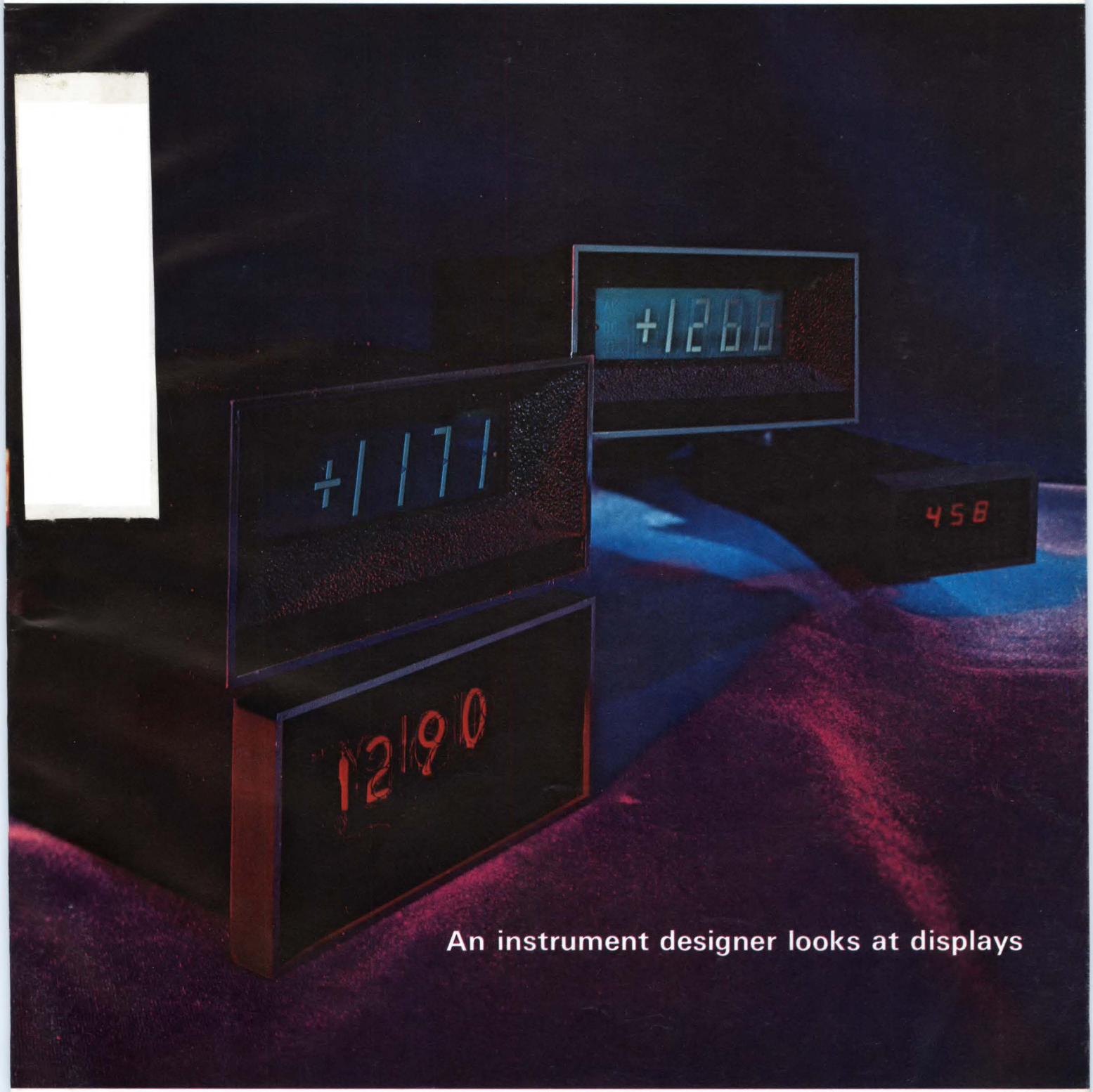
EXCLUSIVELY FOR DESIGNERS AND DESIGN MANAGERS IN ELECTRONICS

EDN

Considerations in designing femtoampere circuits

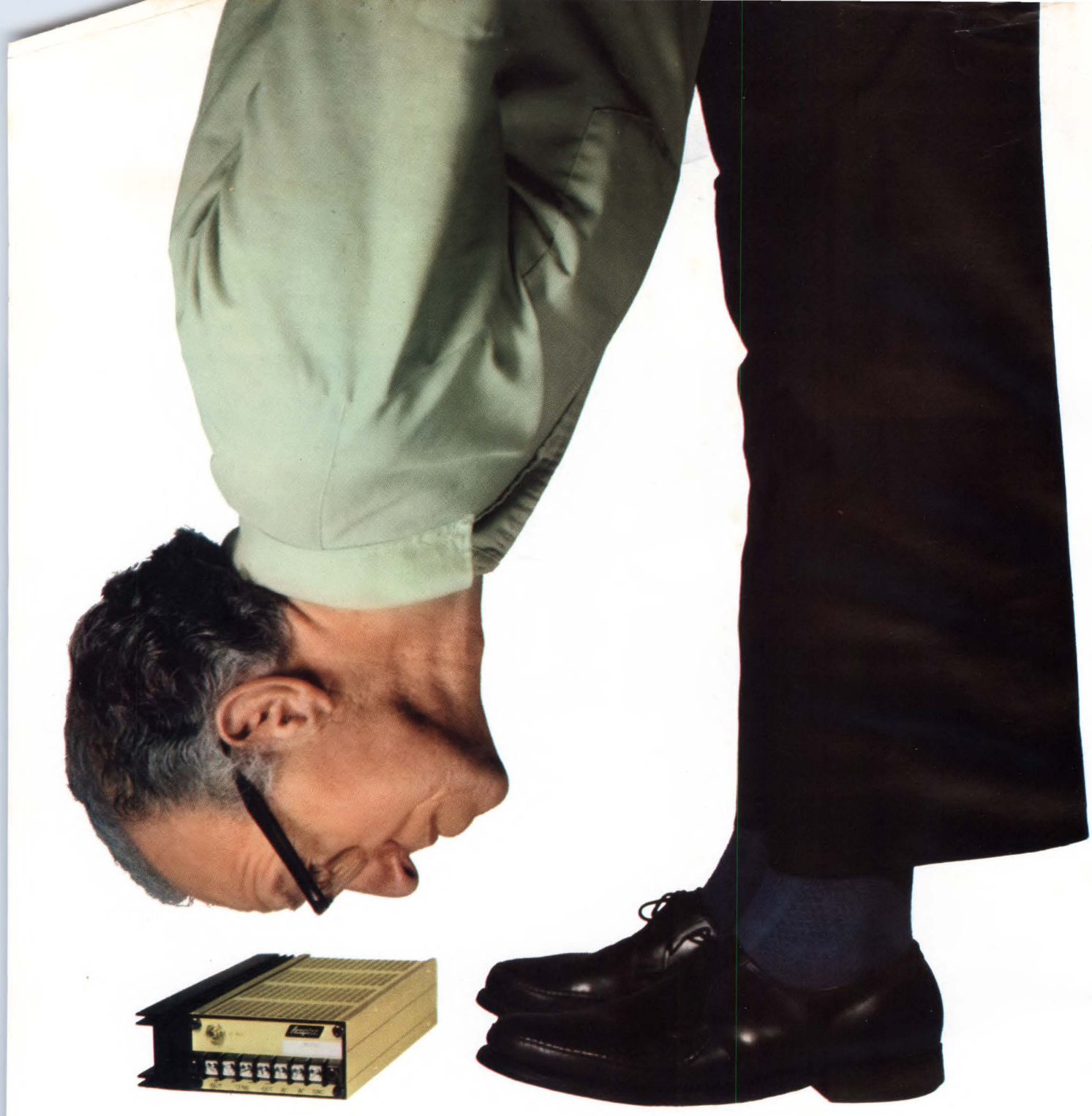
A third party looks at computer terminal design



An instrument designer looks at displays

A CAHNERS PUBLICATION

JULY 1, 1972

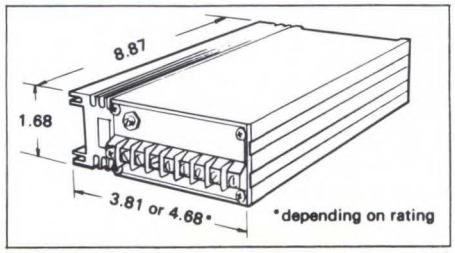


A new low in power supply design.

Acopian's new low profile power supply offers outstanding performance. Line and load regulation is .005% or 1 mv. Ripple is 250 microvolts. Prolonged short circuits or overloads won't damage it. And built-in overvoltage protection is available as an option.

Yet, it's the thinnest, flattest, most "placeable" 4.0 amp series regulated power supply ever offered . . . just 1.68" low. This low profile makes it perfect for mounting on a 1¾" high panel, or vertically in a narrow space. Acopian's new flat package gives you design flexibility never before possible. And a surprisingly low price gives you extra budget flexibility as well.

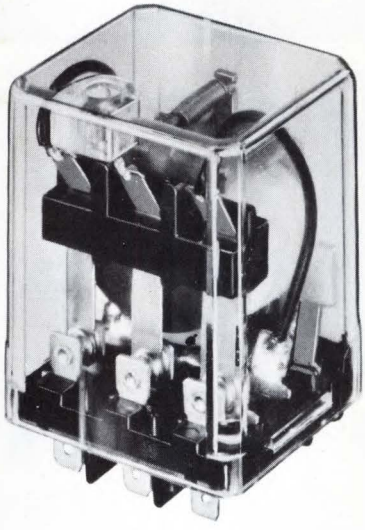
Standard models include both wide and narrow voltage ranges. Outputs from 0 to 48 volts. Current ratings from 1 to 4 amp. Prices from $80.00.



CIRCLE NO. 1

For the full low-down on the new low-down power supply, write or call Acopian Corp., Easton, Pa. 18042. Telephone: 215-258-5441. And remember, Acopian offers 82,000 other power supplies, each shipped with this tag . . .

GP



MAGNECRAFT'S NEW CLASS 388 GENERAL PURPOSE RELAY

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

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

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

FREE!

DESIGNER'S CATALOG

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

Magnecraft® ELECTRIC COMPANY

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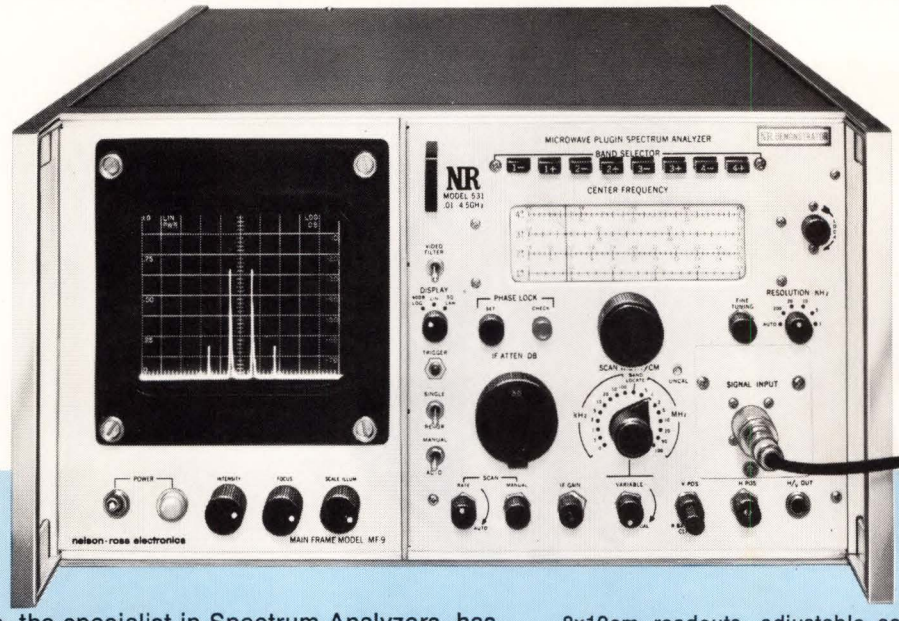
CIRCLE NO. 2

14 NEW Lowest Cost Spectrum Analyzers

From Sub-Audio to Microwave



Nelson Ross Spectrum Analyzer Model 531
10 MHz to 4.5 GHz
Dispersion 0-1 GHz
Phase locked 1 KHz resolution
Price: $3,050

Nelson Ross, the specialist in Spectrum Analyzers, has the **Biggest Selection, Most Versatile Specifications and Proven Reliability . . . All This For The Lowest Prices.**

Now you can select a Spectrum Analyzer from 0.5 Hz to 6.5 GHz which is just right for your application. And, with Nelson Ross you'll save 50% or more by not paying for unnecessary extras that you'll probably never use.

The versatile Spectrum Analyzers illustrated here are typical of 14 complete analyzers and more than 30 plug-in analyzers available from Nelson Ross.

The complete instruments include the new MF-9 Calibrated Display Main Frame which provides bright, long persistence 8x10cm readouts, adjustable scale illumination and camera mount facility.

Our plug-in analyzers come in 3 complete series: • for the Tektronix "540/550 letter" series scopes • for the Tektronix 560 series scopes • for the HP 140/141 series scopes and the Nelson Ross MF-9 Display Main Frame.

Compare specifications, quality, ease of use and price. We're sure you'll join the thousands who have been selecting Nelson Ross Spectrum Analyzers for more than a decade.

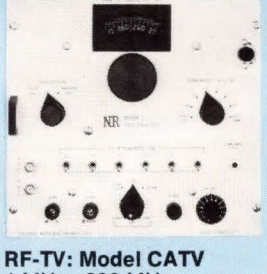
Call, write or circle the Reader Service Number to get your new 44-page Nelson Ross Spectrum Analyzer Catalog. Then **you** can compare and save.

Typical Plug-In Spectrum Analyzers for Nelson Ross MF-9 Display Main Frame or HP 140/141 series scopes.

Sub-Audio: Model PSA-036
0.5 Hz - 2 KHz
0.5 Hz Resolution
Plug-In: $1,200
With MF-9: $2,200

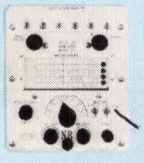
Broadband: Model PSA-235
1 KHz - 25 MHz
200 Hz Resolution
Plug-In: $1,700
With MF-9: $2,700

Audio: Model PSA-031
10 Hz - 20 KHz
10 Hz Resolution
Plug-In: $ 850
With MF-9: $1,850



RF-TV: Model CATV
1 MHz - 300 MHz
Plug-In: **$1,500**
With MF-9: **$2,500**

Typical of more than 25 Plug-In Analyzers for use with Tektronix scopes.



For "540/550 letter" series
SSB Narrow-Band RF
Model PSA-201
0.6 - 36 MHz
10 Hz Resolution
$1,675

For 560 Series
Ultrasonic
Model PSA-023
0.15 - 500 KHz
150 Hz Resolution
$850

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CIRCLE NO. 3

Cinch Dura-Con 0.050″ centers Small. Dependable. Available.

Now you have an effective source for your micro-miniature connector needs. Cinch can produce and deliver these rugged reliable connectors on a timely basis, with size 24 contacts on 0.050″ centers.

These connectors utilize the proven pin-socket contact system, where the pin, made from a precision spring cable, is the spring member. The seven cable strands are fused in a hemispherical weld, resulting in a strong flexible shock and vibration resistant contact with assured alignment and no discontinuities.

The Dura-Con pin is available in five sizes of Dura-Con D-configurations as well as single row strip configurations. It can also be supplied in custom insulators.

The size 24 contacts with 0.050″ centers are supplied factory terminated, with pigtail or wire leads. Size 22 contacts, on 0.075″ and 0.100″ centers, are crimp removable.

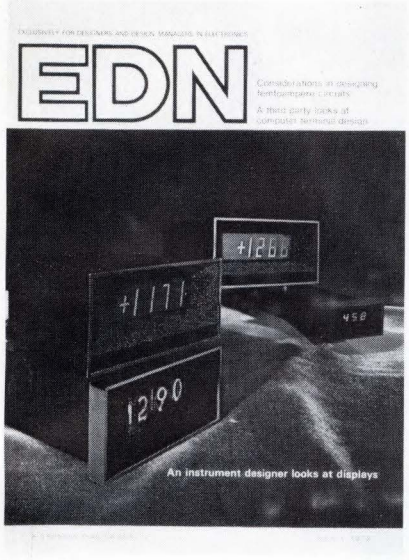
Cinch Dura-Con Micro-Miniature Connectors are described in Bulletin PBC-174, available free on request from Cinch Connectors, an Operation of TRW Inc. Electronic Components, 1501 Morse Avenue, Elk Grove Village, Illinois 60007. CM-7203

TRW®
CINCH CONNECTORS

CIRCLE NO. 4

JULY 1, 1972
VOLUME 17, NUMBER 13

EDN with EEE
EXCLUSIVELY FOR DESIGNERS AND DESIGN MANAGERS IN ELECTRONICS



COVER
Instruments, like these Digilin DPMs, can use various types of displays. For the factors involved in selecting the best type for a particular application, see p. 24. (Photo by Ortega-Orr Assoc.)

DESIGN NEWS

DESIGN FEATURES

PROGRESS IN PRODUCTS

DESIGN PRODUCTS

DESIGN DEPARTMENTS

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Everybody wants your components business.

But we're doing 6 things to earn it.

1 **Better components.** From ER through industrial, from precision through general purpose – we give you documented reliability. You'll find our metal film resistors outperform other metal films (including glazed), wirewounds and carbon comps. And our Glass-K™ capacitors outdistance monolithic ceramic capacitors on all counts.

2 **Better prices.** And this extra reliability costs you no more. The fact that we've become the country's largest supplier of metal film resistors says clearly that we're more than *just* competitive.

3 **Better delivery.** Our distributors can give you off-the-shelf delivery from an inventory of over 50,000,000 components. And you'll find our "ball parks" are the most accurate and dependable in the industry. You benefit in reduced expediting and inventory costs.

4 **Better QC.** Enough better so that many of our customers find they can totally eliminate incoming QC testing of our parts. Couple this with our unique product configurations that cut component insertion costs and you'll find it costs you less to do business with Corning even when our per unit price is the same.

5 **Better new products.** Our CORDIP™ Component Networks let you replace most of the outboard discretes you can't design into an IC. With a pretested, dual-in-line package of up to 23 discrete resistors/capacitors/diodes. Our FAIL-SAFE™ flame proof resistors give you an economical replacement for non-inductive and semi-precision power wirewounds. But ours open – never short – under overload.

6 **Better support.** We've built the largest technically-trained field force in the industry. And have contracted with the 30 most competent and service-oriented distributors in the country to give you in-depth assistance whether your needs are big or small.

Just let us prove it. Write for full details to: Corning Glass Works, Electronic Products Division, Corning New York 14830. Or call: (607) 962-4444. Ext. 8381.

CORNING
ELECTRONICS

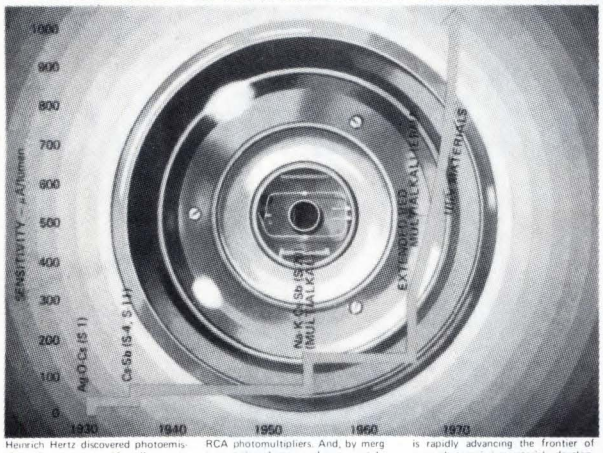
Resistors & Capacitors

for guys who can't stand failures

CIRCLE NO. 6

RCA

RCA PHOTOMULTIPLIERS WOULD HAVE FASCINATED HERTZ



Heinrich Hertz discovered photoemissive phenomena accidentally – in 1887. Now, the achievements of science minimize dependency upon luck, accident, or the "intelligent guess." Today, scientists synthesize materials to suit their needs.

As portrayed above, in the last two decades, solid-state physics has proved to be the effective impetus in understanding existing photoemissive materials. New materials which exhibit high quantum efficiencies and broadened spectral responses make up the photocathodes in today's extensive line of RCA photomultipliers. And, by merging semiconductor and vacuum-tube technologies, RCA has become the acknowledged industry leader of new photomultiplier developments.

