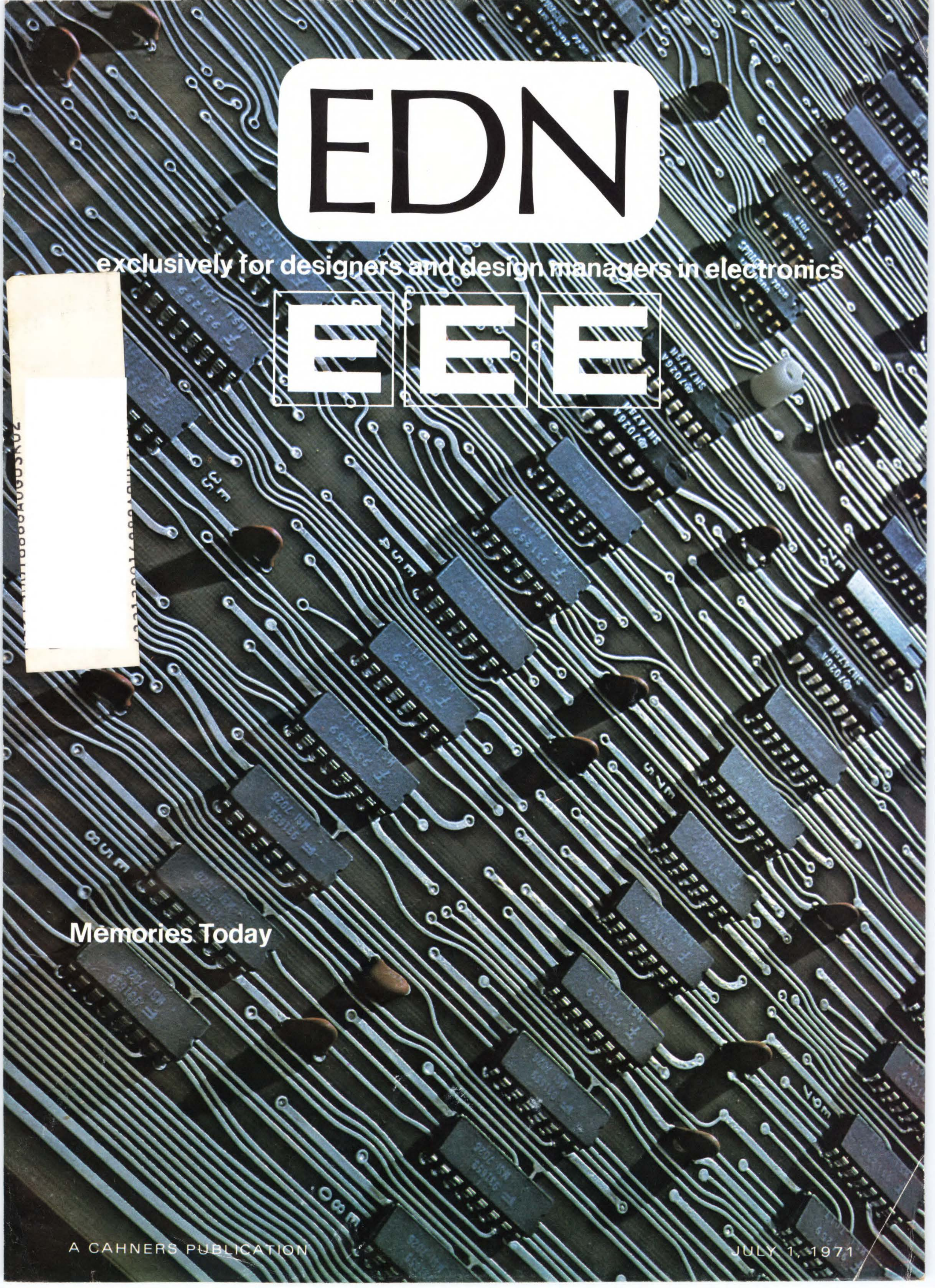


EDN

exclusively for designers and design managers in electronics

EEE

Memories Today

A CAHNERS PUBLICATION

JULY 1, 1971

Leave my power supply system alone! You can get your own in only 9 days from Acopian.

"I tried struggling through that old power supply system catalog. It was like a jigsaw puzzle, hunting for the pieces I needed for my new power system. There had to be a better way.

"Then I remembered the Acopian hotline. I called it. I told them the DC voltages and currents I wanted. Discussed panel size. Meters. Switches. And other accessories.

"They gave me a firm price. Right on the phone. It was a lot less than I expected. I had our buyer phone in the P.O. And Acopian designed, built, tested and shipped it in nine days. Completely wired.

"So go order your own Acopian power system . . . It's easy!"

HOW TO ORDER ACOPIAN POWER SYSTEMS

- **Call** Acopian collect
- **Tell us** the outputs and accessories you need
- **Get** a firm price
- **Shipment** of completely wired system will be made in 9 days.

For immediate service, call the Acopian hotline: (215) 258-5441. For literature, write Acopian Corp., Easton, Pa. 18042. And remember, Acopian also offers 82,000 different DC power modules, every one shipped with this tag . . .

CIRCLE NO. 1

Introducing: "The Portables" from HP

1 V calibrator connected internally.*

The 1707A—Fastest in Its Class

If you're looking for speed in a $2000 portable scope, then the new dual-channel HP 1707A is your baby. It gives you 75 MHz bandwidth (<4.7 ns risetime)—more than any other scope in its class. And you get 10 ns/div sweep speed, delayed sweep, and 10 mV/div over the full bandwidth. With this capability, you can measure T²L or ECL pulse timing and propagation delay. Yet the 1707A costs only $1925.

And, you get this performance in a truly portable scope. The 1707A weighs only 24 lbs. And it can be powered from an internal, rechargeable battery pack ($200)—or from any dc source from 11.5 V to 36 V, as well as any standard ac outlet.

Its low power requirement not only allows battery operation—but also eliminates the need for fans, or even dust-admitting vent holes. And although the 1707A is small and light, you still get a large 6 x 10 cm CRT viewing area—larger than competitive scopes. Compare the display brightness, too!

If you need even more measurement capability, a $125 option gives you our "lab package" which includes mixed sweep, calibrated delay, and external trigger input for delayed sweep. It also includes external horizontal input, and cascading capability at reduced bandwidth. (How's that for a bargain?)

Our new 1700 Series of portable scopes begins as low as $1680—for the dual-channel, 35 MHz 1700A (<10 ns risetime). Add delayed sweep, and you've got our 1701A, for only $1800.

The philosophy behind the 1700 Series is simple—providing the maximum in useful capability per dollar. The 1700A, 1701A, and 1707A offer wide flexibility, giving you everything you need for digital field service work. And they won't cost you a fortune. Compare them with anyone's competitive models—prove to yourself that the HP 1700's are the best values in portable scopes today.

For further information on "The Portables"—HP's new 1700 Series scopes—contact your local HP field engineer. Or write Hewlett-Packard, Palo Alto, California 94304. In Europe: 1217 Meyrin-Geneva, Switzerland. *Option 020 Shown, HP's lab version of the 1707A, $2050.

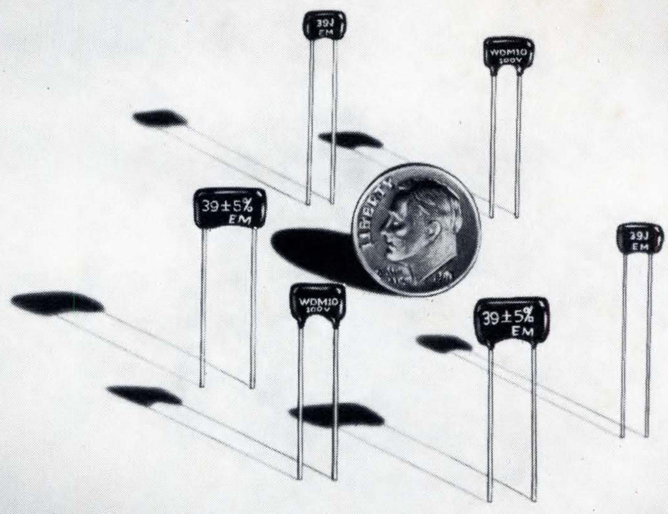
Scopes are changing.
Are you?

081/12A

HEWLETT hp PACKARD

CIRCLE NO. 2

El-Menco BETTER QUALITY AND RELIABILITY THROUGH CONTROL



They're Small and Reliable*

EL-MENCO DM5 — DM10 — DM15 — ONE COAT DIPPED MICA CAPACITORS

STYLE	WORKING VOLTAGE	CHARACTERISTIC	CAPACITANCE RANGE
DM5	50VDC	C	1pF thru 400pF
		D, E	27pF thru 400pF
		F	85pF thru 400pF
DM5	100VDC	C	1pF thru 200pF
		D, E	27pF thru 200pF
		F	85pF thru 200pF
DM10		C	1pF thru 400pF
		D, E	27pF thru 400pF
		F	85pF thru 400pF
DM15		C	1pF thru 1500pF
		D, E	27pF thru 1500pF
		F	85pF thru 1500pF
DM5	300VDC	C	1pF thru 120pF
		D, E	27pF thru 120pF
		F	85pF thru 120pF
DM10		C	1pF thru 300pF
		D, E	27pF thru 300pF
		F	85pF thru 300pF
DM15		C	1pF thru 1200pF
		D, E	27pF thru 1200pF
		F	85pF thru 1200pF
DM10	500VDC	C	1pF thru 250pF
		D, E	27pF thru 250pF
		F	85pF thru 250pF
DM15		C	1pF thru 750pF
		D, E	27pF thru 750pF
		F	85pF thru 750pF

Where space and performance are critical, more and more manufacturers are finding that El-Menco miniaturized dipped mica capacitors are the reliable solution. The single coat is available in three sizes: 1-CRH, 1-CRT and 1-CE.

The 1-CRH DM "space savers" easily meet all the requirements of MIL and EIA specifications, including moisture resistance. The 1-CE and 1-CRT units also meet the requirements of MIL and EIA specifications, except that they have less moisture protection because of their thinner coating; these capacitors, therefore, are ideally suited where potting will be used. Note: DM10 and DM15 units are still available in the standard 4-CR size.

Specify "El-Menco" and be sure . . . the capacitors with proven reliability. Send for complete data and information.

*Normally, El-Menco 39 pF capacitors will yield a failure rate of less than 0.001% per thousand hours at a 90% confidence level when operated with rated voltage and at a temperature of 85°C. Rating for specific applications depends on style, capacitance value, and operating conditions.

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Dipped Mica • Molded Mica • Silvered Mica Films • Mica Trimmers & Padders
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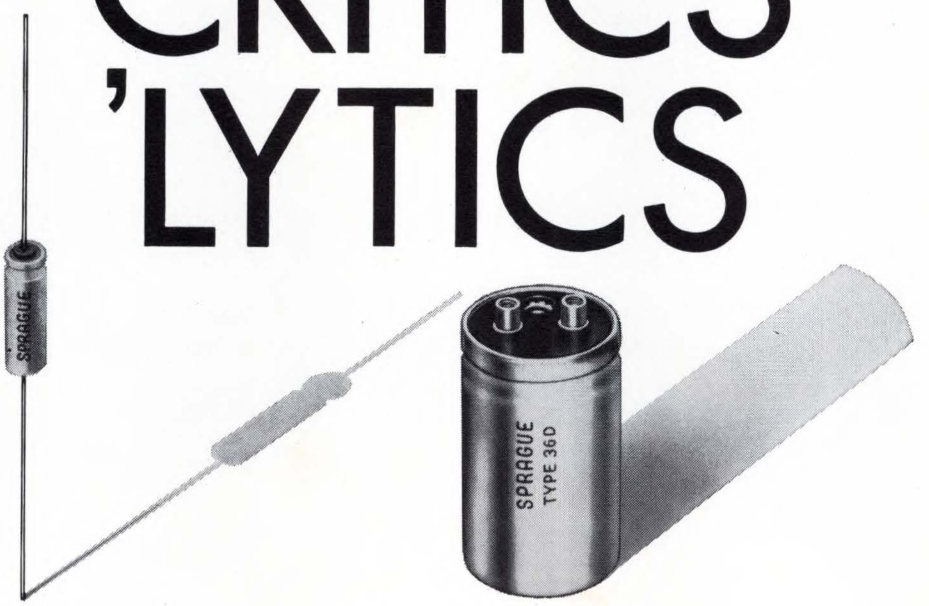
CIRCLE NO. 5

THE CRITIC'S 'LYTICS



Be critical. Specify Sprague Powerlytic® Capacitors for maximum capacitance in minimum space.

Type 39D Tubular Case

Case sizes from ½" x 1⅛" to 1" x 3⅝". Operate at temperatures up to 85 C. Unique construction—anode and cathode terminals are welded—no riveted or pressure connections—prevents open circuits, even in microvolt signal range. Standard ratings include capacitance values to 18,000 μF, voltages from 3 to 450 VDC.

Write for Engineering Bulletin 3415.

Type 36D Cylindrical Case

Improved materials and processes now permit extended capacitance ratings. New, large case size, 3" x 8⅝", allows capacitance values up to 650,000 μF. Ideal in applications such as computer power supplies, industrial controls, high gain amplifiers. Low equivalent series resistance, low leakage current, excellent shelf life.

Write for Engineering Bulletin 3431C.

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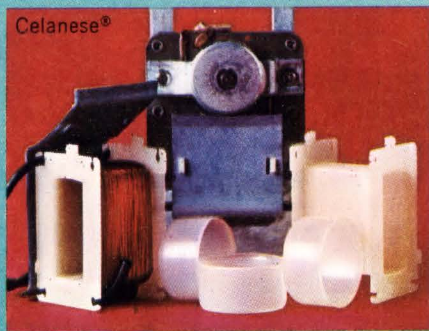
CIRCLE NO. 4

CELANESE NYLON. THE HEAD START MATERIAL.

Give your products a head start on top product design, performance and economics. With Celanese Nylon.

General Electric does. In GE hair dryers, for example, the resilience of Celanese Nylon gives coil bobbins the kind of snap-fit that holds parts together snugly. So assembly is simple, less expensive.

But of course there are lots of other reasons for choosing Celanese Nylon. Like the fact that it has U/L rating on electrical properties of 105° C. Or its great mechanical strength and toughness. Or its high dielectric properties,



so you can design more compact units with thinner walls. Or the fact that Celanese Nylon is made in a totally continuous process. So it's whiter in the pellet. Whiter in your product. Whiter through successive regrinds. And more consistent from lot to lot.

Maybe that's why retainer rings in GE hair dryers are also molded in Celanese Nylon. And why GE uses Celanese Nylon for gears and bushings and bobbins in their broad line of oscillating fans and heaters.

Give your products a good head start by writing for a copy of our brochure on electrical applications of Celanese Nylon. And a U/L Yellow Card. Celanese Plastics Company, Dept. N-502, 550 Broad St., Newark, N.J. 07102.

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CIRCLE NO. 6

JULY 1, 1971
VOLUME 16, NUMBER 13

EDN/EEE

EXCLUSIVELY FOR DESIGNERS AND DESIGN MANAGERS IN ELECTRONICS

Cover

Cover photo by Data General Corp., portrays the impact of MSI/LSI on the evolution of memory technology. See the article on p. 19.

Speakout—Evelyn Berezin of Redactron, compares the right and wrong ways to design MOS systems, p. 30.

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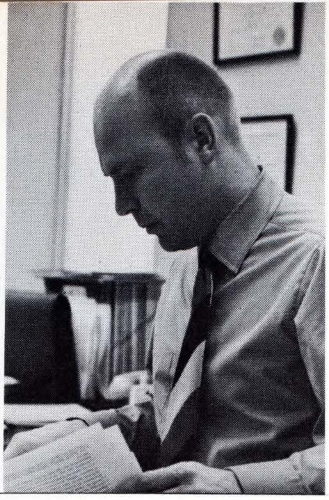
Staff



Editorial

We Need Some Technological Wilderness Areas

Conservation-minded people around the country have successfully sought to rescue an area here and there from the press of civilization. For good reason these efforts are almost universally appreciated and endorsed.

But what are the reasons? Preserving natural beauty for its own sake? Saving part of what once was, as sort of a souvenir? Catering to the special interests of back packers? Perhaps one of the basic reasons is that man does not want to be totally insulated from natural earth by a layer of civilization.

Just as civilization has nibbled away at Mother Earth, technology is nibbling away at man's opportunity for personal achievement. One of the saddest sights I ever saw was an automated steel mill run by the men who used to do it with knack and muscle. Their work day was reduced to passing the hours by whittling and occasionally checking chart recorders. Yet, who can argue against automation when it concerns the production of steel and other materials and products crucial to man's well-being?

There are some areas, though, that might be better off if they were left alone. Computer-generated "art" and computer-composed "music" might qualify as unnecessary and even undesirable applications of technology.

Then there is the news of a new electronic organ that can change keys at the flick of a switch—which kind of negates those endless hours of practicing scales and arpeggios in 12 keys. And we have accepted the boob tube as a satisfactory substitute for the art of conversation. How about the prospect of test tube babies and controlled heredity?

In our effort to make everything automatic and efficient, we may be robbing man of his chance to be creative. Ultimately we may be shoving a computing electronic interface between him and anything he can gain a sense of accomplishment from.

Society is showing signs of rebellion, and agitation for technological wilderness areas is just as strong as it is for the geographical version. Perhaps engineers should begin assessing the psychological impact of technology as seriously as they now are assessing the environmental and ecological overtones.

A human being needs more out of life than a fistfull of pushbuttons.

G Boe

Editor

SAMPLE RATE
OFF
HOLD
10.0000
MHz
RESET
5300A MEASURING SYSTEM
HEWLETT · PACKARD
SENSITIVITY
TIME BASE
FUNCTION
SENSITIVITY
FREQ
A
B
PERIOD B
PERIOD / T.I.
AUTO
T.I. A TO B
AVG B
A 50 MHz
B 10 MHz
CHECK
OPEN/CLOSE B
5302A 50 MHz UNIVERSAL COUNTER

Introducing the little counter that can.

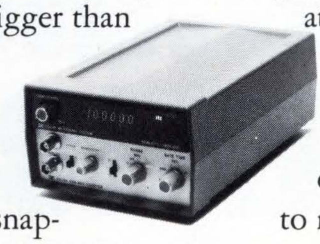
It can become four different systems.

It can go anywhere you do.

It can protect you against obsolescence.

It can make buying and maintaining a counter less expensive than ever before.

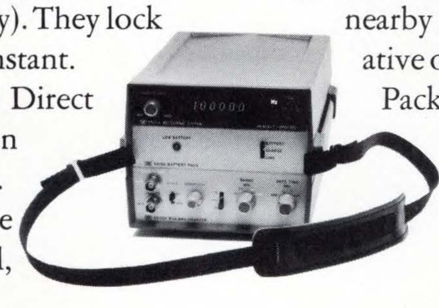
Meet the Hewlett-Packard 5300, the snap-together counter that's not much bigger than the palm of your hand. It has six digit accuracy, solid state display and autoranging. It'll make period, frequency, time interval and ratio measurements, operate on its own snap-on battery pack and drive a printer. Prices start at only $520.



If everything sounds too good to be true, we'll tell you how we did it: snap-together construction that lets you choose the module that makes the counter you want and also avoid obsolescence. Plus the most advanced LSI circuitry ever used in a counter. That means you get a compact instrument with high reliability, performance and versatility at a cost lower than ever before.

To make the counter you need, take the $395 mainframe and add any of the following 4 modules (more are on the way). They lock right onto the mainframe in an instant.

- 10 MHz frequency module. Direct frequency counting to greater than 10 MHz. Model 5301A, just $125.
- 50 MHz all-purpose module with period average, time interval, and ratio functions. Model 5302A, $250.
- 500 MHz frequency module, both 50Ω and 1 MΩ impedances. DC to 500 MHz. Model 5303A, only $750!
- Time interval module with features you'd expect to pay twice as much for: 100 ns resolution; attenuators and slope and trigger level controls on both channels; counting to better than 10 MHz; period averaging. A unique "time interval holdoff" feature lets you ignore electrical pulses between the events you want to measure. Model 5304A, $300.



You ought to be able to take a counter as small and useful as the 5300 anywhere. And you can. All you have to do is snap on the battery pack (Model 5310A, $175) for 4 to 8 hours worth of cord-free operation. The pack fits between the mainframe and any module. The system's rugged dust-proof aluminum case resists almost any of the bumps it might get in the field.

The 5300 is one system you have to use to appreciate; there is simply no other way. To get you started we'd like to send you more information on this amazing instrument. Just call your nearby HP field representative or write to Hewlett-Packard, Palo Alto, California 94304; Europe: 1217 Meyrin-Geneva, Switzerland.

02104

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ELECTRONIC COUNTERS

CIRCLE NO. 8

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Pick a winner in linears.

Intersil op amps set the pace in every vital parameter. The 8017 slews 130 V/µsec (with 10 MHz bandwidth, 50 nA input). 8021 dissipates less than 30 µW with ± 1.5 V supplies. 8007 FET-input amp has 2 pA bias. Automated test systems have been developed to select an Intersil amplifier for $\Delta V_{OS}/\Delta T$ down to 3 µV/°C. Our 741-LN is specified with a "popcorn" noise free guarantee. In standard analog products we offer general purpose op amps (101, 101A, 108, 741, 748), positive and negative regulators (100, 105, 723) and precision comparators (8001).

In hybrids, switches, discretes.

From a combination of dual FET and IC technology, our hybrid analog gates work twice as fast as the nearest competition. And the 8500A Hybrid Electrometer Op Amp has the lowest input bias anywhere: 0.01 pA!

The 8018 D/A Quad Switches feature 100-ns switching with 12-bit accuracy.

We make over 200 monolithic dual J-FETs and transistors with 3µV/°C thermal tracking and matching to 1.5 mV. Get all discretes and linears in dice, wafer or flip-chip form. Or let us work with you on custom processes or circuits to suit your special needs. Call Murray Siegel or Dave Fullagar (408) 257-5450 for help in any analog requirement. Intersil. First in analog technology. 10900 No. Tantau Avenue, Cupertino, CA 94014.

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Intersil

CIRCLE NO. 9

Low-Cost DVM Is No Toy

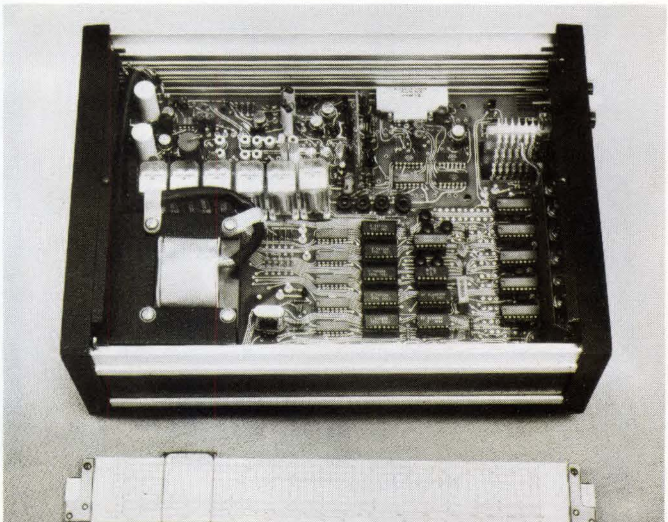
It's refreshing in these days of spiraling prices to occasionally find this trend turned around without any compromises in quality, performance, or effectiveness. This is just what Data Precision Co., Wakefield, Mass., has done in its newly announced line of 5-1/2- and 4-1/2-digit multimeters. Rather than try to cut costs from existing methods of performing A/D conversion and other internal functions, designers at Data Precision stripped away all the trees from the proverbial forest and started over from scratch. What resulted is the new "Tri-Phasic" method of A/D conversion, an "Isopolar" reference standard and "Ratiohmic" resistance measurement, all basically so simple in concept, you wonder, "how come I didn't think of it." These three proprietary circuits are the reasons why you now can buy a precision multimeter for about $700 with as many functions as and with equal or better performance than instruments costing as much as four times that amount. If you don't believe it, check the specs. Normal mode rejection is 60 db at 10 Hz and multiples thereof, automatic zero on all ranges, accuracy 6 months, 23°C ±5°C is ±0.007% reading ±0.001% full scale.

What features do you get besides performance? DC and AC volts – 4 ranges, ohms (4-wire measurement) – 5 ranges, DC ratio – 4 ranges, data input/output, autoranging and auto polarity.

Thanks to the new circuit techniques used, many expensive and space consuming components are eliminated so that this performance and these features all are packed into a 3-1/2- by 8-1/2- by 12-inch cabinet weighing 8 lb. This instrument is available as a full multimeter or in standard lower-cost models with specific features eliminated. Standard display is "Nixie" tubes although 7-segment displays will be available as an option.

An important lesson can be learned from this remarkable instrument. It isn't always necessary for designers to build fences around problems that crop in their design. Maybe the best thing to do is take a step backward, look at the problems, and find new ways to make these problems eliminate themselves from the ultimate solution. It may sound far-fetched, but in the case of this instrument it

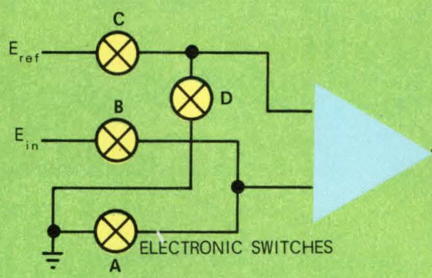
Front panel of full 4-1/2-digit multimeter.

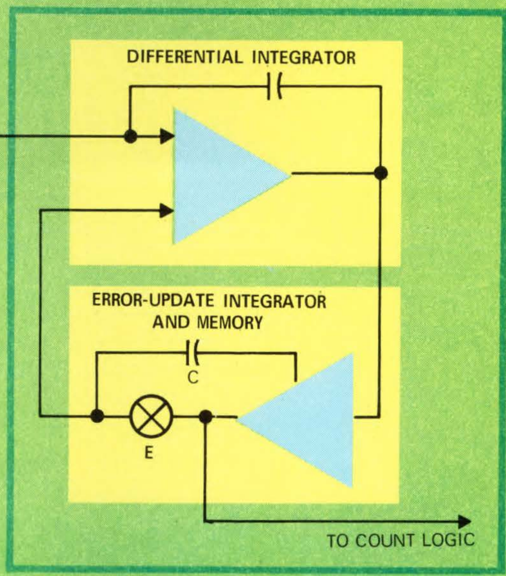


Inside view of cabinet. Top section contains all analog functions and function select relays. Lower half from left to right includes full shielded power supply, ISOPOLAR reference (metal can), counters, latches, auto-ranging section and nixie drivers.

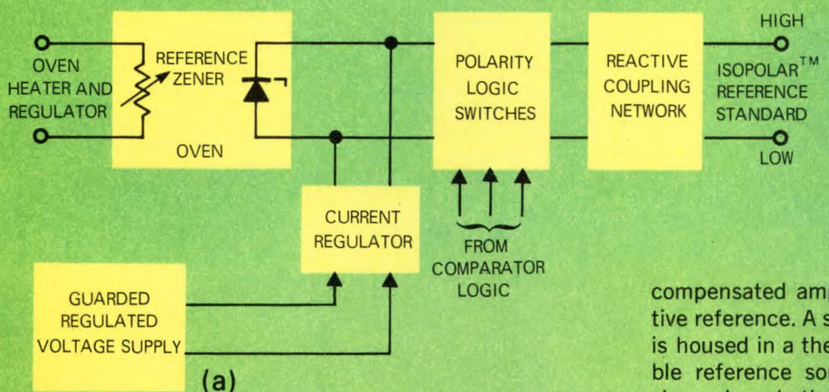
TRI-PHASIC™ MODES	
PHASE	SWITCHES CLOSED
1	A,D,E,
2	B,D
3	C,A

⊗ = FET SWITCHES, A-E

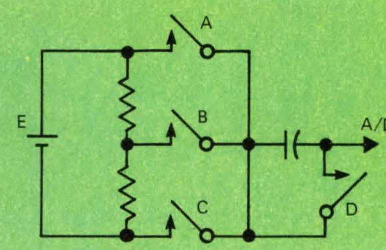




TRI-PHASIC conversion cycle. In first phase (note switch modes) all signals are shorted out except accumulated amplifier drift errors which are stored in memory. During phase 2, the difference between the error and analog input are differentially integrated over set time period. Finally, in phase 3, the analog signal is digitized while the integrator returns to its zero state. Decoded count of clock pulses during this period is displayed as the digital output. Added phase of operation is a self-zeroing feature that eliminates the need for ultra-stable amplifiers with their expensive and bulky compensation circuits.



(a)

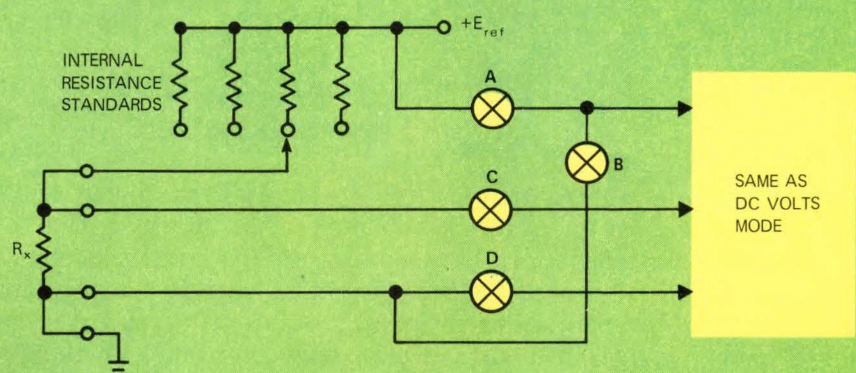


(b)

ISOPOLAR reference. Functional operation of the reference circuit in (**a**) is shown in (**b**). One reference source provides both positive and negative reference voltages. This scheme, with no active elements in the reference control other than the zener and switches, eliminates precision compensated amplifiers and separate circuits for negative reference. A single, premium-grade, cycle-aged zener is housed in a thermally-regulated oven to provide a stable reference source. The simplified schematic in (**b**) shows how both polarities are obtained from a single reference. Reference voltage E is applied across the resistor divider. In phase 1 switches (A) and (D) are closed charging C to E/2. For positive output, switch (A) then is closed supplying +E/2 to the A/D or when the switch (C) is closed −E/2 is supplied to the A/D.

RATIOHMIC™ MODE	
PHASE	SWITCHES CLOSED
1	B,D
2	C,D
3	A,C

⊗ = FET SWITCHES, A-D



RATIOHMIC resistance measurement. Here, using a four-wire system, the unknown resistance is made part of a ratio set. In a four-wire system, current is supplied to the unknown resistance through two wires and the voltage drop is measured-through second two-wires terminated in high impedance circuit. Thus accuracy of readings is only dependent on accuracy of standard resistors. With this technique, system is not current-source dependent which eliminates need for high-stability constant-current-feedback op amps.

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The small matter.

A core memory system is only as reliable as the cores that go into it. When you make 20-million-bit mass memories like our Large Core Store (LCS), you need the highest reliability. So we've invented an exclusive way of making cores uniform in quality, density and size. We have a way of testing every core for mechanical and electrical reliability before it's strung. Quality control all the way. All the way from cores to stacks, and from intermediate systems to the LCS (20,000,000 cores worth of quality...that's no small matter). We'll make a compatible memory for any system you have, or any you have on the board. One with built-in economies. We specialize in specials, so buy only as much memory as you need. Just make your demands.