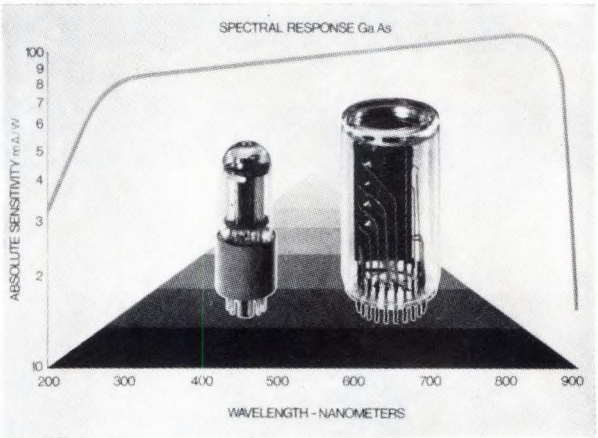
The search for new photoemissive materials was punctuated with the discovery of Silver-Oxygen-Cesium in 1929, and of Cesium-Antimony in 1936. RCA has pioneered the introduction of photomultipliers utilizing Multi-Alkali, Bialkali, Extended-Red Multi-Alkali, Gallium Arsenide Phosphide, Gallium Arsenide, and Gallium Indium Arsenide. In the '70's, RCA is rapidly advancing the frontier of new photoemissive materials development.

Consult RCA about photomultipliers for applications ranging from UV to IR, and from nuclear research to pollution detection. See your local RCA Representative or RCA Distributor for more information, or write: RCA, Commercial Engineering, Section 7ZP12, Harrison, N.J. 07029, International: RCA, 2-4 rue du Lièvre, 1227 Geneva, Switzerland, or P.O. Box 112, Hong Kong.

RCA

Photo courtesy of Science Illustrated

RCA PHOTOMULTIPLIERS WOULD HAVE FASCINATED HALLWACHS



GaAs Photocathode Sensitivity - Highest in the World

Wilhelm Hallwachs is another pioneer like Heinrich Hertz who has made fundamental contributions to our understanding of the photoemissive effect. In 1888, he postulated that "negative electricity" leaves a solid which is exposed to ultraviolet radiation.

More than three-quarters of a century later, this "Hallwach's effect" remains one of the fundamental phenomena in photomultiplier tube technology, technology which at RCA provides tubes with some of the most dramatic performance characteristics ever seen.

As shown above, C31025C is a 9-stage side-on photomultiplier which employs a gallium-arsenide (GaAs) photocathode with highly-stable copper-beryllium dynodes. It is designed to be used in new instruments and as a replacement in many existing spectrophotometers.

C31034 is an 11-stage, head-on photomultiplier utilizing the same GaAs photocathode. A premium version, C31034A, has the highest photocathode sensitivity over the near-UV to near-IR range of any commercially available photoemissive device in the world: typical luminous photocathode sensitivity is 1000 μA/lt.

Both tubes are available in versions with sapphire windows for performance at wavelengths as low as 150 nm.

Consult RCA about these and other photomultipliers. See your local RCA Representative or your RCA Industrial Tube Distributor for more information or write: RCA, Commercial Engineering, Section 10J/ZP16, Harrison, N.J. 07029, International: RCA, Sunbury-on-Thames, U.K., or 2-4 rue du Lièvre, 1227 Geneva, Switzerland, or P.O. Box 112, Hong Kong.

RCA

RCA PHOTOMULTIPLIERS WOULD HAVE FASCINATED THOMSON

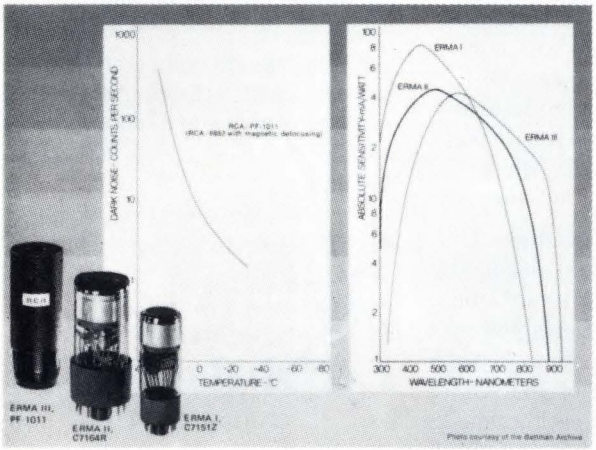


Photo courtesy of the Bettman Archive

Following hard on the fundamental discoveries of Hertz, Hallwachs, and Elster and Geitel, all of which profoundly affected the understanding of photoemission, the work of J. J. Thomson revealed the existence of the negatively charged particle—the electron—as a constituent of all matter. The year was 1897.

This fundamental knowledge in physics provided another vital step in the development of photosensitive devices. RCA has made important strides in the development of new and significant photomultipliers such as those incorporating photocathodes made with an exclusive "ERMA" (Extended Red Multi Alkali) process. Typical spectral response curves are shown above.

C7164R and C7151Z, low-priced 2"- and 1½"-dia. "ERMA" photomultipliers, provide broad spectral response, particularly into the near-IR, with a relatively large photocathode area. Both are designed to be used in existing instruments.

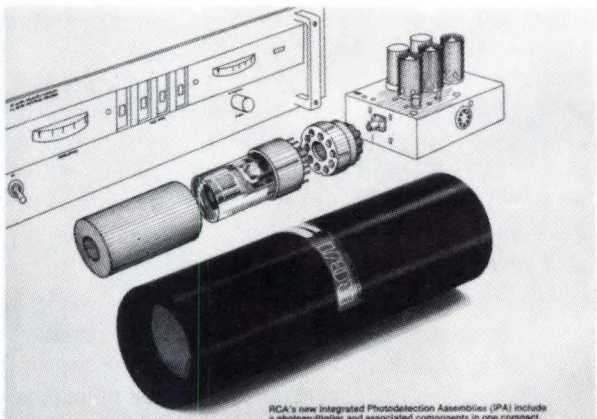
RCA offers similar performance of "ERMA" process tubes with the added advantage of low noise, in the PF-1011, a packaged assembly which includes an RCA-8852 QUANTACON photomultiplier, housing, and shield. Combining a high-gain tube exhibiting broad spectral response into the near-IR with magnetic defocusing of most of the photocathode area and cooling of the assembly provides one of the best signal-to-noise ratio performances available in photodetectors today.

Use these devices in such applications as laser ranging, photon counting, optical character recognition, and Raman spectroscopy.

For more information on RCA photomultipliers, call your local RCA Representative or your RCA Industrial Tube Distributor. For technical data, write: RCA, Commercial Engineering, Section 119K/ZP18, Harrison, N.J. 07029, International: RCA, Sunbury-on-Thames, U.K., or 2-4 rue du Lièvre, 1227 Geneva, Switzerland, or P.O. Box 112, Hong Kong.

RCA

RCA PHOTOMULTIPLIERS WOULD HAVE FASCINATED COCKCROFT AND WALTON



RCA's new integrated Photodetection Assemblies (IPA) include a photomultiplier and associated components in one compact, economical package.

Working together, nuclear physicists John D. Cockcroft and Ernest T. S. Walton used their newly-developed high voltage multiplier power supply as a novel device for accelerating particles in nuclear physics research. The year was 1932.

Today, employing modern solid-state technology, RCA utilizes this power supply concept in compact Integrated Photodetection Assemblies (IPA).

The IPA shown above includes an ERMA photomultiplier; solid-state power supply, voltage multiplier, and signal conditioning electronics (optional); optical filter (optional); magnetic shield; and all necessary connectors and cables.

With these assemblies, the designer need only specify his light input and desired *signal* output, to be *assured* of the performance he needs.

Sturdily constructed and temperature compensated, these new integrated assemblies have an insulated housing for safer operation. Ask about these IPAs for applications in laser detection, scintillation counting, spectroscopy, pollution monitoring, astronomy, medical electronics, and airborne and space experiments.

For information, see your local RCA Representative or your RCA Industrial Tube Distributor. For technical data, write: RCA, Commercial Engineering, Section 7ZP 21, Harrison, N. J. 07029, International: RCA, Sunbury-on-Thames, U. K., or 2-4 rue du Lièvre, 1227 Geneva, Switzerland, or P. O. Box 112, Hong Kong.

RCA

Photos courtesy of *Physics Today*

Design for production, or else!

The following excerpt is from a talk given at a recent EIA meeting by John J. Myers, vice president of the Electronics Div. of the Allen-Bradley Company:

> *For the past two decades or so we as a nation have been training too many of our engineers and scientists in exotica—in the skills required for space exploration, for state-of-the-art military electronics. Or at least we've steered an insufficient number of engineers into what I call the "greasy-thumb" end of electronics engineering—namely, manufacturing technology.*
>
> *As we face world-wide competition and compete effectively, it will be with heavy dependence on improved manufacturing technology, to which our best creative engineers should be contributing—not just those who flunk as product designers or those whose personality keeps them from roles in technical sales.*
>
> *The required action is clear. Encourage young engineers to adopt a manufacturing-oriented personal development program, which is as rewarding from a job-satisfaction standpoint as is product design.*

The significance of these remarks, we feel, cannot be exaggerated. The electronics industry is a supplier of things—from components, to equipment to systems. And these things, which are your companies' products, must be bought by customers, who have many sources of supply from which to choose.

Technology, and other factors such as support and service, will give a product a competitive edge, everything else being equal. But everything is not equal when a product is cheaper than similar items. Price has a very pronounced way of becoming the determining factor in a customer's eyes. And price is very sensitive to manufacturing costs which, like it or not, are the concern of the product designer.

Too many designers, though, still don't either realize or accept this, and go through the paper, breadboard and prototype stages of their designs without ever really considering whether they are manufacturable. The result, all too often, is either high product cost or wasted time in redesigning the product.

Companies that encounter this situation too often are going to have a hard time making it in what appears to be an era of ever-increasing competitiveness. Don't let your company become one of these.

Frank Egan

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How good is the 3469B? Compared to what?—We compared it to all the competitive DMM's we could find up to $1000, and found it equals or exceeds the performance of every 3-digit DMM available.

Make your own comparison. If you want the most capable 3-digit DMM on the market, without paying a lot of money, get HP's 3469B.

Priced at $595, order from your local HP field engineer. Or, write Hewlett-Packard, Palo Alto, California 94304. In Europe, 1217 Meyrin-Geneva, Switzerland.

If you're a comparison shopper... Here's a 4-in-1 DMM that beats them all.

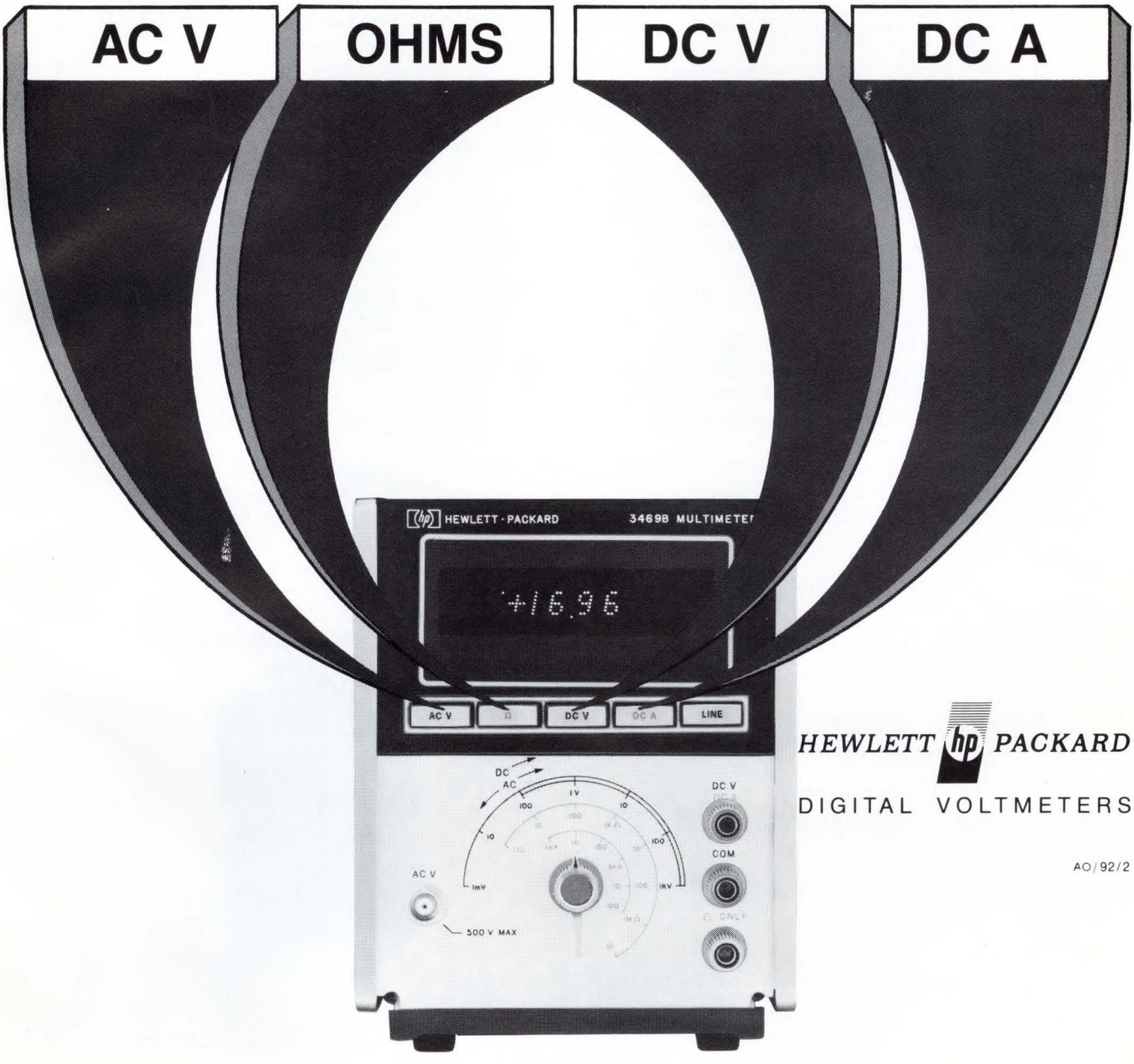
100X More Sensitive Than Most (1 mV F.S. to 500 V F.S.)

100X More Bandwidth Than Most (2 Hz. to 10 MHz.)

100X More Sensitive Than Most (1Ω F.S. to 10 MΩ F.S.) Unique Lead-Resistance Compensation.

3X Sampling Rate of Most (S.R. = 15/sec.)

100X More Sensitive Than Most (1 μA F.S. to 100 mA F.S.)



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DIGITAL VOLTMETERS

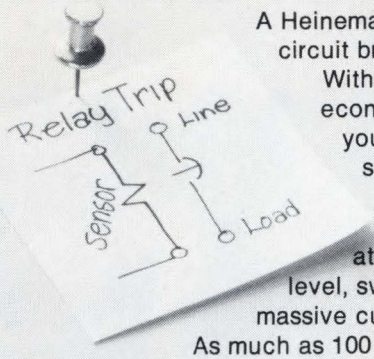
AO/92/2

CIRCLE NO. 10

Low-cost limit control for OEM's.

With a circuit breaker.

With a circuit breaker?



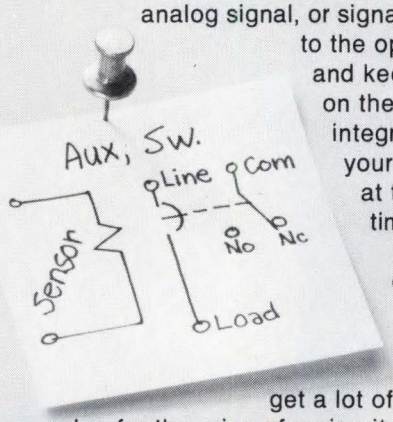
A Heinemann relay-trip circuit breaker.

With this one economical device, you can take a signal from any low-voltage sensor and, at a preselected level, switch off a massive current load. As much as 100 amp, to be precise.

There is no end to the uses you can find for this simple little control device. It will work with pressure sensors, voltmeters, ammeters, tachometers, pH sensors, what have you.

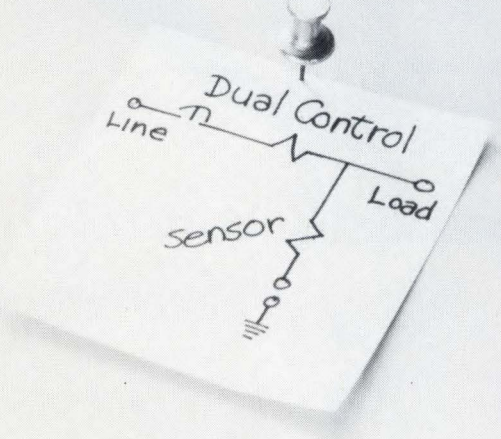
For alarm or other purposes, we can include auxiliary switch contacts right inside the breaker. When the circuit changes state, you can turn on a light, ring a bell, or start another operation.

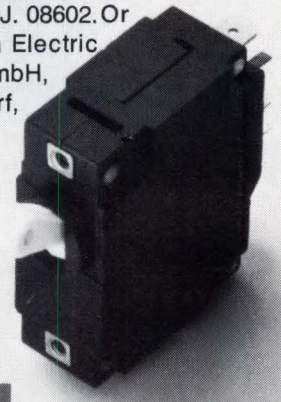
If you want the security of precision fault protection, as well as the relay-trip action, get our Dual-Control breaker (JA or AM Series). It monitors the critical analog signal, or signals, basic to the operation, and keeps tabs on the electrical integrity of your equipment at the same time.



Whichever design you choose, you can get a lot of functional value for the price of a circuit breaker.

Like to find out more? Send for our Engineering Guide, and we'll include a copy of Bulletin 3352 on Dual-Control breakers. Free, of course. Heinemann Electric Company, 2626 Brunswick Pike, Trenton, N.J. 08602. Or Heinemann Electric (Europe) GmbH, 4 Düsseldorf, Jägerhof-strasse 29, Germany.





HEINEMANN

5066

CIRCLE NO. 14

The one in the middle is a Weston Series 660 VOM. And it's the only one of the three that's warranted to keep working even if it's accidentally dropped from a height of five feet. Weston is the only manufacturer who is making that statement.

A Weston Series 660 is also smaller and lighter in weight than competitive meters. It has an easier-to-read scale and range plate. And it costs no more than the meters that don't offer a drop-proofed warranty.

Like the others, it's available with a protective leather carrying case. But who needs one with a drop-proofed Weston VOM?

Five models are ready for inspection at your Weston distributor. Drop in and try one. Or drop one. Weston Instruments, Inc., 614 Frelinghuysen Ave., Newark, N.J. 07114.

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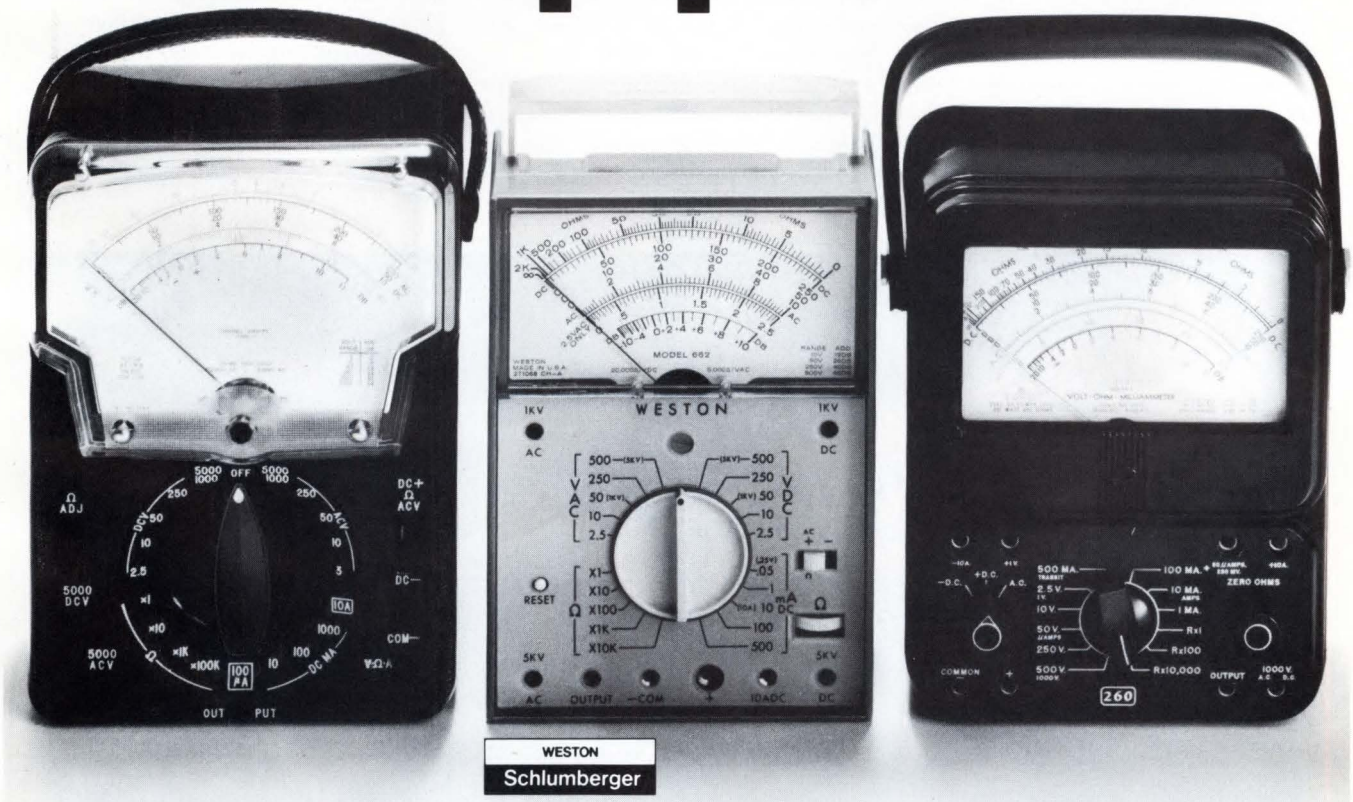
Only one is drop-proofed.



CIRCLE NO. 12

Circuits formed on ceramic substrates with laser "machining" process

A new laser "machining" process is capable of forming complex electronic circuit patterns directly onto ceramic substrates, or circuit bases, in one single step.

Present-day conventional methods for producing equivalent precise circuit patterns on ceramic require clean-room conditions and many processing steps, including mask-making, photoresist application, and chemical etching. The new process, developed at Bell Laboratories, and still in the experimental stages, makes use of a laser assisted by information stored in a computer that is programmed to describe the type of circuit pattern to be machined.

An important application for ceramic circuits formed by the laser machining process is the interconnection of electronic devices such as silicon integrated circuits. Interconnection via ceramic circuits has advantages over other techniques, such as printed wiring boards, in that it permits finer line conductor patterns, higher packing density of electronic components and superior circuit performance.

In the new laser machining process, substrates coated with a thin film of conductive metal are mounted to the outside surface of a circular drum. As the drum rotates, each substrate is successively exposed to a focused laser beam that is modulated, or switched on or off. The modulation of the laser beam allows microscopic regions on the metal coating of each substrate to be either selectively vaporized or left intact. Unwanted material is then removed from the substrate along a line that extends all the way across each substrate.

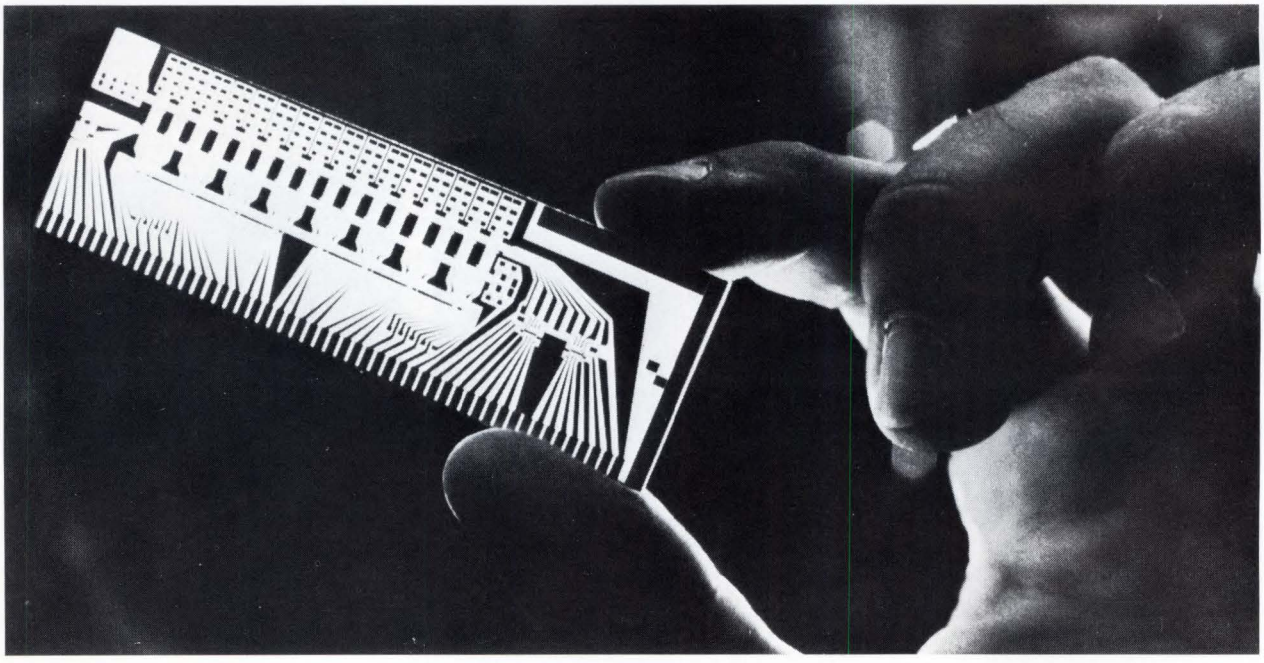
After one complete revolution of the drum, a reflecting mirror moves or "steps" the laser beam to the next line to be machined. This action continues until every point needed to form circuit patterns on the substrates has been scanned by the laser.

All of the metal film portions that are not vaporized from the substrate constitute a circuit pattern after the nonconventional laser machining process has been completed.

During the machining, as each flat substrate rotates past the laser beam, the distance between the lens that focuses the laser beam, and the substrate, changes slightly. To compensate for this, the process incorporates a movable lens to keep the laser beam perfectly focused at each point on the substrate.

Modulation of the laser beam in the machining process is achieved by a train of coded signals stored in a computer. These signals represent the electronic circuit pattern to be machined on the substrates.

With the new process, most of the fabrication steps of conventional methods are eliminated. It leaves the surface uncontaminated by organic residues, and is a noncontact process which avoids damaging the metal film. In addition it is insensitive to dust, eliminating the need for clean-room conditions, and the laser's depth of focus easily overcomes substrate surface irregularities. Also, it is repeatable, since there are no photographic masks to wear out. □



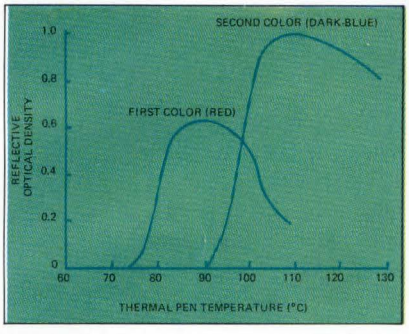
Circuit patterns like this one can be machined onto a ceramic substrate with the laser machining process developed at Bell Labs.

Two-color inkless recording made possible with new dichromatic technique

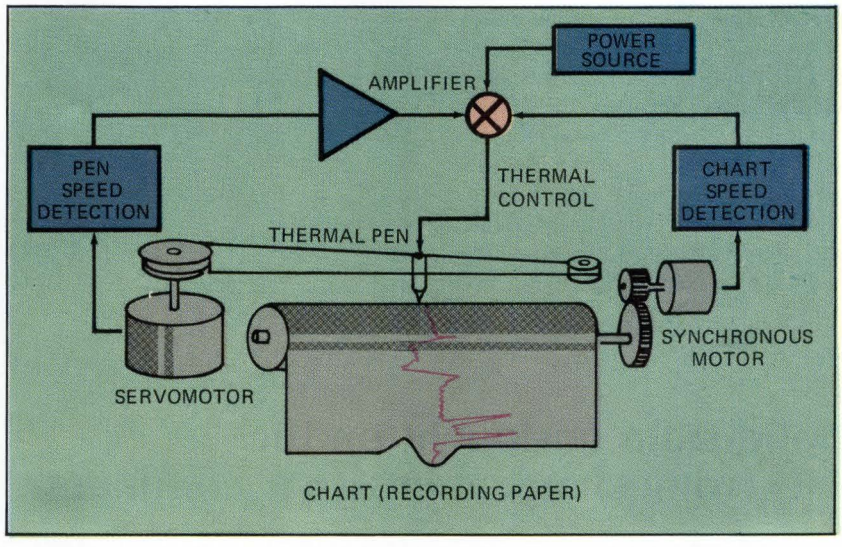
A strip-chart recorder that can record in two different colors has been developed by Matsushita Electric of Japan. The recorder uses a thermal writing technique together with special thermosensitive recording paper which changes its color when heated to certain temperatures.

The first color, which is red, appears when the paper is heated to 80-90°C. The second color, blue appears at a paper temperature of 100-110°C.

Line widths and densities are accurately maintained by a control system that regulates the current to the thermal writing head according to the recording speed. □



Dichromatic chart paper used with the new recording technique has a color characteristic that is temperature dependent.



Current pulses to the thermal writing head, or pen, are controlled in accordance with the writing speed. The recorder was developed by Matsushita Electric.

Louvred film sharpens image on low-light-level displays

A common problem in display systems is that of ambient light interfering with vision while observing low-light-level displays. This happens in areas such as liquid-crystal displays, cathode-ray tubes, aircraft-cockpit displays, hospital-patient monitoring machines and television screens, just to name a few.

Many of these problems can be overcome with a simple display film developed by 3M Company. Essentially, the film is a thin sheet of clear plastic containing closely-spaced opaque microlouvres, which function like miniature venetian blinds, allowing light to pass through at a predetermined angle. The result is highly increased contrast in light-emitting or backlighted display applications, making them easier to read when ambient light is present.

In liquid-crystal applications **(Fig. 1)** the film is placed between the light source and the liquid crystals. In self-lit, low-light displays, such as cathode-ray tubes, the display film is placed directly over the display surface (**Fig. 2**). In this type of application the film shades the subject from ambient light, which usually comes from above, while allowing a clear visual path for the viewer.

The film itself can be produced in

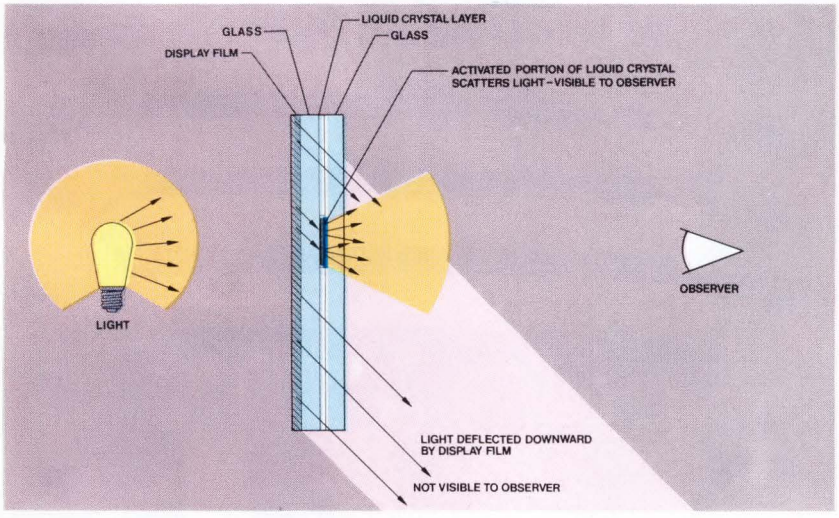


Fig. 1 – In transmissive-type liquid-crystal displays the display film allows light to pass through from behind to illuminate the liquid crystals, while providing the necessary opaque background for the viewer.

standard thicknesses, from 0.020 to 0.040 in. in thickness, while the louvres can be slanted at angles up to 45 degrees. Various decorative effects also can be achieved by changing the color of the louvres or the film itself. Standard colors for both film and louvres are read, white, green, yellow and blue. For highest-efficiency light control, black louvres are the most effective.

The colors and thicknesses of the display film can be silk-screened, machined, engraved or printed, and can be laminated to various substrates, including glass and transparent acrylic sheeting. For curved surfaces the film can be vacuum molded, while still retaining the light-control function. □

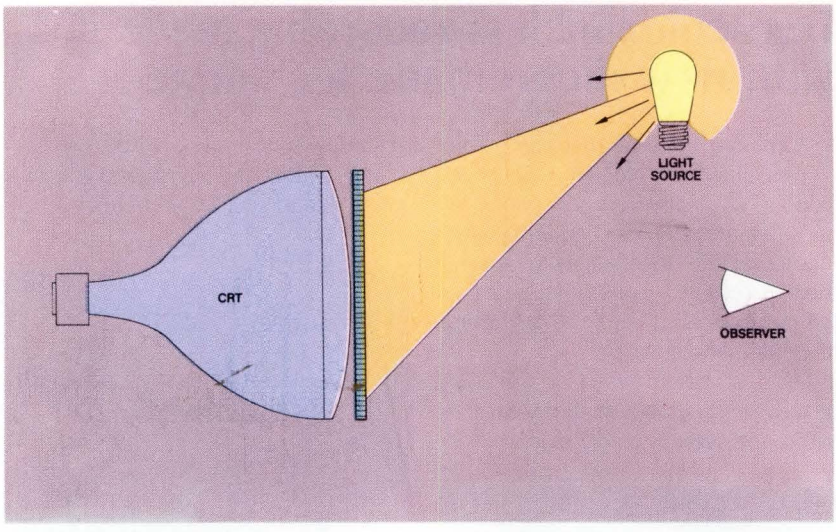


Fig. 2—In a CRT display, the display film passes the light from the CRT but blocks the unwanted ambient light.

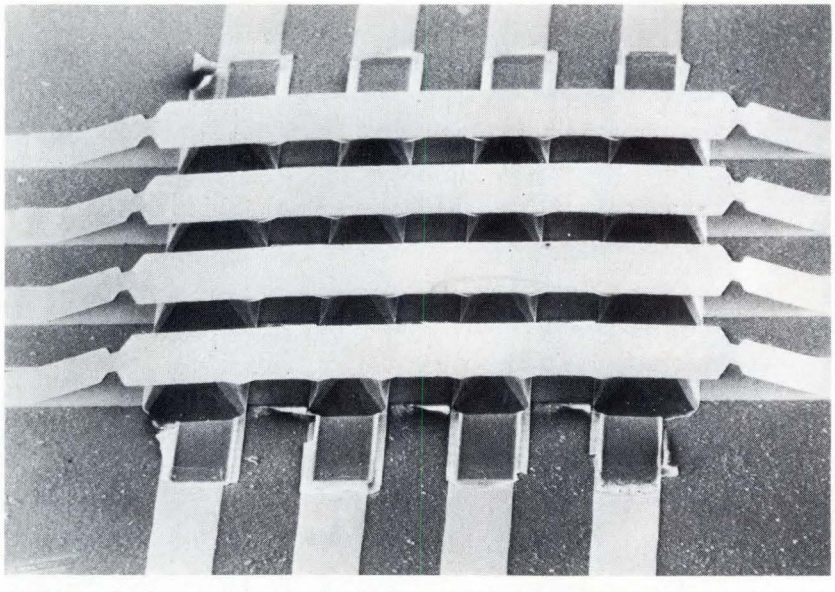
Solid-state onslought on the electromechanical crossbar continues

A new type of semiconductor switching matrix which promises to extend the bandwidth of future fully-electronic telephone switching systems has been developed by Bell-Northern Research in Ottawa, Canada. The new device, designed specifically for use in experimental switching matrices, consists of 16 PNPN diodes joined only by thin gold beams and arranged in a 4 × 4 array. Tests of the unit have already demonstrated the wide (12-MHz) bandwidth and speed advantages of solid-state crosspoints by switching a wide variety of telephone, data and video signals at the same time.

Switching matrices composed of solid-state crosspoints offer extremely high switching speeds, enabling them to interface directly with electronic central controls. Operating time for electronic switches is on the order of only 0.0003 msec, compared to about 1 msec for reed relays, 4 msec for wire spring relays and 18-70 msec for crossbar switches.

The new switching matrix provides high bandwidth by significantly reducing crosstalk. This is accomplished by using two techniques: First, beam-lead, air-isolation technology is employed to electroplate thin (0.0005 in.) gold beams over and under the diodes and to etch away the silicon chip to leave 16 isolated diodes in the 4 × 4 array, separated from electrical interference with each other by air gaps of 0.025 in. And second, a unique configuration of dummy PNPN diodes is placed in the vacant, opposite corners from station-connecting diode pairs to cancel out electrical charges transmitted along the connecting gold wires.

By employing the beam-lead, air-isolation concept, 16 diodes can be formed into a 4 × 4 unit, reducing the cost over using individual packaging. In addition, by attaching sixteen of the 4 × 4 PNPN arrays onto a ceramic substrate approximately 2 in. by 2 in. in size, an experimental switching matrix card of 256 crosspoints is attained, further reducing packaging costs. Five of these ceramic arrays of PNPN crosspoints (1280 diodes) with a present size of about 2 × 2 × 3 in., would be roughly equivalent in capacity to a large crossbar (1200 crosspoints) of size 35 × 9 1/2 × 5 1/2 in., but with significant speed and flexibility advantages. □



Gold beam-leads over and under the diodes are used in the new switching matrix, shown here greatly magnified. Spacing between diodes is 0.025 in.

More TI integrated circuits are
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More TI integrated circuits are used in today's electronic systems than any other brand in the world. And for the reasons you'd expect: Technology. Volume. Price. Breadth. Dependability. Service. Quality. Weigh them all when you buy low-power logic.

SCHOTTKY

TI announces low-power Schottky MSI: 10 ns at less than 2 mW.

TI's new low-power Schottky TTL line provides all the performance of low-power TTL (Series 54L/74L) with increased speed of 10-ns/gate and power dissipation of less than 2 mW.

Improved performance in power-critical applications

Low-power Schottky offers greatly improved speeds in portable or remote systems, or in any application where minimum power is a prime consideration. Compared to their low-power TTL counterparts, low-power Schottky circuits require less than 1 mW/gate more power—but offer a three-fold increase in gate speeds.

Typical Speed/Power Performance Comparison

Family	54H/74H	54/74	54S/74S	54L/74L	54LS/74LS
Average Propagation Delay (ns)	6	10	3	33	10
Average Power Dissipation (mW)	22	10	19	1	2
Speed/Power Product (pJ)	132	100	57	33	20

Full compatibility

TI's new low-power Schottky series is compatible with all TTL—standard, high-speed, low-power and Schottky. Together, these TI families offer more than 250 integrated circuit functions with compatible logic levels, voltage swings and noise margins. No interface circuits or level shifters are required.

Broad MSI line available now

TI's low-power Schottky TTL line now includes 13 high-complexity functions. These circuits offer you the full benefits of MSI design—fewer packages, smaller PC boards, fewer system interconnections—all contributing to lower component and system costs per gate, plus added reliability.

And within weeks, TI will introduce a full line of low-power Schottky SSI, including 13 gates and eight flip-flops.

Here are the MSI functions available now:

	DESCRIPTION	TYPICAL SPEED	TYPICAL POWER (mW)	100-PIECE PRICE
SN74LS83N	4-bit full adder	35 ns	80	$ 3.51
SN74LS95AN	4-bit left-right shift register	30 MHz	52	4.78
SN74LS138N	3 to 8 line decoder. 1 to 8 line demulti-plexer	20 ns	30	4.78
SN74LS139N	Dual 2 to 4 line decoder. Dual 1 to 4 line demultiplexer	20 ns	35	4.78
SN74LS153N	Dual 4 to 1 data selector/multiplexer	15 ns	35	4.78
SN74LS155N	Dual 2 to 4 line decoder	20 ns	30	4.78
SN74LS181N	Arithmetic logic unit/ function generator	30 ns	105	25.85
SN74LS194N	4-bit bidirectional universal shift register	30 MHz	60	4.78
SN74LS195N	4-bit parallel-access shift register	30 MHz	52	4.78
SN74LS196N	Presettable decade counter	30 MHz	55	4.78
SN74LS197N	Presettable binary counter	30 MHz	55	4.78
SN74LS253N	3-state version of SN74LS153	20 ns	45	5.74
SN74LS295N	3-state version of SN74LS95A	30 MHz	60	5.74

Immediate availability

Low-power Schottky circuits are available in the plastic dual-in-line package. Evaluation quantities are available immediately from your authorized TI distributor or direct from factory inventories. Production quantities are available four weeks ARO.