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CIRCLE NO. 10

Design News

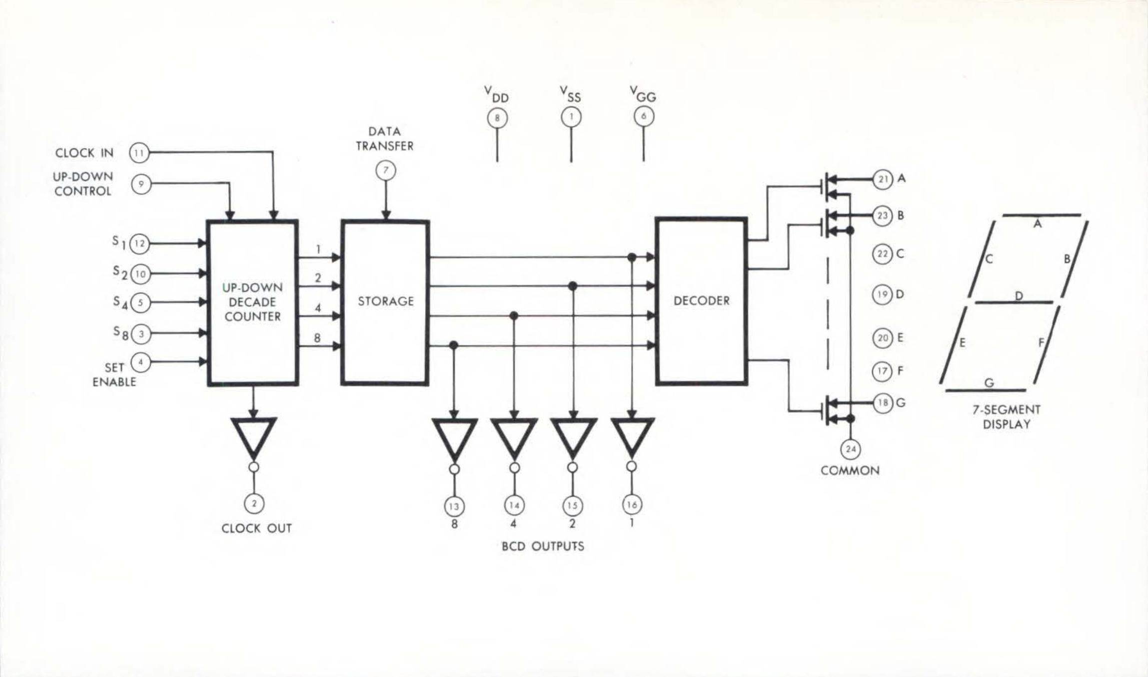
Multibeam He-Se Laser Debuts

A broad line of gas lasers, including a new multibeam helium-selenium laser were featured at the 1971 Electro-Optical Systems Design Conference by RCA Electronic Components.

Equipped with a prism wavelength selector, the multibeam unit demonstrates the profusion of laser beams available from a single laser (see table). Such a selection of visible beams makes the He-Se laser an important laboratory tool in spectroscopy and materials investigations.

Evaluation samples are available at the developmental price of $5000 each with 120 day delivery. Under development are both larger and smaller versions – the larger to deliver more power and a wider variety of lines and the smaller to provide a simple low-cost blue-green laser that is more efficient than argon.

WAVELENGHTHS (Nanometers)	POWER (Miliwatts)
460.5	2.2
464.9	2.0
476.4	0.3
484.5	2.8
497.6	6.8
499.3	6.8
506.8	5.0
517.6	4.0
522.8	7.8
530.5	4.3
552.3	2.2
559.2	2.5
569.8	0.4
586.9	0.7
605.6	0.6
644.4	3.0



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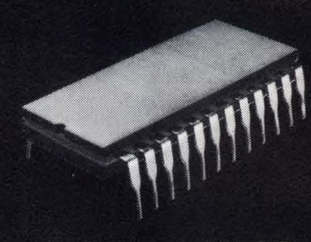

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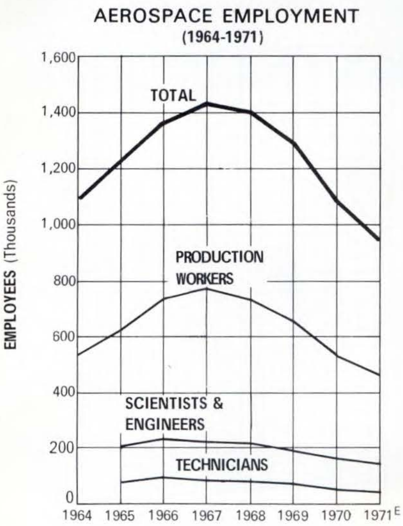
SST Demise Accelerates Aerospace Nosedive



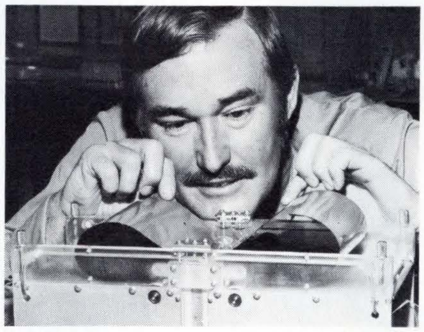
E – ESTIMATED
SOURCE: AEROSPACE INDUSTRIES ASSOCIATION

According to Aerospace Industries Assoc.'s semiannual employment survey, aerospace employment will drop 11.8% in the 12 months ending December, 1971. By year's end, it is estimated that the number of aerospace workers will drop to 943,000 – the first time it has dropped below 1 million since such data were first reported in 1959. During the 3-year period 1969-71, the industry will have released nearly 500,000 people, or slightly more than one third of its labor force. By year's end, scientific and engineering employment will be 151,000 compared to the 1967 peak of 235,000.

Arc Strips Insulation From Wires

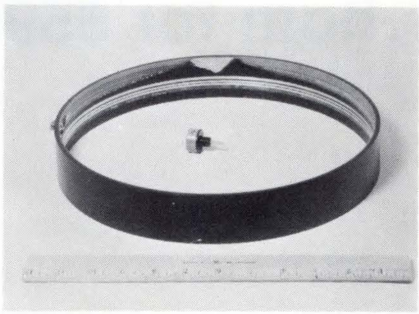
If you're tired of stripping insulation from wire with a jackknife, IBM has the answer. The systems manufacturing division in Poughkeepsie has pressed an electrical arc into service as an insulation stripper. Capable of vaporizing insulation from wires as small as 1 mil diam, the arc also can accommodate different gauges and twisted or multitwisted wire.

Piezoceramic Film Advance



Instead of using conventional rotary mechanisms, a new precision film advance employs piezoelectric devices to move the film. Film advance accuracies of 1 μm are claimed for the transport which can move film either continuously or in discrete steps and over a wide range of speed. Developed for the Air Force by Teledyne Ryan Aeronautical, the transport is undergoing tests at Wright-Patterson AFB.

Big Pot



Bucking the trend in precision potentiometers to miniaturization, is a new pot going in the other direction. The pot shown is the largest ever built by New England Instrument Co. yet it is being produced with precision normally obtainable only from laboratory standard potentiometers. The new unit is actually two potentiometers in one; a sine-cosine section which provides an output to 0.10% conformity, and a linear section providing an output to 0.02% linearity. This particular potentiometer is slated for a lens control system on a large aerial reconnaisance and mapping camera.

A full-function digital multimeter + A lab-quality digital AC voltmeter

...both for $595

HP's new 3469A gives you a general-purpose digital multimeter *plus* a lab-quality digital AC voltmeter—for the price of the AC voltmeter alone. Now, you don't have to buy two (or more) instruments to get the capabilities you need—or compromise on quality to stay within your budget.

As a general-purpose multimeter, the 3469A gives you exceptional capabilities. Its 1Ω range lets you measure low-resistance components and even contact resistances of a few milliohms, with an accuracy of ±0.25% reading ±0.5% range. To make the low range easily useable, a unique offset adjustment lets you compensate for lead resistance. In the higher ranges (100Ω to 10 MΩ), accuracy is ±0.3% reading ±0.2% range. The 3469A also gives you five DC voltage ranges (100 mV to 1000 V) and six DC ampere ranges (1 μA to 100 mA), with accuracy of ±0.2% reading ±0.2% range or better, depending on range.

As an AC voltmeter, the 3469A is unmatched at any price. You get seven voltage scales, ranging from 1000 V full-scale down to 1 mV full-scale—100 times the sensitivity of other digital meters. You also get a 10 MHz bandwidth capability—100 times greater than other digital multimeters—with a basic accuracy of ±0.3% reading ±0.3% range. And you get a bright, ultra-reliable, shaped-character GaAsP display, that's easier to read than tubes or bar-segment numerals.

Compare the 3469A's specs with any other meter's – and you'll agree that there's no better value, at any price. For further information on the 3469A, contact your local HP field engineer, or write Hewlett-Packard, Palo Alto, California 94304. In Europe: 1217 Meyrin-Geneva, Switzerland.

091/16

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DIGITAL VOLTMETERS

CIRCLE NO. 13

MEMORIES–

MODERN-DAY "MUSICAL CHAIRS" PART I

Each computer system need not use all types of memories, but there is a significant trend toward using all forms of memories to reduce system cost for a given range of performance and application.

HARRY HOWARD, Technical Editor

One of the difficulties with memories is the proliferation of potential technologies. Each technology is competitive with the others and with the old. Each requires a large investment in materials, processes and structures. And each has an impact on the organization of software and hardware.

Each factor increases the risk that a new technology will become obsolete before its innovation is complete. We have seen too many costly innovations land on the shelf—or that had only a limited range and time of use. Today, there are more opportunities to lose your shirt on, than on which you can make a killing. These feelings were expressed by Jack A. Morton, vice president of Electronics Technology at Bell Telephone Laboratories, in a keynote speech presented at the International Magnetics Conference in April.

From all appearances, the 1970s are going to be eventful years for a new industry—plug-to-plug compatible peripherals. With IBM-compatible disc pack memories, product differentiation is primarily price and product line support. For the non-IBM-compatible systems, anything goes. Techniques, parameters and prices become bewildering because of the range of customer requirements. Apparently, it is quite difficult for a customer to weigh his real needs, choose and know that he has selected the right memory for his specific needs.

Computer architecture, of course, shifts to take advantage of peripheral changes that improve price/performance characteristics of the system. Irving L. Wieselman, vice president of Product Programs, Data Products Corp., explains that an interesting phenomenon called "perpetual improvement" results from the impact of peripherals on each other. As new peripherals are developed, they do not replace the old, because in the same time span, the old ones are improved. Thus instead of new peripherals obsoleting the old, we see a "perpetual improvement" in which the whole technological front seems to move forward. Consequently, a designer's expectation of a market displace-

(Continued)

YEAR	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Computer Industry										
Core	3.76	8.25	16.72	30.72	44.45	68.45	108.58	156.79	218.37	217.17
Plated Wire	.009	.021	.035	.134	.802	2.77	4.03	5.17	5.13	3.51
MOS	—	—	—	—	.075	.639	2.05	4.71	9.91	21.4
BiPolar	.012	.016	.019	.036	.093	.212	.439	.825	1.71	3.14
Sub-Total	**3.781**	**8.287**	**16.774**	**30.890**	**45.420**	**72.071**	**115.099**	**167.495**	**235.12**	**299.22**
Communications Industry										
Core	—	—	—	—	.47	.81	1.22	2.0	3.97	6.57
Defense Industry										
Core	.376	.825	1.67	3.12	3.12	3.12	3.12	3.12	3.12	3.12
Plated Wire	.001	.002	.004	.013	.08	.277	1.02	1.83	3.37	6.19
Sub-Total	**.377**	**.827**	**1.674**	**3.133**	**3.20**	**3.397**	**4.14**	**4.95**	**6.49**	**9.31**
Grand Total Bits	**4.16**	**9.11**	**18.45**	**34.02**	**49.10**	**76.28**	**210.46**	**714.45**	**245.58**	**315.10**
Total Bits-Subdivided by Technology (Billions)										
Core	4.14	9.07	18.39	33.84	48.05	72.37	112.92	161.91	225.46	280.85
Plated Wire	.009	.023	.039	.148	.882	3.04	5.05	7.00	8.50	9.7
MOS	—	—	—	—	.075	.639	2.05	4.71	9.91	21.4
BiPolar	.012	.016	.019	.036	.093	.212	.439	.825	1.71	3.14

This chart reflects worldwide accumulative bit usage from 1965 to 1970 with a forecast for 1974. (*Signetics Corp.*)

(Continued)

FOR A FREE REPRINT OF THIS ARTICLE, **CIRCLE NO. L61**

ment with a new unit turns out instead to be a market modification.

Scene of Action

Memory technology has become a perplexity of chips, devices and subsystems. Somehow, these pieces must fit together to yield a desired performance at an acceptable cost. Looking ahead, Rolland Smith, manager of Marketing Research for Signetics Corp., forecasts that the memory market will grow from 27.1 billion bits in 1970 to 69.5 billion bits in 1974. Revenue from this market will be $813 million in 1970 and $1.598 billion in 1975, including in-house producers. The semiconductor market portion is expected to grow from 684 million bits in 1970 to 12.9 billion bits by 1974, with revenue growth from $25.2 to $331.6 million for open market producers.

In rotating memories (disc and drum), cost/bit runs 0.5 to 0.0002 cents/bit, assuming a capacity range of 10^7 to 10^9 bits. These memories are relatively slow (10-msec cycle time for the fastest) and they normally function as on-line support for the main frame memory. Since IBM controls about 70% of the disc market, most of the activity is slanted toward plug-to-plug replacements for the Model 2311 (50 tracks/inch, 1100 bpi), Model 2314 (100 tracks/inch, 2200 bpi) and Model 3330 (200 tracks/inch, 4400 bpi).

Large main frame processors and extended-core systems account for approximately 94% of the memory requirements for cores. According to John Guyett, director of marketing for Core Memories, Inc., there were approximately 50 billion cores produced in 1970; 3 billion are used in minicomputers. The present core prices of $1.50/1000 will soon approach $1.00/1000.

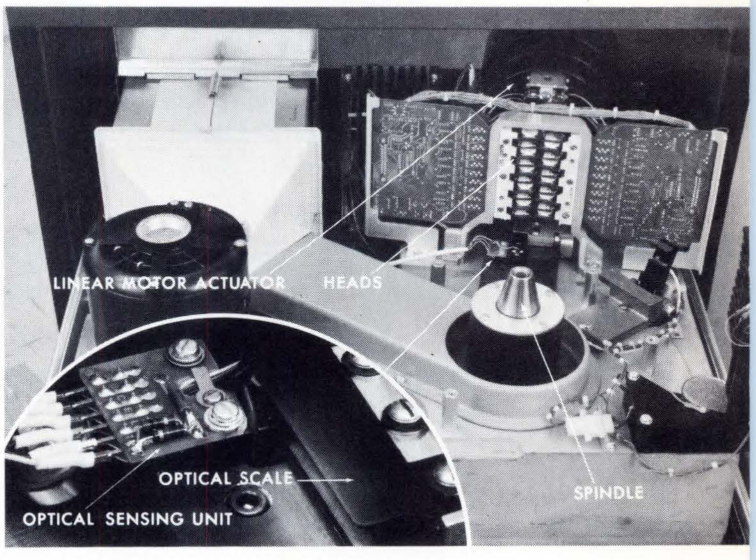
Mr. Guyett feels that the 2D organization looks best from a price/performance viewpoint in the OEM market because of the consistent lowering of prices for semiconductor circuits. By using a 2D organization with 200-nsec access and 500-nsec cycle times, a selling price of 0.75 cent/bit exists for production quantities. Memory modules may be as small as 8 by 10 by 2 inches for a 4k-word, 18-bit system. Performance is in the area of 750-nsec cycle time with typical costs in the area of 1.5 cents/bit for the total modular package.

For the end user, Mr. Guyett points out that the recent rash of offerings by independents to supply plug-compatible memory systems has not been limited to "peripheral storage". Without the overhead of software and systems architecture to soften the punch, memory suppliers are providing each other with competition in the largest field of add-on-memory, namely IBM System/360.

Presently plated wire finds two areas of application: military and control systems. In mainframe application, Univac still uses plated wire even though this application appears to be falling by the wayside. Dr. Jerome S. Sallo, manager of the Magnetic Thin-Film Memory Devices Dept., Lockheed Electronics, notes that Japan and England are major users of plated wire in main frame application. All of their new computers contain plated-wire memories. Cutbacks in research and development by many companies in this area have not helped this technology.

Bob Fillingham, president of Nemonic Data Systems, Inc., points out one of the biggest computer problems of the 70s—brownouts and blackouts. Every year, these phenomena are causing total confusion with computers, numerical controls and process controls. Companies are running huge amounts of machinery under computer control and are processing volumes of data that they cannot afford to lose. All face the problem of power interruption. Plated wire exhibits a very important property that makes it ideal for these situations—true nonvolatility. This natural ability to retain information also makes these memories ideal contenders in the mass storage department. With mini-wire (2- to 3-mil diam), there is the potential of reduced size with increased capacity. Even though the cost/foot may be higher, the cost/bit will be lower because twice as many bits/foot will be available once in production.

Two to 3 years ago, the use of semiconductor memories was projected to be 5 to 6 years off. However, the



In the Century Data Model 215 disc drive, an electromagnetic servo-controlled positioner moves the carriage to position the recording heads on a selected cylinder. A fixed transducer is mounted above and below a precision optical scale that is attached to the carriage. The optical scale has dark and light areas in its opaque emulsion covering. Light areas correspond to the cylinder position. As the positioner moves the optical scale through the transducer, the light areas on the transducer align with the areas on the optical scale. Photo diodes in the transducer sense light passing through the etches and produce a pulse. This pulse is applied to the drive logic that determines when the heads are in proper position over the selected cylinder. (*Century Data Systems*) cost of interface electronics put economic restraints on magnetic to IC logic systems. Consequently, semiconductor memories are fast becoming the workhorse of the computer industry.

A strong trend is developing for the use of read-only memories (ROMs) as microprogramming circuits, now dominated by cores. Mr. Smith of Signetics predicts this to be a $127-million market. The random-access market, comprised of both read/write and dynamic serial memories, is forecasted to be $204 million by 1975. The MOS market will grow from $18.4 to $25.7 million and bipolar from $6.8 to $74.6 million by 1975. Bipolar or MOS? Dynamic or static? Hybrid or monolithic? These decisions face the designer considering semiconductors for storage.

Reese Brown, manager of Semiconductor Engineering, Electronic Memory Systems Div. of Burroughs Corp., explains that for memories requiring <150 nsec access time, bipolar is the choice. For >250 nsec, MOS is the obvious selection. In the region of 150 to 250 nsec, either bipolar or hybrid can be considered. There are indications, however, that bipolars are becoming both competitive and practical for slower and larger systems because manufacturers are finding out how to make 1024-bit memories. Several companies are devoting their attention to newer processes that are making bipolar competitive with MOS. Mr. Brown continued by saying that core and wire are now the only way to achieve mass storage. The dynamic devices appear to be the obvious answer for mass semiconductor storage. But dynamic devices require standby power and refresh cycles. If there was an efficient way to use static devices, the refresh problem would be solved. Of course the big problem is still retention or volatility. When power drops, who can afford to lose the information within the mass storage system?

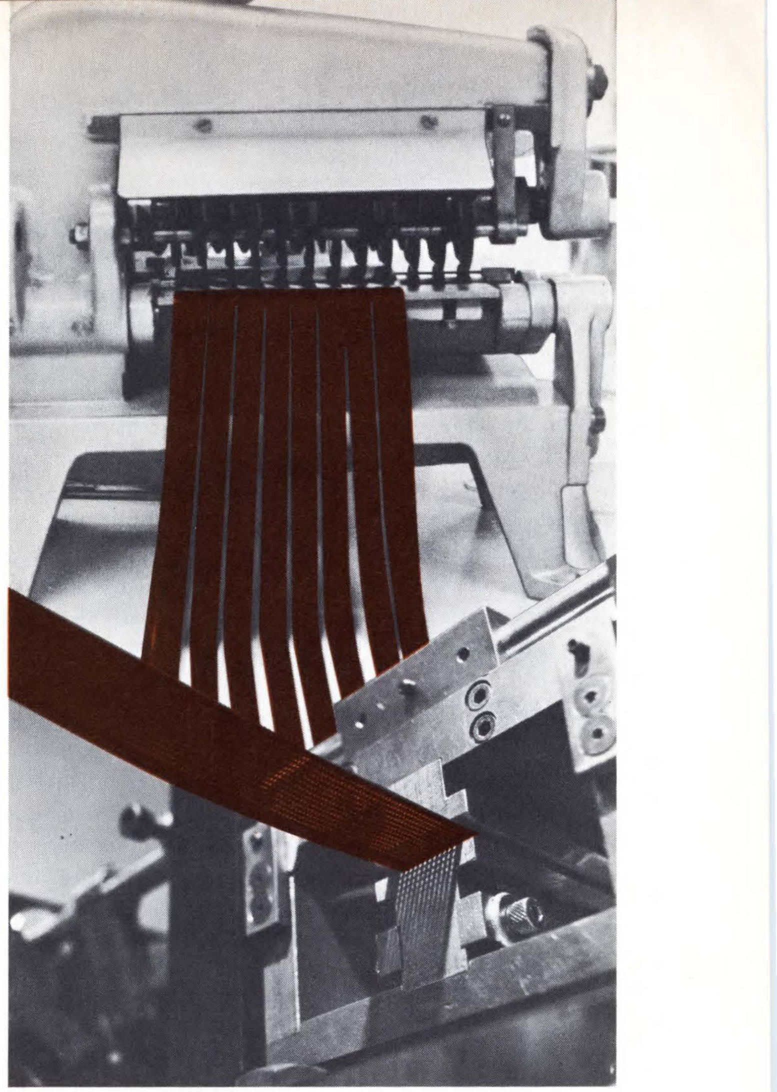
Organizational Categories

Three characteristics define the status level of a technology within the memory system hierarchy—size, speed and volatility. Access times range from a few nanoseconds to seconds, capacities are from a few bits to trillions of bits, and recently there has been concern about volatility—loss of memory is acceptable for small size memories, unacceptable for bulk storage.

Magnetic technology dominates the computer storage because of the broad range of applications—from bulk to mainframe. To understand the considerations involved in the hierarchy of memories, definitions of uses and types should be reviewed:

MAINFRAME—Its function is to hold data that either awaits processing or that has just been processed. Because speed is critical, today's processing systems, designed around IC technology, use a popular scheme labeled "Cache".

CACHE—A high-speed buffer storage placed between the mainframe memory and the processing unit. Cache is used when a large number of accesses are made to one area of memory and then a large number of accesses are performed in another portion. A block of information from the first region accessed in mainframe memory is transferred into the Cache. Consequently, successive accesses to locations within the same portion will not require access to the mainframe but need only to go to the Cache storage with its shorter access time. When access to another portion of the mainframe memory is required, Cache is updated with this new block of information.



"Roll cut" technique produce 18-mil (O.D.) cores with uniform electrical characteristics, simplifies tooling and permits recycling of waste material. (*Core Memories Inc.*)

BULK STORAGE—Referred to as "secondary storage", bulk storage retains large quantities of three types of data: unprocessed input information, processed output information and information for long term storage. Often, bulk storage is referred to as either "on-line" or "off-line" storage. Popular devices include discs, drums and tapes.

VIRTUAL MEMORY—Incorporating mainframe meory, auxiliary or backup storage and software, a large extended memory is created that is capable of handling sequential segments of many programs simultaneously. With the virtual memory, program data is segmented in blocks called "pages". The pages are

(Continued)

Memories *(Cont'd)*

stored in the backup storage—usually a high-speed drum system. Using a paging technique (controlled by software), pages are rapidly swapped between the mainframe storage and the backup storage until a job is completed. Each time space is available in the mainframe, a waiting page is entered immediately. From the programmer's point of view, a virtual memory releases him from complex memory management.

CONTROL MEMORY—A number of processors operate under control of "microprogramming". Microprogramming controls individual gates and logic blocks by means of very rudimentary hardware-oriented instructions. The memory is either a non-alterable read-only memory (ROM) or a high-speed control memory which could be part of the computer main memory. Thus, the control storage is usually a ROM.

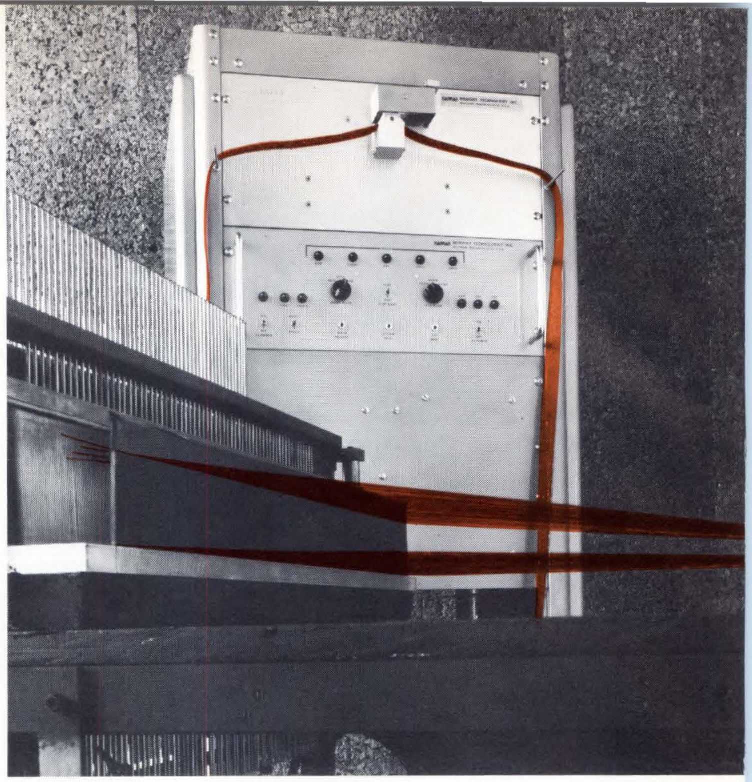
LOCAL STORAGE—External device operations (card readers, printers, communication equipment) require control information only for local functions and storage. Transfer of data to and from a subsystem may require buffering so that access to the mainframe occurs only when full memory width is available. Also local storage is used in performing a "bootstrap" or restart operation in case of a malfunction or error. The processor is restored under control of the local storage to its earlier state, and can repeat the operation in progress when the malfunction occurred.

REGISTERS—Another means of avoiding system degradation resulting from a slow mainframe memory is the use of registers. These registers are high-speed and have relatively small storage capacity (32 to 64 bits/register). Frequently accessed information is placed in these registers, thus avoiding continuous accessing of the mainframe memory. Also, they can be used to temporarily store hold addresses, instructions and control information.

Large Storage in Demand

Technology used for peripheral equipment depends on performance characteristics, time of the original design and the design approach. Grant Savier, manager of Mass Storage Development, Digital Equipment Corp., segregates the mass memory devices in terms of access times that range from 1 μsec to seconds. At the 1-μsec point, magnetic cores dominate. Domain devices, bubbles and semiconductor devices such as charge-coupled, bucket brigade technology and shift registers may invade the 1-μsec to 1-msec region. Rotating media operate from 1 to 500 msec.

Consider first the rotating media. Primary performance factors are **access time**, **transfer rate** and **total capacity/device**. There are three basic designs, each with different performance characteristics. These are *fixed-head, fixed-media; movable-head, removable-media;* and *movable-head, fixed-media*. Minimum access time is achieved with the *fixed-head, fixed-media* systems, since no time is required for moving the heads to the desired track. Minimum off-line cost/bit is attained with the *movable-head, removable-media*, because disc packs are low cost units. *Movable-head, fixed-media system* achieves minimum on-line cost/bit.



Using paper tape input for describing ROM content, the weaving machine generates wire braids that are placed into a set of U-cores and capped with I-bars. (*Memory Technology*)

The storage capacity of a disc is the product of the number of bits/track and the number of tracks. Movable head systems use at least two orders of magnitude fewer magnetic read/write heads than the fixed-head systems—the positioner moves the heads to the track rather than requiring one head/track. For an equivalent number of tracks, a positioner and its heads are less costly than an equivalent number of heads. Therefore, a fixed-head system with one-third the access time of a movable head system costs about three times as much per bit.

Irving L. Wieselman of Data Products Corp, indicates that the user price/bit for movable-head rotating memories is between 0.005 and 0.15 cent/bit. Future systems will reduce the price by maximizing bit and track density through the use of more effective components, and not by increasing their number.

Mr. Wieselman continues with a description of the trend of movable-head systems. A limiting factor in track density is the minimum width track that can be read. This factor is a function of the magnetic properties of the disc, the flying height of the head and the manufacturing tolerances. On a movable-head, the next most important factor is the positioning accuracy of the head relative to the track. Track spacing must be equal to the minimum width read track, plus three to five times the total head positioning tolerance.

Today's movable-head systems use tracks of 3.5 to 5×10^{-3} inches. Head positioning accuracies are within 0.5 to 1.5×10^{-3} inches for most types of positioners and down to 0.05×10^{-3} inches for positioners that servo on disc tracks. Track densities vary from 100 to 200 tracks/inch. Within the next 5 years, practical systems will have minimum read-track width of 1.5 to 3×10^{-3} inches. With additional improvement of positioning capabilities, track densities should range from 300 to 500 tracks/inch.

Bit densities in today's movable-head systems range from 1500 to 4400 bits/inch. Flying the heads lower and using a more uniform magnetic material should increase the bit densities by a factor of two. A more effective coding scheme could also increase the bit densities by another factor of two. Since these densities are achieved by improvement of component technology, the cost for components should not increase more than 25%—decreasing the cost/bit by a factor of three to eight times in the movable-head systems.

Data Products' System/7000 uses a movable-head fixed disc approach. It is organized so that it is compatible with either the IBM 360 or the Univac 418, 490 or 1100 series. The unit is a direct replacement without software changes for two Univac Fastrand II's and has approximately 1/2 the latency and double the transfer rate in one-half the floor space.

Disc storage, pioneered by IBM, has become a widely used concept for storage requirements that are not economically feasible for mainframe storage. Removable disc packs provide the user with an unlimited amount of data and programs in addition to the flexibility of selecting the desired units for on-line operation. Recently, IBM announced the 3330 disc system which triples the storage capacity and halves the access time of the popular 2314.

The 3330 system consists of a control and one to four dual disc modules, each with 200-million-byte capacities. Each module contains two independent disc drives. The 3330 uses a 3336 disc pack, each with 100-

An 18-head twin-pad, plug-in unit is an integral part of the DISC*CELL head/track disc file system. (*Dataflux Corp.*)

million-byte capacity. These packs contain 12 discs with 20 recording surfaces—19 used to store data, with the 20th used for timing.

Another unit developed for the System/360 Models 85 and 195 is the 2305, a fixed-head system. Two models are available and they can share a single control unit, effectively allowing very high-speed access to 10.8 to 22.4 million bytes. Data is stored on six nonfixed discs while the read/write heads are fixed in position to access each track on the drive's 12 recording surfaces. Both the 3330 and the 2305 have performance features that permit them to take advantage of block multiplexing. Among them are:

—rotational position sensing that disconnects the drive from the channel during most of the rotational latency period;

—multiple requesting that permits many channel programs to operate simultaneously within a 3330 or 2305.

Century Data Systems, Inc. recently introduced a two-drawer unit, Model CDS 215. William Sewalk, vice president of Marketing, describes this unit as a logical technical progression following the Model CDS 114 (Century Data's plug-to-plug replacement for the IBM 2314) in that the Model 215 uses 200 track-per-inch technology. The operational characteristics are the same as the 114, but it has twice the storage —116 megabytes (8 bits/byte). To increase the access time and provide better control in positioning the head, a voice coil actuator with an optical positioning scheme is used.

At the Spring Joint Computer Conference in May, Century Data introduced an equivalent to the IBM 3330. Designated Model CDS 230, the unit consists of two separate and independent disc drives and incorporates the 192 track/inch technology at 4040 bits/inch. Consequently, the total on-line capacity is 100 million bytes/drive or 200 million bytes/unit. The Model 230 can be configured in a system with 2, 4, 6 or 8 spindles providing up to 800 million bytes total capacity. According to Mr. Sewalk, Century Data is now directing their attention toward the development of units exceeding 200 track/inch and 4000 bit/inch capability.

Potter Instrument Co., Inc., offers two plug-to-plug units—D 4311 and DD 4314. Totally compatible with the System/360, the DD 4311 replaces the IBM 2311 disc drive, plugs directly into the IBM 2841 storage control unit and uses the IBM 1316 disc pack. Storage capacity is 7.25 million bytes. The DD 4314 has a storage capacity of 29 million bytes and uses an 11-high disc pack, IBM 2316 or equivalent. A direct connection with the IBM System/360 requires Potter's DC 5314 controller.