Send for data sheets

For complete information on TI's new, low-power Schottky family, circle 210 on the Reader Service Card. Or write Texas Instruments Incorporated, P. O. Box 5012, M/S 308, Dallas, Texas 75222.

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More TI integrated circuits are used in today's electronic systems than any other brand in the world. And for the reasons you'd expect: Technology. Volume. Price. Breadth. Dependability. Service. Quality. Weigh them all when you buy high-speed logic.

SCHOTTKY

TI announces more Schottky MSI:

decoders, D-registers, shift registers, multiplexers and arithmetic elements.

In any logic form, complexity is the key to low system cost, maximum performance and reliability.

You'll find your best choice of high-complexity, high-performance Schottky TTL circuits at TI – now and in the future.

We've just added more MSI circuits to the 3-ns 54S/74S line (nearly doubled it) and all are in volume production now.

Your best high-performance logic choice

TI's Schottky TTL reaches back through the evolution of transistor-transistor logic for reliability, design simplicity, volume availability, low cost and versatility – and combines these advantages with superior performance previously achieved only with unsaturated logics.

Here are the benefits of designing with TI Schottky MSI:

- Improved system speeds – internal-gate propagation delays as low as 1.5 ns, with an average of 2.4 ns.
- Reduced power dissipation – as low as 8 mW/gate, with an average of 13.7 mW.
- Total compatibility with all other 54/74 TTL families.
- Design rules similar to 54H/74H TTL.
- Guaranteed operation over full military (–55°C to 125°C) and industrial (0°C to 70°C) temperature ranges.
- Full package range – plastic and ceramic DIP and flat pack.
- Fewer system interconnections for increased reliability.
- Fewer packages, smaller PC boards.
- Lower component and system costs per gate.

For new systems – or easy upgrading of existing designs

Not only can new systems incorporate the performance advantages of Schottky MSI, but existing designs can in many cases be upgraded by replacing 54/74 MSI functions with a pin-compatible, functionally identical 54S/74S version.

TI's Series 54S/74S Schottky TTL is totally compatible with all TTL...standard, high-speed, low-power and low-power Schottky. Together, these TI families offer more than 250 integrated circuit functions with compatible logic levels, voltage swings and noise margins. No interface circuits or level shifters are required. In addition, Schottky TTL will interface directly with DTL and most low-threshold MOS.

Broad choice of functions

Series 54S/74S offers you 17 MSI functions, supported by an SSI line that includes 13 gates, a power buffer, a line driver, and 4 dual flip-flops. MSI circuits available now include:

100-MHz Shift Registers/Storage Registers

SN54S/74S174	Hex D-type storage register
SN54S/74S175	Quad D-type flip-flop, complementary outputs/clear
SN54S/74S194	4-bit bi-directional shift register
SN54S/74S195	4-bit parallel-access shift register

Arithmetic Elements

SN54S/74S86	Quadruple Exclusive-OR
SN54S/74S135	Quadruple Exclusive-OR/NOR
SN54S/74S181	4-bit arithmetic logic unit and function generator
SN54S/74S182	Carry look-ahead generator for SN54S/74S181

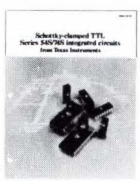
Data Selectors/Multiplexers

SN54S/74S151	8 to 1-line
SN54S/74S251	8 to 1-line with tri-state outputs
SN54S/74S157	Quad 2 to 1-line, true output
SN54S/74S257	Quad 2 to 1-line with tri-state true outputs
SN54S/74S158	Quad 2 to 1-line, inverting output
SN54S/74S258	Quad 2 to 1-line with tri-state inverting outputs
SN54S/74S153	Dual 4 to 1-line

Decoders/Demultiplexers

SN54S/74S138	8 to 3-line
SN54S/74S139	Dual independent 2 to 4-line

Send for brochure



For details on TI's TTL Schottky family, get a copy of Bulletin CB-147. Circle 211 on the Service Card or write Texas Instruments Incorporated, P. O. Box 5012, M/S 308, Dallas, Texas 75222.

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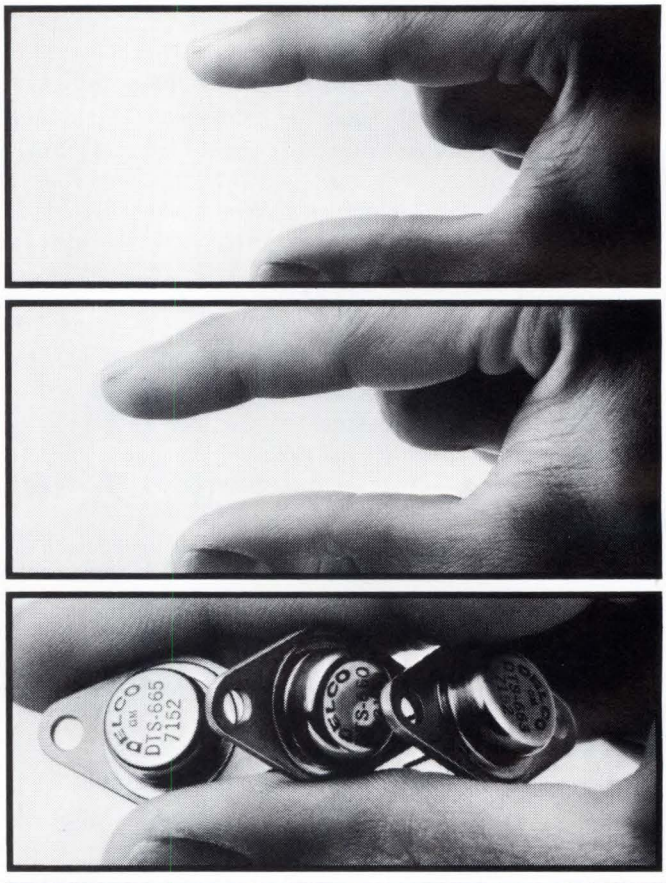
Delco's TO-66 silicon transistors for BIG POWER



Now the high-energy capability of Delco's silicon power transistors is available in the TO-66 package.

Like all the Kokomoans' silicon power transistors, they're triple diffused and built to survive the most rugged applications. Their high-voltage ratings make it practical to operate them directly from rectified 117-volt or 220-volt ac line. This allows lower weight and smaller circuit size because fewer, less bulky components are required than with low-voltage higher current systems. And, their energy capability is backed by the surest rating in the business—Pulse Energy Testing.

Use the new DTS-660 series when you need the high-voltage capability of our DTS-410, DTS-423 or DTS-425 but, in TO-213MA (TO-66) size.

They're in stock at Delco distributors now. For additional information, prices, and complete data, give yours a call or contact us at our nearest regional office.

Type	I_C(Cont)/(Peak)	V_{CEO}	h_{FE} @ I_C=1.0A min./max.	V_{CEO}(sus) min.	P_D min.	Suggested resale price 1-99 quantity
DTS-660	3.5A / 10.0A	200V	30 / 90	200V	60W	$5.93 ea.
DTS-663	3.5A / 10.0A	400V	30 / 90	325V	60W	$9.57 ea.
DTS-665	3.5A / 10.0A	500V	30 / 90	400V	60W	$14.94 ea.

NPN triple-diffused silicon transistors in JEDEC TO-213MA (TO-66) packages.

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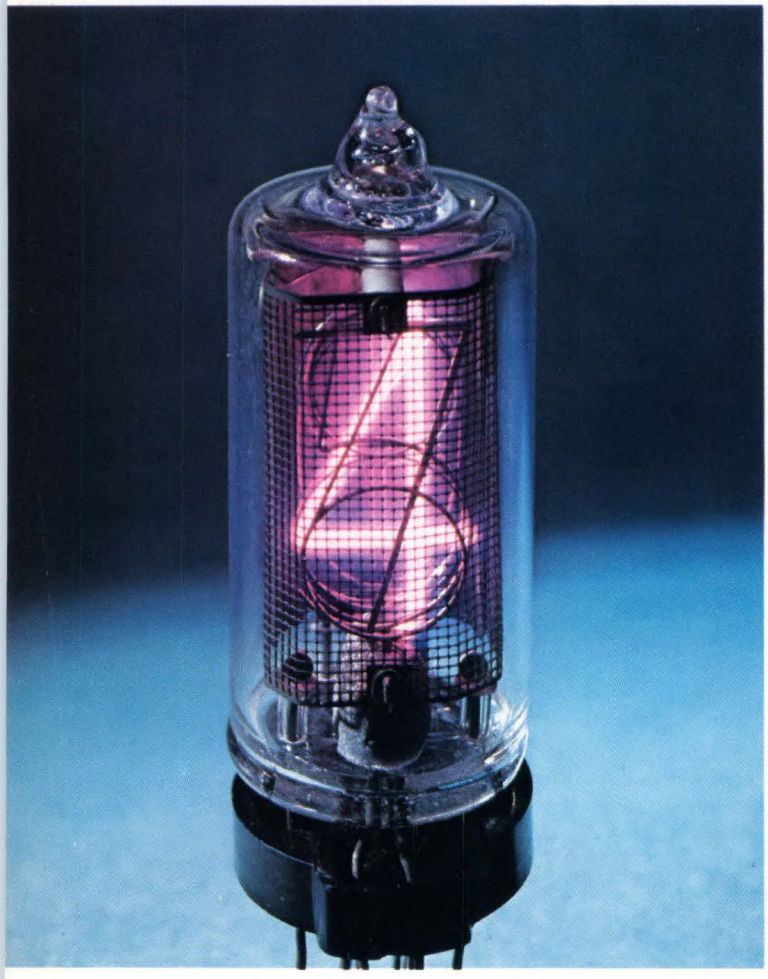
CIRCLE NO. 13

An instrument designer looks at Nixie,™ LED and liquid-crystal displays

When should you use an LED display? One with "Nixies"? The new liquid-crystal type? Consider these factors when deciding which one best fits your application.

James Masatsugu, Digilin, Inc.



The "daddy" of all digital readouts: The Nixie tube.

As you might expect, no one type of digital readout device is best for every application. "Nixies" are fine when you want a low-cost readout, and have line power and space available. LEDs are unbeatable for situations where the ambient temperature range is very wide, vibration and shock are severe, small character size is desired and a 5V logic supply is available. Liquid crystals are particularly suitable for battery-powered instruments. They provide good readability in direct sunlight and are ideally suited for interface with MOS circuits.

Any type of display that you consider, though, must be studied and evaluated thoroughly if you hope to make the right choice.

To make it easier to pick the most suitable one, we will look at the three from several angles. First, we'll review a sample of what is currently available. Second, we'll compare display types on several separate bases such as COST and LIFE. Finally, we'll look at them in a summary chart.

Gaseous-discharge devices

First of the three types to reach the market, and still in use with little obvious change from the original offering over 15 years ago, are the "Nixies". They have always been a highly readable device, but with the obvious drawback of not having the numerals in one plane. Instead, the numeral electrodes are physically stacked within the envelope, which causes the display to jump in and out as the digits are changed, and limits the useful angle of view.

"Nixies", and other more recently introduced gaseous-discharge devices, continue to enjoy a large share of the readout market. They offer long proved life and low price.

Typical units offered. Burrough's B5750 Nixie tube with 0.5-inch-high characters is representative of today's conventional gaseous discharge devices. Housed in a round glass "tube" envelope, it requires the usual high ionization voltage (170V max). Another representative nonsegmented type is the Amperex ZM-1000 that has 0.55-inch characters and is contained in a slightly larger envelope.

A very different device line is offered by Sperry-Rand. Their units have flat-plane 7-segment characters, and are offered in 1-1/2-, 2- and 3-digit packages. Characters are 0.33 inch high for the SP-730 series, or 0.55 inch high for the SP-750 series. All gaseous-dicharge types require a high-voltage supply. The SP-730 series devices give a display that, in character size, resembles that of Monsanto's "MAN 1" LED readouts.

LED displays edge in

LED displays have taken over an appreciable part of the display business in the last year or so. Much of this is new, (not robbed from other types), and has come about because of the properties that distinguish LED devices: high reliability, long life, "superfast" response time, operation from low-voltage dc and ready adaptability to miniature displays.

Monsanto's "MAN 1" was among the first commercially-available LED numerical displays. It featured 0.27-inch-high 7-segment readout in a 14-pin DIP package. Several other manufacturers now offer a pin-for-pin replacement, making this type somewhat of a standard. It started out at $45 but is now down to $7.50/digit (1000 lots). Also, during the last 2 years several LED displays with different character size and configurations have emerged.

Texas Instruments and Hewlett-Packard both offer LED numeric displays that have TTL-compatible logic circuits contained within the same package.

Texas Instruments' model TIL 306 contains a 0.27-inch-

™Nixie is a registered trademark of Burroughs Corp.

high, 7-segment LED readout, a BCD counter, a 4-bit latch, and a decoder LED driver—all in one 16-pin DIP package. Their TIL 308 is identical to the TIL 306 except that it lacks the decade counter. The TIL 306 sells for approximately $12 each in 1000-piece quantities. Hewlett-Packard's 5082-7300 series units feature a 4-by-7 LED dot-array numerical character 0.29 inch high, and an MSI, TTL-compatible, 4-bit latch-decoder-driver circuit. They are priced at $10 a digit in 1000's.

These configurations cut package size and help minimize the number of interconnects to the display. However, as yet, they do not offer any real cost advantages. In fact, replacement cost could increase, for a failure in the readouts makes the logic circuits worthless and vice versa.

Smaller LED readouts, which use less GaP and GaAsP material, are becoming increasingly popular. In hand-held instruments like an electronic calculator, their small size (0.1- to 0.2-inch-high characters) becomes more of an asset than a liability. Power, cost and package size are reduced, and their inherent long life and ruggedness given them a definite edge in this market. The Monsanto "MAN 3" display has an 0.115-inch-high, 7-segment character and requires less than 160 mW of power. Its compact size permits mounting 16 digits in a 3-inch span. Others include the Litronix "Data-Lit 8" with 0.25-inch characters, and the Fairchild FND10 with 0.122-inch characters.

Recently, HP introduced the 5082-7400 series 7-segment monolithic LED readout. This display is similar to their 5082-7200 line, which features five digits in a 14-pin DIP package, except that it uses a unique integrally-molded lens. This lens magnifies the character height by a factor of 2, which reduces the amount of GaAsP material required and considerably lowers the cost of the display. What the viewer sees is a display with an apparent height of 0.112 inch, with no visible hint that a magnifier lens is in use. These units must be strobed, but offer very low (7 mW/digit) power consumption. Price is in the range of $2.25 per digit in quantities of 100,000.

LED displays can be made to look larger than their actual physical size by the use of magnifying lenses. This technique is used in the readout of the Hewlett-Packard Model 35 hand-held calculator.

LED numerical displays first became available about 3 years ago when Monsanto introduced its MAN-1, which is used in this DPM.

To counter this intrusion by the LEDs, Burroughs introduced their 8-digit "Panaplex II" gaseous-discharge panel display. This display can be driven by MOS circuits and bears a per-digit tag of $1 in 500,000-digit quantities. Height of the 7-segment characters is 0.209 inch. Power consumption is approximately 21 mW/digit and the display can only be operated in the multiplexed mode.

The advent of the liquid-crystal display brings still another serious contender into this volatile market. Commercial units in any quantities are still very difficult to obtain.

Liquid crystals—fast emerging

Liquid-crystal displays differ from "Nixies" or LEDs in that they do not emit any light. As a result, they cannot be seen in low ambient light without the aid of external backlighting.

There are two basic types of liquid-crystal displays, transmissive and reflective. Transmissive crystal displays are normally used where low ambient light conditions may exist. Such a display is made with both glass sheets clear, so that the auxiliary light can shine through. What is desired for use here is a backlighting technique that allows diffused light to shine through the display at certain angles, and which presents a dark background to the viewer. A cool white fluorescent lamp, about the most efficient backlighting source, gives one of the more aesthetically pleasing displays. Power consumption of the transmissive liquid-crystal display is largely dictated by the power required for the backlighting source.

Reflective-crystal displays are made with a sheet of clear glass and a sheet of glass coated with silver or some other reflective material. The coated sheet (used in the rear) reflects incident light to enhance the display. With this type, the higher the ambient light level, the better the display. Since power consumption is that of the display alone, it totals less than 700 μW/digit.

Most liquid-crystal displays require ac rather than dc drive if they are to have reasonable display lifetimes. Drive voltage is typically 24V at 50 to 200 Hz. Typically, the backplane of the crystal is driven by a 24V pk-pk square wave with 50% duty cycle. Segments that are not to be energized receive, from the decoder outputs, a drive signal in phase with the backplane. To drive segments, a 180° out-

of-phase square wave is applied to them. A special MOS chip is normally required to generate and decode this ac drive signal. No such item is commercially available today, although several manufacturers are currently working on them. Also, because MOS technology is being used, more manufacturers are now including their specialized digital functions on the same chip so they can minimize size, power and cost. Liquid-crystal displays offer a cost advantage that is difficult for LED and "Nixie" manufacturers to combat. Raw materials for the liquid-crystal devices—the nematic liquid crystal and tin-oxide-coated glass—are relatively inexpensive. Once manufacturers have perfected the critical sealing technique and their production lines are fully set up, the cost per digit is likely to drop below $0.50.

Optel was first on the market with a liquid-crystal display. Their offering was a 3-digit module with 0.45-inch-high characters. Price is $5 per digit on a 1000-module order. Several other formidable competitors are emerging, among them North American Rockwell Microelectronics Co. (NARMEC), American Microsystems, Inc., and RCA Solid State Div. These companies also can offer the MOS circuits, custom or standard, along with their liquid crystal displays. The advantage of this is that the buyer can be assured of a compatible interface between the MOS and the liquid-crystal display.

Both NARMEC and AMI have been supplying calculator chips to foreign and domestic manufacturers and now are manufacturing compatible liquid-crystal displays. AMI offers an 8-digit display with 0.32-inch characters, and a 12-digit unit with 0.84-inch-high characters.

Clearly, there are many types, kinds and sizes of displays competing for each designer's business. The trick is to find the best one for a particular application, while keeping a sharp eye out for new developments that might change the picture.

One of the three display types we are discussing in detail probably will serve for most any application, but other types could be equally advantageous. For instance, there are incandescent segmented displays that compare quite well with LEDs on the basis of character size, drive requirements, power consumption and price. Another type that has had considerable acceptance is the fluorescent segmented. This shares mounting ease with "Nixies," uses low-voltage dc power, and its display is an easy-on-the-eyes blue-green color.

Whichever type you consider, the best approach is to try it in your instrument, for this is the only way to be sure that it really fits your needs.

COST

Probably the single most important factor that influences the choice of a display is its cost. Comparisons, to be valid, must be on total cost and not on the price of the readout alone. That is, they must include all necessary adjuncts such as the decoder/driver and the power supply. These additional considerations are what complicate the choice.

Gaseous-discharge devices

Looking at the price of the display plus its driver, the gaseous-discharge "Nixie" is one of the most price-competitive types on the market today. The price is less than $2/digit in 1000-digit quantities. The BCD-to-digital decoder/driver adds about $1.56 each in the same quantities.

"Nixie" displays, like those used in this Digilin DPM, have proven, useful lives in excess of 100,000 hours.

Another highly competitive type of gaseous-discharge device is Sperry-Rand's SP-730 and SP-750 series of segmented displays. These were introduced at $2.52/digit in 1000-digit lots, plus $1.55 each for the companion DD-700 monolithic decoder-driver.

Because the useful life of "Nixies" has been proven (by actual life tests) to be in excess of 100,000 hours, it is unlikely that many users will need to replace their display tubes during the normal life of the instrument in which they are installed. However, tubes can be broken during either instrument production or shipping, which could make replacement costs significant.