Memorex offers three disc drives that are IBM-compatible—660, 630 and 620. With the 660, a 29-

(Continued)

million-byte unit, data is interchangeable with the 2314 or 3600 systems using Memorex Mark VI, IBM 2316 or equivalent pack. In a similar manner, the 630 (7.25 million bytes) and the 620 (5.4 million bytes) are interchangeable with the 2311 drives using Mark I, IBM 1316 or equivalent packs. The 660 controller, Memorex 661, has a fast ROM for resident microprogramming, on-line diagnostics and recycles automatically on a ROM read error.

Control Data's mass storage subsystem consists of up to eight disc units, Model 844-2, with a single or dual 7054 or 7654 controller. A track-packing technique yields 4000 bits/inch coupled with 200 tracks/inch – total capacity of 708 million bits/drive. With the disc rotating at 3600 rpm, the average latency time is 8.3 msec and the average positioning time is 30 msec.

At Spring Joint Computer Conference, Caelus Memories Inc. announced a series of single and dual spindle configurations with 1025 to 2200 bit/inch packing densities and the drives offering 11, 22 or 44 million bits of storage. Two models, CD-11 (single drive) and CDD-22 (dual drive) are compatible with IBM's 2310 data transfer rate. The 2200-bit/inch models are the CD-22 (single drive) and the CDD-44 (dual drive). All units use an electroservo scheme for precise head position control. Caelus Memories is in the process of developing discs for packs with typical performance attributes of 200 tracks/inch nominal and a transfer rate of 6.5 million bps. Bit density is aimed at 4040 bpi with 404 tracks/surface, plus seven spares. This disc is comparable to the IBM 3336.

More Bits Per Size

In 1969, Singer/Librascope initiated an evolution of mini discs with the introduction of a 9- by 6-inch unit that stores 20,000 bits/track on 25 tracks. In 1970, they had four models (500k, 750k, 1M and 1.5 megabits) in a 9- by 6-inch package. Then they upped the density to 40,000 bits/track, yielding 4 megabits at 3600 rpm. With still another breakthrough, they went to 70,000 bits/track, 1800 rpm. This 12-lb unit, still 9 by 6 inches, is called the L107A and has 7 million bits of storage with an average access time of 17 msec.

This same memory, L107A, provides 4 million bits of storage at an 8.5-msec average access time. The memory uses double frequency phase modulation recording which is inherently more reliable than non-return-to-zero (NRZ). There are no mechanical adjustments or shims and a single set of duplex angular contact bearings is used to increase the mean-time-between-failures. One or two disc surfaces are used for recording. Ferrite cores mounted in coined flying pads are used to magnetize the disc surface. According to Robert D. Fuchiek, product manager for Librascope, their next venture in small capacity files will be 20 million bits.

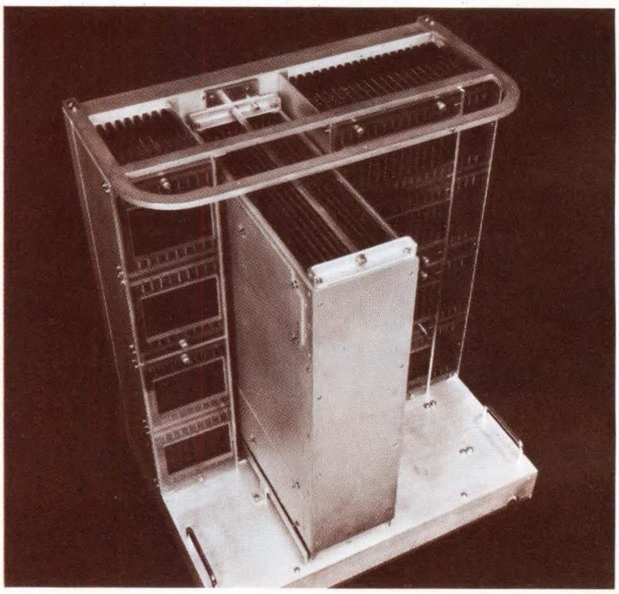
Data Disc offers two fixed-head, parallel disc memory systems. A popular application is digital TV refresh. The 5200 and 5250 Series operate with 12-inch discs containing 72 tracks with up to 100k bits/track. The tracks may be recorded or read separately or in parallel at rates ranging from 3 to 216 million bps. In 1969, the 5200 unit was used to store TV data sent back from Mariner 6 and 7. Also Data Disc produces the 7200 series – head-per-track units for minicomputers. The smallest unit provides 800k bits of storage, the largest 17-million bits. They occupy only 8.75 inches of rack space (2 million bits/inch of rack space for the largest unit.

For the OEMs, system houses and end users, Hewlett-Packard offers the Model 7900A. This unit can access on-line data base of 5 million, 8-bit bytes with an average response time of 50 msec. The 7900A uses a single fixed-disc and an interchangeable 2315 cartridge. The unit has four moveable heads, controlled by a photo-optical system.

Basing their design for the Series 6000 Disc Memory on the minicomputer industry, Magnafile, Inc. developed a single-disc, head-per-track unit that has 2.4 to 9.6 million bits of capacity at 17.4-msec average access. Also, their controller, Series 100, drives up to four disc systems and interfaces with any conventionally-organized 16-bit processor's I/O bus.

Information Storage Systems, Inc. uses a data organization in their 724 System that allows 92,000 individually addressed 256-byte records to be written on a single 2316 disc pack. This is equivalent to 23.5 million bytes or 188 million bits of usable data storage. Average access time is 32 msec.

For the "Nova" line of minicomputers, Data General



A 2-wire, 2-1/2D core memory, designated MEGAMEMORY 1000, stores up to 524,288 words, 8 to 14 bits/word. Access time is 850 nsec, cycle time 1.5 μsec. (*Electronic Memories*)

Corp. offers a 2311-type moving-head disc system. These units operate at 2400 rpm, giving an average latency time of 12.5 msec. The disc store 16-bit words in blocks of 256 words each, and are available with a capacity of 3.072 million words.

Digital Equipment Corp. offers a fixed-head design, RC11, that has the heads floating 50 to 60 μinches above the disc surface. Disc coating is made of nickel, cobalt and a proprietary protective coating. This unit operates in conjunction with the PDP 11 computer and has a capacity of 128k bytes.

Disc Packs

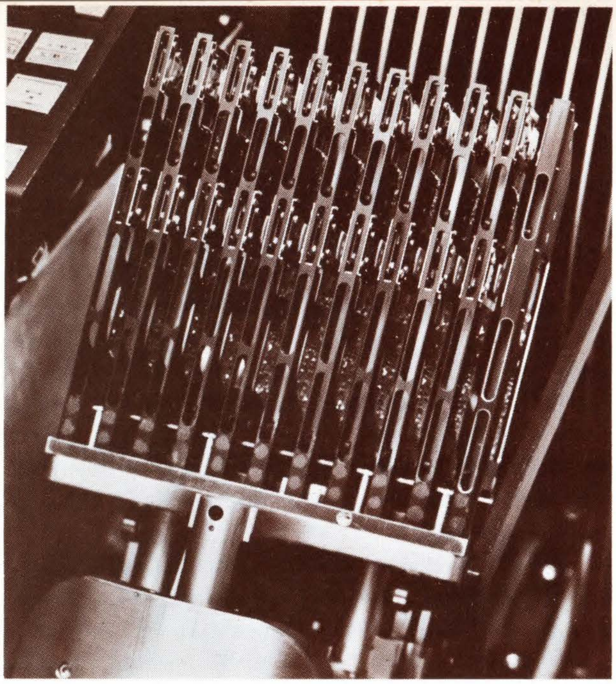
Three types of IBM-compatible disc packs are available: single disc cartridge, 6-high (6 discs per stack) and 11-high. Donald Decof, marketing manager for Computer Products at BASF Systems, Inc., explains that the first successful third-generation drive was the IBM 2311—using a 6-high disc pack. However, the IBM 2314 (11-high unit) is quickly replacing the 2311. The national average is about 5.2 packs/spindle or drive. The compatible disc pack offered by BASF for the 2314 is the Model 1100.

The average distance between the head and the disc surface is 70 μinches, notes Mr. Decof. The IBM standards call for 90 μinches for a flying-head operation but BASF test their units at 40 μinches. All packs are dynamically balanced by the addition of weights—similar to balancing an automobile wheel. Surface coating is applied by either a *spinning* or *spray* technique. The disadvantage of the *spray* approach is the even dispersion of coating it produces. Because of density variation, the inside coating (toward the center) should be thinner than at the outside.

In making a disc, there are about 64 inspection steps performed for each disc. Disc price is approximately 1×10^{-6} dollars/bit or $1/megabit.

Recently Dataflux Corp. introduced a head-per-track memory device designated DISC*CELL. To attain the advantages in terms of price, reliability and performance indices compared to other disc packs, according to Sung Pal Chur, president of Dataflux, is that their read/write head manufacturing and assembly methods employ batch processes. Consequently, Dataflux is able to offer 12.8 megabits of on-line storage (DISC*CELL and a twin carrier) for 0.046 cent/bit with a projected cost of 0.025 cent/bit within the next four years.

Diablo Systems Inc. offers Model 31 with different transfer rates—781, 720, 1562 and 1440 kHz. The 781-kHz rate is generally associated with the 1100 cpi disc pack and the 720 kHz is compatible with the IBM 2310 drives using IBM 2315 disc cartridge at 1020 bpi. An electronic servo scheme controls the precise positioning of two read/write heads. Once in position, the same servo circuitry holds the heads over the track. A dc motor drives the spindle whose rotational speed is under control of a crystal oscillator to within ± 1 percent of 1500 rpm.



Moveable head position modules of System/7000 Large Disc Store in a retracted position show arrangement of heads. (*Data Products Corp.*)

For the mini/midi computers, Datum Inc. has a family of drum memories, Series 88, that use military-type read/write heads, restricted to one degree of mechanical freedom. Storage capacities range from 132k bits to 6.4 megabits. All drums are nickel-cobalt plated and feature head-per-track, flying head design.

Ye Olde Standby

Cores have experienced many changes but still remain the leaders. Richard Dadamo, president of Electronic Memories & Magnetics Corp., emphasized the fact that core manufacturers have years of experience to rely on when encountering their competition. For example, the evolution of core material went from magnesium manganese to lithium-ferrite to lithium nickel, acheiving both speed and increased range of operating temperatures. Military systems for severe environment specifications are now available to cycle times below 1 μsec. Drive currents vary from 400 to 900 mA. The high currents are used in 500 nsec or faster memories, 400 mA in 1 μsec or slower. Cores now available in the 400 mA region permit MSI compatibility with drive circuits. Planar packaging techniques have reduced manufacturing costs significantly, and tighter packaging allows higher speed operation with proven cores and circuitry. To answer another challenge, Electronic Memories recently introduced their non-destructive readout memory using a core as the element.

At Honeywell, Dana Moore, manager for Memory Products Engineering also emphasized the impact of ICs on packaging core memories at lower cost. Mr. Moore described their modular packaging approach which takes advantage of high density 3D-3W core arrays and IC selection circuitry. He pointed out how

(*Continued*)

this approach is now superior to earlier 2-1/2D implementation of large mainframe memories. The performance and reliability are equivalent, cost is lower, serviceability is better and this packaging approach when used for magnetic memory is suitable for MOS memory as well. A change in technology can now be made by merely replacing a core module with a semiconductor equivalent or the reverse in the event the core design is to serve as an alternative to semiconductor memory.

In 1969, Cambridge Memories Inc. introduced their domain concept, labeled DOT. Richard Egan, vice president of Marketing explains that this concept is ideal for plug-compatible memories because they are static, nonrotating and have no latency time. However, all new technologies require time for development and acceptance within the equipment. Thus, Cambridge Memories' present market is plug-to-plug core memories. Mr. Egan describes three markets:

—**A market for extending the life of the IBM machines on lease.** The introduction of the IBM 370 with larger storage capability caused companies to terminate their 360 leases and buy 370s. One way to prevent this mass termination was to increase the memories. As a result, a market for plug-to-plug and extended-core memories developed.

—**A market for people who bought the IBM 360 and require more memory, but cannot afford a 370.** Again, core-extended memories are available with lower price tags than a new system.

—**A market for people renting from IBM who find that they can return their memory units according to terms** and obtain a unit for less money from the plug-to-plug manufacturers. This market includes approximately 12,000 Model 30, 5000 Model 40, and 2000 Model 60 units. The Model 30 can have up to 64k bytes, Model 40, 256k bytes, and Model 50, 512k bytes.

Cambridge Memories displayed the 360/CORE system at the Spring Joint Computer Conference. Initial models are plug-compatible with IBM System/360, Models 30, 40 and 50. The memory is expandable in small modules from 8192 to 524,000 bytes. Design features include 3-wire planar array, 8k bytes/board, no internal adjustments and integrated circuits used throughout the control circuitry.

Ampex Corp.'s recent entries are Model ARM-30 and Model ARM-2365. The ARM-30, replacement for the 360/30 mainframe core storage, offers capabilities of 16,384, 32,768 and 49,125 bytes. Up to four ARM-2365 modules (1,048,576 bytes) may be used with the IBM 360/65 or /67 and up to eight (2,097,152 bytes), with the 260/75.

According to Ralph Gabai, marketing manager for Data Storage Products, Lockheed Electronics offer both OEM and end-user products. The OEM product is a unit containing only the memory stack with required electronics. Memory families falling in this category include the CE-100 and the CB-65. The end-user product is an OEM unit with required interface circuits. For example, the MPM-100 is a plug-to-plug system for the PDP-10 computer, based on the CE-100 memory family. The MM-365 system, comprised of the CB-65 with IBM 2365 interfacing circuits, operates with the IBM 360/65 system.

Core Memories Inc., a subsidiary of Data Products, uses a patented "roll cut" technique. Bill Rumble, Engineering Department manager, points out that this approach not only reduces core costs by 50 percent, but produces cores with uniform electrical characteristics, simplifies tooling, and allows any waste material to be recycled. Using this technique, Core Memories manufactures cores for their System/6000 Large Core Store, compatible with the 360 system. Even though the system is plug, timing and software compatible with the 2361, the cycle time is 2 μsec.

Specialties of several manufacturers are in-house design and application—Di/An Controls, Inc. is such a company. They build miniature core memories for special purpose and extreme environmental applications. Their Model 6085 is a serial access memory used in telemetry buffering and program data storage. Another unit offered by Di/An is the Model E-1599 random access memory for aerospace programs.

Until recently, Litton Systems, Inc. (Guidance and Control Systems Div.) specialized in core memory systems for military and space application. They developed systems such as the CORX random-access, read-only memory, the SCM sequential access unit and the CORCT general purpose 2-μsec random-access memory. For high-performance multiprocessors, Litton offers the LCM 800, a 16k 1-μsec multiported memory system. The advent of computer-aided design led to the development and production of a modular memory card, LCM-5000, and the multilayer laminate LCM-6000 series (4k $\times$ 32-bit system, operating at 1 to 2 μsec). R. V. Nino, marketing manager for Memory Products and Technology, feels that the trend is toward customer purchase of complete memory systems even though they are designing and building their own processors. According to Mr. Nino, this approach gives the user the benefit of a mature design that has already solved the power stability, thermal and structural problems he would surely encounter.

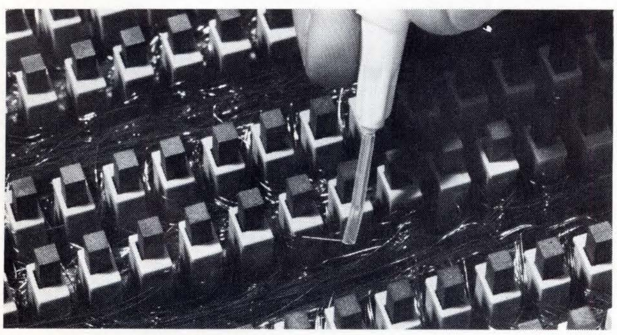
ROMs Made With Cores

Microprogramming has introduced another need for ROMs. Many types of ROMs are available but the advantages of cores include simple construction, large output signals, low cost and easy alterability of the stored information. Either a closed, toroidal ferrite core or open cores comprised of two matched ferrite elements are used for these ROMs. However, the closed core has the disadvantage in threading.

Jozef Furst, director of Advanced Development at DataPac, Inc., explains two principal methods, using the open ferrite core. U-shaped ferrite elements are mounted in rows with I-bars positioned across the open end of the U-core to close the flux path as well as providing easy accessibility for wiring and alteration. Sense windings are wound on either the I-bar or one leg of the basic U-core. Word lines, enameled copper wires, are routed through the rows of cores, going through the center for a "1", around for a "0". The second method, developed by IBM and employed in the 360/40 computer, uses flexible Mylar tapes incorporating two ladder-shaped conductor paths. DataPac's designs are TTL/ECL compatible and they permit over 100k bits to be mounted on a standard 13- by 11-inch board. Other characteristics include 200-nsec cycle time, 725-nsec access time and 50 uW/bit power dissipation. DataPac also offers a portable automatic rebraiding machine so that customers can perform field alterations.

Memory Technology offers 72-hour service for their SBS (small braided system) and MSBS (multiple small braided system). According to Paul Rosenbaum, vice president of Marketing, the only requirement is a paper tape to describe the memory content. Under control of this tape, primary wires are woven automatically and separately from the cores. Then the braid is placed into the U-cores and capped with the I-bar. For the 72-hour service, the primary wires are potted and then slipped down over the U-cores mounted on the customer's printed-circuit board. A recent product introduced by Memory Technology is the NANOROM 90, with 190-nsec cycle time and 90-nsec access time.

QUADRI Corp. uses another approach – the "Q Core" system. John Bruder, manager of Advanced Product Development, describes the "Q Core" as being composed of ferrite rods with sense coils wound circumferentially around the rods. According to Mr. Bruder, this approach withstands mechanical shock better than the U-core and offers a wider operating temperature range. A 13- by 11-inch card holds up to 100k bits with a cycle time of 200 nsec.



Users can easily alter memory contents of ROMs built with U-cores. With "I" bar removed, hand wiring is simple and quick.

Donald McNabb, president of QUADRI, described a new product, an optical ROM that is based on fiber optic technology. The unit, designated Model 401-22, offers up to 160k bits of storage on an 11- by 13-inch printed-circuit board. It is TTL-compatible and can be wired-OR to any desired capacity. Access time is 150 nsec standard with lower access times available on request.

Plated Wire – A Sleeping Giant

Production lines and noisy environments require true nonvolatility. Responding to this challenge, Memory Systems Inc. developed the MiniRam, a 128-word by 10-bit memory mounted on an 8- by 10-inch board. According to Bruce Kaufman, president of Memory Systems Inc., an important point for plated-wire technology is to demonstrate that it is available, that the prices are competitive and that the stuff works. Mr. Kaufman emphasized the fact that one of the things that has made costs drop in this technology is the integrated circuits used in the "overhead" or control circuits. Because of the ICs, the price tag for the MiniRam is $200.

Memory Systems Inc. also offers a series of electrically-alterable ROMs called "OmniROMs". The OmniROM may be used for developing new firmware sets as a dynamic device integrated within the computer mainframe. An adapter card is inserted into the host computer and to provide the required interface between the units. Presently, the OmniROM is used with the Micro 800 Series, Interdata Model 2, 3, 4 and Data General's NOVA and SuperNOVA.

Carlos Chong, vice president of Engineering at Nemonic Data Systems, Inc., explains why they are seriously considering mini wire for commercial application. Presently, the major user of mini wire (produced by Honeywell) is the military and they are packing 100 wires/inch. Considering packing density along the length of the wire, 33 bits/inch is attained, thus yielding a total packing density of 3300 bits/inch^2. Presently, 800 bits/inch^2 is being achieved with 5-mil wire. For an equivalent number of bits, the stack is reduced 25% in size using 2-mil wire. The cost to make the first square inch has doubled but the total cost/bit decreases 50%/stack.

Nemonics data system is at present selling 4k by 16 and 16k by 36-bit memories at $0.3/bit and $0.015/bit respectively. With the high speed and NDRO capability these memories are priced/performance competive with either core or semiconductors. With the miniwire, plated wire will be even more competitive. The role of the semiconductor and their application will be discussed in the August 15th issue of EDN/EEE, "Memories – Modern-Day Musical Chairs", Part II. □

(Continued)

ACNOWLEDGEMENTS

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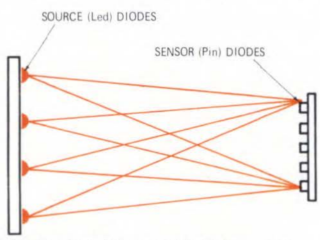
Moving Media: BASF SYSTEMS INC., Bedford, Mass.; BELL LABORATORIES, Murray Hill, N. J.; BURROUGHS CORP., Detroit, Mich.; CAELUS MEMORIES INC., San Jose, Calif.; CENTURY DATA SYSTEMS INC., Anaheim, Calif.; COMPUTER PERIPHERALS CORP., San Diego, Calif.; CONTROL DATA CORP., Minneapolis, Minn.; DATA DISC INC., Sunnyvale, Calif.; DATAFLUX CORP., San Jose, Calif.; DATA GENERAL CORP., Southboro, Mass.; DATA PRODUCTS CORP., Woodland Hills, Calif.; DATUM INC., Anaheim, Calif.; DIABLO SYSTEMS INC., Hayward, Calif.; DIGITAL EQUIPMENT CORP., Maynard, Mass.; HEWLETT-PACKARD CO., Palo Alto, Calif.; IBM CORP., White Plains, N.Y.; INFORMATION STORAGE SYSTEMS, INC., Cupertino, Calif.; IOMEC, INC., Santa Clara, Calif.; MAGNAFILE INC., Phoenix, Ariz.; MEMOREX CORP., Santa Clara, Calif.; POTTER INSTRUMENT CO., INC., Plainview, N.Y.; SINGER/LIBRASCOPE, Glendale, Calif.; UNICOMP INC., Northridge, Calif.

Cores and Plated Wire: AMPEX CORP., Redwood City, Calif.; CAMBRIDGE MEMORIES, INC., Newtonville, Mass.; COMPUTER MICROTECHNOLOGY INC., Sunnyvale, Calif.; CORE MEMORIES, INC., Mountain View, Calif.; DATAPAC INC., Santa Ana, Calif.; DI/AN CONTROLS, INC., Boston, Mass.; ELECTRONIC MEMORIES, Hawthorne, Calif.; FABRI-TEK Inc., Minneapolis, Minn.; HONEYWELL INC., Framingham, Mass.; LITTON SYSTEMS, INC., Woodland Hills, Calif.; LOCKHEED ELECTRONICS, Los Angeles, Calif.; MEMORY TECHNOLOGY INC., Sudbury, Mass.; MEMORY SYSTEMS INC., Hawthorne, Calif.; NEMONIC DATA SYSTEMS, Inc., Denver, Colo.; QUADRI CORP., Phoenix, Ariz.; RCA MEMORY PRODUCTS DIV., Needham Heights, Mass.; VARIAN DATA MACHINES, Newport Beach, Calif.

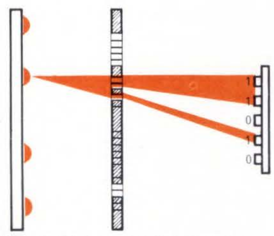
Other Types: OPTICAL MEMORY SYSTEMS, Santa Ana, Calif.; SIGNETICS MEMORY SYSTEMS, Sunnyvale, Calif.

OPTICAL READ-ONLY MEMORIES

Fig. 1—**Diagrams** illustrate operational theory for an optical ROM. (*Optical Memory Systems*)

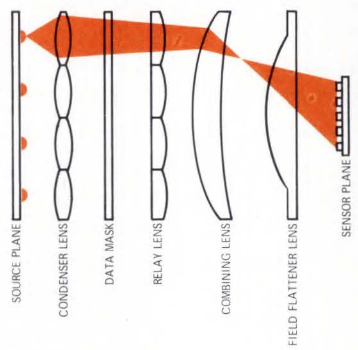


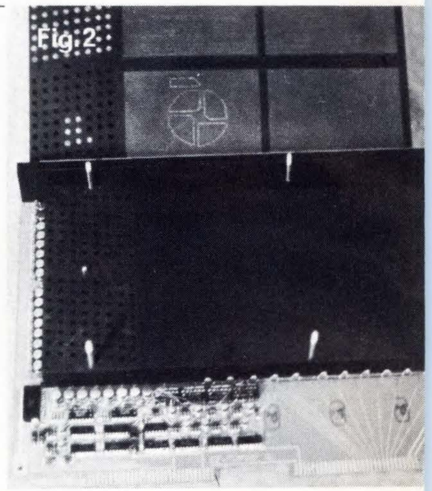
(a) BASIC SOURCE AND SENSOR PLANES Note each LED produces a solid seam of light that floods the sensor array. In operation, only a single LED is enabled at any one time.



(b) SOURCE AND SENSOR PLANES WITH MASK Data mask either passes or blocks light to sensors to define a memory word. (11010). Optical system directs light from the same bit order in every mask word to a single sensor. For example, LSB of all words is always sensed by the same diode in the sensing array.

(c) LENS CONFIGURATION Visualize the entire memory as a group of miniature slide projectures (one for each LED) with a common screen (sensor plane). Data Mask contains unique slide (one/zero data pattern) for each projection system.





Many potential advantages of optical technique have spurred the quest for a practical approach to an optical ROM. Photographic materials with high resolution promise extremely dense data packing. Lasers and holographs offer densities in the millions of bits per square inch. Absence of capacitive and inductive storage elements can mean extremely high speeds. Recently, Optical Memory Systems and QUADRI Corp. introduced optical ROMs, each using a different approach.

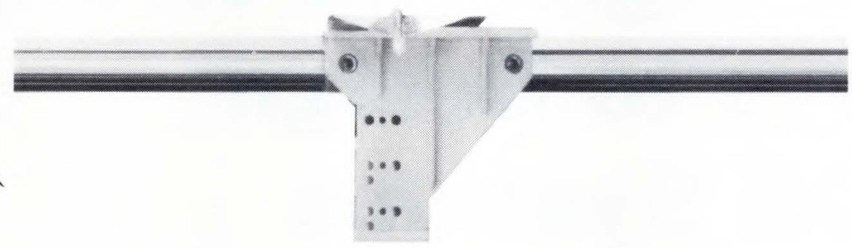
Optical Memory Systems ROM, the OM-1000, uses lenses and has a total capacity of 147,456 bits within 0.28 cubic feet. The ROM has <70-nsec fully decoded access time, and is field alterable—remove a photographic plate containing data and replace it with another.

A simplified diagram of the cross section of the memory is shown in **Fig. 1.** Light-emitting diodes (LEDs) are electrically arranged in a 32×32 matrix for a 1024-bit array. Light sources are selectively energized, transmitting light through the photographic mask and providing a bit pattern sensed by reverse biased PIN diodes.

To operate, the light sources are individually addressed and each energized diode projects up to 144 bits of data onto the sensor array. Wideband amplifiers process the signals from the photodiodes and generate TTL levels at the output. Each time a light source is activated, an instruction word, 4 to 144 bits, is generated.

Quadri Corp. replaces the lens system with a fiber optic system in their Model 401-22 optical ROM. Storage capacity is 50k bits per each 11- by 13-inch printed circuit board (Fig. 2). This system is TTL-compatible, features a lift-off top for mask replacement with visual self-check capability and is expanded through wired-OR techniques. The use of fiber optics eliminates mechanical alignment problems and optical crosstalk. Word-drive transistors select one unique LED which illuminates through fiber optics a specific line of holes via the "radiation distribution plate" to the photo mask. The mask either blocks or permits the light to pass (according to predetermined program) and the light is directed by fiber optics to light-detecting diodes. Signals are amplified and transmitted to the output terminals.

A very uncomplicated new OEM recorder with just one thing going for it...

()

You'll like what you see in our new approach to dedicated OEM strip chart recorders. First, we eliminated all those complicated moving parts from the writing mechanisms. No more pulleys, cables and slip clutches. Instead, there's just one simple moving part—the slider/pen assembly. That's because a linear servo motor keeps the pen going magnetically . . . and very reliably.

When you see the HP Model 7123, you'll notice how the low power servo system makes the recorder smooth, precise and trouble-free. You could drive it off scale around the clock without noise or danger.

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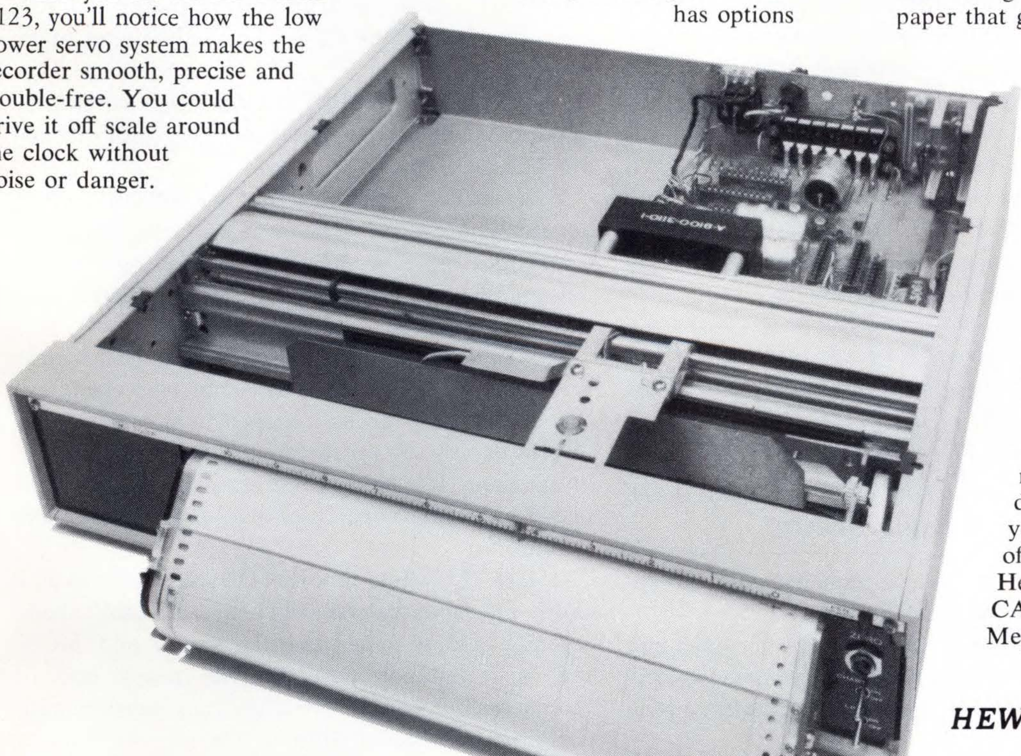

HEWLETT hp PACKARD

GRAPHIC RECORDERS

CIRCLE NO. 14

Evelyn Berezin Of Redactron Compares The Right and Wrong Ways to Design MOS Systems

The introduction of large-scale integrated circuits has made radical changes in the way engineers think about the design of new systems. The major new factor of course is MOS technology, which lends itself to building large arrays of specialized logic circuits very inexpensively. Of particular interest to the designer today are read-only memories and random-access memories, but these do the same thing as their predecessors, although better and perhaps less expensively. Many engineers have ignored MOS LSI technology on the ground that it is geared only to very high volumes. But in the case of some, the real reason they don't use it is a feeling that this takes a lot of specialized and still very new knowledge. It does take a lot of rearranged thinking by logic designers (and their managers); they do have to change their approach to engineering design in order to use MOS chips successfully.

An MOS chip designed as most of them now are could cost as much as \$75,000 more than an equivalent IC printed-circuit board. However an MOS chip need not cost anywhere near this if its design is approached properly.

It might be worthwhile to consider what the approach to custom MOS has been:

1. After the idea for a system is discussed and there is some agreement on function, somebody sits down and writes functional specifications describing what the system must do.

2. The generalized design is laid out, and sets of equations are set up to represent the various algorithms.

3. Final representations are made in some form to represent the individual circuits used to implement the system.

4. An IC system is constructed and tested to be sure that it's all correct. (This has taken anywhere between 4 months and a year, depending on the size of the system.)

5. Now management has something on which to base a decision (on the basis of the total amount of equipment needed and marketing's projected volume) on whether the thing is a candidate for MOS design.

6. If it is ripe for MOS, the engineers are turned loose to decide how to partition the system into individual MOS chips.

Many of the companies that manufacture MOS devices have design staffs to help in this operation. Companies often turn over a logic design to the manufacturer whose engineers first partition it, and then design the pieces as MOS chips.

This process however is often a disaster, because well-designed logic cannot be cut up very easily except in the way it was designed to be cut up. The interfaces are set up to provide logical points for attachment. It would be an accident if they happened to be proper partitioning points for an MOS design.

In fact, the whole process of design for MOS is, I think, much misunderstood. I hear people talk about taking a piece of some particular system and "MOSing" it. It reminds me of the way people used to "transistorize" equipment when they were redoing designs from tube circuits, or the way we used to take transistor circuit drawings and turn them into ICs. This kind of thing was possible, without too much impact on the logic, by taking each particular element, or small group of elements, and converting

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them to the new technology. With a little patching, the basic logic structure of a machine was retained. Of course, the cost of the various elements changed, and the cost relationship of different elements changed, but the structure of a system didn't.

It's a whole new ballgame with MOS design and it has to be considered as such. All the rules and concepts behind the usual ideas of minimization become rather meaningless in view of the problems of designing in this new technology.

7. Let's go back and determine what is usually done now. The problem is to partition a logic structure into some form translatable to an MOS design. This means that each partitioned group of circuits that is to be represented by one MOS chip has got to fit on that MOS chip. In particular, it cannot have more than, say, 40 pin connections. What is worse, each pin connector eats up vast areas of usable logic space and thus costs much more than a great deal of the logic circuitry. It turns out that the number of pin connections available is usually the limiting factor in determining the system structure, and also the cost of the system.

The number of pins actually seems to be the limiting problem throughout the history of all the logic design I've seen. Even in the days when we used to try to fit five or six tubes on a board so they were easily packageable, we were limited by the number of pins we could get on that board. Later on, when we started to use integrated circuits, the same thing happened. Decreasing connector size made more pins available, but the number never matched the amount of logic which could be put on a particular printed circuit board, or MOS chip, or whatever. So

this problem has always been with us. It differs now in degree, however, because the cost of additional logic is (a) almost zero if the logic goes on an existing chip, and (b) something if one needs an extra pin, and (c) a great deal if one runs out of pins. The proper partitioning therefore becomes essential in the design.

Let's suppose that we put ourselves in the hands of an MOS manufacturer. This manufacturer somehow partitions the system and then redoes the design to conform to his particular fabrication technique. The MOS manufacturer's engineers must first reconfigure the logic in a schematic design analogous to the way in which the pattern will be set down on the MOS chip. This schematic design is not very different from the kind of thing that was done in the tube logic of the early 1950s. Since one was designing with more basic elements, it was possible to perform design tricks to limit the number of individual elements used. As the basic elements became more complex, this kind of freedom was no longer available to the designer.

It is, however, available all over again now, because the elements of an MOS chip are so basic that a great many more degrees of design freedom are possible than is available with ICs. The design problem is compounded, however, by the fact that the size of each of the elements on the MOS chip is related to the speed of operation of the element.

This is, in turn, related to the speed of operation of the system, and to defining the amount of logic which can be integrated on the chip. Thus some understanding of the speed of each particular part within the system must be taken into consideration in the logic design. Although designers must always understand their path speeds, the high speed of ICs means that only in particular areas (such as high-speed computers) is the problem serious. I would guess that most logic designs are not limited by the speed through each path. Because MOS circuits are still rather slow in their present stage of development, greater attention has to be paid to this problem throughout the design effort.

The trickiest and most difficult parts of the problem—the partitioning of a system into units amenable to MOS design, are often relegated to the MOS design houses that have little understanding of the system.

That's why there is often a great deal of rework needed in order to achieve a workable design. It is extremely difficult to transmit all the thinking behind the system design to another group that is not very close to the problem.

8. After the MOS partition is done, it should be implemented in ICs in order to debug the repartitioned logic thoroughly.

9. This requires another complete cycle of design and test, after which the MOS schematics can be drawn, and the chip designed. No wonder MOS costs so much!

10. Another problem has to be faced when the chips are ready to be tested. Test patterns are used by MOS testers to insure that the chip does the things it was supposed to do. Someone knowledgeable about the chip design must write the test patterns. This is a difficult part of the job. It is not uncommon to find at this point that there is no very good way of testing the chip even when you have it. In fact, it may be necessary to redesign the logic of the chip in order to allow it to be tested properly.

What it all comes down to is that the job has been done the wrong way 'round. The wrong things have been considered important and the wrong people have done them. In fact, the whole process of thinking should be changed and the design group should be re-educated if it is to take advantage of the technology now available to it. I have no doubt that this will happen, but it should be happening a lot faster than it is.

It's not surprising that with all the work and re-

work that this procedure makes necessary, the cost of designing an MOS system can be three times the cost of the same design using bipolar integrated circuits. If one then adds $20,000 to $25,000 for the design of the chips, it is not surprising that companies think very long and hard before going to MOS technology.

O.K., having talked a lot about how it shouldn't be done, let's see how it should be done.

1. After the system engineer has some idea of what the functions of the system are, he should first decide on the physical structure for the system. This structure should be the partitioning plan.

2. The use of a large blackboard is helpful. The chips can be marked on it, and the connections required for each chip can also be marked down. Every function should be defined for each signal going to and from each chip. This definition procedure willy-nilly defines the functions that each chip must perform. The outcome is essentially a set of specifications for each chip.

3. During this process a rough estimate is made of the number of equivalent ICs the chip will include.

4. From this and an estimate of the "regularity" of the logic internal to the chip, and the required circuit operating frequency, the number of elements can be estimated that can be incorporated in a chip of produceable size. (It's a good rule of thumb to leave 20% extra space at this stage.)

The sensible approach is to make the chip as big as you think you can get away with. MOS manufacturers often show graphs of lowest cost per element in terms of chip area. I think it is wisest to plan for at least 30% larger area than that at the lowest point, because that minimum is moving to larger areas all the time. (How much larger you're willing to go defines your guts/intelligence/gall/stupidity.)

5. In the process of defining the functions to be carried out within each chip, the design of the test patterns should also be considered. It almost makes sense to start by designing the test patterns, and by this means define the function, at least roughly. All the details of the test pattern need not be done at this time, but sufficient thinking about it has to be done to insure that testing is feasible, sensible and uses equipment available both to the user as well as the manufacturer.

6. In the course of this design, a number of different ideas on partition and system structure can be tried out to determine the optimum approach. After the general structure has been determined and each signal between chips defined, the designer can start on the logic of each chip. He should have some understanding of the predesigned cells used in computer-aided design of the MOS chip. These differ from the basic logic elements which are available in ICs, but they will be closer to the final MOS design.

7. The designer should make sure that the delays through the system are not excessive.

8. A check must be made to insure that the circuitry will fit on a chip.

9. Now at last, the system can be built and checked out. This requires a translation from the MOS design into ICs, which requires a conversion from "MOS logic" into "IC logic". This conversion however isn't difficult to do. There is, of course, absolutely no reason to try to minimize the logic for the IC design; in fact, it's probably not a good idea, since one wishes to check the logic as it will be in its final MOS implementation. It's a good idea to build each equivalent MOS chip as an IC board, with the pin connector of that board imitating the MOS chip. (A fast way to check out the MOS logic is by replacing each IC board with its equivalent MOS chip when it finally comes in.)

10. After the IC logic has been checked out, the MOS logic is converted to detailed MOS schematics. This can be done by computer-aided design techniques, if the chip is small enough to be handled by such design; if not, it must be done by hand, and will take about 2 weeks for, say, a 60 IC chip.

11. Once the schematic is done, the implementation of the chip itself is turned over to the manufacturer for conversion to the mask stage. This might be called "Tooling". It is possible to have this done by design houses so that one is not tied to a particular manufacturer. Care has to be taken to insure conformity with the standard techniques of a number of manufacturers, so as to allow for multiple sourcing.

Using this technique, what does it cost to design an MOS chip equivalent to, say, 60 ICs? The extra cost of design might be about $20,000, even if one presumes a moderate number of mistakes are made. The average cost of the chip design is about $20,000, even without computer-aided design techniques. The design cost is thus at most $40,000 per chip more than it would be in conventional IC logic.

Now we can examine the payoff of using MOS design against using ICs. First, the 60 IC board probably would be closer to 45 ICs if the design were not MOS-oriented, —the designers have been throwing in extra circuits to cut down the number of connectors. But even with the present low cost of integrated circuits, you still might have a printed-circuit board and the power to drive the circuits. The cost of a 45 IC array on a single printed-circuit board, including the cost of insertion, soldering, testing, and the associated power, would probably end up at about $65 if the company were buying and building in comparatively small quantities. It could be closer to $20 if the company bought, built, and tested the IC boards in very large quantities. The equivalent MOS chip would cost about $20 in small quantities (say 1000 units), but goes down to the range of about $10 in quantities of 10,000.

Thus, a small company building comparatively small numbers of systems would save $45 per chip and would break even at about 1000 units; for a large company, the break-even point is about 4000 units. This doesn't take into account the company's desired return on investment, but the numbers are certainly way below the 20,000 to 40,000 units which are now bandied about. It isn't hard to see that by using computer-aided design techniques throughout, instead of laborious hand work, the cost of the design could become less than half of the $40,000 estimated here. It can be expected that the

cost of the MOS chips themselves will go down in price just as it has for ICs. One begins to see that the break-even point will get to be a rather low number very quickly.

There is another point which should be made:

Once you decide to implement in MOS, you have a completely revised attitude towards the capabilities or functions which should be included in the system, in that comparatively complex functions can be included for very little added cost.

Also, one has to have a rational attitude towards potential design changes. Indeed, it is a good idea to try to define the places where changes are to be expected and to provide a system which can tolerate them.

It is plain that the art and method which have heretofore constituted the designer's bag of tricks require radical restructuring in order to be ready for the MOS technology now available. New structures and new architectures are necessary. Although it's hard to make the transition of thinking in terms of the cost of pin connections rather than logic functions, new kinds of algebra are needed to help deal with these facts of life. Until the time such mathematical conveniences are common-place, the systems engineer must start at the end and work backwards, with less orientation toward mathematical solutions and much more orientation toward the engineering realities. As the cost of tooling for electronics decreases, one can expect a radical re-ordering and re-education of the whole concept of logic design for digital systems. ▭

Who is Evelyn Berezin?

Evelyn Berezin is credited with many firsts in equipment design including the first commercial high-speed communications terminal in the country (put into operation in 1961 by the Social Security Administration and still being used) and the first nation-wide on-line airline computer reservations system (designed in 1957 for United Airlines and still in operation). She also designed computer on-line systems for three major banks, the American Stock Exchange and Roosevelt Raceway.

Before founding Redactron Corp., Hauppauge, N.Y., in 1969, Mrs. Berezin was director of product planning, with long-range responsibility for marketing and product planning at Digitronics Corp. Earlier in her career she was head of logic design for the Teleregister Company and for Underwood Corp.'s computer division.

At Redactron, her favorite project has been the development of an editing typewriter, one version of which includes 20 MOS integrated circuits, 13 of these are custom chips.

Mrs. Berezin was a serious dance student for many years, majoring in Haitian and East Indian dance, and ballet. But her interests turned to other directions when she enrolled at NYU and decided to study physics. She had completed most of the requirements for a Ph.D. in physics, when she changed directions again, leaving school to embark on a career in computer design.

Mrs. Berezin, 46, has been married for 19 years to Dr. Israel Wilenitz, a British born chemical engineer. She lives in New York's Greenwich Village.

FOR A FREE REPRINT OF THIS ARTICLE, **CIRCLE NO. L62**

National presents the Tri-State-of-the-art.

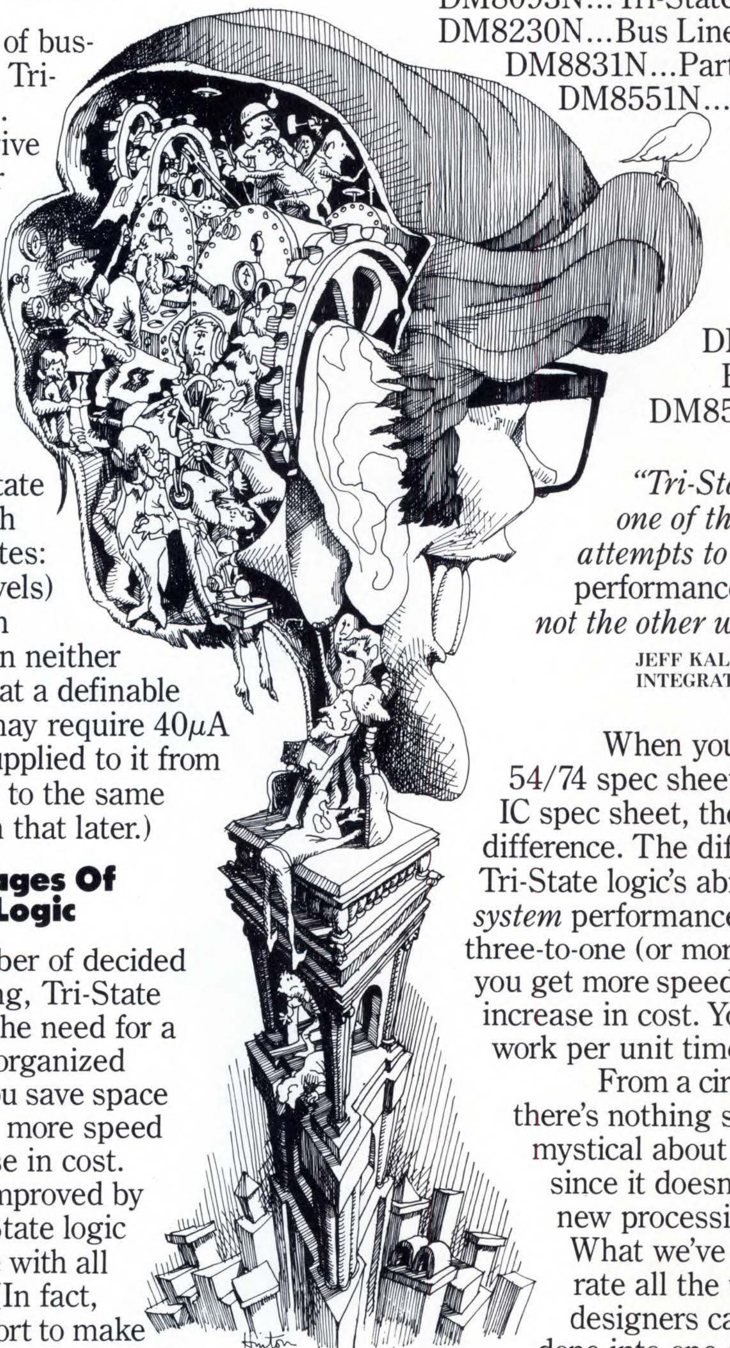
(A timely, information-filled discussion of the National Tri-State logic scene featuring systems design input by Jeff Kalb and systems applications data by Dale Mrazek with introductory notes by Floyd Kvamme.)*

*Tri-State is a Trademark of National Semiconductor Corporation

"The first DTL devices were designed with passive pull-up. Then, to improve speed, you went to an active pull-up which caused havoc with the bus OR'able system. So, the next step in evolution was to use an uncommitted collector output.

Tri-State logic, then, is the next step beyond that". FLOYD KVAMME, DIRECTOR OF MARKETING

To the designers of bus-organized data systems, Tri-State logic is good news. Tri-State logic devices give you all the speed, power and noise immunity of TTL plus the ability to interconnect outputs of similar devices to a common bus line.



Three States, Explained

Basically, a Tri-State IC is a logic element with three distinct output states: "0", "1" (normal TTL levels) and OFF which is a high impedance state that can neither sink nor source current at a definable logic level. (At most, it may require 40μA leakage current to be supplied to it from other devices connected to the same output line. But more on that later.)

The Advantages Of Tri-State Logic

There are a number of decided advantages. For one thing, Tri-State logic totally eliminates the need for a pullup resistor in a bus-organized system. Which means you save space and money. You also get more speed with no effective increase in cost. Noise susceptibility is improved by a factor of 10. And Tri-State logic is completely compatible with all existing 54/74 devices. (In fact, we've made a special effort to make conversion to Tri-State logic extremely easy.)

Tri-State Logic Is, At This Very Moment, Being Second-Sourced

Happily, other companies have jumped onto the Tri-State logic bandwagon. Which is good news for you. And good news for us, since it's always nice to be followed.

Speaking of second-sourcing, it would be well to list *our* devices so you can see what all the others are copying.

Right now, we have eight Tri-State logic devices. All available off-the-shelf. They are as follows:

DM8093N...Tri-State Quad Buffer
DM8230N...Bus Line Demultiplexer
DM8831N...Party Line Driver
DM8551N...Quad-D Flip Flop
DM8094N...Tri-State Quad Buffer
DM8214N...Dual 4-Line-to-1-Line Multiplexer
DM8598N...256-Bit Expandable ROM
DM8599N...64-Bit RAM

"Tri-State logic is really one of the very first attempts to relate systems performance *to circuit design, not the other way around".* JEFF KALB, DIRECTOR OF DIGITAL INTEGRATED CIRCUITS

When you compare a 54/74 spec sheet to a Tri-State IC spec sheet, there's really little difference. The difference lies in Tri-State logic's ability to improve *system* performance by a ratio of three-to-one (or more). In the end, you get more speed with no effective increase in cost. You also get more work per unit time.

From a circuit standpoint, there's nothing spectacular or mystical about Tri-State logic since it doesn't require any new processing techniques. What we've done is incorporate all the things that designers can do and have done into one overall *systems oriented* concept. A refinement of existing techniques specifically aimed at solving the problems of bus-organized data systems.

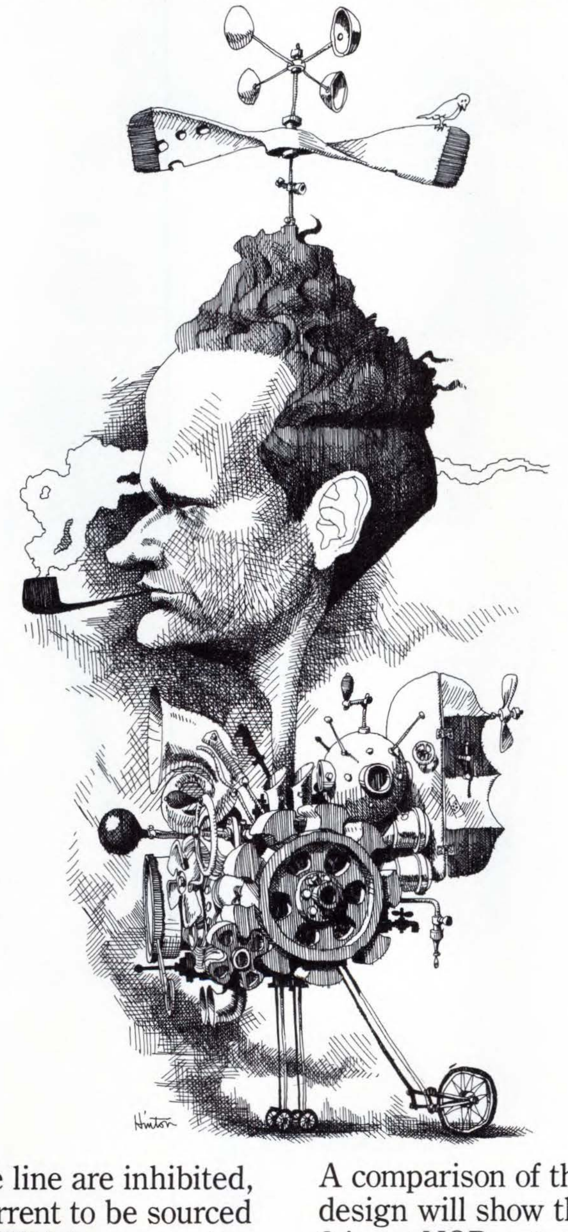
How It's Done

Actually, the concept of creating a

Tri-State TTL device is relatively simple. We've just provided a means of removing the drive current from the totem-pole output of the TTL device. The output then resembles two semiconductor junctions biased in the non-conducting or high impedance state. The only load they offer to the common bus line is the junction leakage which must be provided by the output of the device that's driving the bus line.

In addition, the inputs of many Tri-State circuits also disable and, in doing so, load the driver with only leakage current. In effect, this makes both output bussing and fan-out into other inputs virtually unlimited.

Thus, all Tri-State logic elements have been designed with a Darlington-connected power stage to provide a source current of at least 5.2mA in the logic "1" state (13 times the TTL norm of $400\mu A$!). The lower output transistor sinks the 16mA normally required for a fan-out of 10 in the "0" state.



Some Interesting Calculations

A source current of 5.2mA in the enabled "1" state means that at least 128 Tri-State outputs can be bus-connected. If one output drives while 127 other outputs on the same line are inhibited, the maximum leakage current to be sourced is $127 \times 40\mu A - 5.08mA$. Which means at least three TTL loads can be driven with the minimum of $120\mu A$ remaining.

Another Tri-State logic benefit is that lines longer than 10 feet can be driven reliably, while standard TTL can drive only 10 to 12 *inches* of line before noise immunity becomes a problem. The higher power of the Tri-State IC output also improves "1" level noise immunity by a factor of 10.

Finally, one of the unique things about the Tri-State logic gating system is that it runs *in parallel* with the existing logic functions. It doesn't slow down the logic function itself while it's operating, it just provides a means of turning it off—in parallel. So, you're not adding any time to the system, you're really adding a control.

"One of the functions of Tri-State logic (as we were designing it) was to make any previously-designed MSI elements bus-structurable."..

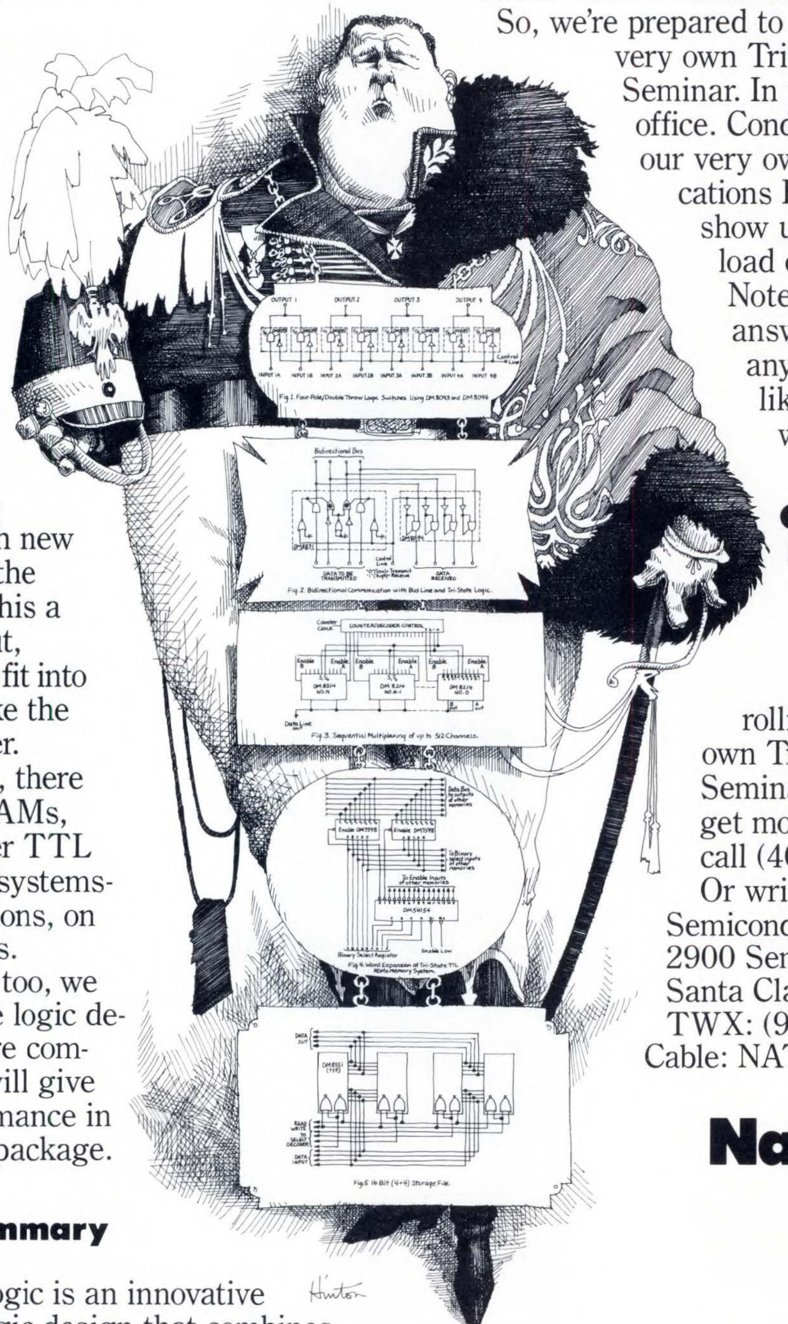
DALE MRAZEK, DIGITAL APPLICATIONS MANAGER

Reduced to its most basic and flexible form, a Tri-State IC output is a special kind of gate. And so, the most universal Tri-State devices we've designed to date are the DM8093 and DM8094 Quad Buffers. With these buffers, any other TTL-compatible device or MSI module can be given Tri-State input or output characteristics. Using Tri-State Buffers, many logic circuits can be saved. For example, in Fig. 1, they operate in pairs on a single control line to perform the two-wide multiplex function so commonly needed in logic design. A comparison of this design with a standard design will show that an inverter and four 2-input NOR gates are saved in just this one subassembly. And, the subassembly can be expanded modularly.

More Nice Things You Can Do With Tri-State Logic

There are, obviously, many different

bus-structured systems applications using Tri-State devices. Some are relatively simple, others very complex. On this page we've diagrammed some typical applications. Each contains a Tri-State device or a series of Tri-State devices. All improve overall system performance substantially in addition to reducing the physical number of elements required.



Future Tri-State

Our eight Tri-State devices are just the beginning of a logic family which will continue to expand at a rapid rate.

And as we expand our line of devices, we are looking at each new function *not* from the standpoint of "Is this a nice function?"; but, rather, how does it fit into the system to make the system work better.

As a result, there are a variety of RAMs, ROMs, Low Power TTL devices and more systems-related MSI functions, on our drawingboards.

Very soon, too, we will offer Tri-State logic devices which feature common I/O, which will give even more performance in an already small package.

A Summary

Tri-State logic is an innovative new concept in logic design that combines the speed, power and noise immunity of TTL with the wire-OR'able flexibility required for real-life bus systems.

But even more importantly, Tri-State logic is a *systems-oriented* concept that not only simplifies the design and construction of bus-organized systems, but improves overall system performance by a factor of three-to-one.

How To Get Your Very Own Tri-State Logic Seminar

Obviously, there's a lot more to talk about when it comes to Tri-State logic. So, we're prepared to offer you your very own Tri-State Logic Seminar. In your very own office. Conducted by one of our very own Field Applications Engineers who'll show up with an armload of Applications Notes and a headful of answers to just about any question you're likely to come up with.

Our Operators Are Standing By For Your Calls

To get the ball rolling on your very own Tri-State Logic Seminar, or simply get more information, call (408) 732-5000. Or write National Semiconductor Corporation, 2900 Semiconductor Drive, Santa Clara, Calif. 95051. TWX: (910) 339-9240. Cable: NATSEMICON.

National

CIRCLE NO. 15

DESIGNING LINEAR SWEEP GENERATORS

New approach offers improved linearity

by Ronald C. Scheerer

Most methods of sweep generation employ the almost linear portion of an exponential characteristic, generated by applying a dc voltage to an RC circuit. By careful design it's possible to obtain quite good linearity with these techniques. But because the ramp waveform is based upon an exponential relationship, it will never be truly linear.

Before going on to investigate an alternative circuit let's look briefly at the advantages and disadvantages of some widely-used sweep-generator circuits.

Simple RC circuit

Probably the simplest and least expensive approach is the circuit shown in Fig. 1. This consists of a resistor, a capacitor, a voltage source and an electronic switch.

Initially the switch is closed and the output voltage E_o equals zero. When the switch is opened (by an external control signal) the capacitor begins to charge exponentially toward the supply voltage V. At the end of the desired sweep period Δt, the switch is closed and output E_o returns to zero. This opening-closing action of the electronic switch is maintained at the desired repetition rate, yielding a continuous sweep signal at the output. The period of the sweep Δt and the repetition rate can be altered by making the appropriate change in the control signal to the electronic switch. Of course, a negative sweep signal can be obtained simply by using a negative voltage source.

To obtain a relatively linear sweep with this network, one must use a high voltage source V, and must ensure that the sweep period is only a small percentage of the time constant $T = RC$. In this way the sweep will be obtained from the so-called "linear" portion of the exponential curve. This circuit is short-circuit proof, exhibits low switching transients on the output and can easily be modified to give a different sweep period Δt. But it has several disadvantages:

- External loading on the output exaggerates nonlinearity in the sweep signal—therefore a buffer stage is required.

Author: Ronald C. Scheerer is an engineer at Westinghouse's Defense and Space Center at Baltimore, Md.

- Buffer stage nonlinearities degrade the overall linearity of the circuit.
- The offset voltage of the electronic switch appears at the output.
- Though the circuit operates in the so-called "linear" regions, the sweep is still dependent on an exponential relationship.
- Repetition rate of the sweep is limited by the discharge characteristic of the capacitor.

Miller integrator

In Fig. 2 we see how the simple RC circuit can be improved by adding a high-gain dc amplifier. For this Miller-type sweep generator the capacitor is connected in the amplifier's feedback path.

Initially the switch is closed and output voltage E_0 equals zero. When the switch opens, capacitor C begins to charge exponentially toward a voltage E_F, which is the value of the voltage source V multiplied by amplifier gain $-K$. If the switch never closed, the capacitor would continue to charge toward $E_F = -KV$ until the dc amplifier reached its saturation level. By proper choice of the values for R and C, however, the desired sweep period Δt occurs before the amplifier reaches saturation. At the end of the sweep, the electronic switch closes and the output voltage returns to zero.

The basis for operation of this circuit is essentially the same as for the previous circuit in that the sweep signal is obtained from the so-called "linear" portion of an exponential curve. Note, however, that—unlike the simple RC circuit—the Miller circuit gives quite good linearity without the use of a high-voltage source.

Sweep period Δt can be modified either by changing the values of R and/or C, or by changing the control signal to the electronic switch to allow for a longer or shorter charging time before "end of sweep" occurs. As with the simple RC circuit, opposite polarity sweeps can be obtained simply by reversing the polarity of the source voltage.

The Miller circuit offers quite linear sweeps with relatively short recovery times. And because the dc amplifier has a low output impedance, external loading doesn't cause too much degradation of sweep linearity. But this circuit also has several disadvantages:

- Though the circuit operates in the so-called "linear" region, output waveform still depends on an exponential relationship.
- The need for a floating electronic switch causes design difficulties.
- The circuit is not short-circuit proof, unless this particular characteristic is designed into the dc amplifer.
- Offset voltages of both the switch and the amplifier affect the output.
- Switching transients are likely to appear on the output due to the relatively high input impedance of the amplifier.

Bootstrap sweep generator

Yet another popular approach to sweep generation is shown in Fig. 3. This "Bootstrap" circuit needs a few more components than the circuits previously described.

The circuit works as follows. Initially the switch is closed and output voltage E_0 equals zero. In this state, voltage E is determined by the ratio of the resistive divider R_1 and R_2.

$$E = V\ [R_2/(R_1 + R_2)] \qquad (1)$$

This voltage constitutes the initial potential across C_2.