A further cost item to be noted is the high-voltage power supply that must be used with gaseous discharge devices. If the instrument is to be line powered, this is a relatively minor factor, but when battery power is necessary it may become a major consideration.

LED displays

Those who followed transistor prices in the first few years will see a direct parallel in what has happened to LED prices over recent months. Competition, mushrooming demand and automated production have all helped make prices drop drastically. In 1969 Monsanto's "MAN 1" sold for around $45 per digit. Today it is at the $7.50 point in 1000-digit lots, plus $1.65 for the matching BCD-to-7-segment decoder/drivers. To this must be added the cost of eight external current-limiting resistors that are required per digit. Further price reductions on LED displays are certain, but will be less dramatic unless the cost of GaP and GaAsP materials is lowered. One final factor that favors LEDs is that they work from a low-voltage dc power supply, so they can often share a 5V source with logic circuits.

Another factor affecting LED prices is the industry's drive to achieve equal or greater light output from units that use less material. One approach that is practical with GaP is optical in nature, and consists of using reflectors to increase the apparent emitting area (and thus the amount of useful light).

Opcoa has employed this to form apparently rectangular display segments from single small-area diodes.

Another material-saving technique is to use magnifying lenses to give large apparent character size while using smaller actual emitting elements. This was very successfully employed by Hewlett-Packard in the display of its vest pocket Model 35 scientific calculator.

Latest contender—the liquid-crystal devices. Almost nonpower-consuming, and potentially capable of selling for as little as $0.50 a digit, these newest display devices are beginning to reach competitive price status.

CHARACTER SIZE AND CONFIGURATION

In "Nixies," 10 individual characters are stacked, in a certain sequence, from front to back. Each is a separate addressable cathode. This sort of device is electrically and mechanically simple, but does produce an undesirable "in-and-out" movement as characters are switched. It also limits the vertical and horizontal viewing angles.

Characters are aesthetically pleasing. Unlike those in most LED displays, they are complete at the corners, and the segments are continuous rather than being made up of bar or dot elements. In the Amperex ZM1000, the decimal point is located to the left of the characters, while the Burroughs B 5750s have one located on each side.

Character sizes from 0.3 inch to 2 inches are available in a variety of glass envelope packages. Some are furnished with wire leads for soldering in directly, while others are intended for plugging into tube sockets. The socket concept allows for easy removal or replacement and the sockets can be cushion-mounted to help absorb mechanical shock.

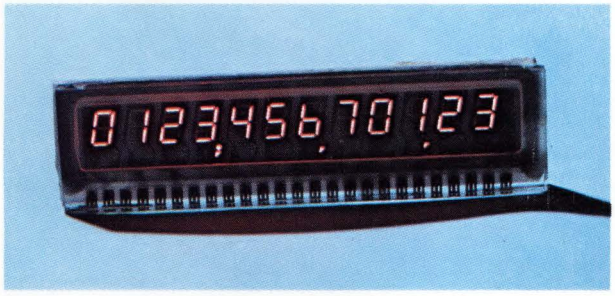
LED displays

Most LED readouts are constructed with seven segments mounted in a single plane. These are excited in various combinations to form the 10 numerical characters. Some, such as the Monsanto "MAN 1", are connected with a common anode. Others—among them the Monsanto "MAN 3" and "MAN 4", and the Fairchild FND 10 and FND 7—employ a common cathode.

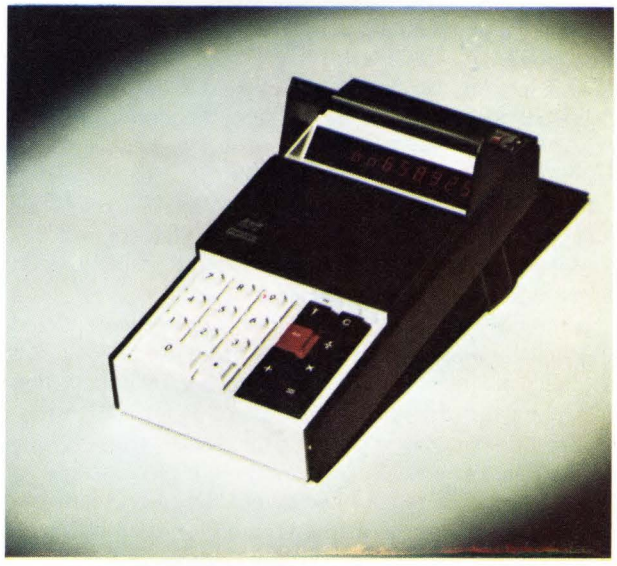
Unlike the "Nixie", with its one-piece characters, which is "fail safe" because the failure can be easily detected, segmented LED devices can give incorrect readings as a result of either segment diode(s) or decoder/driver failure. Thus, a failure of the center bar of the figure "8" to light will change the displayed numeral to a "O". To help avoid such false readings, most decoder/drivers incorporate a LAMP TEST input to verify that all segments are operating.

Another approach that makes false readings less likely is to form the characters with a dot array. One such display is the HP 5082-7300, which has a 4 by 7 dot matrix.

Currently-available LED displays range in character height from nearly an inch to less than 0.1 inch. The two most common sizes are 0.27 to 0.25 inch ("MAN 1" and others) and 0.125 to 0.1 inch ("MAN 3" and others).



MOS compatibility and power consumption of 21mW/digit characterize Burroughs' "Panaplex II" gas-discharge panel display.



In the flat-plane, gas-discharge displays of Sperry-Rand, the digits appear to be continuous, even though each is actually made up of 7 discrete segments.

Liquid-crystal displays. These also use 7-segment characters that can readily be tailored to meet the user's requirements for height, width, angular tilt and decimal point location. It is usually not practical to make single-digit liquid-crystal displays, for the manufacturing cost is nearly the same for any number of digits up to about eight.

One 3-1/2-digit liquid-crystal display now being produced by American Microsystems has 0.65-inch-high characters, while character height in their 8- and 16-digit displays is 0.32 and 0.84 inch, respectively. The maximum feasible size for a liquid-crystal display is primarily limited by the quality (flatness) of available glass. The 10.8-inch-high by 1.64-inch-high by 0.25-inch-deep package of American Microsystems' 16-digit unit is about as large as is commercially feasible today.

READABILITY

Digital displays have two major advantages over conventional analog meters: they can be made readable at a considerable distance, and the reading accuracy is not dependent on interpolating skill.

Typical analog meters must be read from distances of less than 2 or 3 ft and with the reader positioned at a specific angle with respect to the meter face and pointer, if accuracy is to be had. Not only that, but the reader must be able to interpolate properly if the greatest possible resolution is to be obtained.

Contrast these analog meter reading limitations with the utter simplicity of observing a digital display. Here, if you can read the numerals, the reading is accurate within the accuracy of the instrument. Of course there are some limitations, such as reading distance. "Nixies" with 0.5-inch character height can easily be read at distances up to 25 ft if the ambient light is not too bright. Similarly, an LED display with 0.25-inch characters is readable to about 10 ft.

Liquid-crystal displays can be read at distances essentially the same as for "Nixies" with the same character height. They are unique in that when operated in the reflective mode they give ideal viewing with high levels of

ambient lighting. Equally unique is that they are useless in situations where there is too low a level of ambient light, such as in a lab that has been darkened to aid in studying faint oscilloscope traces. For the latter situation a transmissive display should be used—and this type is useful in both high and low ambient light levels.

Contrast. Regardless of the type of display, a key factor affecting readability is contrast. A good high-contrast display that is only moderately bright is more usable than an excessively-bright one with poor contrast.

To improve contrast, and often to reduce the cluttered appearance, most types of displays make use of some sort of filter. This often is made more effective by polarization and by having it contain a color dye that favors transmission of the light color emitted by the device. Thus "Nixie" displays are often made easier and more pleasant to read by using a red or amber filter. With LEDs, a circularly-polarizing red filter is normally required for good character definition and contrast ratio under medium and high ambient lighting. Liquid-crystal displays—at least the reflective type—do not need filters because their contrast ratio increases with increasing incident light.

Viewing angle. Often overly stressed in comparisons, the angular range over which a display can be read is also difficult to specify. Of the three types of displays, "Nixies" have the most restricted angle of viewing. This is generally given as about 100°, but can vary quite a bit depending on their physical mounting and the placement of a filter. LEDs and liquid crystals are usually specified as having about a 150° useful angle, but with the transmissive liquid-crystal displays there may be a reduction of the vertical viewing angle because of the backlighting source.

MOUNTING EASE

Mounting considerations play an important part in the choice of a display device, especially if it is to be used in low-priced equipment. Some display types are relatively easy and inexpensive to mount, but others call for both ingenuity and a flexible budget before they can be made to serve. Too often mounting considerations are ignored in the design stages, which is the very time when they should be settled. Waiting until later can be costly in materials, in time and in a less satisfactory product.

Usually displays should be mounted so they are most easily read from the normal viewing angle. For panel or rack mounted instruments, this means mounting them vertically. "Nixies" or other tube mounted devices are best suited for this situation, for their display is in line with the mounting wires or pins and they are easy to mount to a main horizontal PC board. LEDs, on the other hand, generally require mounting on a second PC board that plugs into some right-angle interconnect. This becomes expensive if the number of interconnect leads exceeds 25—as it would, for example, with a 3-digit nonmultiplexed 7-segment display that must have 29 leads between it and its decoder/drivers and power supplies.

Liquid-crystal displays present somewhat of a problem to mount in any position. The glass plates are usually 1/8 inch thick, and no suitable edge-card connectors are currently available. Also, liquid-crystal interconnects are tin-oxide leads etched on glass, so solder cannot be used. Careful design is required to minimize abrasion of the interconnects. Fortunately, a fairly high contact resistance is tolerable because the device is one of low-current and high-impedance.

Fig. 1 shows a very satisfactory mounting scheme devised for one of Digilin's instruments. Inexpensive pin material was used for the especially designed right-angle connector. This design eliminates the need for any soldering, and provides a simple, inexpensive disconnect that permits easy insertion and removal.

Hand-held or benchtop instruments usually require a display that is tilted slightly from the horizontal. Here it is easier to mount LED displays than to work with the tube-type ones such as "Nixies."

USEFUL LIFE

With LED and liquid-crystal displays, only estimates or educated guesses can be made as to their lifetime. However, "Nixies" have been around long enough to have proved their useful life, which is in excess of 100,000 hours (10 years) under normal operating conditions.

"Nixies," once they have passed a screening for infant mortality and malfunctioning, usually have relatively few catastrophic failures. Aside from failure caused by mechanical damage, or resulting from faulty assembly, "Nixies" usually deteriorate through sputtering from the active cathodes. This weakens the structure, and the material deposited on other electrodes can produce areas of spurious glow. This type of deterioration is hastened by operation at high cathode currents or in high temperatures.

LED display life expectancy is anticipated to be over 250,000 hours, based on accelerated life tests. One failure mode of LEDs occurs when the junction dissipation rating is exceeded. Just as with a transistor, this can cause sudden catastrophic end of life. Another instant failure can result from improper mechanical bonding. This is most likely to show up under temperature cycling over the specified operating temperature range.

Barring catastrophic failures, LED light output is believed to decrease very slowly during the anticipated lifetime, and the figure of 250,000 hours does not necessarily represent the end of useful life. It usually is defined as the point at which light output is expected to have dropped to half its original value.

Unlike the LED manufacturers, those who make liquid-crystal displays are usually quite conservative in specifying lifetime, particularly when they don't have adequate sup-

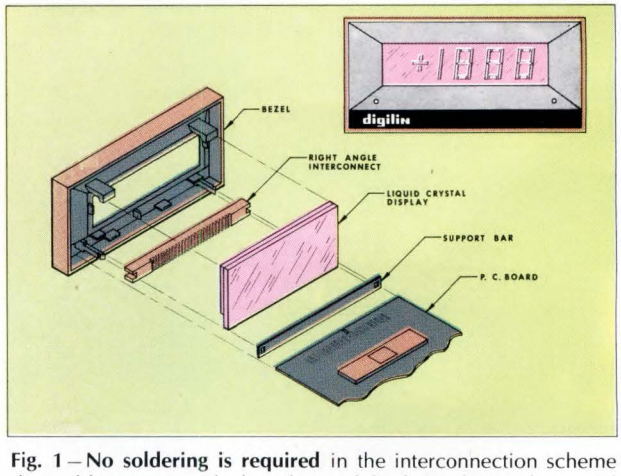
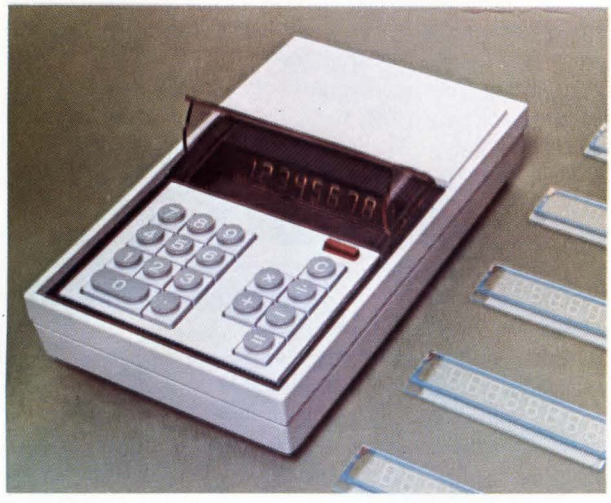


Fig. 1—No soldering is required in the interconnection scheme devised for mounting the liquid-crystal display in the Digilin Model 4352 DPM.



A liquid-crystal display is used in this prototype calculator being made for Lloyd's Electronics of California by North American Rockwell Microelectronics Company.

porting data. Minimum lifetime of 10,000 hours can be guaranteed today, although some manufacturers believe that 50,000 hour life is readily achievable. The uncertainty comes from a lack of both adequate test data and operating experience.

The end of life is usually based on aesthetic aspects rather than being of sudden and final nature. Display degradation is believed to be caused by de-ionization of the liquid crystal material. Dc drive hastens this, so an ac (usually square wave) drive is usually specified for long life. The frequency chosen for the square-wave drive is commonly between 50 and 200 Hz.

Segment failure is quite unlikely with liquid-crystal displays. What does occur is more likely to be a slow trend toward the display being on continuously, so that the end of useful life becomes a matter of opinion as to when the display is no longer easy to read.

Liquid-crystal materials are relatively cheap, and only small quantities of them are used per display. Also, the other component—the tin-oxide-coated glass—should be available at considerably lower prices as soon as the demand for it creates competition among the suppliers.

Standard decoder/drivers are not yet commercially available, but should be soon, particularly since liquid-crystal displays are highly MOS-compatible. Already, some custom MOS circuits that do more than just decoding and driving are emerging. One of these has a 3-1/2 decade counter-decoder/driver on a single chip. Another, built by American Microsystems Inc., drives a liquid-crystal display in a clock. It performs all of the functions of an electromechanical unit—and is on a single P/MOS chip.

Such IC technology drastically reduces material cost, assembly labor and the size of the device. It also offers further savings because of decreased power requirements, greater reliability and faster troubleshooting and repair.

POWER CONSUMPTION

It costs money to provide power, but equally important are the numerous indirect ways in which the power consumption affects instrument designs. For example, power consumption has a direct influence on both the package size and the materials that can be used for its construction.

When power consumption is low, plastic or other inexpensive materials can be employed without concern about their heat insulating properties. This leads to smaller, lighter and more portable construction—and possibly to more pleasing or distinctive appearance.

Higher power consumption calls for the use of heat-conducting (and radiating) package design. This usually requires that it be constructed of aluminum or other relatively heavy materials. It is also likely to result in increased product size and cost.

LED displays. Of the three display types we are comparing, the LEDs normally require the most power. This is true despite the fact that their character size is generally smaller than that of the gaseous-discharge types. With most LEDs, the emitted light intensity is proportional to the amount of current passed through them. This permits several options, including wide-range control of display intensity and practical operation in a strobed mode.

As an example of the power consumption of LED displays, Monsanto's 0.27-inch-high "MAN 1" requires 20 mA per segment (160 mA per digit if the decimal point is included). A 5V supply is normally used, even though individual diode drops are only around 1.6 to 1.7V at normal operating current. The balance of the 5V is dissipated in series resistors, which seems like an inefficient approach until it is realized that it provides the LEDs with essentially constant current drives.

To the 800 mW power per LED digit must be added that used by the decoder/driver. A standard BCD-to-7-segment decoder/driver consumes around 300 mW when operated from a 5V supply. Thus the total per-digit consumption of the "MAN 1" is about 1.1W.

Multiplexing of LED displays is both practical and effective, but does not appreciably lower the total power consumption. It does increase luminous efficiency, with some resultant power savings, but normally requires peak currents of 50 to 80 mA per segment.

Aside from improving the basic efficiency of the LEDs (increasing the light emitted per watt of dissipated power) there are only three general ways to reduce power consumption: decrease the character size, make-do with a lower light intensity, and use a form of drive that reduces the power normally wasted in the dropping resistors. In a monolithic 5-digit, 7-segment LED display recently intro-

Low-power consumption, especially for the reflective-types, is one of the major advantages of liquid-crystal displays.

duced by Hewlett-Packard, power consumption was reduced in several ways: decrease of character size, use of a unique integrally-molded lens containing a red dye that increases contrast by absorption of all visible wavelengths except those emitted by the LEDs, and employment of a form of strobing that operates from a 3.8V supply and incorporates an energy-storage device instead of dropping resistors. These combined steps reduced the total power consumption to a remarkably low 7 mW per digit.

"Nixies" require a 200V (dc) supply, and draw 3 mA per numeral anode and 0.3 mA for the decimal point. The BCD-to-decimal decoder/driver chip requires approximately 75 mW, making the total power consumption approximately 735 mW per digit.

Liquid-crystal displays. Very low power consumption is where liquid crystals show a clear advantage. When the reflective mode of operation is used, total per-digit consumption is measured in microwatts, instead of the milliwatts needed for "Nixies" or LEDs. A typical figure is around 800 μW, including the decimal point.

Drive voltage is low, typically 24V pk-pk square wave at 50 to 200 Hz. This, together with the very low power consumption, makes liquid-crystal displays highly compatible with MOS devices. As an example, a 3-1/2-digit display with MOS driver chip that contains three decades of counting plus an overrange digit, plus decoder, plus latch requires less than 50 mW *total*—certainly an attractive choice for portable instruments!

Where the liquid-crystal display must be backlighted (instead of reflecting the ambient light) the reflective coating is omitted and an auxiliary light source is provided. Light from the auxiliary source shines through to illuminate the display. The power for the added light source can make the display draw as much as one using "Nixies".

How the three compare

Point of comparison	DISPLAY TYPE			
	Gaseous discharge "Nixie",etc.	Light emitting diode (LED)	Liquid - crystal	
			Reflective	Transmissive
Readability (1) Brightness	Good in low to medium ambient lighting. Acceptable in fairly high ambients with polarizing lens.	Same as the Nixies	Poor in low ambient lighting. Excellent in high ambients or bright sunlight.	Excellent under both low and high ambient conditions.
(2) Maximum viewing distance	> 25 feet	≈10 feet	> 25 feet	> 25 feet
(3) Viewing angle	Horizontal ≅100° Vertical ≅100°	≅150° ≅150°	≅150° ≅150°	≅150° ≅100°
Lifetime	>150,000 hrs	>250,000 hrs	>10,000 hrs	>10,000 hrs
Character size and configuration	0.3 to 2 inch character heights; normally 10 individual character cathodes; seven-segment configuration also available.	0.12" to 0.61" character heights; seven-segment and dot array configurations available.	No real size limitation; seven-segment configuration	Same as reflective
Operating and storage temperature	Operating: -20° to +70°C Storage: -55° to +85°C	-55° to +100°C -55° to +100°C	+10° to +90°C -20° to +90°C	Same as reflective
Response time	Turn-on: 10μsec Turn-off: 10μsec	<1μsec <1μsec	10msec 200msec	Same as reflective
Power consumption Display	660 mW/digit	800 mW/digit	800 μW/digit	Same as reflective
Decoder/driver	75 mW/digit	300 mW/digit	Counter/decoder/-driver 40mW for 3 - 1/2 digits	Same as reflective
Backlighting				≈2W for 3 - 1/2 digits
Cost Display	$2/digit	$7.50/digit	$5/digit	Same as reflective
Decoder/driver	$1.56/digit	$1.65/digit	None currently available	

RESPONSE TIME

Display response time, as discussed here, is the sum of the device's turn-on and turn-off times. This is an important characteristic, for it determines both the update rate, which is the rate at which you can refresh the display without producing erroneous or multiple display characters, and the strobing rate for display multiplexing.

Usually the response of the viewer's eye is the factor that limits the maximum update rate, for the eye can only follow changes up to a rate of about 10/sec. Because of this, display refresh rates of from 4 to 6/sec are considered ideal, though slower rates can minimize "run around" effects (last-digit toggling). Update rates of this magnitude (4 to 6/sec) require a device response time of 200 msec or faster.

LEDs have submicrosecond turn-on and turn-off times, so permit high strobing rates with low-duty-cycle pulses.

Gaseous-discharge tubes such as "Nixies" also turn on and off quickly under most circumstances. Typical "Nixie" response time is 10 μsec, and update rates of from 4 to 6/sec are ideal.

Liquid-crystal displays are the slowest of the three, with typical turn-on and turn-off times of 10 and 200 msec, respectively. Ambient temperature has considerable effect on these rates, as discussed under "Operating and Storage Temperatures." There is reason to believe that improvements in glass quality may, in the future, reduce the turn-off time to as little as 20 msec. With today's units, the ideal update rate is around 1 to 2/sec. This is adequate for most applications and may well become standard for the liquid crystal displays.

OPERATING AND STORAGE TEMPERATURES

Wide differences exist in the way that ambient temperature affects gaseous discharge, LED and liquid-crystal displays.

LED units have the widest range of operating temperature: −55 to +100°C. Their brightness is greatest at the lowest temperature, decreasing slowly as the temperature is raised. Their power dissipation must be derated from its specified value at 25°C to zero at the 100°C point. Response time is so fast that temperature influence on it can be ignored for normal applications.

"Nixies" are specified as having an operating range of −20 to +70°C, with storage permitted between −55 and +85°C. No power derating is specified, although lifetime is reduced when they are operated at the high temperatures. Their response time is not appreciably affected by temperature.

Liquid crystals are the most temperature sensitive of the three. There is no commonly-agreed permissible temperature range, because each one of the many liquid-crystal materials has its own tolerance in that respect. RCA's units have operating and storage ranges of +5 to +55°C and −20 to +80°C, respectively. AMI's are rated at +10 to +90°C for both operating and storage. Extensive testing is still being done, but most manufacturers believe that liquid-crystal displays will still be capable of satisfactory operation after exposure to more extreme temperatures. Response time of liquid-crystal displays is temperature-sensitive. Low temperatures slow the response time and higher ones speed it up. □

Short suggestions for designers

•See 'em working, before you choose. Photos of operating displays are often touched up to "improve" the display appearance.

•Be color- and vision-conscious. Some of your customers could be color blind—or the display you choose could cause user eye strain.

•Ignore published brightness specs. They aren't a safe guide for choice, so compare operating displays and judge for yourself.

•With LEDs, be sure the display you choose doesn't have objectionable brightness differences from segment to segment or digit to digit.

•Check with suppliers as to the burn-in or aging they do on their display products. If you have to do it, the cost of doing it plus the mortalities may make some other supplier's product a better buy.

•LED displays made with GaP instead of the more commonly-used GaAsP are somewhat different to apply, particularly if you are considering multiplexing. Better know these differences before judging them.

•Displays packaged in tubes (such as the gaseous-discharge "Nixies," Tung-Sol's fluorescent-segmented "Digivac" and RCA's incandescent-segmented "Numitron") often can be made more reliable by shock mounting them.

•Keep in mind that most segmented display devices are not "fail safe"—nor are their decoder/drivers. Some sort of checkout circuit may be needed when they are used in critical applications.

•Remember that multiplexing may cut display costs when permitted by the particular display device under consideration.

•Some study of basic optical principles is often helpful to the designer who has not heretofore been concerned with this technology. If nothing else, it will help when interpreting these device specifications that are optical in nature.

Author's biography

James Masatsugu is the engineering manager at Digilin, Inc., Glendale, Calif., and has been employed there for two years. He was previously with Autonetics Div. of North American Rockwell where he designed A/D and D/A converters. Jim received his BSEE from Purdue and his MSEE from California State College.

New bi-polar power-dac* solves five major system problems in automatic test equipment

*TM

A new programmable power source from the John Fluke Company solves several big system problems. Appropriately called a Power-DAC, the Models 4250A and 4265A provide up to ±65 volts at 1 amp, with a 100 micro-second settling time to 0.01% accuracy. A full complement of options provide needed flexibility in both price and performance.

1. Parallel or series operation — just like batteries

Have you ever needed just a little more current or voltage to test a new device? (Probably this slight extra capability is only needed for a very few tests.) With the 4200 Series Power-DAC, you can double, triple or quadruple your current or voltage capability by a simple parallel or series connection with external relays. No special hardware or software protection features are required. With several Power-DACs in your system you have both single unit control and unlimited power configuration at the discretion of the programmer.

2. AC or DC outputs provide versatility

In addition to the standard internal dc reference, an external reference option allows any external ac or dc signal to be used as the reference for the bi-polar D-to-A ladder network. The Power-DAC can perform many different functions within the test system. Operate it as a programmable amplifier, attenuator or multiplying DAC for either ac or dc signals up to 30 kHz. Amplitude of fixed level function generators and special purpose signal sources can be precisely controlled from microvolt levels up to 50v rms at 0.7 amp rms. By accurately controlling the level of the external reference, programming resolution can be varied from 1 millivolt to several microvolts. Either the internal or external reference is selected by a 1-bit control line. The 100 μsec settling time includes polarity change, range change and selecting either the internal or external reference.

3. Fast programmable current limiting protects circuits under test

Standard models provide a gross 1.2 amp current limit as an overload protection feature. One option provides a programmable current limit in two ranges, 100 ma and 1 amp. Each range is programmable in 10 percent steps, yielding 10 ma or 100 ma resolution. When the overload occurs, transition from the constant voltage mode to the current mode requires less than 20 microseconds, the crossover time being a function of the load. The larger the overload, the faster the transition. This fast crossover capability minimizes the energy transients to the circuits under test.

Model 4265A

4. Programming glitch reduction

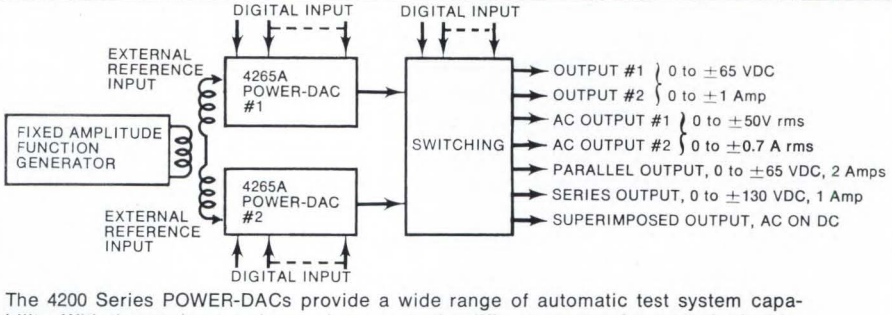
A unique track-and-hold technique during the programming interval reduces the peak glitch and transient excursions to less than 50 mv in the 16 volt range, and less than 100 mv in the 65 volt range. Transitions from computer generated waveforms or incremental slewing operations take place smoothly.

5. Isolation and guarding reduces noise and ground loops

Digital and analog portions of the 4200s are separated by a metal guard to eliminate both ground loops and digital noise which severely affect the system performance of conventional power supplies and D-to-A converters. With the isolated control logic option, impedance between the digital control logic and the analog circuits is 10^9 ohms in parallel with 3 picofarads. This isolation provides significant rejection of system noise on the analog output. Up to 1000 volts of common mode voltage can be applied between chassis ground and the guard terminal without harming the instrument, or causing severe common mode errors.

Prices and options

For $1295, the basic 4250A and 4265A are equipped with direct coupled control logic and blank front panel. The isolated control logic option which also contains a memory register for storing the program command is $300. The external reference, programmable current limit and front panel digital display options are priced at $200 each. Delivery is 30 days. For complete specifications on all 4200 Series Power-DACs, write Fluke, P. O. Box 7428, Seattle, WA 98133.

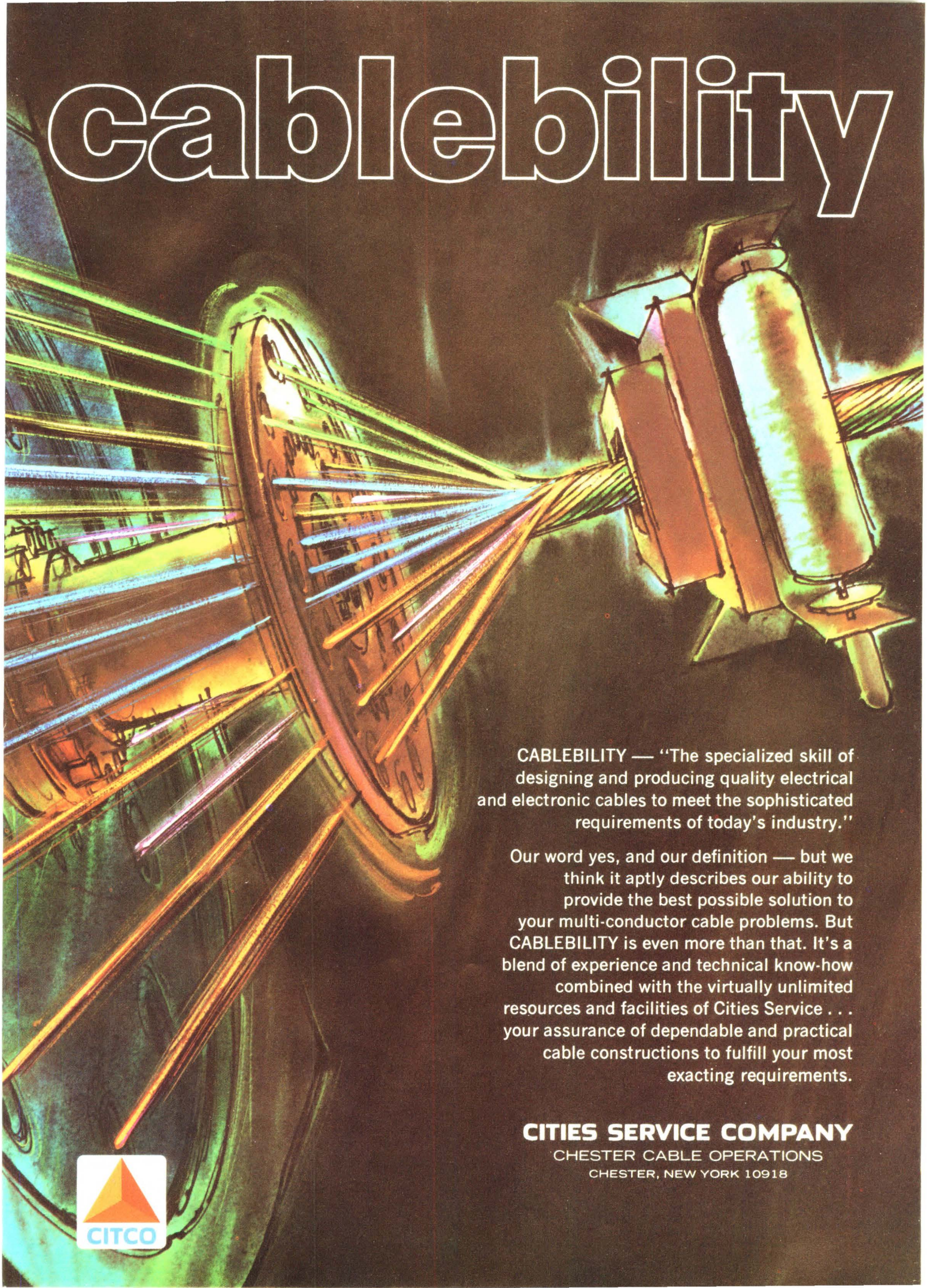


The 4200 Series POWER-DACs provide a wide range of automatic test system capability. With the equipment shown above, note the different types of output obtainable.

FLUKE®

CIRCLE NO. 11

CIRCLE NO. 15



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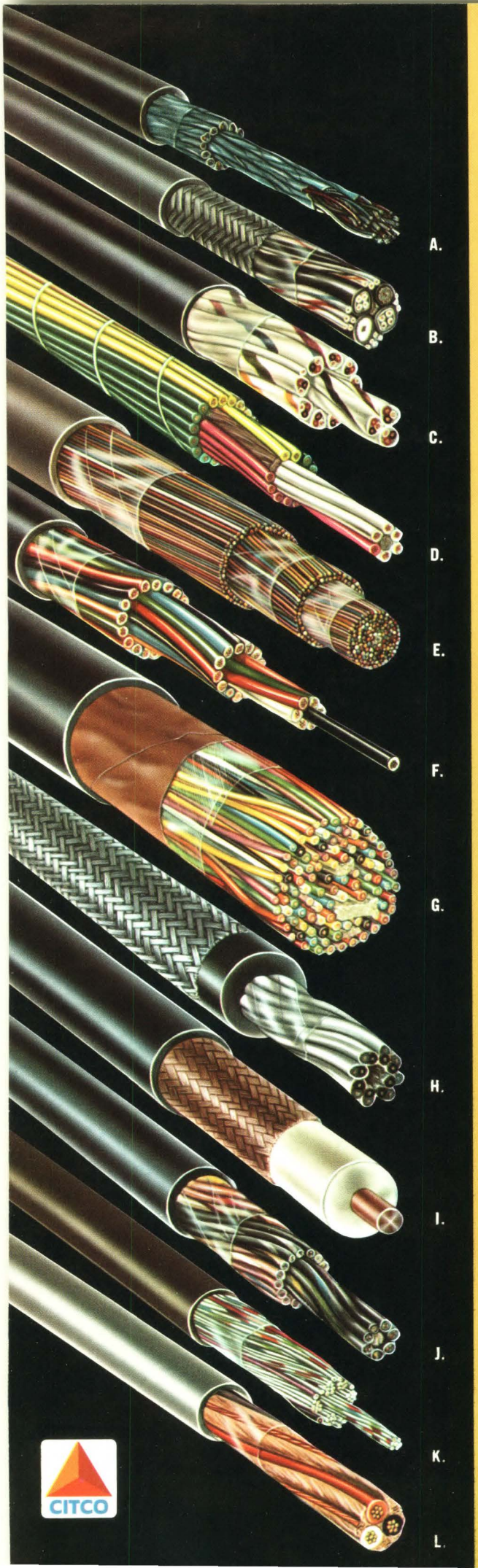

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B. **CITCO TV CAMERA CONTROL CABLE:** Camera control cable for Audio and Video signals: a composite of PVC and polyethylene insulated conductors, cabled, overall braid shield, PVC jacket.

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E. **CITCO INTEROFFICE COMMUNICATION CABLE:** 250 conductor interoffice communication and signaling cable: solid bare copper, PVC insulation, paired, cabled, PVC jacket; U/L listed.

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H. **CITCO SHIPBOARD CABLE:** Stranded conductors, nylon-jacketed PVC insulation, pairs shielded and jacketed, cabled, PVC jacket, and aluminum braid armor overall; per spec. MIL-C-915.

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J. **CITCO REMOTE CONTROL BROADCASTING CABLE:** Stranded conductors, polyethylene insulation, pairs and triples shielded and jacketed, cabled, PVC jacket overall.

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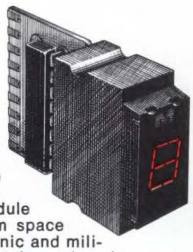
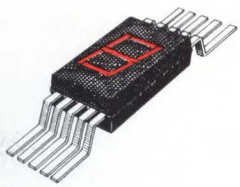
MAN6 — .6″ high, the MAN6 looks an inch high from across the room. The complete, gapless font makes all ten digits and nine letters unmistakably clear. It should find application in many instruments, consumer electronics, and cockpit displays.

MAN1 — The standard of the industry, the .27″ MAN1 is mounted on a 14-pin DIP and encapsulated in clear epoxy. Directly compatible with IC's, it is being used in a wide variety of alphanumeric display sockets. (Shown in a demonstration clock face.)

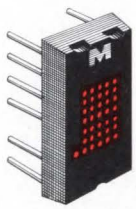
The Monsanto GaAsLITE Display display.



MDA6101 — Typical of our modules, the MDA6101 single-digit display module requires minimum space in computer, avionic and military systems. Contains a decoder-driver circuit designed to accept four-input BCD (8, 4, 2, 1) code and to provide .27″ visual readout of decimal numbers and nine distinct letters. Provides decimal point input and has ripple-blanking input and blanking input/ripple-blanking output terminals for zero suppression and intensity control.



MAN3A — Encapsulated in transparent red epoxy, this small (.115″) readout is very useful in desk calculator displays, portable instruments, and film annotation sockets. Displays ten digits and nine letters.



MAN2 — A 5 x 7 light-emitting-diode matrix, the .35″ MAN2 alphanumeric displays the full 64-character ASCII code. Finds application as keyboard verifier, avionics display, in computer peripherals and has 2^{35} bits available for film annotation work.

MAN1002 — A .27″ 7-segment hexinumeric display, the MAN1002 provides all numbers and the letters A, B, C, D, E, F, H, I, J, L, O, P, S, and U for digital and cockpit readouts that require this capability. Like all our GaAsLITE displays, it is shock resistant and impervious to vibration.

We're displaying our array of light-emitting diode displays to point out the obvious: We've got them all.

Big GaAsLITEs—the new .6″ MAN6.

Low-cost little MAN3's, in single-digit or multi-digit packages.

5 x 7 dot matrix MAN2's.

9-segment hexidecimal MAN1002's.

Red, green, and yellow.

And a line of display modules that will answer the industry's felt need: pre-designed display sub-assemblies for nixie retrofit, edge-card plug-ins, etc.

So what more can you look for in solid-state, TTL-compatible, long-lived light-emitting-diode displays? They're all in stock at our distributors. And the time is right. Get into GaAsLITEs. Display your wisdom.

If you'd like more information on our expanding line of module display products, clip the coupon and shoot it in.

If you need more information on displays, circle the bingo card number below. And if you're smart enough already, just tuck this name into your head when you order displays: **Monsanto Commercial Products Co.,** Electronic Special Products, 10131 Bubb Road, Cupertino, California 95014.

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I'm curious about your new line of display modules. Do some contain complete IC driving circuits? Send me the Module Brochure, please.

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CIRCLE NO. 16

Designing femtoampere circuits requires special considerations

New levels of performance in high-impedance, low-current applications are possible, but only if you follow these very important design rules.

Walter Patstone, Teledyne Philbrick

One femtoampere is 10^{-15} amperes, or, to put it in another perspective, it is one millionth of a nanoampere. It's difficult for most people to conceive of such a small current. Yet, varactor-input op amps, vibrating capacitor amplifiers, electrometer tubes and MOSFET amplifiers can be used to measure and manipulate femtoampere currents.

Choosing the right amplifier and then obtaining optimum performance from it requires careful considerations and trade-offs. First we'll examine the choice of amplifiers. And then we will discuss the ways to realize the full potential of the amplifier.

Low-bias current is the key specification

The bias current of the measurement amplifier is the most important source of error in high-impedance, low-current applications. These applications generally fall into two basic categories: Inverting or non-inverting. Inverting configurations are used to measure small signal currents. Non-inverting circuits are utilized to measure voltages, usually in connection with high-impedance signal sources where source-loading is a problem.

Inverting applications often employ the "current to voltage converter" configuration, shown in **Fig. 1**. Teledyne Philbrick Model 1702 varactor op amp is used for the example shown. Included in this category are photomultiplier tube preamps, ionization gages, gas chromatographs and radiation detectors. Special inverting applications include integrators and charge amplifiers.