Now, when the switch is opened C_1 begins to charge toward voltage V. As the voltage across C_1 increases, the amplifier's output voltage E_0 increases by the same amount, and, if C_2 is very large, voltage E increases by the same amount. This means that the voltage across resistor R_2 will theoretically remain constant. Capacitor C_1 is charged by an essentially constant current, producing a linear sweep. At the end of sweep the electronic switch is closed and the output voltage E_0 returns to zero.

But linear sweeps can occur only in an ideal situation. Capacitor C_2 is not infinite and the potential across it does not remain constant. Discharge is exponential, with a time constant,

$$T = C_2\ [(R_1\ R_2)/(R_1 + R_2)] \qquad (2)$$

Thus the generated sweep is based on an exponential function.

With careful design the circuit can yield fairly linear sweeps, provided the time constant of Eq. 2 is much larger than the desired sweep period Δt. Switching transients at the output are usually small enough to be neglected. With this type of sweep generator, ampifier performance isn't too demanding and practical designs will usually prove adequate. If the amplifier has fairly low output impedance, external loading causes little degradation of sweep linearity. Either positive or negative sweeps can be obtained by

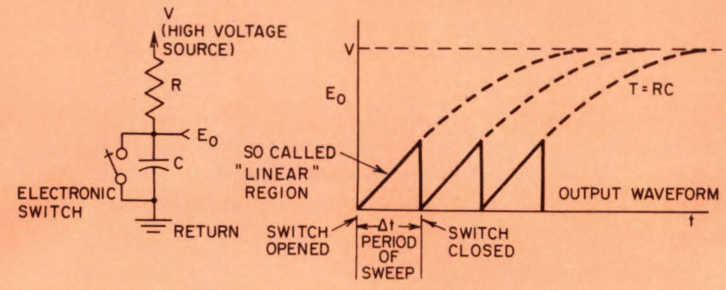


Fig. 1. Simple RC sweep generator gives poor linearity unless high voltage is used for reference source V.

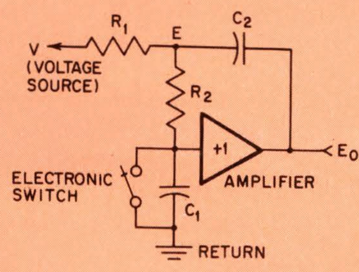


Fig. 3. Bootstrap circuit can generate quite linear sweeps but has other disadvantages.

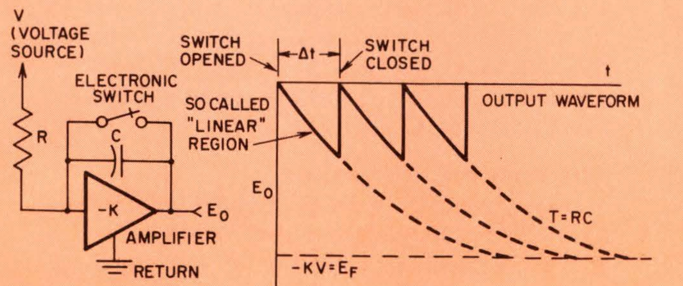
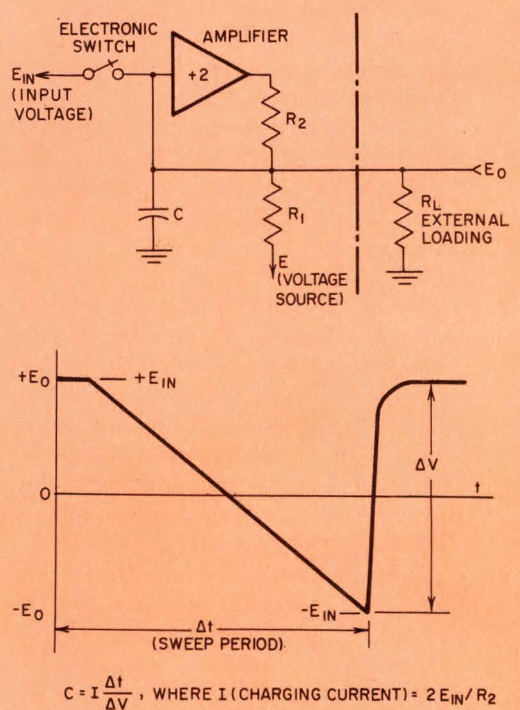


Fig. 2. Miller sweep generator gives better linearity than a simple RC circuit, and doesn't need a high voltage source.



$C = I \frac{\Delta t}{\Delta V}$, WHERE I (CHARGING CURRENT) = $2E_{IN}/R_2$

Fig. 4. New sweep generator circuit and its output waveform. With this circuit, capacitor charging current is constant.

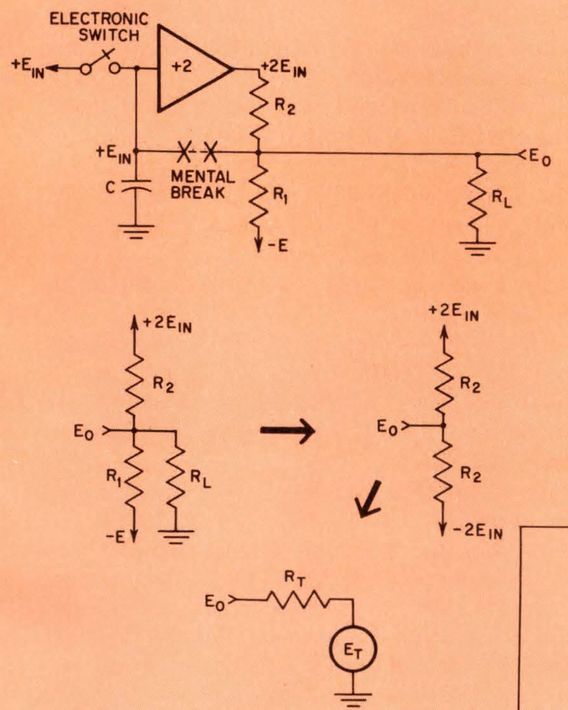


Fig. 5. New circuit partitioned to show how Thevenin equivalent circuits are derived.

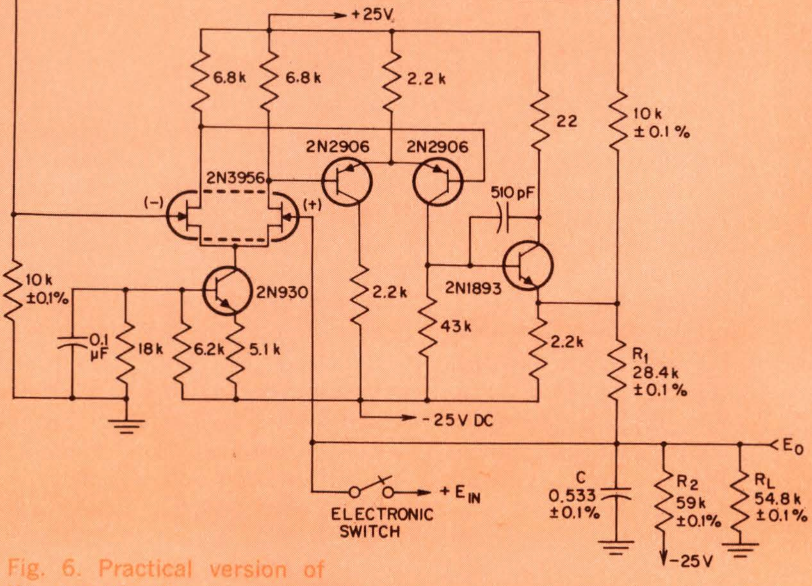


Fig. 6. Practical version of the new circuit.

selecting a suitable polarity for voltage-source V. But the circuit has these disadvantages:

- Though relatively linear sweeps can be generated, there is still an exponential relationship.
- Recovery time tends to be long.
- External shorts will damage the circuit unless short protection is designed into the amplifier.
- Offset voltages of both the amplifier and the switch appear at the output.

New technique

An unusual new sweep-generator circuit suffers from none of the disadvantages seen in the other circuits. The circuit, shown in Fig. 4, can generate truly linear sweeps, and need be no more complex than, say, a Miller or "Bootstrap" circuit. Though the circuit needs a capacitor, the output waveform is independent of an exponential relationship.

Circuit performance depends on the ratios of sets of resistors. For linear sweeps, the following equations must be satisfied.

$$[R_L R_1/(R_L + R_1)] = R_2 \qquad (3)$$

and,

$$E\ [R_L/(R_L + R_1)] = -2E_{in} \qquad (4)$$

Later we will see how the foregoing relationships are derived. To understand clearly how the circuit works and why it generates linear sweeps, we will examine circuit operation at three specific times during the sweep period Δt. During the analysis, we will assume that input voltage E_{in} is positive and that voltage source E is negative. We will assume, also, that the relationships of Eq's 3 and 4 are true.

Initially, with the electronic switch closed, voltage E_{in} appears across capacitor C, and the output of the amplifier is $2E_{in}$. When the switch is opened, C starts to charge towards the negative E. To see what happens now, let's mentally break the circuit as indicated in Fig. 5. With this break between the capacitor and resistors R_1, R_2 and R_L, we can substitute a Thevenin equivalent network for the combination of the three resistors and voltage source $-E$. If the conditions of Eq's 3 and 4 have been met, then we can prove that the equivalent Thevenin resistance $R_T = R_2/2$ and the equivalent voltage $E_T = 0$. Since the capacitor voltage is initially $+E_{in}$, the differential voltage between output and input is $(E_{in} - 0) = E_{in}$, while the charging current for the capacitor is $2E_{in}/R_2$.

Now let's examine the situation when the voltage across the capacitor is zero. The output of the amplifier will be zero also. Again, mentally breaking the connection between the capacitor C and the resistors R_1, R_2, and R_L, we can substitute a Thevenin equivalent network for the three resistors and the voltage source $-E$. For this particular case we can show the equivalent Thevenin resistance is again $R_T = R_2/2$, while the equivalent Thevenin voltage is $E_T = -2E_{in}$. Once again the differential voltage equals $[0 - (-E_{in})] = E_{in}$ volts and the capacitor charging current will be $2E_{in}/R_2$.

Finally let's look at the third case where the voltage across the capacitor is equal to $-E_{in}$ volts. With a gain of 2 through the amplifier, its output voltage is will be $-2E_{in}$ volts. Mentally breaking the connection between the capacitor and the resistors, we can substitute another Thevenin equivalent network. We find that the equivalent Thevenin resistance is again $R_T = R_2/2$ and the equivalent Thevenin voltage is $E_T = -2E_{in}$. Once again the differential voltage equals $[-E_{in} - (-2E_{in})] = E_{in}$ volts and the charging current for the capacitor C will be $2E_{in}/R_2$.

No matter what the capacitor voltage is, the effective differential voltage will always be E_{in} and the equivalent resistance will always be $R_2/2$. Since the charging current is constant, the output sweep will be linear. To end the sweep, the electronic switch is closed and the output E_o returns to E_{in} volts.

Advantages and disadvantages

In our example (with E_{in} positive and E negative) the circuit yielded a negative-going sweep. If we reversed the polarities of E_{in} and E we would get a positive-going sweep. The circuit has several significant advantages:

- Output sweep is definitely linear because it doesn't depend on the exponential charging of a capacitor.
- Offset voltage at the output is a function only of the switch offset voltage.
- Switching transients at the output are low.
- The circuit is short-circuit proof.
- Recovery is fast.
- The amplifier doesn't present severe design problems and ICs can be used if desired.
- A buffer stage isn't needed at the output because load resistor R_L is incorporated in the design equations.
- Period of the sweep Δt can easily be changed by using a different value capacitor.

Even with these overwhelming advantages, it is only fair to point out the possible disadvantages of the circuit:

- Both a positive and negative voltage source are needed.
- The amplifier must be able to handle twice the peak-to-peak swing of the output signal.

Figure 6 shows a practical version of the new circuit, which was designed to generate the horizontal and vertical sweep signals for a military radar system. Tests on prototype and production versions confirmed the predicted performance. Linearity was so good that deviations could not be measured. Performance was stable over the temperature range −55 to +100°C.

An interesting feature of the new circuit is that the sweep waveform source can be deliberately made concave upward or concave downward, merely by varying resistor values.

This feature is useful if the external circuitry being driven by the sweep circuit exhibits a nonlinearity. The sweep circuit can be adjusted, to a certain degree, to compensate for this nonlinearity and thus to linearize the overall performance. □

FOR A FREE REPRINT OF THIS ARTICLE, **CIRCLE NO L63**

Notch Filter Has Passive Q Control

Proper attention to selection of passive components is all that's needed to get a high performance notch filter.

HOWARD T. RUSSELL, Texas Instruments Incorporated

This active band reject or notch filter has a variable Q feature that is controlled by a single passive RC network. The circuit consists of a positive unity-gain amplifier, an RC twin-T network and an RC T network that determines the circuit Q. Through derivation of the transfer function, it is determined that once the notch frequency is fixed, the Q can be changed without any effect upon this frequency.

Observations made on three filters, each with a different value of Q, indicate that neither the notch frequency nor notch depth is affected by Q changes. By examining certain sensitivity functions, stability of the notch frequency and Q are found to be dependent on the passive elements in the T networks. By choosing proper elements, a low-sensitivity filter can be built.

The generalized circuit configuration, along with its transfer function, is given in **Fig. 1** and **Eq. 1**.

$$H(s) = \frac{e_0(s)}{e_i(s)} = \frac{-y_{12a}(s)}{y_{22b}(s) + y_{12b}(s) - y_{12a}(s)} \quad (1)$$

By replacing network a with an RC twin-T network, and network b with an RC T network (**Fig. 2**), the transfer junction becomes

$$H(s) = \frac{s^2 + (1/RC)^2}{s^2 + (4/R_1C)s + (1/RC)^2} \quad (2)$$

If each s-term coefficient in this equation is equated to the corresponding coefficient in the generalized equation for a notch filter, the expressions for the notch frequency and Q may be found. That is, given that

$$H(s) = \frac{s^2 + \omega_0^2}{s^2 + (\omega_0/Q)s + \omega_0^2} \quad (3)$$

for a notch filter, then

$$\omega_0 = \frac{1}{RC} \quad (4)$$

and

$$Q = \frac{R_1}{4R} \quad (5)$$

Based on these equations, observe that the notch frequency is controlled by the twin-T network (network a), while the Q is controlled by the single T network (network **b**), once ω_0 is fixed.

To test the theory, several filters were designed and tested. The unity gain amplifier was built from an SN72741 op amp in a noninverting 100% feedback mode. The twin-T network was built to produce a notch at approximately 4.22 kHz, and the single T network was left as the variable so that the Q could be changed. Data presented in **Table 1** indicate that these filters have respective Q values of 9.8, 18.4 and 25.

The results gathered from these test circuits indicate that the realization of a notch filter with a passive Q control is a valid one. Through the use of a single RC network, the circuit Q may be varied without producing any changes in notch frequency or notch depth. Even though a high quality operational amplifier was used in these test circuits, any other high impedance, unity gain amplifier may be used. Previous test circuits have been evaluated using only a single stage emitter-follower as the active device. However, the most important requirement is the need for high quality, low-tolerance passive elements to insure a stable, low-drift design. ▭

Circuit Sensitivity

Stability of ω_0 and Q of this filter may be determined by examining how sensitive these parameters are to changes in circuit elements. The percentage change of a parameter based on the change of an independent variable may be defined as

$$\frac{\Delta Q}{Q} = S_Z^Q \left[\frac{\Delta Z}{Z}\right]$$

where Q is the parameter being investigated, Z is the independent variable, and S_Z^Q is defined as the differential sensitivity of Q with respect to Z, i.e.,

$$S_Z^Q = \frac{\partial Q}{\partial Z}\left[\frac{Z}{Q}\right]$$

Since the Q of this filter is a function of R_1 and R, then the percentage change in Q may be written as

$$\frac{\Delta Q}{Q} = S_{R_1}^Q \left[\frac{\Delta R_1}{R_1}\right] + S_R^Q \left[\frac{\Delta R}{R}\right]$$

Once $S_{R_1}^Q$ and S_R^Q are found from **Eq. 5**, then the above equation is found to be

$$\frac{\Delta Q}{Q} = \left[\frac{\Delta R_1}{R_1} - \frac{\Delta R}{R}\right]$$

The notch frequency ω_0 is a function of R and C, the elements of the twin-T network. The percentage change in ω_0 is found to be

$$\frac{\Delta\omega_0}{\omega_0} = -\left[\frac{\Delta R}{R} + \frac{\Delta C}{C}\right]$$

From the above two equations for Q and ω_0 sensitivity, it can be seen that, by properly selecting the passive components to make the ΔR and ΔC fractions in the brackets cancel, both Q and notch frequency will remain stable.

(Continued)

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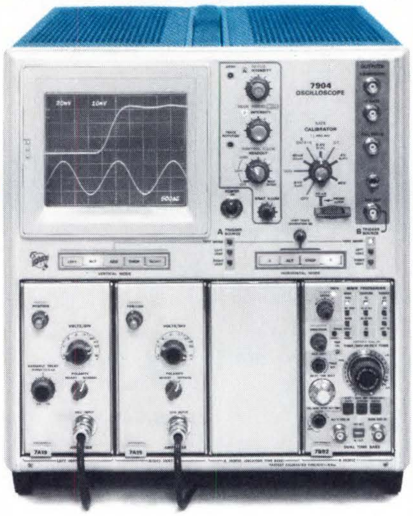

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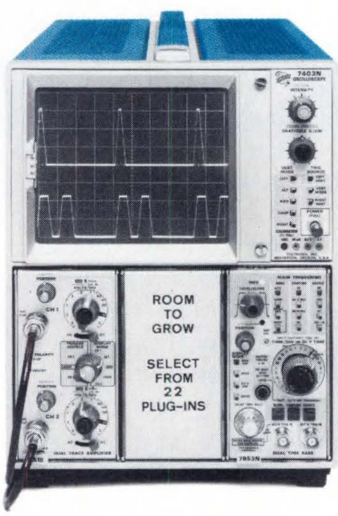

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CIRCLE NO. 16

Notch Filter (Cont'd)

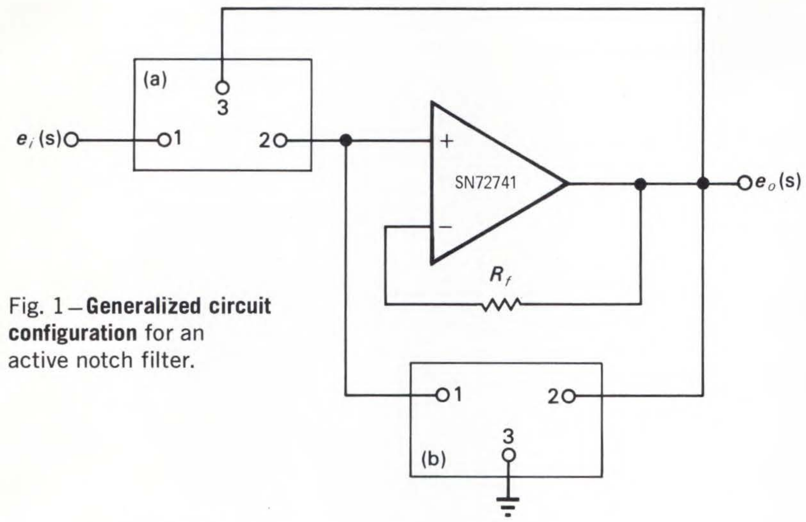


Fig. 1—**Generalized circuit configuration** for an active notch filter.

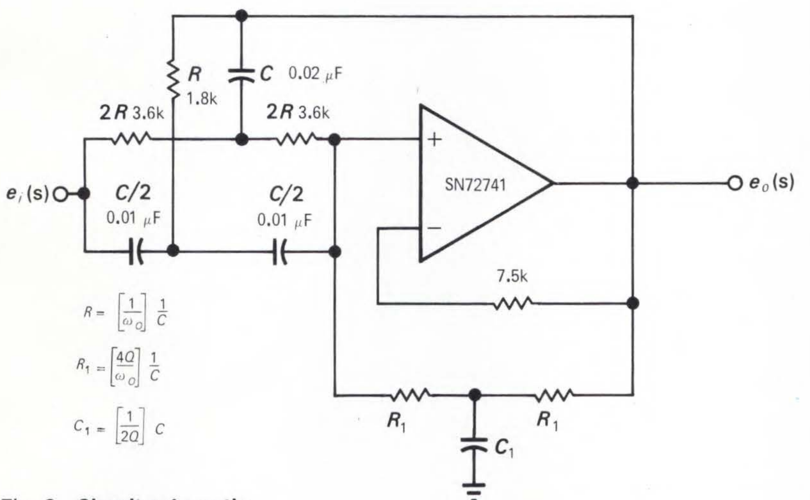
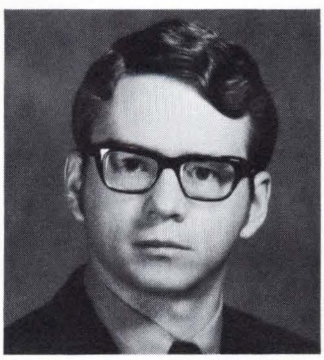


Fig. 2—**Circuit schematic** and component values for the notch filter.

R_1	C_1	Q	f_{notch}	NOTCH DEPTH
75 kΩ	0.001 μF	9.8	4.22 kHz	62 dB
150 kΩ	660 pF	18.4	4.22 kHz	62.7 dB
220 kΩ	360 pF	25.0	4.22 kHz	62 dB

Table 1—**Measured values of notch frequency** and notch depth with changes in circuit Q.



Howard T. Russell (M.S.E.E.), formerly an applications engineer at Texas Instruments Incorporated, Dallas, Texas, where his duties included the design of audio and low frequency circuits, is now employed at Eagle Signal Co., Davenport, Iowa.

FOR A FREE REPRINT OF THIS ARTICLE, **CIRCLE NO. L64**

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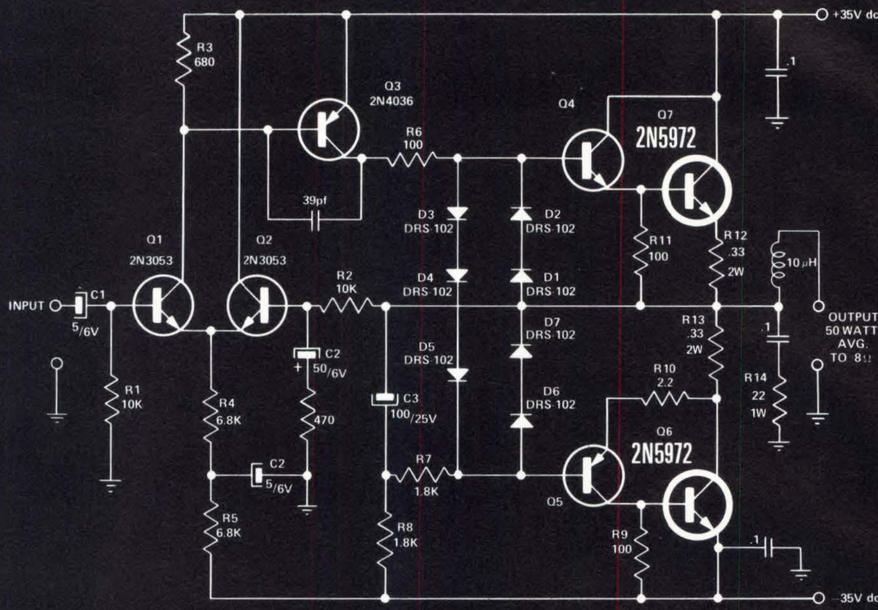

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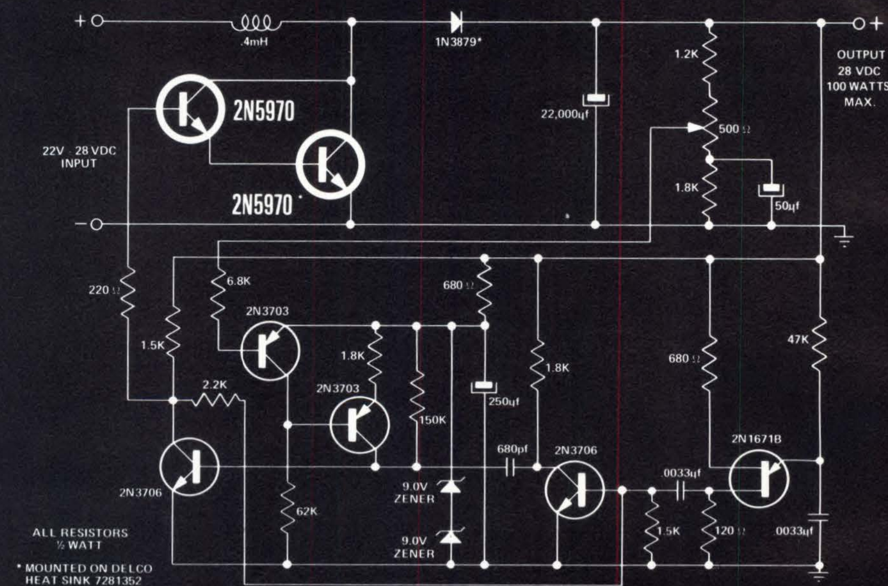

TYPE	I_C Cont. Amps.	I_C Pulsed Amps.	V_{CEO} Volts	V_{CEX} Volts	V_{CEO}(sus) Volts	h_{FE}(min.) @ I_C=5A	h_{FE}(min.) @ I_C=15A	V_{CE}(sat.) Volts @ I_C=10A, I_B=1A
2N5970	15	20	60	80	60	20	10	2.0
2N5971	15	20	60	80	60	50	20	1.5
2N5972	15	20	80	100	70	25	10	1.8
2N5973	15	20	100	120	80	25	10	1.8
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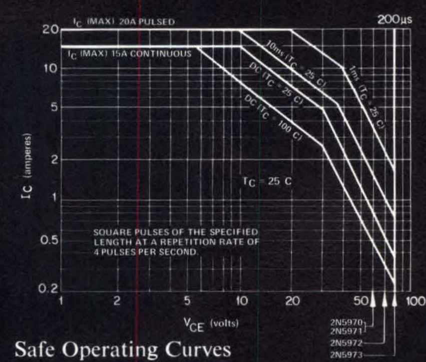

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Application Notes 42 and 43 provide the data on the circuits.

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GILBERT BANK, Westinghouse

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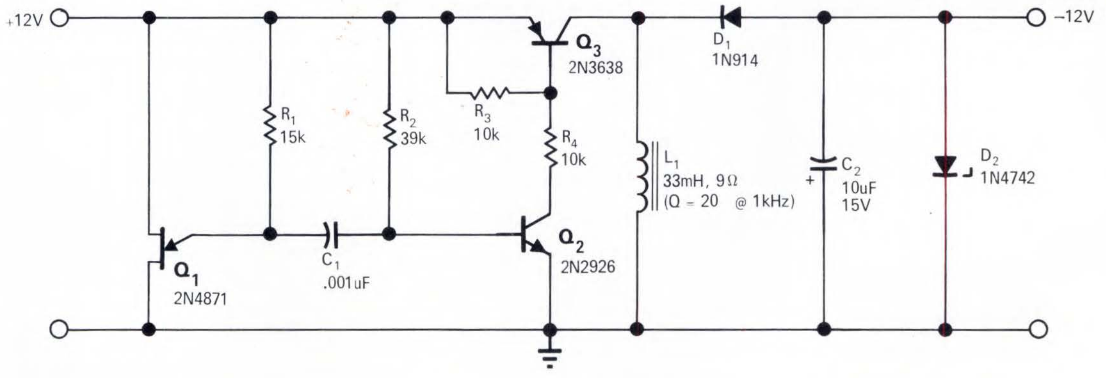
For this application the multivibrator frequency must be high enough to permit adequate current storage in the inductor, but low enough to avoid loss of efficiency by the switching components. In practice there is a fairly wide frequency range that permits moderate efficiency. R_1, R_2 and C_1 are the frequency-determining elements.

Operating Q_3 at 50% duty cycle gives an output voltage equal to that of the input. Increasing the duty cycle raises the output voltage, while decreasing it lowers the output. R_1 and R_2 determine the duty cycle, which for equal input and output voltages must be greater than 50% to permit the zener regulator to function.

With the component values shown, more than 40 mA of output is available and efficiency at full load exceeds 55%. Power losses appear to be fairly evenly-shared by the multivibrator, the switching transistor, the inductor and the zener diode. ▭

When this article was written, **Gilbert Bank** worked as a designer of circuitry and systems at the Westinghouse Ocean Research Laboratory. Mr. Bank holds a B.S.E.E. from Cooper Union and an M.S.E.E. from San Diego State College. He is now working toward an advanced degree in applied ocean sciences at the Univ. of California at San Diego.



DC-DC converter. Multivibrator frequency is 25 kHz and duty cycle is 60%.

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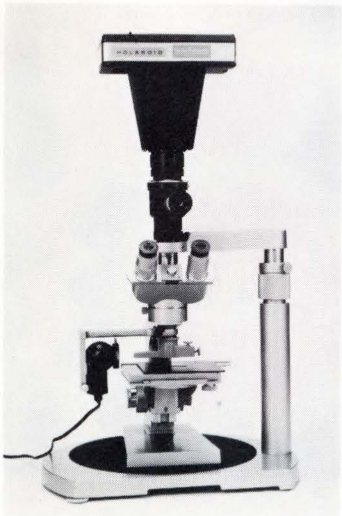

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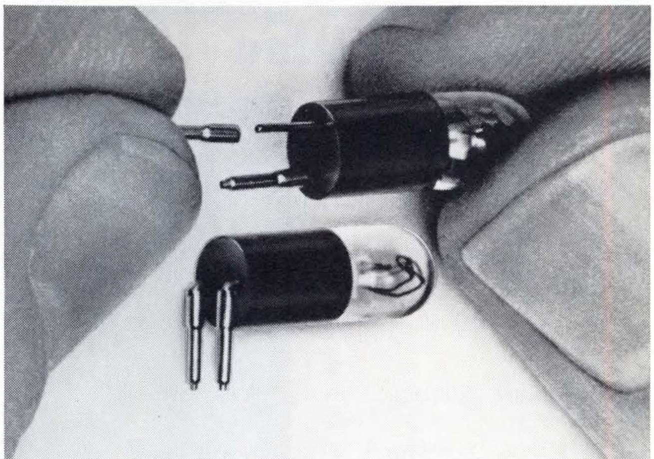

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CIRCLE NO. 22

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Gated clock generates pulse train or single pulse

To Vote For This Circuit Circle 151

by J. V. Sastry
Westinghouse Electric
Pittsburgh, Pa.

The circuit shown in **Fig. 1** either gates a train of full clock pulses through or it generates a single output pulse, as required.

When the control line is held at logic 0, the circuit transmits a train of complete clock pulses, beginning with the first clock pulse that starts to rise after application of the gate signal and ending with the last clock pulse that starts to rise before the gate signal falls.

In other words, regardless of the relative timing of the gate signal, full clock pulses are always gated through.

When the control line is held at logic 1, the circuit transmits one complete clock pulse after the gate signal rises. Continuance of the gate signal thereafter is immaterial. To send another signal pulse, the gate signal must be removed and reapplied. (A logic-1 gate signal is assumed.)

In **Fig. 2**, timing diagrams show the outputs for various combinations of clock and gate signals.

The circuit uses a total of seven gates and can be constructed with only two ICs. A working model has been built using a Fairchild LPDTμL 9047 (triple 3-input NAND) and a 9046 (quad 2-input NAND). Other compatible DTL or TTL NAND gates can be used.

For the circuit mode in which the control line is held at logic 0, gate G_5 provides an additional output line (with a train of full clock pulses). ■

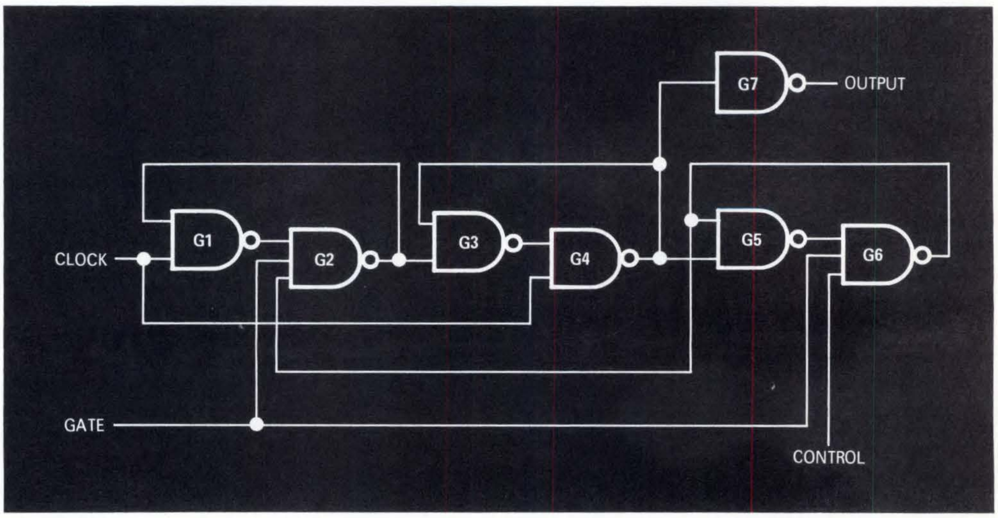


Fig. 1 – With logic 0 on the control line, this gate circuit transmits a train of clock pulses; with logic 1 it transmits a single pulse.

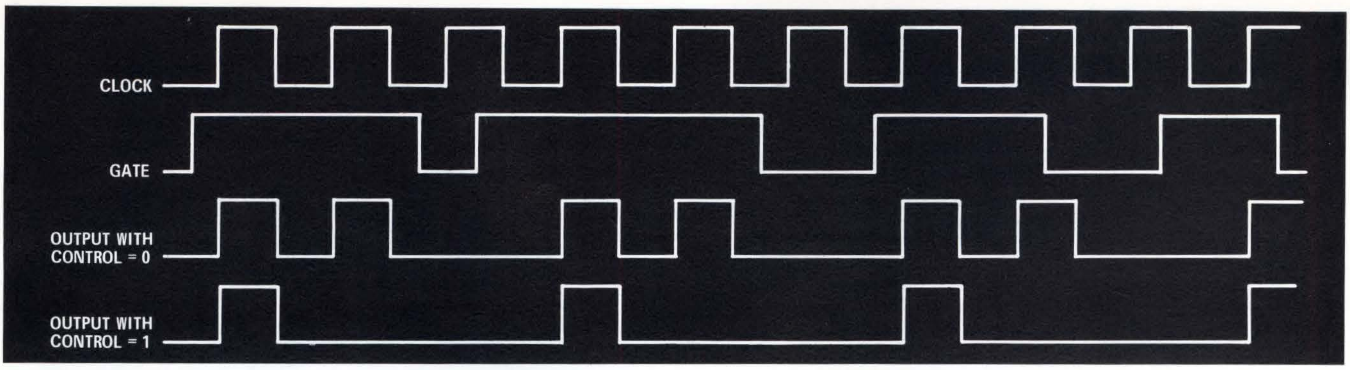


Fig. 2—As can be seen in this timing diagram, full clock pulses are transmitted; if the gate signal falls to logic 0 during a clock pulse, the remainder of the pulse is still transmitted.

Current-Pulse Generator for LED's

To Vote For This Circuit Circle 152

by James Dimitrios
Zenith Radio
Chicago, Ill.

It is often necessary to pulse a light-emitting diode (LED) with high peak currents of substantial pulse width with low time-averaged current drain. For example, the resolving power of some low-light-level (LLL) systems improves when the scene is illuminated with high peak radiation (as contrasted with constant illumination having the same time-averaged radiated power). Also, for portability, many LLL systems require battery operation of LED circuitry. In addition, pulsed operation of LEDs is useful in applications where timing of the radiated light pulse in relationship to a cyclic mechanical motion is under study.

The circuit shown in **Fig. 1** can generate peak currents in excess of 1A with pulse widths greater than 10 msec at repetition rates of 12 kHz with greater then 90% efficiency (100-mA dc current drain from 2.5V dc). Rise time of the pulses is 0.2 msec.

Circuit action can be described as follows: Assume Q_1 is saturated by a current through R_B. The battery voltage is then impressed across the primary inductance, L, with a consequent linear increase in Q_1's collector current, I_c. The Q_1 base current, I_{b1}, rides on a dc level, V/R_B, and is a rectangular pulse of current. Collector current I_c increases until it reaches $\beta_1 (2V/R_B)$, where β_1 is the beta of Q_1. At this time, Q_1's collector voltage starts to increase from its saturated value. The base-emitter junction of Q_1 becomes back-biased due to the phase reversal of the transformer, and the transistor goes into the cut-off mode. Pulse repetition period is determined by L, R_B and β_1.

Since the transformer has stored energy, $1/2LI_c$, and Q_1 is switched open at time T, a large voltage spike develops across the transformer windings. The current through R_b turns on the transistor, initiating the next cycle. The large voltage pulse is stepped down to drive the base-emitter junction of Q_1. A large current is needed to saturate Q_2 which has the LED in its emitter circuit. (The LED has a dynamic impedance of roughly an ohm.)

Pulse width and rise time are determined by base current drive and the saturation and switching characteristics of the transistor selected for Q_2. The peak current is of course determined primarily by the battery voltage and dynamic impedance of the LED. Larger battery voltages will require greater base drive to Q_2 to obtain saturation. This, in turn, will necessitate greater stored energy in the transformer, with larger Q_1 base drive and, therefore, a larger I_c, before Q_1 switches to the cut-off state. Fortunately, all this is provided automatically by the increase in battery voltage.

As an alternative, the transformer feedback winding can be deleted, and the base of Q_1 returned to a trigger source which provides the saturation of Q_1 needed to initiate the cycle. Then the pulse rate of the current pulse becomes variable—a desirable feature for testing LLL systems. ■

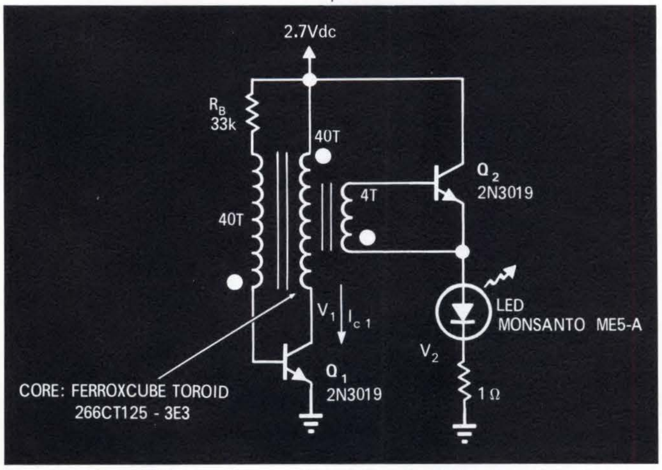


Fig. 1—The LED in the emitter circuit of Q_2 is subjected to a train of rectangular current pulses instead of a continuous dc voltage. Pulsed light is useful in low-light-level TV systems or for strobing cyclical mechanical equipment.

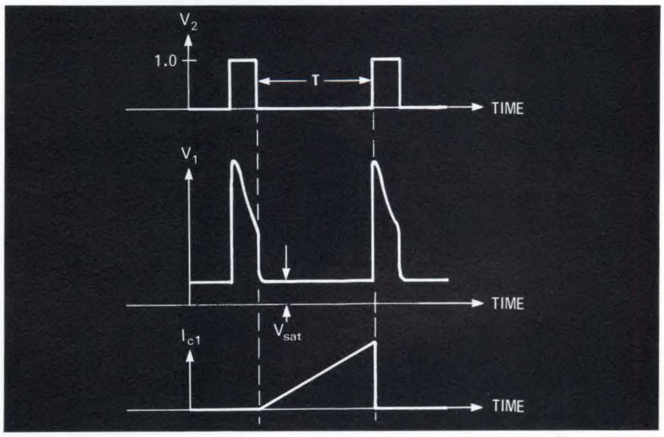


Fig. 2—Typical waveforms at various points in the pulse-generator circuit. The top waveform shows the rectangular current pulses through the LED, while the bottom waveform shows the ramp of current through the transformer primary which determines pulse-repetition frequency.

Monolithic-Triad Current Summer

To Vote For This Circuit Circle 153

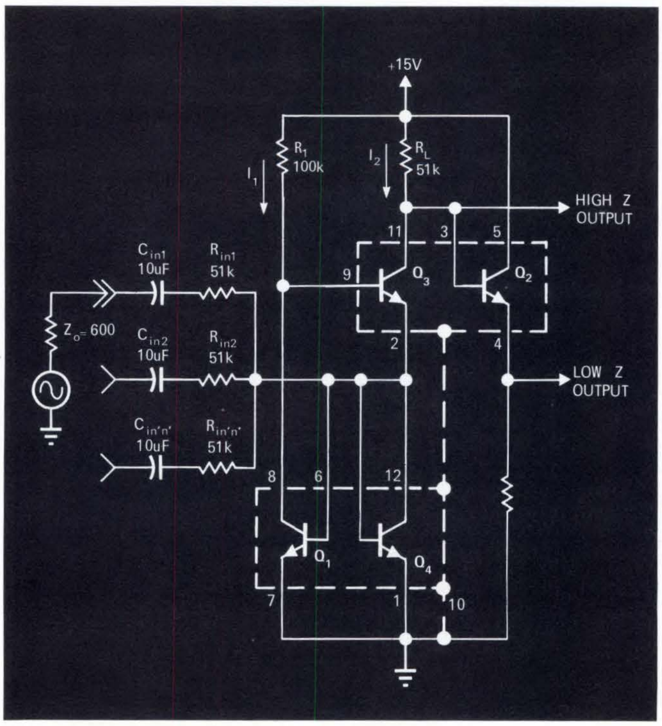
by Walter C. Jung
Forest Hill, Maryland

A simple and economical, yet high performance summing amplifier can be made with a matched-transistor current-regulator triad. If a number of audio signals are summed at the current junction of the triad, excellent isolation between the various inputs results because of the circuit's low dynamic impedance.

In the figure, an RCA CA3018 monolithic four-transistor array is used as a current-mirror triad with a low-impedance buffered output. Resistor R_l sets the reference current I_l to 140 μA. Resistor R_L is half R_l's value, to bias Q_3 between supply and ground.

The feedback loop around Q_1 and Q_3 maintains a three-ohm impedance at Q_3's emitter in spite of the relatively low d-c current of 140 μA. The emitter of Q_3 serves as a virtual ground for scaling resistors R_{inl} through $R_{in''n''}$. With R_{in} equal to R_L, this results in unity voltage gain and excellent isolation. Isolation from one 600Ω source to an adjacent one is roughly 123 dB. Voltage gain or greater than one can easily be obtained by lowering R_{in}. This modification develops the same modulation current in Q_3 for a smaller input voltage, thereby producing gain.

The circuit is quite distortion free, with measured harmonic distortion less than 0.1 percent, even at voltage gains up to 50 and with an output swing of 10v pk-pk. Input resistance equals R_{in}. The high output impedance of 51 kΩ can be buffered by the fourth transistor of the array (Q_2). This transistor acts as an emitter follower. ■



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CIRCLE NO. 23

More Competitors for "Wire-Wrap"

PROGRESS IN PACKAGING

Three radically different PC processes are vying with each other to put a crimp in Gardner-Denver's "Wire-Wrap" business. Photocircuits, a long-time PC manufacturer, has developed its "Multiwire" process, and Infobond, a newcomer to PC manufacturing, has come up with still another system. In addition, two California firms, Microtechnology and Accra-Point Arrays Corp. (APAC), are using a stitch-wiring process. ("Stitch Wire" is APAC's trade name.) The new systems use from one to six numerically-controlled wiring heads to feed insulated wire to a similar number of boards.

None of the new systems requires the preliminary artwork needed for a "Wire-Wrapped" PC, and three of the four systems don't require costly DIP sockets. APAC's process requires an inexpensive DIP socket called a "DIP-CLIP". All the new systems claim higher wiring density, quicker turnaround time and lower cost per connection than is possible in the "Wire-Wrap" process.

In the "Multiwire", Infobond or "Stitch-Wired" processes, the only information needed to start a job is a "from/to" wiring list and a drawing showing placement of DIP ICs. This information is digitized and converted to a punched-tape format. This tape, in turn, programs a single-head (APAC), 2-head (Microtechnology), 4-head ("Multiwire") or 6-head (Infobond) wiring machine. From then on the systems become dissimilar, with the "Multiwire" method producing a grid of insulated wires on one side of an adhesive-coated card, the Infobond method soldering a network of insulated wires to pads on a universal PC card and the APAC and Microtechnology methods cold-welding a network of insulated wires to a matrix of pins on a glass-epoxy card.

Photocircuits' "Multiwire"

In the "Multiwire" process, four glass-epoxy boards are coated on one side with an adhesive layer about 5 mils thick. The opposite sides of the boards usually have standard PC plating for power lines, DIP or component leads, grounds and connector fingers.

First step in this process is to "write" a grid of 7-mil polyimide-insulated wire over the adhesive-coated sides. Four special wiring heads (each having an ultrasonic pressure foot, cutter and wire feeder) sequentially feed the wire, press the wire into the adhesive, heat the adhesive to ensure its stickiness and cut the wire if necessary.

When wiring is completed, each individual board is heat-treated to insure that the entire wire matrix is embedded in the adhesive. Holes are then drilled through the printed side of the board and plated with copper to complete the interconnection. Photocircuits also makes units with embedded wire grids on both sides of a board.

Infobond's Boards

Infobond's process has a special universal PC board as a starting point. One side of the PC has a series of pretinned pads to accept 14-pin DIP ICs whose leads must be preformed to an L-shape (with the L ends pointing away from the DIP). The other side has more pretinned pads which are used for automatic wiring. The DIP pads and wiring pads are connected by plated-through holes whose sole purpose is to act as interconnects. Six of these cards, with the wiring side up, are slipped onto the wiring-machine table and fixed in a jig.

Polyurethane-insulated copper wire (38 AWG) is fed through compression-bonding tips on each of six stationary heads. The table, under numerical control, moves the

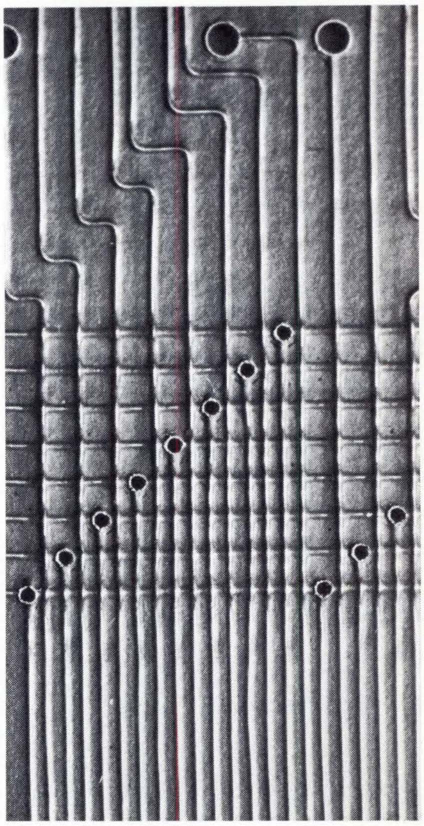


Fig. 1—Wired side of a Photocircuits "Multiwire" board, showing the grid-like structure embedded in adhesive. This particular board is equivalent to a 3-layer PC.

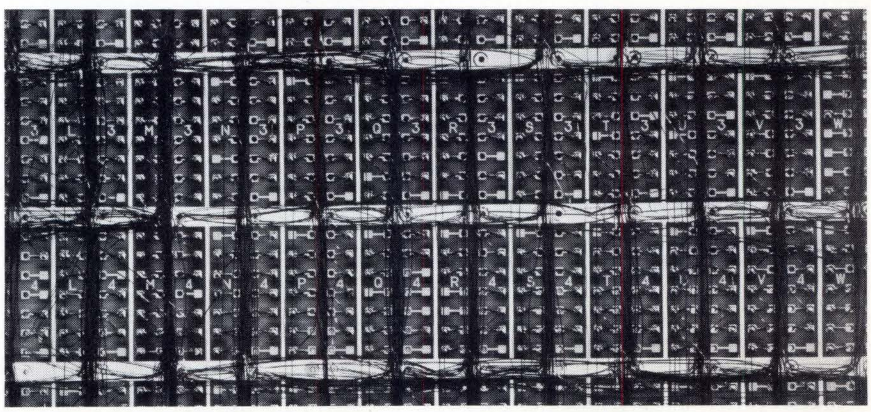


Fig. 2—The back of a board wired by the Infobond process. All wires are connected to pretinned pads in this socketless construction.

heads into contact with the bonding pads on the boards. Then all six wires are soldered—simultaneously—through the insulation. A blast of air cools the bonds quickly. Automatically, all connections are tested for mechanical strength and electrical continuity. If everything checks, the table moves to the next wiring position. After all wiring is finished, all bonds are checked for shorts and opens. DIP ICs are then flow-soldered to the opposite side. Each completed board's logic functions are checked by a minicomputer-controlled automatic tester before shipping.

Welding the Wires

In the "Stitch-Wire" process, a matrix of gold-plated steel pins are staked into a glass-epoxy board. The pins are 0.050 inches in diam and are from 0.200 to 0.450 inches long. Each pin has a 0.020-inch head that rests against the wire side of the board and serves as a welding terminal. The remainder of the pin serves as a DIP or component terminal on the other side of the card. This basic card is used in either Microtechnology's dual-head or APAC's single-head numerically controlled systems.

A programmed head feeds "Teflon"-insulated nickel wire (AWG 30) to the matrix of pins. The welding head then cold-flows through the "Teflon" coating and resistance welds the wire to a terminal. The head then proceeds to wire and weld according to its taped program.

Even though Microtechnology and APAC do wire stitching identically, they differ in their DIP-mounting methods. Microtechnology uses the dead-bug approach where a DIP is mounted with its leads up and is soldered to the matrix of pins. APAC also mounts DIPs in the dead-bug position but eliminates soldering with a special socket called a "DIP-CLIP". This unit is simply a 0.085-inch-thick piece of nylon with two rows of holes with DIP spacing. The inverted IC is first inserted into the "DIP-CLIP" and the combination is forced down over the appropriate pins. These sockets cost $0.17 in large quantities.

Making Repairs

Infobond claims a DIP IC can be changed in "only about a minute". However, this repair needs a special $425 tool kit. The same kit (cutter, wire feeder and special iron) can also be used to make wiring changes or repairs on the wired side of an Infobond board. The wired side of a "Stitch-Wired" board can be repaired easily with an ordinary soldering iron. APAC's "DIP-CLIP" socket makes it simple to change a DIP on its board, but Microtechnology's soldered dead-bug ICs or Photocircuits' conventionally—soldered ICs won't be quite as easy to remove. However, soldered or welded pin connections are inherently more reliable than any socket-pin connection, expecially if shock and vibrations are a problem.

All of the processes have one thing in common with "Wire-Wrap". Two and one-half to three 14-pin DIPs can be packaged per square inch no matter whose process is used. Where the new processes shine is in volumetric efficiency. APAC, for instance, says that it can package five DIPs per cubic inch to "Wire-Wrap's" two and one-half DIPs per cubic inch. Also, because of the use of insulated wire in all the new processes, wiring densities equal to those of multilayer boards are possible.

Infobond furnishes a fully-tested circuit, Microtechnology and APAC furnish untested boards with all components already mounted and Photocircuits supplies a wired, componentless board. Photocircuits, APAC and Microtechnology deliver their boards within 2 to 3 weeks while Infobond delivers in 5 to 6 days.

Photocircuits prices its process at about $0.10 per wired connection. Microtechnology's cost is about $0.075 per connection and APAC charges about $0.07 per connection. Infobond says merely that its process is competitive with the cost of automated "Wire-Wrap".

Photocircuits Corp., 31 Sea Cliff Ave., Glen Cove, NY 11542. **194**

Infobond Corp., 21 North Ave., Burlington, MA 01803. **195**

Microtechnology, Div. of Sterling Scientific Industries, 5388 Sterling Center Dr., Westlake Village, CA 91360. **196**

Accra-Point Arrays Corp., 2005 S. Ritchey St., Santa Ana, CA 92705. **197**

Gardner-Denver Co., Gardner Expressway, Quincy, IL 62301. **198**

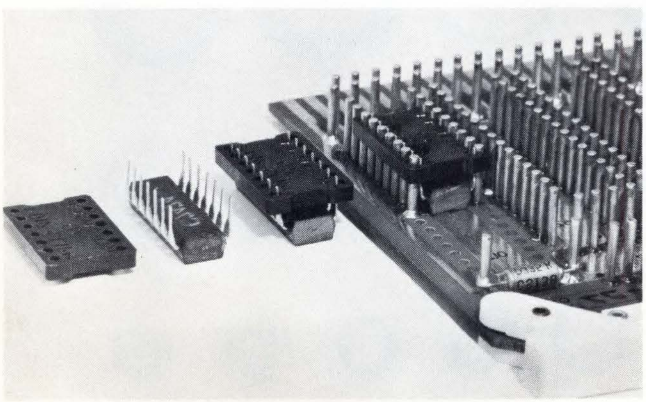


Fig. 3—"DIP-CLIPs" mount 14-pin DIPs to the pin matrix of an APAC "Stitch-Wired" board.

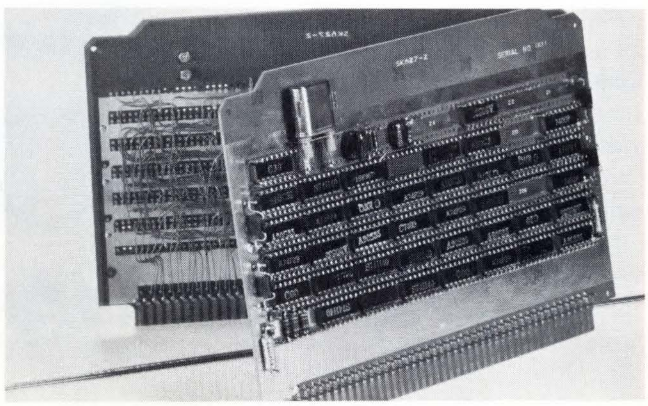


Fig. 4—Front and back views of a Microtechnology "Stitch-Wired" board. Note the dead-bug method of mounting DIP ICs.

Flexible Film Extends Pot Life

PROGRESS IN PRECISION POTENTIOMETERS

Infinite-resolution precision potentiometers of the nonwirewound variety usually take the form of bulk-type conductive plastic elements, flat-track units, or the new flexible resistive film patented by New England Instruments. Recent comparative tests run at NEI show that flexible film has significant advantages with regard to output smoothness and operational life (when operated in a dither mode).

Dither is a controlled amplitude and frequency force applied to a servomotor driven device so that it is constantly in small amplitude motion, thus preventing sticking at its null position. Output smoothness includes the effects of contact resistance variations, resolution, and other micrononlinearities in the output. Short-term linearity error is the limiting factor for achieving overall linearities below 0.01% in single turn potentiometers of 1-inch diam or less.

Manufacturers of nonwirewound precision pots will often machine trim a portion of the resistive track to make the electrical output more closely approach desired output characteristics. However, because the short-term linearity errors are confined to angles of less than 1°, it is impossible to trim each peak without adversely affecting the overall linearity. It is possible to minimize the short-term linearity errors by laser trimming when automatic trimming devices are employed.

Fig. 1 shows a typical bulk plastic pot used in the test. It was trimmed to produce an overall linearity of less than ±0.05%. **Fig. 2** shows some flat-track units both linear and nonlinear. Flat track units should satisfy most applications short of the most stringent requirements where life in excess of 100 million dithers is required. Illustrated in **Fig. 3** are a few of the forms and shapes that can be created using NEI "Resistofilm." Its advantages over other types of material used for infinite resolution pots include excellent linearity as manufactured (0.25%), output smoothness, and its ability to resist the effects of wiper dither. Shown in the table are results of these tests performed on 1.5/16-inch pots of comparable resistance values.

NEI has taken a material approach to prolong life of infinite resolution precision pots and with apparent success. An alternate mechanical design approach was described in **EDN May 1, 1971**, "Potentiometer Has No Brushes or Wipers." The specific goal in this design was also to improve dither life and it, too, appeared to be successful although life testing was not as extensive as that done by New England Instruments. New England Instrument Co., 14 Kendall Lane, Natick, MA 01760. **199**

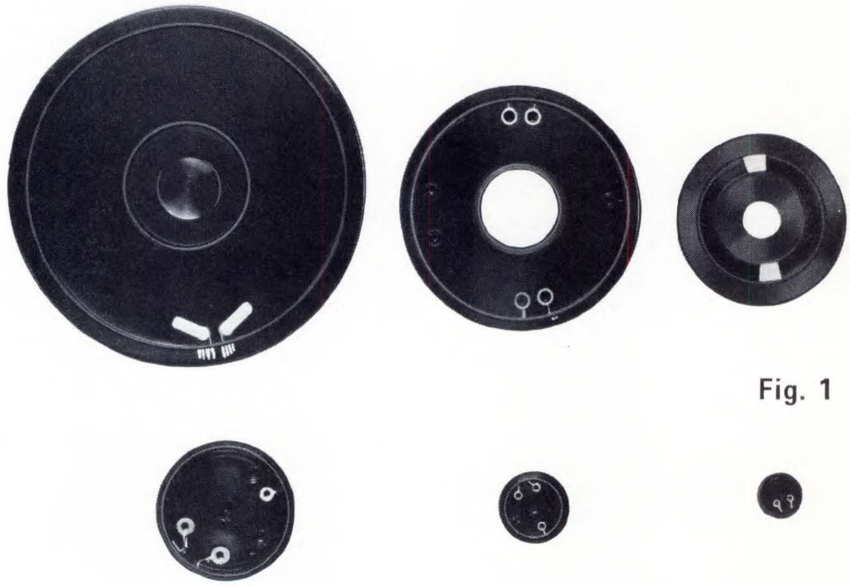


Fig. 1

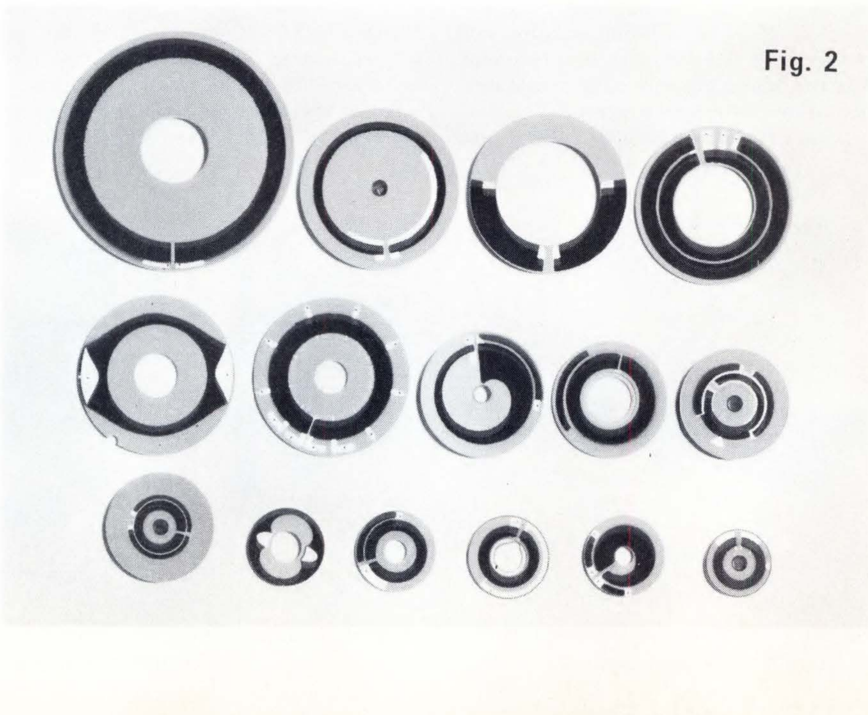


Fig. 2

Type	As-Molded Linearities	Short-Term Linearity Errors % of Applied Voltage	Dither Life	General Description	Characteristics
Bulk	2%	0.02 - 0.05	$2\text{-}3\times10^6$ cycles for 0.06% error	Conductive track is a raised ridge, .020-.060 in height and .025-.035 width at the base.	Very good rotational life. Very poor dither life. High contact resistance. Resistance stability not as good as flat track or film.
Flat Track	1%	0.02 - 0.05	4.0×10^7 cycles for 0.05% error	Conductive track is flush with insulating substrate. Track width usually between .090"-.200".	Technique very well developed for manufacturing non-linear functions. Lends itself well to comolding of housing and element. Good rotational life. Moderate life in dither.
Resisto-film	0.25%	0.02 - 0.04	$> 2\times10^8$ cycles with no perceptible error	Film on flexible substrate can be punched, stamped, and formed into a variety of shapes.	Dither life superior by at least an order of magnitude to any other known infinite resolution material. Linearity as manufactured much better than either flat track or bulk.