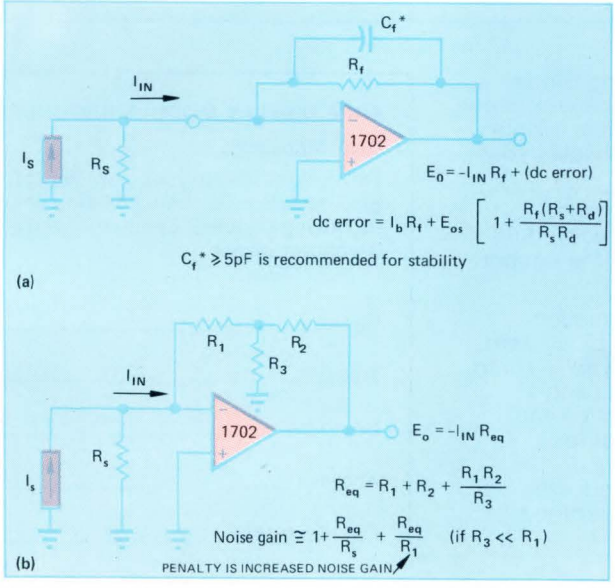


Fig. 1—A simple current-to-voltage converter (a) can be used for many applications. If R_f becomes too high to be realized with a single component, a T-network may be used **(b)**. In either case, the important amplifier specifications are low bias current (I_b) temperature coefficient and high input impedance (Z_D). The bias current must be much less than the input current (I_{in}).

In inverting applications, a dc error is produced at the output by the bias current at the inverting (−) input. This error is equal in magnitude to the bias current times the feedback impedance. That is, it appears that the bias current flows through the feedback impedance to cause an output voltage error. Further, the bias current limits the ultimate resolution of current-measuring circuits, and causes an output drift in integrator and charge-amplifier circuits. For integrators, the drift rate equals the bias current divided by the feedback capacitance (I_b/C).

Non-inverting applications, such as buffer amplifiers, PH meters, microvoltmeters, and long-term track-and-hold devices, use the "follower" configuration of **Fig. 2**. A dc

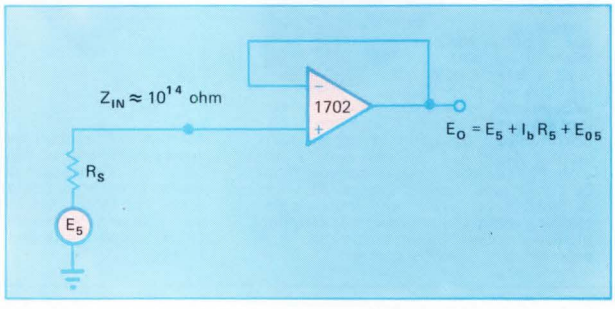


Fig. 2—The non-inverting input is used to obtain an ultra-high-impedance buffer follower. The bias current following into the impedance of the signal source causes an output error.

error due to bias current is developed in this type of circuit when the bias current of the non-inverting input flows into the impedance of the signal source. This error is referred to the output by the gain of the circuit ($1 + R_f/R_i$). In applications which have a capacitive source, such as a track-and-hold circuit, the bias current of the amplifier will cause an apparent drift at the output as it charges up the source capacitor (**Fig. 3**).

If minimizing bias-current errors was the only consideration it would be very easy to choose a particular type of amplifier for any application. But, as is the usual case, there are other considerations—bandwidth, stability, noise, size and cost. **Table 1** lists the basic types of low bias current amplifiers and rates their relative performance with regard to several of the most important parameters.

Optimize circuit performance

Once an amplifier is chosen, the next step is to optimize circuit performance. Because the amplifier's extraordinary sensitivity makes possible high-performance applications,

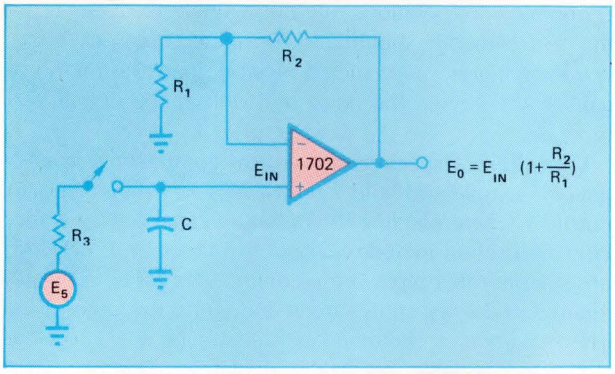


Fig. 3—A non-inverting configuration can provide gain as in this track-and-hold amplifier. The amplifier's bias current causes an apparent output drift as it charges the source capacitor. If C is 10 μF, the drift rate, due to the 1702 only, is less than 100 μV/day.

error considerations which are insignificant in less sophisticated applications now become the limiting factor in circuit operation. For example, even a 10^{14}-ohm insulation resistance between the signal input of the 1702 and a power-supply lead can cause a leakage current to flow that is 75 times the bias current of the amplifier!

Since total circuit performance is strongly dependent upon the amount of careful consideration given to the selection and layout of components, we have listed several of the most important factors.

Wiring. Hard wiring with good quality insulation (teflon, etc.) is preferable to printed-circuit wiring. For example, the amplifier should be plugged into a socket with teflon insulators rather than soldered directly onto a PC board. Insulated wiring would then connect input terminals to external components. If possible, it would be advisable in inverting applications to solder the feedback components directly between the pins of the socket. If a PC board layout must be used, a high insulation resistance coating should be applied to the entire circuit to minimize the detrimental effects of dirt and moisture.

Further, all hard wiring should be short and supported in such a way that movement due to vibration is limited as much as possible, because motion of input wiring will cause corresponding variations in parasitic capacitance. Such variations produce changes in stored charge (assuming that the voltage potential on the wire remains constant), which effectively look like noise currents to the circuit.

A guard is a signal shield which is designed to float at the common-mode voltage of the critical signal points which it protects. Its purpose is to minimize the effects of both parasitic capacitances and leakage resistances. For high impedance op-amps, a guard is normally a foil on the printed-circuit board which surrounds all points connected to the "hot" input terminal of the amplifier. If the op-amp is connected in an inverting configuration, the "hot" terminal is the inverting (or "−") input, and a guard around this terminal would normally be connected to signal ground. For non-inverting applications, a guard surrounding the non-inverting (or "+") input and connected to the amplifier output is normally employed. **Fig. 4** illustrates typical guarding schemes.

Coaxial cable should be used wherever possible to minimize RFI pickup. A type with an internal graphite coating or conductive tape will also minimize any noise generated in vibration environments.

Switches. Reed relays make good switches for many applications where reset or hold operations are required. Ceramic switches should also be considered. Use guarding around the switch.

Resistors. Many applications require extremely large resistors, typically up to 10^{14} ohms. Several firms manufacture special components which can be used. These include Victoreen Instrument Div. of VLN, Cleveland, Ohio; Pyrofilm Corp., Whippany, N. J.; Electra/Midland Corp., San Diego, Calif.; and Mini Systems Inc., North Attleboro, Mass.

Table 2 lists the advantages and disadvantages of each type. Critical parameters include tolerance, temperature coefficient, long term stability, and physical size. Price and delivery also may be of great importance.

For inverting applications, if electrical, mechanical, or

TABLE 1 AMPLIFIER COMPARISON

Parameter	Amplifier type				
	Varactor Bridge	Vibrating Capacitor	Electrometer Tube	MOS FET	Junction FET
I bias	very good (10^{-15})	excellent (10^{-16})	good (10^{-14})	good (10^{-14})	good (10^{-13})
I bias vs time	very good	excellent	good	good	fair
Eos vs time	excellent	good	poor	poor	good
Bandwidth	narrow	narrow	wide	wide	wide
CMRR	excellent	excellent	poor	fair	good
Noise (.01Hz to 1 Hz)	excellent	excellent	good	fair	good
Size	small	large	large	small	small
Price	low	high	medium	medium	low
Overload protection	easy	easy	easy	difficult	easy
Microphonics	good	fair	poor	good	good
Warm-up	fast	fast	slow	fast	fast

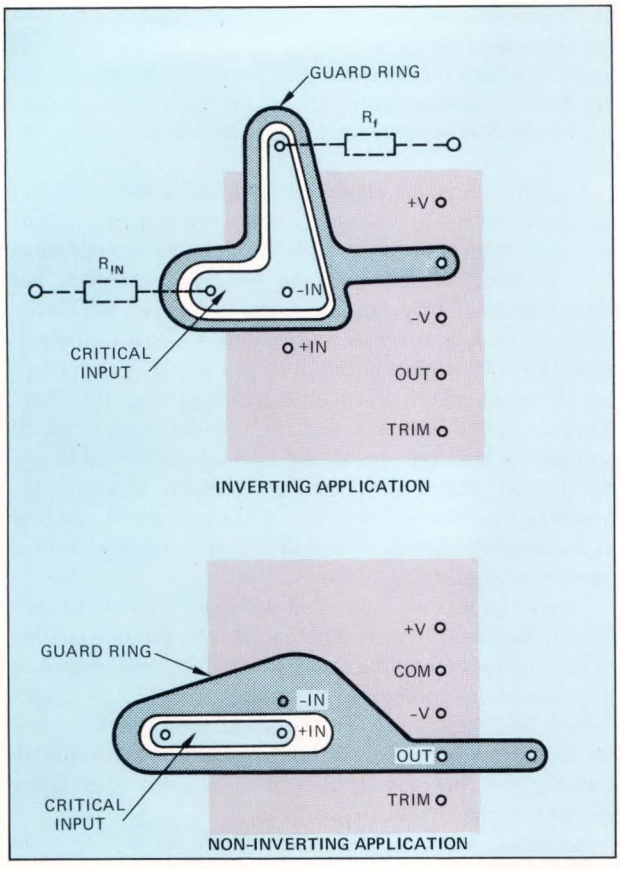


Fig. 4—Typical PC-board guard ring configuration shows the guard is referenced to the common (or ground) for inverting applications **(a)** and to the output for non-inverting applications **(b)**. The small break in the guard ring prevents current loops.

economic considerations rule out a single feedback resistor, a T-Network should be considered (**Fig. 1**). Note, however, that because such a network increases the noise gain of the circuit, the noise and drift at the output will increase.

Capacitors. Capacitors are critical components in integrators, sample-and-hold circuits, etc. Key parameters to consider when selecting the optimum capacitor for a specific application include leakage resistance and dielectric absorption. Mica types are recommended for small capacitance values and polystyrene and teflon for larger ones. The maximum recommended capacitance is 10 μF. The decreased leakage resistance of larger capacitors can cause significant problems in most circuits. □

Author's biography

Walter Patstone is product manager at Teledyne Philbrick in Dedham, Mass., where his duties include initiation of product development projects and customer applications assistance. He was previously with Microsonics Corp. and Hughes Aircraft. Walter received a BSEE from Rensselaer Polytechnic Institute, an MSEE from Northeastern Univ. and is currently studying for an MBA.

TABLE 2 RESISTOR TYPES

Type	Advantages	Disadvantages
Wire-wound	High initial accuracy Excellent stability Excellent T.C. Excellent T.C. tracking Low noise	Expensive above 1MΩ Relatively large size Relatively high shunt capacitance and series inductance, depending on particular construction
Metal film	Low noise Very good temperature stability Low shunt capacitance and series inductance Relatively low cost	Relatively large size over 300kΩ
Glass enclosed deposited carbon (Pyrofilm and Victoreen types)	Specifically designed for very high values up to $10^{14}\Omega$ Low flicker noise Good stability Very good high frequency operation ±1% precision available up to $10^{14}\Omega$	Relatively noisy Relatively expensive Only fair T.C. Extremely large Fragile Sensitive to handling
Carbon composition	Low cost High reliability Small sizes available	Poor T.C. Easily affected by humidity Moderate tolerances only

THE 1024-BIT TTL RAM IS HERE

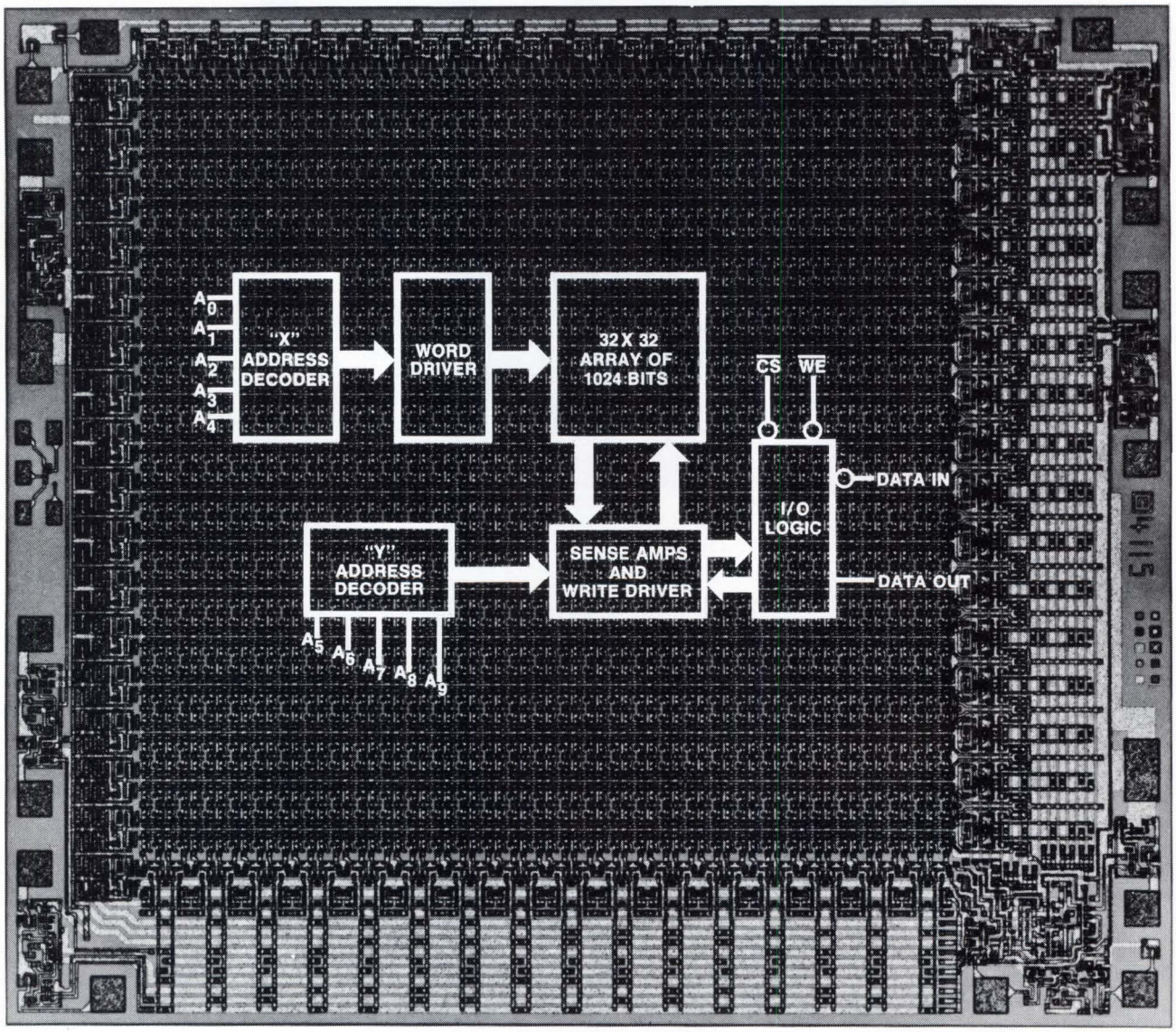
Our new 93415 RAM: 1024 x 1 bit. TTL. 60 ns access time at 0.5 mW/bit. And Isoplanar did it.

The 93415 RAM is the most complex monolithic bipolar read/write memory ever made.

This self-contained subsystem also features 30ns chip select access time, open collector (expandable) output, static TTL operation and decreasing power dissipation with rising temperature. Available now in prototype quantities in 16-pin hermetic DIP.

What this means to designers of high-speed digital systems is that for the first time they have available a major TTL memory building block that can operate at speeds compatible with those of their systems' logic. Because it's static, the 93415 is simple to use, requires no complicated peripheral electronics. And because of its functional density and capability, the 93415 gives the designer a fine opportunity to realize significant cost savings by 1) reducing package count, 2) reducing circuit board number and size, 3) reducing number of connections, 4) increasing system reliability.

Functional diagram of the 93415 TTL RAM

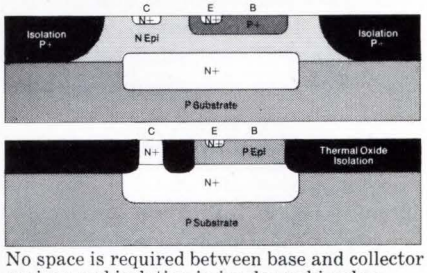


Significant Memory Applications
Some of the more exciting applications of 93415 are: as a fast writeable control store for microprogramming, eliminating many present needs for fixed ROMs; as a large high-speed scratchpad to make multiprocessing more feasible; for simulation of long high-speed shift registers; for improvement of buffer or cache memory performance by increasing capacity without any power or size trade-off; and obviously for building cost-effective high-speed main-frame memories.

Isoplanar did it. Again
Our 93415 is the most recent, and most important, product of our isoplanar technology. Isoplanar proved itself last year with the successful introduction, and volume production, of our 93410 256-bit TTL RAM and our 95410, world's first 256-bit ECL RAM.

The introduction of the 93415, another industry first, is just one more demonstration of what isoplanar can do. Soon, isoplanar will do it again, with even more complex TTL and ECL memories.

What is Isoplanar? It's a bipolar fabrication process that replaces conventional planar P+ isolation diffusion with an insulating oxide. Result: High density. High yield. Low cost. Improved speed/power performance (from lower parasitic capacitance). Improved reliability (from planar surface). Isoplanar is the designer's assurance of proven reproducibility and deliverability.



No space is required between base and collector regions and isolation in isoplanar bi-polar (bottom) compared to conventional planar bi-polar (top).

Fairchild Bipolar Memories

BIPOLAR READ/WRITE MEMORY APPLICATIONS SUMMARY

ORGANIZATION	REGISTERS SYSTEM SPEED 5-30ns	SCRATCHPAD SYSTEM SPEED 15-60ns	CONTROL SYSTEM SPEED 20-70ns	BUFFER SYSTEM SPEED 50-80ns	MAIN SYSTEM SPEED > 75ns
8 x 1	(TTL) 9338, 93S39* (ECL) 9539*				
16 x 1		(TTL) 93407, 93433 (ECL) 95401			
16 x 4			(TTL) 93403 (ECL) 95400		
256 x 1				(TTL) 93410‡ (ECL) 95410‡	
1024 x 1					(TTL) 93415‡ (ECL) 95415‡*

*IN DEVELOPMENT ‡ISOPLANAR DEVICES.

Availability
Some 93415 RAMS are already out in the field in evaluation quantities. Prototype quantities are available now from your friendly Fairchild distributor at the following prices:

1-24	25-99	100-999
$87.50	$80.50	$70.00

Volume shipments available during 4th quarter.

FAIRCHILD SEMICONDUCTOR, A Division of Fairchild Camera & Instrument Corp., 464 Ellis St., Mountain View, Ca. 94040. (415) 962-5011. TWX: 910-379-6435

CIRCLE NO. 17

Measure frequency and propagation delay with high speed ECL circuits

Build yourself a test circuit that can measure and display both frequency of operation and propagation delay between two high-speed signals.

William R. Blood, Jr., Motorola, Inc.

The performance of emitter-coupled logic (ECL) system functions can best be demonstrated by building a test circuit to measure and display such high-speed parameters as frequency of operation and propagation delay. The circuit in **Fig. 1** can also be used as a measuring device for system checkout, incoming inspection and quality control. Although it was designed to measure frequencies up to 100 MHz and propagation delays in 100 psec increments, the circuit is also suitable for measuring TTL performance.

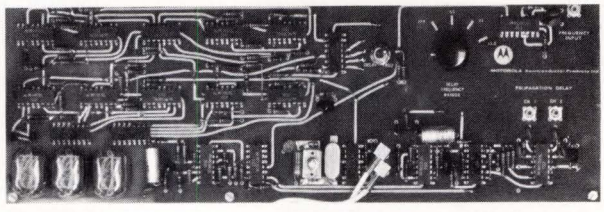


Fig. 1—Complete circuit for making frequency and propagation delay measurements fits on one pc card.

Making frequency measurements

Operation of the circuit is illustrated by the block diagram in **Fig. 2**. Test results are accumulated and stored in counter chain A. By opening a fixed duration window with gate A, and counting the input frequency during this time interval, the output display will read frequency. If the input frequency is counted for a 1 μsec interval, readings will be in MHz.

The 1 μsec window is generated by counting 100 pulses from the 100 MHz crystal oscillator and using counter chain B (÷ 100). Because counter B is synchronous, no error will result due to propagation delay in this counter.