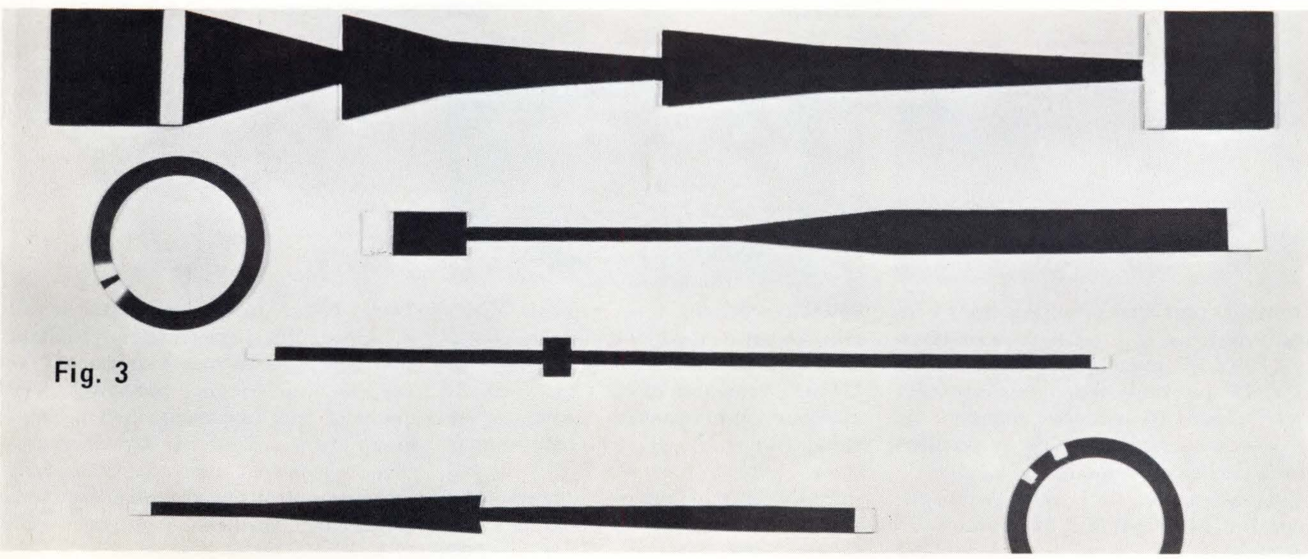
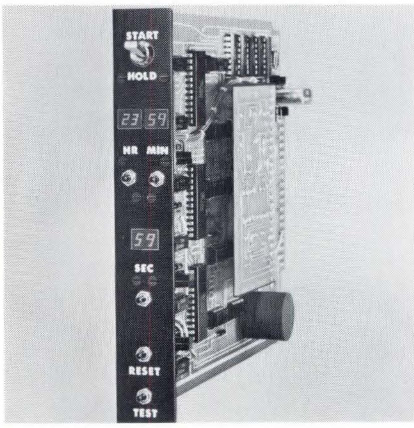
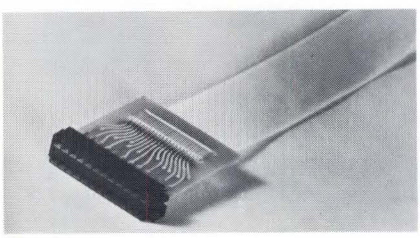


Fig. 3

Electrostatic printing tube produces character images on a dielectric coated paper. A matrix of fine wires (62,500 wires/square inch) replaces the usual phosphor screen. As the electron beam strikes the wires, the resultant current generates an electrostatic pattern or a latent image made visible by developing the paper. GTE Sylvania Inc., 730 Third Ave., New York, NY 10017. **200**

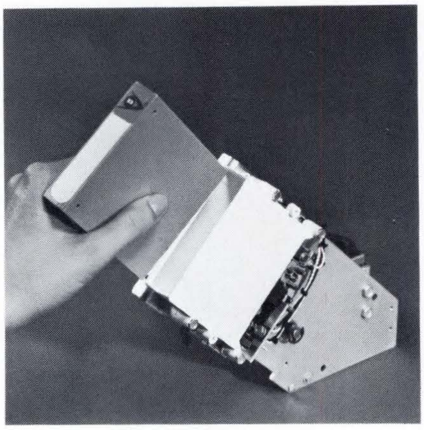


Time-code generator, K35402 Series, produces either IRIG Format A or B in both modulated and dc level shift form. An integral 7-segment LED display on the front panel indicates a time range of 24 hours, minutes and seconds. Unit dimensions are 0.94 by 6.25 by 9.43 inches. The A. W. Haydon Co., 232 N. Elm St., Waterbury, CT 06720. **201**

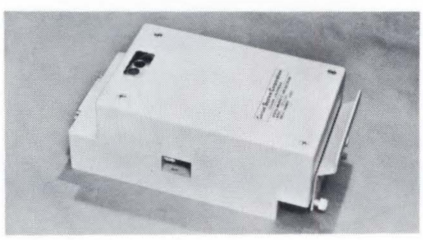


Transmission cable assemblies are specifically designed to interface with IBM System/360 back planes. Assemblies consist of PTFE insulated round conductor flat cable terminated to a socket connector via a printed-circuit board. Three standard units are being produced: 20-, 22- and 10-signal assemblies. W. L. Gore and Associates, Inc., 555 Paper Mill Rd., Newark, DE 19711. **202**

Keyboard test set enables keyboard manufacturers and users to checkout encoded keyboards by simply plugging them into the set. Appropriate code (ASC II or EBCDIC), positive/negative logic, odd/even parity and input function modes (TTL or MOS) are all selected by front-panel switches. Unit is not limited to keyboard testing. Maxi-Switch Co., 3121 Washington Ave. N., Minneapolis, MN 55411. **203**

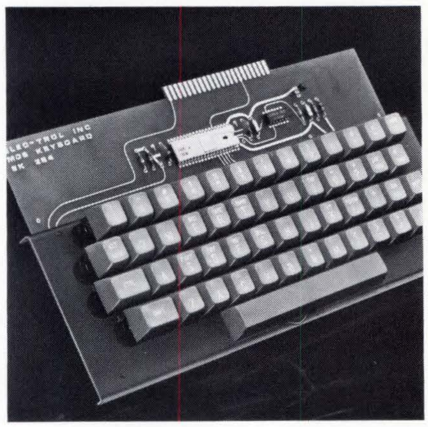


Magnetic tape cartridge transport features simplified loading and uses a design that eliminates the need for a pressure pad thus reducing torque losses. The tape contained in a cartridge is wound on coaxial reels which are held under constant torque. The cartridge case also contains a pinch roller. Digitronics Corp., Albertson, NY 11507. **204**

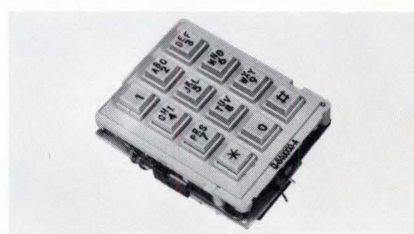


Portable magnetic tape recorder, Model DTU-250, is a bit-serial system that has a track capacity of 2.4 Mbits on 250 ft of 1/4-inch computer grade tape. Unit dimensions, complete with electronics for either two tracks or write/read or four tracks write or read, are 8 by 5 by 3.5 inches. Weight is 6 lb including the tape. Circuit Systems Corp., 816 E. Edna Place, Covina, CA 91722. **205**

Disc drive, Model 230, is pack interchangeable with the IBM 3330. The unit consists of two separate and independent drives. Total on-line capacity using IBM format is 200 million bytes (100 million bytes/drive). It can be configured in a system with 2, 4, 6 or 8 spindles, providing up to 800 million bytes total capacity. Century Data Systems, Inc., 1270 N. Kraemer Blvd., Anaheim, CA 92806. **206**



MOS keyboards employ a metal mounting panel to support "Snap-Lock" data keys and protect the PC board from operating stresses. Available optional features include: ASCII coding, custom coding, multikey rollover, interlock, 4-mode shifting, delayed strobe and odd/even parity. Electrol, Inc., 26477 N. Golden Valley Rd., Saugus, CA 91350. **207**



Twelve-button, alpha-numeric touch calling keyset has a one-transistor oscillator that generates all tone frequencies. Two variable tank circuits provide a "low" group of four frequencies and a "high" group of three. Different combinations of tone frequencies encode each of ten digits and two control symbols. GTE Automatic Electric Inc., Northlake, IL 60164. **208**

Memory power supply offers a combination of output voltages to 50V dc with crowbar overvoltage protection. Unit dimensions are 9 by 4 by 4 inches. Arnold Magnetics Corp., 11520 W. Jefferson Blvd., Culver City, CA 90230. **209**

Magnetic tape formatter contains either two NRZI formatters and a computer adapter board, or one NRZI and one phase-encoded formatter. Unit provides logic for reading and writing IBM-compatible 1600 cpi magnetic tape. Wang Computer Products, Inc., 2000 Stoner Ave., Los Angeles, CA 90025. **210**

Magnetic tape transport operates at 45 inches/sec and is an addition to the 100X Series, IBM-compatible tape transports. Other features include seven- and nine-track configurations and 1600-bpi recording density. Cipher Data Products, 7655 Convoy Ct., San Diego, CA 92111. **211**

Fully-buffered CRT terminal/tape cassette system, 2000+, features "dual" tape drives (cassette), paper tape emulation and on/off line data storage and retrieval capabilities. Hazeltine Corp., Little Nec, NY 11362. **212**

Core handler, Model CH-25R, meets the need for low-cost testing of cores (12 to 80 mil O.D.). It features 100% A.Q.L. testing from 0 to 65°C. Ramsey Engineering Co., 1853 W. County Rd. C, St. Paul, MN 55113. **213**

Minicomputer Alpha 16 sells for $3550 with 1600-nsec cycle time, 4k core memory, hardware multiply/divide, three direct memory channels and three vectored priority interrupts. Computer Automation, Inc., 895 W. 16th St., Newport Beach, CA 92660. **214**

Modem 4800/72 operates at 7200 bps, provides 4800 bps data at low error rates and features an optional forward error correction. Multiport capability is also available. International Communications Corp., 7620 N. W. 36th Ave., Miami, FL 33147. **215**

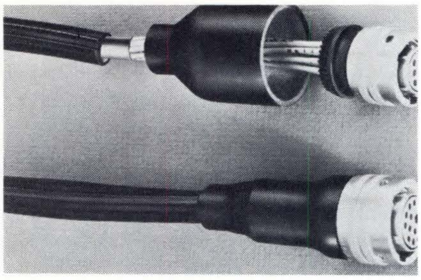
Programmable video display terminal couples a small computer with an input keyboard and a 14-inch CRT monitor. The computer element (microprocessor) has a 4096 8-bit byte semiconductor memory expandable to a memory 16 times as large. Raytheon Data Systems Co., 1415 Boston-Providence Turnpike, Norwood, MA 02062. **216**

Decoder, Series 745, converts BCD to an output that will drive a solid-state readout display (7-segment). Price is $5.95 for 1 to 9 quantities. Dialight Corp., 60 Stewart Ave., Brooklyn, NY 11237. **217**

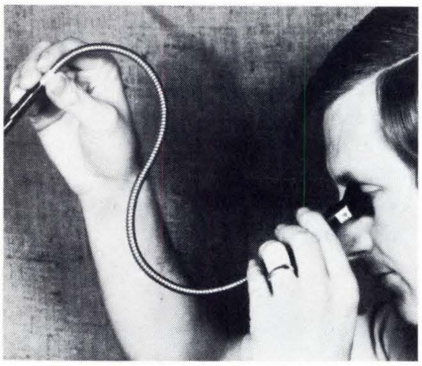
Desk-top calculator NCR 18-03 has 12-digit capacity and a drum printer for output. Price for the 17.5-lb machine is $795. The National Cash Register Co., Dayton, OH 45409. **218**

Printed circuit boards called "Castlecards" come in 4.5- by 6.25-inch standard rank mounting widths containing 16- to 36-DIP packages in any combination. Castle Rock Designs, Box 1437, Santa Cruz, CA 95060. **219**

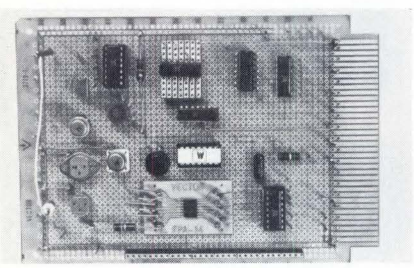
Punched card reader C-10 interfaces with most keyboard terminals. Transmission speed is 10 cps. Cards are read serially. Tally Corp., 8301 South 180th St., Kent, WA 98103. **220**



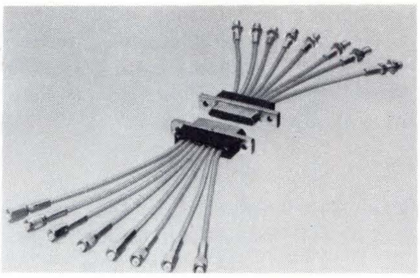
Cable and termination shielding system consists of a conductive coated, polyolefin-based heat shrinkable boot, re-accessible Zippertubing and shrink-jacketing material. The system provides 360° shielding and the boots shrink rapidly under application of 275 to 310°F heat. The Zippertubing Co., 13000 S. Broadway, Los Angeles, CA 90061. **221**



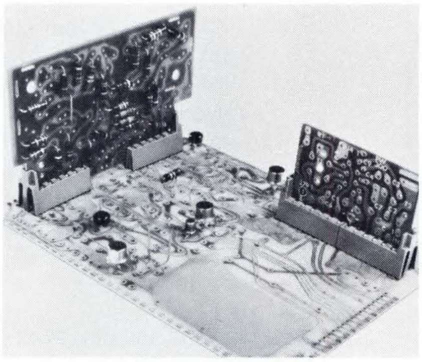
Flexible fiberscope permits viewing in any 3/8-inch-plus opening, and has built-in 7X magnifying eyepiece that focuses from <1/2 inch from the subject to infinity. Length is 18 inches and it contains over 4000 coherent glass fibers protected by semirigid sheathing. Price for Stock No. 60,857 is $40 each. Edmund Scientific Co., 380 Edscorp Bldg., Barrington, N J 08007. **222**



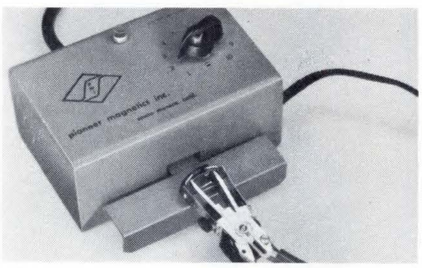
High density "plugboards" for DIPs and discrete components accommodate any component with lead spacing on a 0.1-inch multiple. Boards are made from FR-4 or FL-PH glass epoxy, or FR2 phenolic in either 4-1/2- by 6-1/2-inch or 2.73- by 4.5-inch size. Numerous accessories and contacts are offered. Price ranges from $6 to $8 each, depending on type. Vector Electronic Co., Inc., 12460 Gladstone Ave., Sylmar, CA 91342. **223**



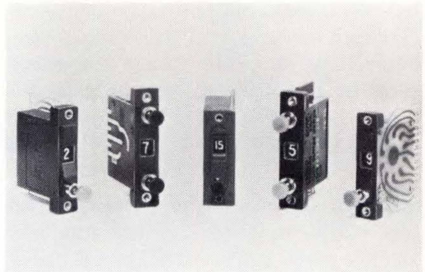
Microminiature multipin connectors, called "Combomate", operate from dc to 2.3 GHz with VSWR between 1.01 and 1.10. Units are available to handle up to 17 RG-196A/U or RG-178B/U coax cables. Mixed coax and standard wire layouts are also available. Microdot, Inc., Connector Div., 220 Pasadena Ave., South Pasadena, CA 91030. **224**



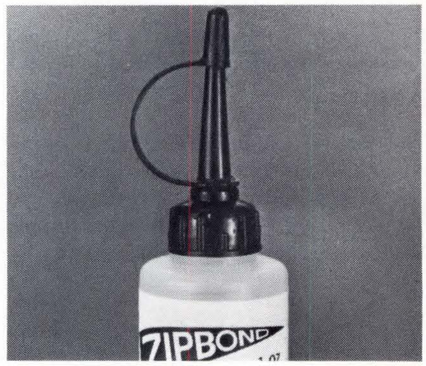
Modular interconnecting blocks with snap-lock features provide highly flexible mounting for daughter boards. They are available as 4-, 6-, or 8-position end blocks or as 6-position center blocks with preassembled spring contacts. Current rating is 7A and insulation resistance is 5000 MΩ minimum. Berg Electronics, Inc., York Expressway, New Cumberland, PA 17070. **225**



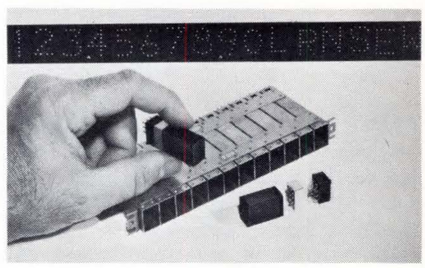
Thermal wire strippers, Model PM 1056, permit the operator to sever and remove the insulation slug in one combined operation without nicking the wire. Model PM 1056D strips all thermoplastic insulation in sizes from No. 12 to No. 36 without adjustment. Model PM 1056H is similar, but for use with "Kapton" insulation and from No. 20 to No. 36 AWG wire. Pioneer Magnetics Inc., 1745 Berkeley St., Santa Monica, CA 90404. **226**



Push-button rotary switches are microminiature, available in unidirectional and bidirectional models and are priced at $4 up. Models are offered with 8, 10, 12, or 16 positions in all standard codes. Options include RF shielding, lighted or unlighted digit positions and a bezel mount. Janco Corp., 3111 Winona Ave., Burbank, CA 91504. **227**



Bonding liquid that sets up quickly at room temperatures requires no heat or pressure treatments. "Zipbond" is impervious to most chemicals, weather conditions and temperatures, and its bonding strength is not affected by most solvents. It is easy to apply from the 1 oz squeeze applicator bottle or a production-line dispenser. Tescom Corp., Instrument Div., 2633 S.E. 4th St., Minneapolis, MN 55414. **228**



Fiber-optic readout has 0.475-inch high Arabic characters and provides nonambiguous reliability by using only one lamp/character. Because of the one-lamp/character design, the FRO Series readouts require only 100 mW power/character yet can be housed in a 0.66- by 0.46- by 0.162-inch space. Price is $10 each in quantities of 1000. Shelly Associates, Inc., 1562 Reynolds Ave., Santa Ana, CA 92711. **229**

Thermal cut-off provides back-up protection against appliance overheating. Units are available for more than 20 temperature ranges between 58 and 242°C. Upon overheat, a thermal pellet melts within a temperature limit of ±3°F, providing positive circuit break. 3M Co., 3M Center, St. Paul, MN 55101. **230**

Hybrid relay in a hermetically sealed TO5² can has self-contained transistor driver and suppression diode, permitting relay control by microwatts rather than milliwatts. General Electric Co., Data Communication Products Dept., Waynesboro, VA 22980. **231**

Reed switches for keyboard (low-level) applications have special plating for stable contact resistance at low level loads. The MARK-3 and MARK-4 are both Form A, SPST switches with maximum diameter of 0.105 inch. Current rating is 10 mA maximum. Price is $0.35 and $0.40 each, respectively, in 1000 lots. Hamlin, Inc., Lake and Grove Sts., Lake Mills, WI 53551. **232**

DC gear motor with speeds from 0.5 to 400 rpm and torque to approximately 50 lb-inches, Series 140R, operates from 12V dc. Start-up current is from 1.75 to 4.5A for standard models. Brevel Products Corp., Broad & 16th Sts., Carlstadt, N J 07072. **233**

Large-cavity DIP packages for 24- to 42-lead devices have 0.28- by 0.28-inch cavity for use with either bi-polar or MOS devices. Price for 40-pin version including lid and preform is $2.20 in 100 lots or $2 in 1000 lots. Dielectric Systems Inc., 3422 Tripp Ct., Sorrento Valley, San Diego, CA 92121. **234**

Low-cost attenuators offer up to 20 dB attenuation with 1W input power at prices that start at $12. Model L Series for dc to 2 GHz, and Model HF for 2 to 10 GHz, comprise the line. Weinschel Engineering, Box 577, Gaithersburg, MD 20760. **235**

Precision 10-turn potentiometer uses a hybrid resistance element that provides 0.015% output smoothness. Model 8136 has diameter of 7/8 inch, offers 5-million-revolution life expectancy and is priced at $6.50 each. Helipot Div., Beckman Instruments, Inc., 2500 Harbor Blvd., Fullerton, CA 92634. **236**

Monochrome CRT for display use in data processing has a 4- by 5-inch screen. Model Y-4064 provides 0.007-inch resolution line width at a price of $35 each in quantities of 100. General Electric Co., Product Inquiries, Rm. 309, Nolan Bldg., 2100 Gardiner Lane, Louisville, KY 40205. **237**

Electrolytic capacitors with unidirectional mount, Series R, for use between −25 and +85°C are available with capacitance from 0.47 to 1000 μF and working voltages from 6.3 to 50V dc. Illinois Elna Electronics Co., Dept. EDN, 1607 W. Howard St., Chicago, IL 60626. **238**

TO-3 power-transistor socket has a collector/strip lug with 6-20 mounting threads and comes with color-coded body to accommodate chassis thicknesses of 0.03, 0.045 and 0.09 inch. Standard contact material is spring brass, cadmium plate but phosphor bronze or beryllium copper contacts with special plating are available. Keystone Electronics Corp., 49 Bleecker St., New York, NY 10012. **239**

Low-cost snap-in switches with mimimum electrical life of 100,000 cycles at fully rated inductive load are U.L. and C.S.A. listed. Ratings up to 10A 250V ac, 15A 125V ac or 3/4 hp are available. Carlingswitch, 505 New Park Ave., West Hartford, CT 06110. **240**

Castable high-alumina ceramic that cures in 60 min at room temperature, RTC-60, is an all-purpose material that is low cost and has fast curing and high strength for all high-temperature applications. A trial evaluation kit is available at $15. Cotronics Corp., 37 W. 39th St., New York, NY 10018. **241**

Flexible conetic cable sheath attenuates magnetic fields, providing protection against both pickup and radiation. Test sample and further information are available on letterhead request. Magnetic Shield Div., Perfection Mica Co., 740 Thomas Dr., Bensenville, IL 60106.

Pressure transducer, Model AF, features a 5V signal level and is unaffected by excitation voltage changes from 22 to 32V. Factory-set pressure ranges are available from 5 to 20,000 psi. Price in small quantities is $250 each. Tyco Instrument Div., 223 Crescent St., Waltham, MA 02154. **242**

Fiber-optics readout, Model 905, features miniature plug-in lamps that operate on 5V at 20 mA. Lamp life rating is 40,000 hrs at nominal voltage. The seven-segment characters are 0.42-inch high. Price is about $18 each in production quantities. Master Specialties Co., 1640 Monrovia, Costa Mesa, CA 92627. **243**

Cable and wire ties in a permanent-installation strap type or in beaded-chain wire tie that can be refastened for repair—as well as cable clamps, comprise the "Fastraps" product line. Grayhill, Inc., 555 Hillgrove Ave., La Grange, IL 60525. **244**

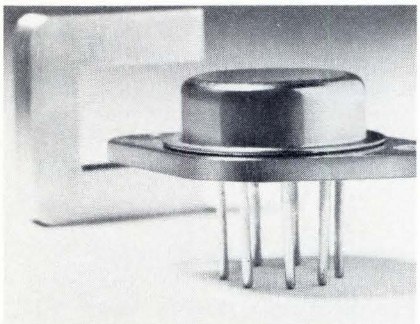
Material for extruding conductive gaskets for RF shielding is a one-part, vinyl rubber composition containing silver particles. Eccoshield SV-C can be cured by heating at temperatures as low as 325°F for 1 hr, and when fully cured has volume resistivity of 0.001Ω-cm. Gaskets can be extruded by caulking gun or syringe. Price is $44/lb. Emerson & Cuming, Inc., Canton, MA 02021. **245**

Polyester drafting film is anti-static and erases cleanly. Clear inking, single-matte and double-matte finishes are available in a variety of sizes and thicknesses. Bishop Graphics, Inc., 7300 Radford Ave., North Hollywood, CA 91605. **246**

Solid tantalum polar capacitors are offered in a 0.05- by 0.04- by 0.1-inch (maximum) package. Capacitance range is 0.0047 μF/20V through 0.47 μF/2V at 5, 10 and 20% tolerance. Price is as low as $0.50 each in 1000 quantities. Dickson Electronics Corp., Box 1390, Scottsdale, AZ 85252. **247**

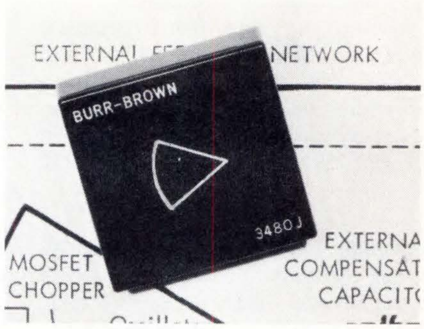
Industrial adhesive bonds such plastics as nylon, PVC, etched "Teflon", acrylics and others to themselves and metal. The "Uralane 8089-A/B" material has shelf life of 1 year in unopened containers. Furane Plastics, Inc., 5121 San Fernando Rd. West, Los Angeles, CA 90039. **248**

Bandpass filters for IF and RF applications feature extremely low time domain spurs −⩾30 dB ringing levels for impulse and step excitation. The FBA/1L Series filters use a helical-toroid resonator with superior temperature stability and high Q. I-TEL, Inc., 10504 Wheatley St., Kensington, MD 20795. **249**

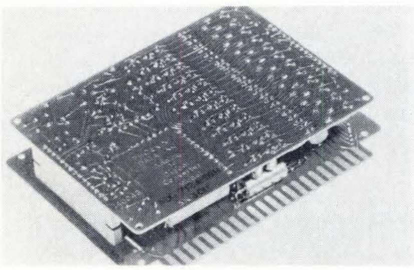


Oneshot power pulser switches high power loads for a precisely timed interval when triggered by a logic level input. The PIC 400/401 pulser handles up to 8A at 60V for interval that can be preset from 500 μsec to 50 msec with 1% tolerance. Price is $8 each in 100 lots. Unitrode Corp., 580 Pleasant St., Watertown, MA 02172. **250**

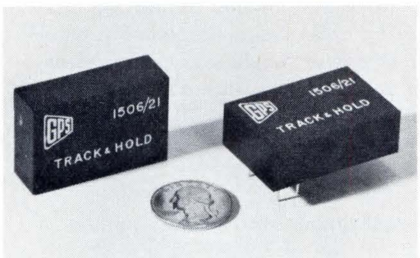
Power supplies, Model P2.12.200 and P2.15.200, provide dual regulated outputs of ±12 and ±15V respectively at 200 mA. Operating from 105 to 125V input, they provide 0.01% regulation. Case size is 3.5 by 2.5 by 1.25 inches. Price in single lots is $75. Semiconductor Circuits, Inc., 163 Merrimac St., Woburn, MA 01801. **253**



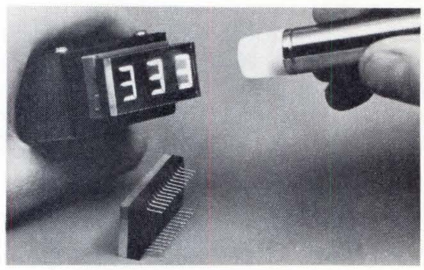
Noninverting chopper amplifier, Model 3480, features input impedance to $10^9\Omega$, voltage drift of 0.1 μV/°C and input noise of 0.4 μV pk-pk. Unit-quantity price for the ±0.3 μV/°C "J" version is $49 and for the ±0.1 μV/°C "K" version it is $64. Burr-Brown Research Corp., International Airport Industrial Park, Tucson, AZ 85706. **256**



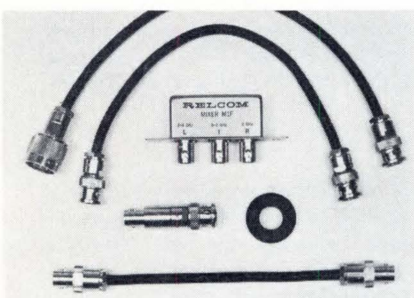
Repairable A/D converters of the ADC700 Series convert 12 binary bits in 6.5 μsec and 8 binary bits in 3.5 μsec, with accuracy up to 0.025% of full range and stability to ±10 PPM/°C T.C. There are six models in the series, and prices start at $375 each. Phoenix Data, Inc., 3384 W. Osborn Rd., Phoenix, AZ 85017. **251**



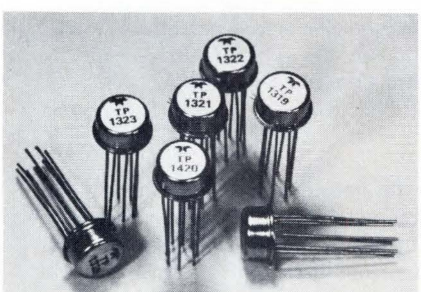
Track and hold module provides gain of 1, accuracy of 0.01% in sample mode and frequency response of 5 kHz. Input and output rating is ±10V, with 10 mΩ input impedance and 0.05Ω output impedance. Price of the model 1506 in single lots is $125. GPS Corp., 14 Burr St., Framingham, MA 01701. **254**



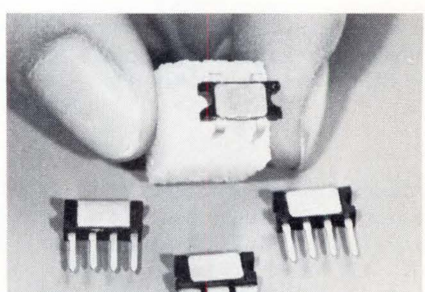
Liquid crystal displays that require only microwatts of power maintain excellent brightness and contrast under high ambient light conditions. Operation is from 15 to 60V at temperatures from 0 to 50°C and with minimum life of 10,000 hrs. Optel Corp., Box 2215, Princeton, N J 08540. **257**



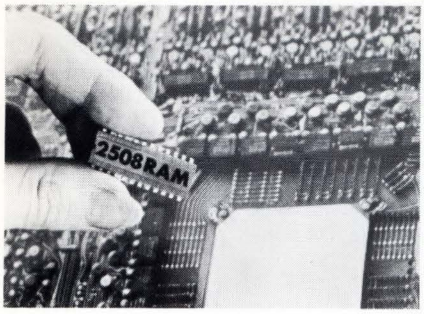
New mixer kit for the HP Model 8551B/851B spectrum analyzer increases its sensitivity by 6 dB, suppresses spurious responses an additional 15 to 30 dB and extends the low frequency range of the analyzer from 10.1 MHz to 200 kHz. It also improves flatness and cuts mixer burn-outs. Model M1F mixer kit installs in 5 min without altering the analyzer. Price is $275. Relcom, 2329 Charleston Rd., Mountain View, CA 94040. **252**



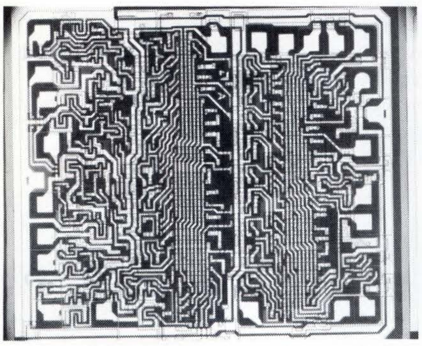
"Optimized 741s" are offered in seven models: high-performance, low-drift Model 1319 at $6, wideband, high-input-impedance Model 1321 at $15, high-slew-rate Model 1322 at $20, micropower general-purpose Model 1323 at $15, economy Model 1339 at $4, low-bias-current Model 1413 at $10 and general-purpose FET-input Model 1420 at $19. All are pin-for-pin replacements for 741s. Teledyne Philbrick, Allied Dr. at Rte. 128, Dedham, MA 02026. **255**



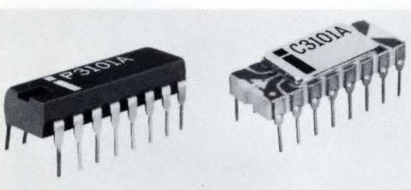
Solid-state switch <1/2-inch long, is based on a Hall-effect chip. The 2SS Series operates at speeds up to 10,000 operations/sec in temperatures from −40 to +70°C. Recommended supply voltage is 4.9 to 5.25V dc, and supply current is 15 mA maximum. Output voltage is 2.9V dc in the "on" state and 0.3V maximum in the "off" state. Micro Switch, Div. of Honeywell Inc., 11 W. Spring St., Freeport, IL 61032. **258**



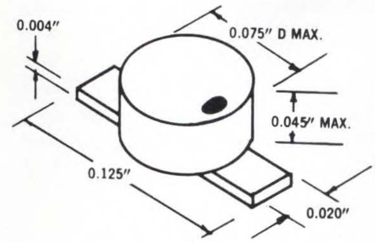
MOS dynamic random-access memory 2508NX is a 1024-bit, four-phase unit with minimum read/write cycle time of 460 nsec, typical read access time of 330 nsec and cell refresh time of 2 msec. Power dissipation is 100 μW/bit at a 500-nsec cycle time, and price in lots of 100 to 999, is $30.75 each. Signetics Corp., 811 E. Arques Ave., Sunnyvale, CA 94086. **259**



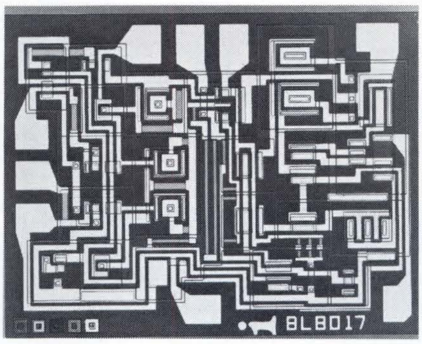
Four-bit arithmetic logic unit Am9340 features an internal carry look-ahead system. The unit operates over 4-bit word lengths at speeds of 20 and 25 nsec for addition and subtraction. In the 100-up mix quantity, prices range from $12 to $28 each depending on package and temperature range. Advanced Micro Devices Inc., 901 Thompson Pl., Sunnyvale, CA 94086. **260**



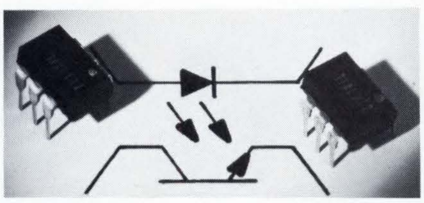
Random-access memory (RAM) 3101A is a 64-bit bipolar unit that offers faster access than any other memory on the market today. Using Schottky clamped bipolar transistors, address-to-output access time is 35 nsec max, and chip-select-to-output time is 17 nsec max. The unit is organized as 16 words of 4 bits each and in lots of 100 items, is priced at $9 (silicone plastic DIP) and $11.25 (ceramic DIP). Intel Corp., 365 Middlefield Rd., Mountain View, CA 94040. **261**



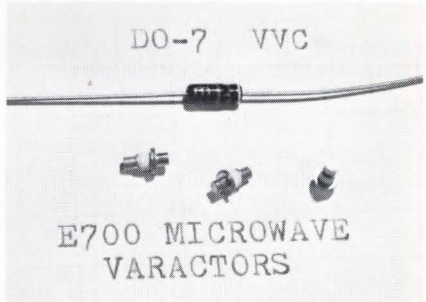
TC voltage reference diodes, MRD821-9 and MRD921-9, are 6.2V devices operating at 7.5- and 2-mA currents, respectively. These units are designed for hybrid and other high density package applications, and offer noise output typically less than 1 μV. CODI Semiconductor, Div. of Computer Diode Corp., Pollitt Dr. S., Fairlawn, N J 07410. **262**



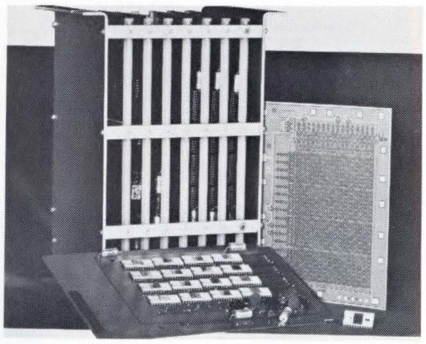
Linear amplifier ICL8017 is the fastest IC linear amplifier available with a slew rate of 130V/μsec, a 10-MHz bandwidth, 2-MHz full power output, 50-nA input current and short circuit protection. In lots of 100 to 999, prices are $14 (military) and $10 (industrial). Intersil, Inc., 10900 N. Tantau Ave., Cupertino, CA 95014. **263**



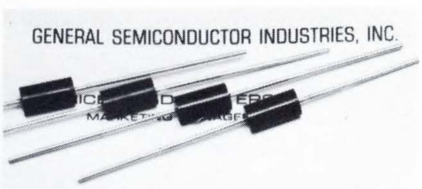
Optically-coupled isolators include the TIXL111 that features an input-to-output voltage of ±1.5 kV and is DTL/TTL compatible. The other, the TIXL112, has a ±500V isolation rating and is industry's lowest-priced coupler. Units combine a gallium-arsenide LED with a high-gain phototransistor. In lots of 100 to 999, prices are $3.35 each (111) and $1.70 each (112). Texas Instruments Incorporated, Inquiry Answering Service, Box 5012, M/S 308, Dallas, TX 75222. **264**



High Q tuning varactors, IN5139-48, IN-5441-56 and IN5461-76, are now available in the DO-7 package. These units come in 20%, 10%, 5%, 2% and 1% tolerance ranges, with capacitance values that range from 6.8 to 100 pF and Q up to 600. Prices start at $2.10 each in lots of 100. Eastron Corp., 25 Locust St., Haverhill, MA 01830. **265**



MOS dynamic random-access memory MCM1173L is a 1024-bit unit that features power dissipation of 50 μW/bit, access time of 400 nsec, write cycle time of 840 nsec max, read cycle time of 525 nsec max, and in lots of 100 items, price of $28 each. Technical Information Center, Motorola Inc., Semiconductor Products Div., Box 20924, Phoenix, AZ 85036. **266**



Silicon junction varistors in the GSV Series offer extremely high surge capability for the protection of electronic equipment susceptible to lightning effects and power surges. Units are rated for 125A peak-pulse current for 1 msec. Breakdown voltage is typically 0.35 to 0.5V at 10 μA and 0.74 to 0.85V at 100 mA. In lots of 100 units, prices start at $0.35 each. General Semiconductor Industries, Inc., 230 W. Fifth St., Tempe, AZ 85281. **267**

P-N photodiode TIL77 is designed to replace less stable cadmium-sulfide cells in exposure meters. The unit is priced at \$0.85 each in lots of 100 to 999 and below \$0.50 in larger quantities. Texas Instruments Incorporated, Inquiry Answering Service, Box 5012, M/S 308, Dallas, TX 75222. **268**

Monolithic chips for use in hybrid microcircuits include single transistors and diodes as well as amplifiers, Schmitt triggers, level detectors, op amps and other ICs. Amperex Electronic Corp., IC Div., Cranston, RI 02920. **269**

Dual 100-bit dynamic shift registers include the GER 1507 and GER 2507 units. The 1507 has a clock rate of 2 MHz, while the 2507 has a maximum clock rate of 5 MHz. Both units have a power dissipation of 0.04 mW/bit at 1 MHz. General Electric Co., IC Products Dept., Electronics Park, Bldg. 5, Room 160, Syracuse, NY 13201. **270**

Building-block MOS/LSI circuits can be combined to form the calculating systems of business and scientific calculators and of other data reduction equipment programmed for up to 1000 steps. North American Rockwell Microelectronics Co., Box 3669, 3430 Miraloma Ave., Anaheim, CA 92803. **271**

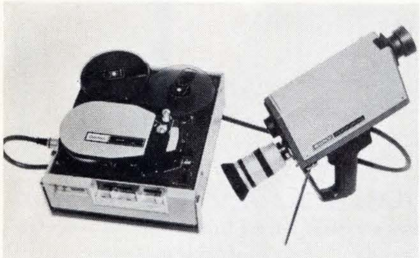
Micro-miniature diodes measuring 100 by 35 mil can be soldered or welded to hybrid circuit substrates and are priced from \$0.15 to \$0.65 each. Computer Components International, Inc., 3804 Burns Rd., Palm Beach Gardens, FL 33403. **272**

Monolithic p-channel dot-matrix character generator UC7541 has a chip enable access time of 350 nsec max, power dissipation of 200 mW typical, operating temperature range from −25 to 85°C and two basic organizations—64 words of 35 bits and 32 words of 70 bits. Solitron Devices, Inc., 8808 Balboa Ave., San Diego, CA 92123. **273**

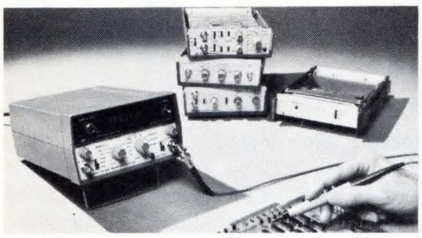
PIN diodes A5S301 and 302 are designed for general-purpose switching, attenuation and phase shifting applications at UHF, VHF and microwave frequencies. Capacitance is 0.3 and 0.25 pF max, respectively, and switching time is 200 nsec typical. Aertech Industries, 825 Stewart Dr., Sunnyvale, CA 94086. **274**

MOS resettable frequency divider GEM 501 provides six stages of frequency division in a 16-lead, plastic, dual-in-line package. IC Products Dept., General Electric Co., Bldg. 5, Rm. 160, Electronics Park, Syracuse, NY 13201. **275**

Silicon photodiodes for fast pulse response at 1.06 μm include the YAG-100 with an active area of 5.1 mm^2 and rise and fall times of 4 nsec; YAG-444 with an active area of 1 cm^2 with rise and fall times of 10 nsec and YAG-444-4 is a quadrant version of the YAG-444. EG&G, Inc., Electro-Optics Div., 35 Congress St., Salem, MA 01970. **276**

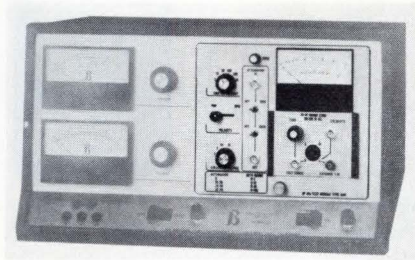


Battery-powered, time-lapse video tape recorder and camera system can be used for real-time recording or for logging up to 15 hrs of time-lapse viewing on a standard 1200-ft reel of tape. The system TP-400 uses 1/2-inch video tape. Odetics, Inc., 1845 S. Manchester Ave., Anaheim, CA 92802. **290**

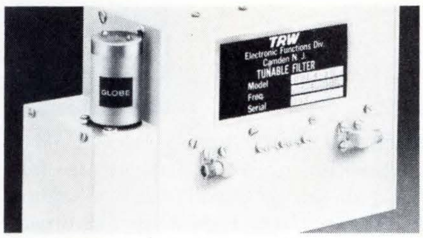


Electronic counter system with 6-digit LSI readout consists of a $395 mainframe and a choice of four snap-on counter and counter/timer modules: the 10-MHz, $125 Model 5301A frequency counter, the 50-MHz, $250 Model 5302A universal counter/timer, the 500-MHz, $750 Model 5303A frequency counter and the 10-MHz, $300 Model 5304A timer/counter. Hewlett-Packard Co., Inquiries Mgr., 1601 California Ave., Palo Alto, CA 94304. **291**

RF signal generator, Model 925, tunes from 50 kHz to 80 MHz in seven bands. The output frequency is monitored on a 6-bit digital counter and a locking circuit holds the tuned frequency constant by sychronizing with the counter's crystal time base. Price is $2975. LogiMetrics, Inc., 100 Forest Dr., Greenvale, NY 11548. **292**



Plug-in module that permits transistor high frequency parameter measurement over the frequency range of 20 to 100 MHz, Model 10RF, considerably extends the use of the Model 70 test system. Price of the module is $790. Precision Standards Corp., 1701 Reynolds, Santa Ana, CA 92705. **293**

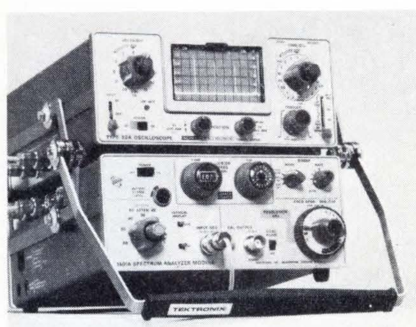


Auto-tuned bandpass filters for 110 to 150 and 225 to 400 MHz, have 20 to 100W power handling capability. They use high-Q cavity resonators, and are useful for eliminating spurious signals and existing noise generated in broad-band transmitters. Options include a visual tuning lock indicator,' high altitude capability and a range of tuning power levels. TRW Electronic Functions Div., Davis & Copewood Sts., Camden, N J 08103. **294**

Sweep/signal generator, Model 1002, covers from 1 to 500 MHz and will sweep any part of all of its range. Both tuning and sweep are electronic, and the RF output system is calibrated from +10 to −80 dBm. Sweep rates include line frequency and from 50/sec to 1 sweep every 100 sec. Base price is $1095. Wavetek, Indiana, Inc., Box 1987, Indianapolis, IN 46206. **295**

Storage display, Model D-10, uses a cathodochromic dark-trace tube that has writing rate of 5 sec for full-screen, and permanent storage until erased. Screen size is 3 by 4 inches, contrast ratio is 5:1 in room ambient and erase time is approximately 3 sec. Optel Corp., Box 2215, Princeton, N J 08540. **296**

Fast Fourier transform analyzer, Model FFT256, is a stand-alone processor that requires no external computer or software. It performs both direct and inverse FFT (real and imaginary), power spectrum, cross power spectrum, square spectrum, auto-correlation, cross-correlation, convolution, convolution spectrum and auto-convolution. Price is $9900. Unigon Industries, Inc., 80 Dupont St., Plainview, L.I., NY 11803. **297**



One- to 500-MHz spectrum analyzer module, when used with the "Sony/Tektronix" 323 or 324 oscilloscopes, makes up a system that provides both a calibrated spectrum analyzer and an oscilloscope for portable use. Model 1401A may be powered from the normal ac line, 6 to 16V dc or internal rechargeable batteries. Tektronix, Inc., Box 500, Beaverton, OR 97005. **298**

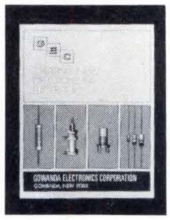
Power semiconductor components covered in Catalog 54-000 range from the highest voltage thyristors, rectifiers and transistors commercially available to power control and rectifier assemblies, prewired and mounted on heat sinks. Semiconductor Div., Westinghouse Electric Corp., Youngwood, PA 15697. **300**

Fluidic sensors and interfaces and their related technologies are described in 32-page Booklet EPD FBR-2. Corning Glass Works, Public Relations Dept., Corning, NY 14830. **301**

Standard ac-dc power supplies known as the "Voltswagon" Series are detailed in this 20-page catalog that lists over 600 models covering the range from 4 Vdc at 500 mA to 125 Vdc at 4A. Nuclear Corp. of America, Power Supply Div., 2 Richwood Pl., Denville, N J 07834. **302**

Control knobs and custom dials are covered in 24-page Catalog R-71. It is a handy reference for the wide variety of sizes, styles and colors of control knobs available for virtually any type of electronic test equipment. Rogan Brothers, Inc., 8019 N. Monticello Ave., Skokie, IL 60076. **303**

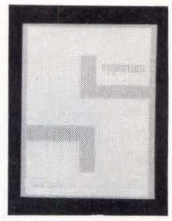
Signal level control circuits including attenuators, pots, pads, ladders, mixers, faders, gain controls and other items are detailed in this 24-page catalog that includes specifications, ordering information and circuit diagrams. Tech Labs, Inc., 52 E. Edsall Blvd., Palisades Park, N J 07650. **304**



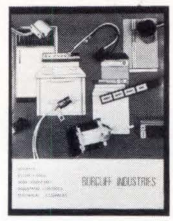
RF molded chokes ranging from 0.1 μH to 10 mH and tunable coil forms are featured in this 28-page catalog. Gowanda Electronics Corp., Dept. C-35, 179 Broadway Rd., Gowanda, NY 14070. **305**

Ruby and glass laser systems are covered in a 19-page bound brochure that describes the operating characteristics and unique features of a new improved line of solid-state lasers. Apollo Lasers, Inc., 6365 Arizona Circle, Los Angeles, CA 90045. **306**

DC power supplies are the subject of this 44-page catalog that permits selection of any of more than 200,000 different power modules. Items included are miniaturized power modules, low-profile power supplies, regulated single and dual output units and low cost unregulated power modules. Acopian Corp., Easton, PA 18042. **307**



TTL ICs in the 54/7400 Series have had 17 new circuits added to the family recently. Technical data concerning these new circuits are covered in this 64-page handbook. Additional information on MSI, MOS and linear ICs also is included. Signetics Corp., 811 E. Arques Ave., Sunnyvale, CA 94086. **308**



Sockets, glow lights, wire harnesses, industrial controls and electrical assemblies are described in this new catalog from Burcliff Industries, Inc., 1022 S. Union St., Mishawaka, IN 46544. **309**

Standard rotary switch catalog contains 32 pages of complete engineering, dimension and test data for over 2200 standard configurations of rotary switches. For a free copywrite on company letterhead to Stackpole Components Co., Box 14466, Raleigh, NC 27610.

Trimmer potentiometers are covered in this expanded 36-page catalog that features new DIP models and gives complete details on more than 50 wirewound and film element trimmers in MIL-R-27208A and commercial/industrial styles. Dale Electronics, Inc., Dept. 860, Box 609, Columbus, NE 68601. **310**

"How Do You Lose It and Still Have It" is the title of a booklet that details a thermocouple with a "dual sensor" tip. Sensor Dynamics Inc., 129 Laura Dr., Addison, IL 60101. **311**

Film capacitors for industrial/commercial electronics are covered in a 40-page catalog from Paktron, Div. of Illinois Tool Works Inc., 1321 Leslie Ave., Alexandria, VA 22301. **312**

Microwave/waveguide components and equipment, electronic test instruments, electromechanical and other components are among those featured in 64-page Bulletin 94 from Lectronic Research Labs., Inc., Atlantic and Ferry Ave., Camden, N J 08104. **313**

Hybrid conversion modules, including both D/A and A/D converters, are covered in Bulletin No. ZD200 from Zeltex, Inc., 1000 Chalomar Rd., Concord, CA 94520. **314**

Copper- or other metal-clad continuous-roll laminates for the PC and flexible cable industry are detailed in a 12-page specification guide from TME Corp., Salem Industrial Park, Salem, N H 03079. **320**

Ultraminiature indicator lights in the 249 Series include light-emitting diodes. They are the subject of Bulletin UM1211 from Dialight Corp., 60 Stewart Ave., Brooklyn, NY 11237. **321**

Interchangeable, curve-matched thermistors and thermistor probe assemblies are covered in Bulletin 8009 that includes a complete glossary of terms, as well as a step-by-step procedure for designing thermistor circuits. Omega Engineering Inc., Box 4047, Stamford, CT 06907. **322**

Industrial and military cermet pots in the 550 Series are 2W units completely described in Catalog Sheet 3550C from CTS of Berne, Inc., 406 Parr Rd., Berne, IN 46711. **323**

Dual FET selection guide compares the specifications of 78 different devices. It is available from Teledyne Semiconductor, 1300 Terra Bella Ave., Mountain View, CA 94040. **324**

PIN diode modulator/attenuator that operates from 200 MHz through 18 GHz is the subject of Bulletin M189 from General Microwave Corp., 155 Marine St., Farmingdale, NY 11735. **325**

Digital frequency meter Model 4034 that measures frequencies to 1 MHz in time intervals from 10 μsec to 10^6 sec is described in Bulletin 2462A. Technical Information Section, Electronic Instruments Div., Beckman Instruments Inc., 3900 River Rd., Schiller Park, IL 60176. **326**

Selenium photovoltaic cells are covered in eight-page Bulletin SPV-5 from Vactec, Inc., 2423 Northline Industrial Blvd., Maryland Heights, MO 63043. **327**

Electrolytic capacitors offering a range from 1 to 200 μF in both axial and single-ended lead configurations with single quantity prices from $0.50 to $3.20 are covered in cross reference data from International Rectifier Corp., Semiconductor Div., 233 Kansas St., El Segundo, CA 90245. **315**

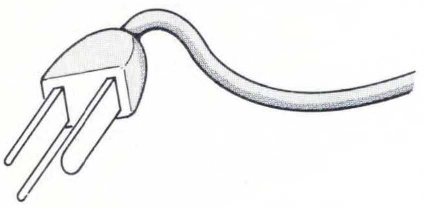
Film capacitors are detailed in this 40-page catalog from Paktron, Div. of Illinois Tool Works Inc., 1321 Leslie Ave., Alexandria, VA 22301. **316**

DC precision voltage reference standard with accuracies to 10 PPM and long term stability of 10 PPM/year are detailed in information from CODI Semiconductor, Div. of Computer Diode, Pollitt Dr., Fair Lawn, N J 07410. **317**

"Stock Relays and Switches" is the title of an eight-page catalog that includes pricing information. GTE Automatic Electric Inc., 400 N. Wolf Rd., Northlake, IL 60164. **318**

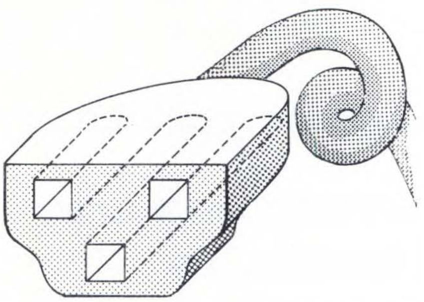
Precision potentiometers are covered in an eight-page brochure from Trimpot Products Div., Bourns Inc., 1200 Columbia Ave., Riverside, CA 92507. **319**

DC-to-3∅ the Easy Way



Gentlemen:
I could not supply a female connector to mate with Mr. Emmerich's dc-to-3∅-ac converter. However, I can supply a drawing of a polarized 3∅ dc connector using both a male and female connector. Details of the internal construction of the female connector have been shown in dotted lines for clarity.

Ansel R. Dickinson
Lovelace Foundation for
Medical Education and Research
Albuquerque, New Mexico



EEE and Job Crisis Revisited

Gentlemen:
It is interesting to note that the present job crisis in the electronics industry ("The Job Crisis", editorial, EEE, April 1971, p. 13) was forecast by the eminent J. M. Bridges, fellow of the IRE and IEEE, as long ago as 1961 ("There will be no Electronics Industry in 2012 A.D.". Proceedings of the IRE, May, 1962, Vol. 50, No. 5. Manuscript received Jan. 15, 1961.) Furthermore, according to the forecast of this famous engineer and administrator, the situation is going to get worse—much worse.

Writing in 1961 for the Proceedings of the IRE, Bridges stated bluntly, "In the year 2012 A.D. there will be no electronics industry . . . ". And further in the same article he made the point even more explicit by saying "The thousands of electronics engineers now required . . . will be replaced by machines and by a relatively few highly specialized and very creative scientists . . .". The fact that this authoritative statement, made by a highly placed governmental official, has been completely ignored is a measure of the short-sighted thoughtlessness which is now condemning thousands of electronics engineers to months and years of misery.

Simple mathematics applied to the Bridges forecast indicates that even if all electronics engineering training were to cease today, there will still be an extreme surplus of electronics engineers between now and the year 2012 A.D. Thousands of these surplus engineers will suffer the tortures of unemployment until some way is found to retrain them.

The Bridges forecast indicates clearly that ALL training of electronics engineers should cease at once, and that the facilities made available should be used to retrain the existing electronics engineers. Practical and humanitarian considerations indicate that this retraining should begin with the most recent graduates, while every effort should be made to provide adequate retirement pay for those older men who will find it hardest to get out of the field, and should therefore remain in it the longest.

Forty-one years may seem a long time, but it is less than the average working life, from graduation to retirement, now expected of the engineer. Furthermore, it can reasonably be expected that the drop off of engineering requirements to substantially zero will be along a logarithmic rather than a linear curve.

EEE can help best by publicizing the Bridges forecast to the utmost, and by urging Congress to provide financial assistance for the extensive retraining which is required now and in the future.

Malcolm S. Morse, P.E.
Morse Associates
Chevy Chase, MD 20015

The Saga of Frank, Charles, Tom, Peter, Julian and Robert

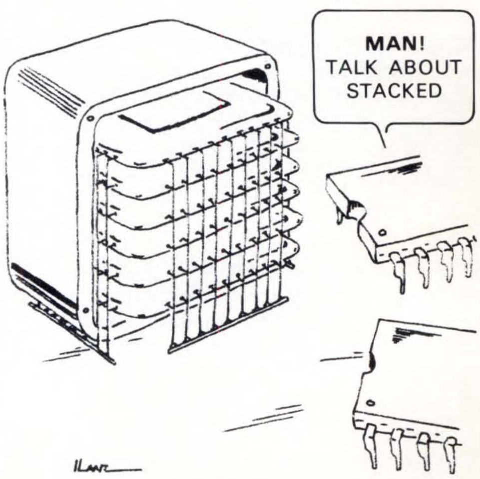
Gentlemen:
I note that you have referred on p. 76 of your April 15 issue to a *copy* of a letter from Frank Sprague to Tom Edison, which apparently hangs on the office wall of Charles Sporck, president of National Semiconductor, which was probably given to him by Peter J. Sprague, chairman of the Board of National Semiconductor and grandson of Frank J. Sprague. Peter is the son of Julian K. Sprague, who was president of the Sprague Electric Co. until his untimely demise in 1960.

While Frank J. Sprague was the founder of a number of companies, including the Sprague Electric Works which was merged into General Electric at the time General Electric was growing through the merger of many of the pioneer electrical firms, the *Sprague Electric Co.* was founded in 1926 by Robert C. Sprague, second son of Frank J. Sprague, and was originally known as the Sprague Specialties Co. until the name was changed at the end of World War II.

A copy of the letter similar to that which Mr. Sporck has is enclosed for your file.

The problem that Frank Sprague was working on at the time he wrote the letter to Edison was that of controlling the volume of a player piano. Sprague was attempting to regulate the current through a solenoid with a large flat hammer which would press against the piano strings. As you know, the volume from a player piano does not have very much of a dynamic range, since it operates pneumatically. With modern electronic amplification, Frank Sprague's scheme would have worked, but it was ahead of its time.

Sid Chertok
Sprague Electric Co.
North Adams, Mass.



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Index to Products, Lit and Advertisers

Application Notes

"Photomultiplier Tube Selection and Housing Design for Wideband Photon Counting" is the title of an eight-page Application Note 71021. A copy of the note and a short form catalog are available from SSR Instruments Co., a Sub. of Princeton Applied Research Corp., 1001 Colorado Ave., Santa Monica, CA 90404. **350**

"A Brief Introduction to Incremental Shaft Encoders and Their Application to the Instrument Display Line" is the title of this eight-page note that outlines the problems encountered with interfacing unidirectional and bidirectional counters to encoders. Instrument Displays, Inc., 223 Crescent St., Waltham, MA 02154. **353**

"Hottips" is a four-page newsletter that features controlled temperature and humidity equipment for electronic testing, quality control and production. Hi-lo chambers from −100 to +400°F and humidity chambers from 20 to 90% RH are included. Hotpack Corp., 5148 Cottman Ave., Philadelphia, PA 19135. **356**

Temperature measurement with thermocouples is the subject of 12-page Applications Brochure 102 that reports on the theory and practice of temperature measurement with thermocouples. Gould Inc., Brush Div., 3631 Perkins Ave., Cleveland, OH 44114. **351**

Planar triodes are covered in this eight-page note that includes operating instructions for an entire family of planar triodes and descriptions of mechanical and electrical characteristics. Eimac Div. of Varian, 1678 S. Pioneer Rd., Salt Lake City, UT 84104. **354**

Holographic studies to solve problems in vibration and stress analysis, shock propagation and nondestructive testing is the subject of 12-page Newsletter No. 1. Union Carbide Corp., KORAD Dept., 2520 Colorado Ave., Santa Monica, CA 90406. **357**

"Laser-Diode Sub-Nanosecond Rise Time Source of Radiant Flux for Photodetector Testing", Application Note AN-4553, describes the use of an injection laser to provide a square wave light output with rise time <200 psec. RCA Commercial Engineering, 415 S. Fifth St., Harrison, N J 07029. **352**

Chroma demodulators that employ two fully-balanced quadrature detectors, operating simultaneously, to recover the blue and red information from the 3.58-MHz chroma subcarrier are detailed in six-page "IC Engineering Bulletin" 27103B. Sprague Electric Co., 491 Marshall St., North Adams, MA 01247. **355**

"A Guide to Evaluating and Selecting Lock-in Amplifiers" is a 16-page booklet about instrumentation for recovering signals that are buried in noise. It includes signal-to-noise improvement along with key factors influencing instrument performance. Keithley Instruments Inc., 28775 Aurora Rd., Cleveland, OH 44139. **358**

Reprints Available **in this issue are offered as follows:**

R.S. No.	Title	Page No.
L61	Memories—Modern-Day "Musical Chairs"—Part I	19
L62	Speakout	30
L63	Designing Linear Sweep Generators	39
L64	Notch Filter Has Passive Q Control	43
L65	Transformerless Converter Supplies Inverted Output	48

Our filter/capacitor family takes experimentation out of circuit design.

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Publication 5409: type FA, FB, FW, SB, SS ceramic disc capacitors for VHF/UHF.

Publication 5410: type FCS, SMFB, SMFO filters for the 50 MHz to 10 GHz range.

Publication 5411: type CL multi-layer, coaxial capacitors for connectors.

Publication 5414: type MT, MS by-passing capacitors for 50 KHz to 1 GHz.

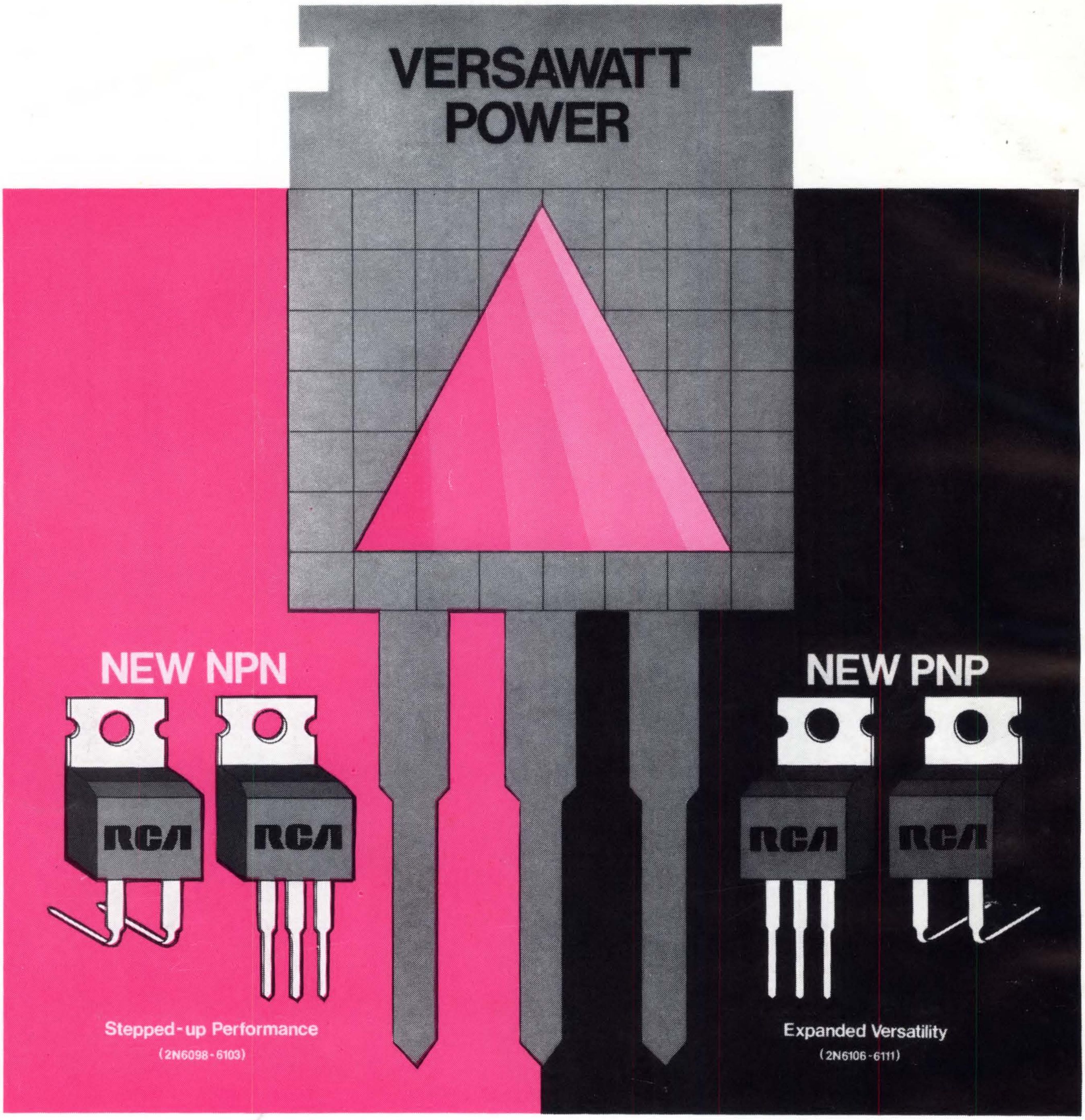
Publication 5416, 5417: type BE, SF filters for RFI/EMI suppression.

Publication 5418: type AB broad band filters in Pi, T and L configurations.

Actual Size

NEW DIMENSION ELECTRONICS
ALLEN-BRADLEY

CIRCLE NO. 30



RCA's 2N6103 series is new! It now makes available to designers an extended current capability in the RCA VERSAWATT line—from 0.5 to 8.0 Amp. Utilizing a chip similar to the 2N3055, this silicon power n-p-n family is the next step up from the 2N5298 and 2N5496. You get all the advantages of Hometaxial-base construction, backed by thermal cycle ratings and safe area operating curves. The 1000-unit prices in the family start at 65¢.

The 2N6103 family is recommended for such applications as hammer drivers, series regulators, motor speed controls, inverters, and output stages of audio amplifiers to 40 W.

Also new, the 2N6111 family is another in the series of RCA epitaxial-base p-n-p power transistors, offering designers new p-n-p versatility in the popular VERSAWATT package. Intended for complementary use with 2N5298 and 2N5496, these epitaxial devices are backed by RCA's exclusive thermal cycle ratings and complete safe area operating specifications. The 1000-unit prices in the family start at 70¢.

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