The display counter is 2 decades plus one flip-flop long. This gives possible output readings of 0-199 MHz; however, the upper frequency may be limited by the logic family selected. Using MECL 10,000 circuits, it is typically limited to about 160 MHz due to the toggle rate of the flip-flops and the bandwidth of the input buffer amplifier (F_{in}).

Propagation delays are more elusive

Propagation-delay measurement is more difficult than frequency measurement because of the resolution required. Since real time measurements of 100 psec intervals would require a 10-GHz counter, some form of averaging technique must be used. Referring again to **Fig. 2**, the count window duration at gate A can be controlled by

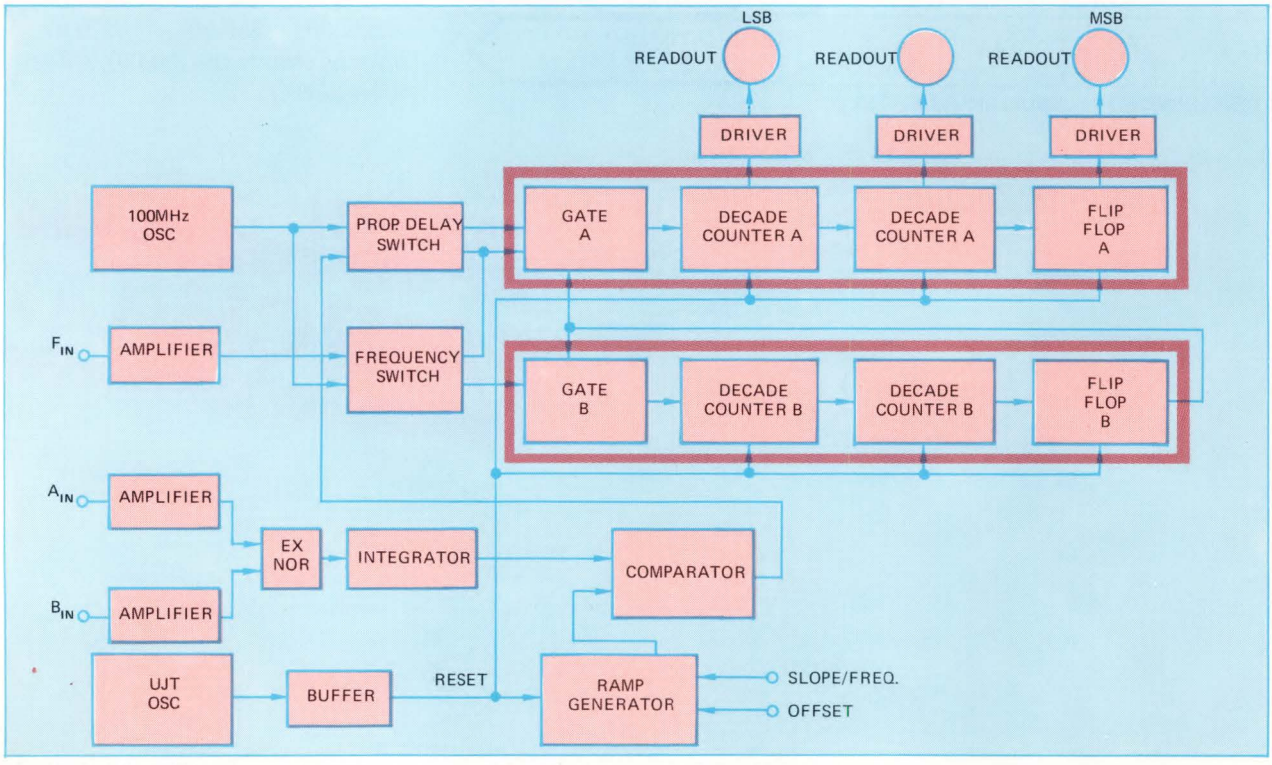


Fig. 2—Standard ECL components fulfill requirements for most measuring circuit functions.

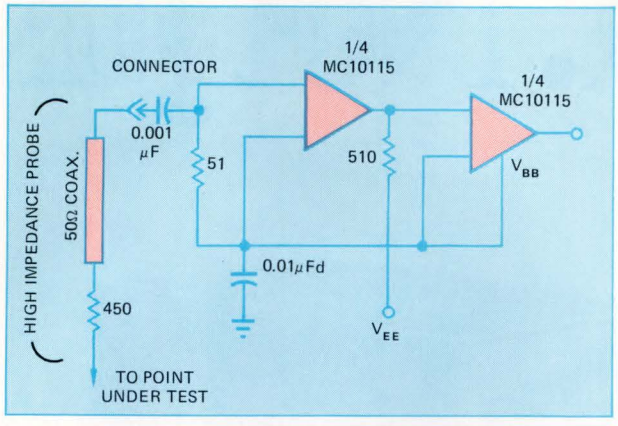


Fig. 3—Input buffer amplifier uses a 500Ω impedance probe.

the propagation difference between A_{in} and B_{in}. By gating the 100 MHz crystal oscillator to the display counter during this window, the circuit can be calibrated to read 0 to 19.9 nsec in 0.1 nsec increments.

The circuits that convert propagation delay to pulse width are the key to the measurement accuracy. The A_{in} and B_{in} signals are buffered and routed to an exclusive-NOR gate, which gives a pulse train with a duty cycle proportional to the propagation delay between A and B. A MECL III exclusive-NOR gate obtains the best time resolution at the measurement extremes. By integrating this waveform with an RC circuit, the signal becomes a dc level proportional to the propagation delay. This dc level is then translated into a pulse-width signal by means of the ramp generator and comparator circuits.

The basic limit to this approach is that the A and B inputs must be at the same frequency and in phase, and the ramp generator must be calibrated for each frequency. The maximum propagation that can be measured is one-half the period of the input signals. For example, if inputs are at 50 MHz, the period is 20 nsec and the maximum measurable delay is 10 nsec.

High impedance probes can be used

The input buffer amplifiers use ECL line receivers connected to permit a wide range of high frequency input signals levels and waveforms (**Fig. 3**). These ac coupled amplifiers exhibit a 50Ω input impedance to properly terminate coaxial cables, and to prevent possible errors due to signal reflections at the test fixture inputs.

Because of the 50 mV input sensitivity of these circuits, a high impedance probe as shown can be used. The 450Ω resistor in series with the 50Ω coaxial cable gives the probe a 500Ω impedance at the point under test. This 10 to 1 attenuation factor provides 80 mV at the amplifier input when measuring an 800 mV ECL signal swing. A similar probe could be used for measuring TTL signals by using a 2 kΩ resistor in series with the 50Ω coaxial cable to produce an attenuation factor of about 40.

Some functions require special-purpose circuits

All blocks in **Fig. 2** are built with standard high speed digital circuits except for the special purpose circuits in **Fig. 4**, and the input amplifier in **Fig. 3**. The buffer between the unijunction oscillator and the ECL logic is a MC10115 line receiver connected as a Schmitt trigger to provide a square reset pulse.

Calibration is accomplished by adjusting the integrator offset and the slope of the ramp. At a given input frequency, the shortest delays are calibrated by the trimmer resistor shown in **Fig. 4b**. As an alternate approach, a constant current source in place of the single resistor gives better linearity throughout the measuring range.

The RC time constant in the ramp generator (**Fig. 4c**) is used to set the longer propagation measurements, and should be set in conjunction with the integrator to insure accuracy throughout the measuring range.

The circuit can also be used for measuring TTL performance by changing the crystal from 100 MHz to 10 MHz. Frequency measurements would read 0-19.9 MHz in 100-kHz increments, and propagation delay could be calibrated to read up to 199 nsec in 1 nsec increments. □

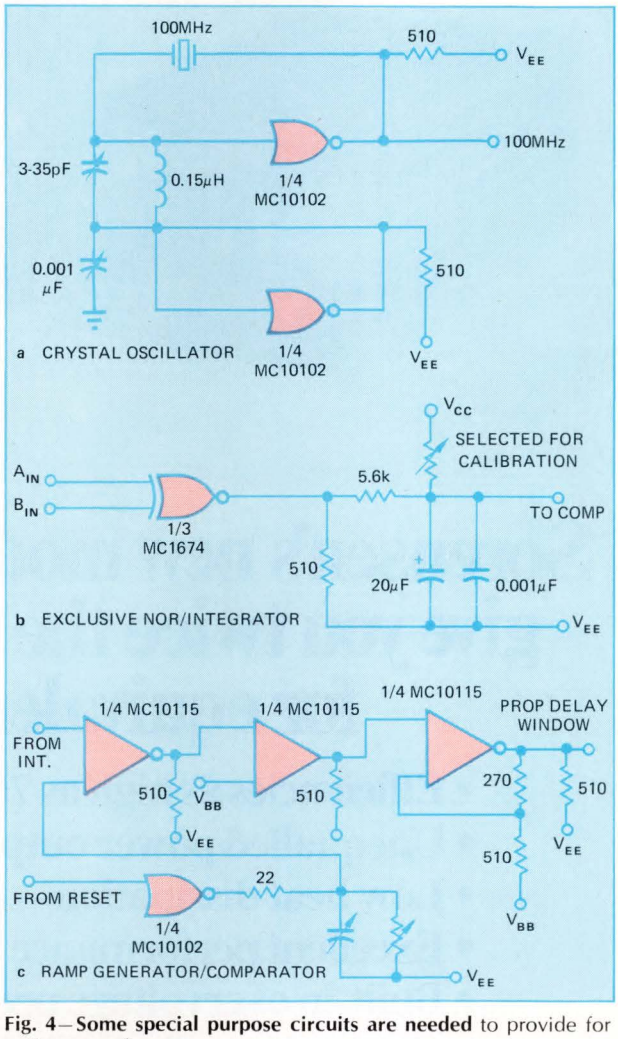


Fig. 4—Some special purpose circuits are needed to provide for optimum performance.

Author's biography

Bill Blood is a computer applications engineer for Motorola Inc., Semiconductor Products Div., in Phoenix, Ariz. Bill previously worked for R. J. Communication Products, Inc., and Motorola Control Systems Div. He received a BSEE from the University of Florida.

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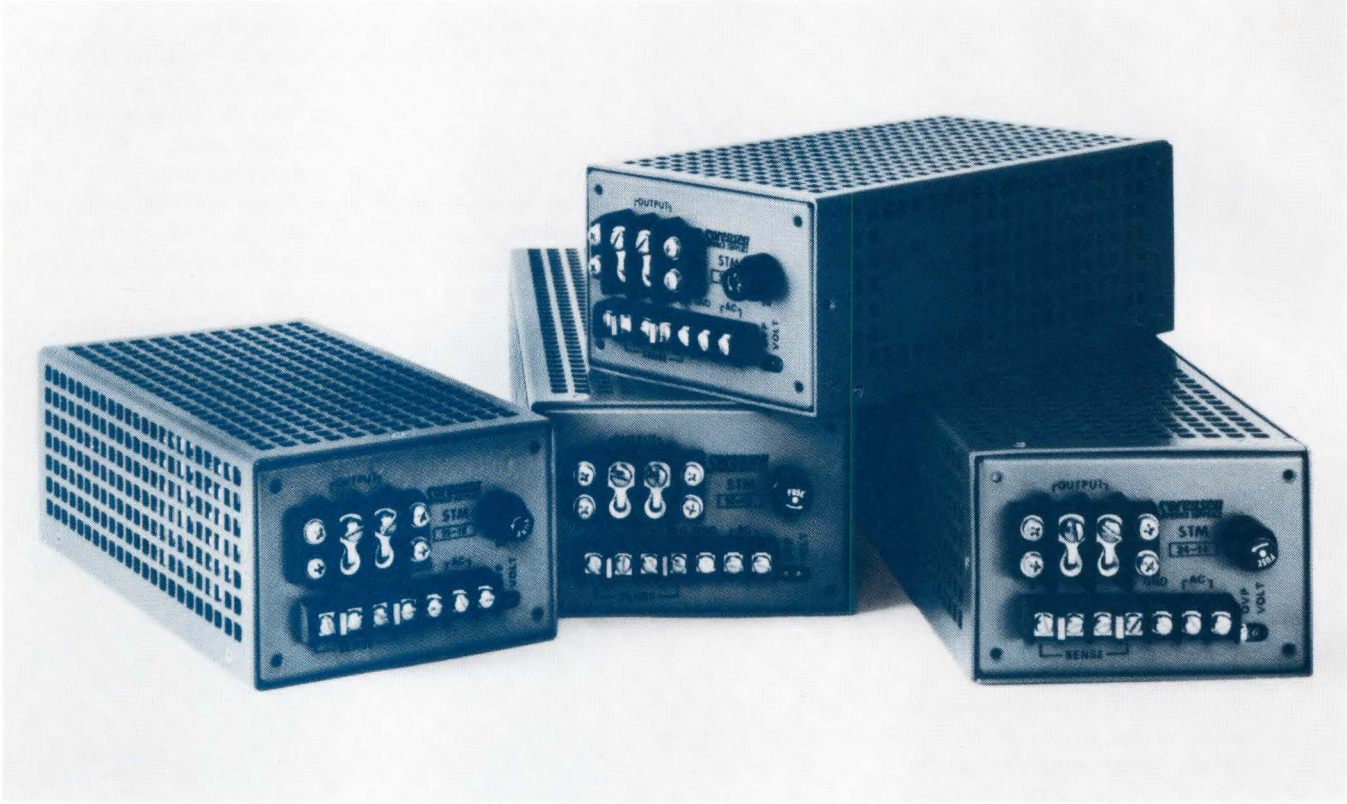

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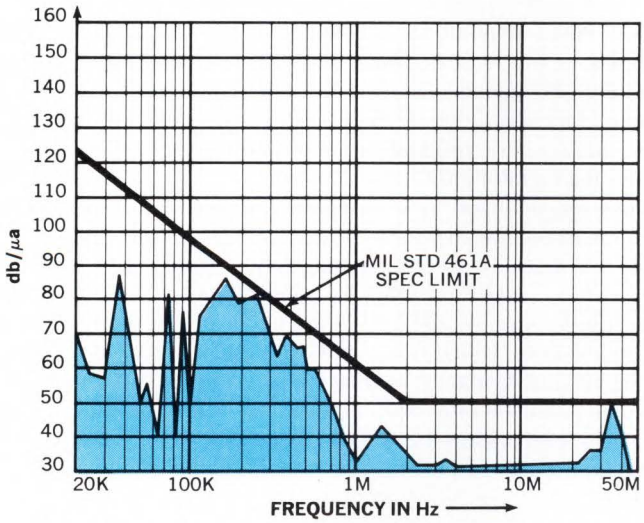
Package Size: Module III – 3-5/16″ x 5-1/8″ x 9-1/2″ – Weight: 6.5 lbs.															
STM3.5-24	3.0	4.5	24	19.4	14.9	9.6	.05%	5 mv	50 mv	105-132	1.8	50-440	150±15%	1.5	$229
STM5-24	4.5	6.0	24	19.4	14.9	9.6	.05%	5 mv	50 mv	105-132	2.3	50-440	150±15%	1.5	229
STM9-12	6.0	10	12	9.7	7.5	4.8	.05%	3 mv	50 mv	105-132	2.1	50-440	150±15%	1.5	239
STM12-12	9.5	13.5	12	9.7	7.5	4.8	.05%	3 mv	50 mv	105-132	2.9	50-440	150±15%	1.5	249
STM15-10	13	17	10	8.1	6.2	4.0	.05%	3 mv	50 mv	105-132	2.7	50-440	150±15%	1.8	239
STM18-10	16	20	10	8.1	6.2	4.0	.05%	3 mv	50 mv	105-132	3.2	50-440	150±15%	1.8	249
STM24-8.5	19	25	8.5	6.8	5.3	3.4	.05%	3 mv	50 mv	105-132	3.3	50-440	150±15%	1.9	249
STM28-7	24	30	7.0	5.6	4.3	2.8	.05%	3 mv	50 mv	105-132	3.2	50-440	150±15%	1.9	249
STM36-4	29	43	4.0	3.2	2.5	1.6	.05%	3 mv	50 mv	105-132	4.0	50-440	150±15%	1.9	259
STM48-4	42	56	4.0	3.2	2.5	1.6	.05%	3 mv	50 mv	105-132	4.0	50-440	150±15%	1.9	269
Package Size: Module IV – 3-5/16″ x 5-1/8″ x 14″ – Weight: 9.0 lbs.															
STM3.5-36	3.0	4.5	36	29.1	22.3	14.4	.05%	5 mv	50 mv	105-132	3.8	50-440	150±15%	2.2	319
STM5-36	4.5	6.0	36	29.1	22.3	14.4	.05%	5 mv	50 mv	105-132	4.2	50-440	150±15%	2.5	324
STM9-20	6.0	10	20	16.2	12.4	8.0	.05%	3 mv	50 mv	105-132	3.8	50-440	150±15%	2.2	299
STM12-20	9.5	13.5	20	16.2	12.4	8.0	.05%	3 mv	50 mv	105-132	4.8	50-440	150±15%	2.8	289
STM15-15	13	17	15	12.1	9.3	6.0	.05%	3 mv	50 mv	105-132	4.3	50-440	150±15%	2.6	289
STM18-15	16	20	15	12.1	9.3	6.0	.05%	3 mv	50 mv	105-132	5.0	50-440	150±15%	3.0	299
STM24-13	19	25	13	10.5	8.0	5.2	.05%	3 mv	50 mv	105-132	5.5	50-440	150±15%	3.2	309
STM28-11	24	30	11	8.9	6.8	4.4	.05%	3 mv	50 mv	105-132	5.5	50-440	150±15%	3.2	309
STM36-6	29	43	6.0	4.8	3.7	2.4	.05%	3 mv	50 mv	105-132	4.5	50-440	150±15%	2.6	329
STM48-6	42	56	6.0	4.8	3.7	2.4	.05%	3 mv	50 mv	105-132	5.5	50-440	150±15%	3.2	329

*Free – air rating – no external heatsink **Worst case. Typically less than 30 mv †U.S.A. list prices



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CIRCLE NO. 18

Demodulate DPSK signals coherently using a Costas phase-lock loop

This loop provides a form of matched filter for acquiring the desired center frequency while rejecting false locks.

Robert Hennick, Bell Aerospace Co.

In the transmission of digital information, phase-shift keying (PSK) offers the best noise and power-consumption performance over other digital-transmission methods, such as amplitude-shift keying (ASK) and frequency shift keying (FSK). PSK involves the sequential transmission of carrier pulses having constant amplitude, angular frequency and duration, but of different relative phase.

The simplest PSK case involves the double-sideband suppressed-carrier (DSB-SC) modulation of a carrier at discrete 0 and π radian phase-angle steps. Differential phase-shift keying (DPSK), where phase differences are detected, offers a better error probability than PSK for the same signal-to-noise ratio.

Demodulation or detection of a differential phase-shift keyed DSB-SC signal essentially involves reinsertion of the missing carrier by a process known as synchronous or coherent detection. This is done by multiplying a receiver's input signal with a locally generated carrier signal, accurately controlled in frequency and phase, and following this by low-pass filtering. Thus, the transmitted message is recovered undistorted but reduced in magnitude by the cosine of the phase error between the ideal and actual modulation/demodulation process. Maximum signal amplitude occurs for zero phase error and complete loss of the message results from a phase error of $\pi/2$ radians.

The demodulation at the receiver's output can be accomplished either by use of various forms of automatic frequency/phase controlled loops that automatically lock the local oscillator in frequency and phase to a received vestige of the carrier, or by use of a nonlinear circuit to regenerate the carrier term from the received DSB signal.

One such phase controlled loop is the Costas[2] phase-lock loop (PLL) which is designed to extract phase information from a modulated signal (**Fig. 1**). This synchronizing system, which requires no unmodulated carrier, can function only if the difference between the carrier-loop initial voltage-controlled-oscillator frequency and the actual carrier frequency is of the order of the PLL noise bandwidth. A means of sweep search may be used in either a manual or automatic mode for frequency differences greater than the PLL bandwidth.

The received signal spectrum is that of **Fig. 2**, which indicates the desired modulation sidebands and other significant angle modulation products in the required frequency search range.

The Costas loop, operating on the data sidebands, is used for locking and tracking the data signal, and the residual reference carrier is demodulated as a correct lock and "steering" indicator. In a sense, this provides a form of matched filter for acquiring the desired center frequency while supplying "rejection" of false locks.

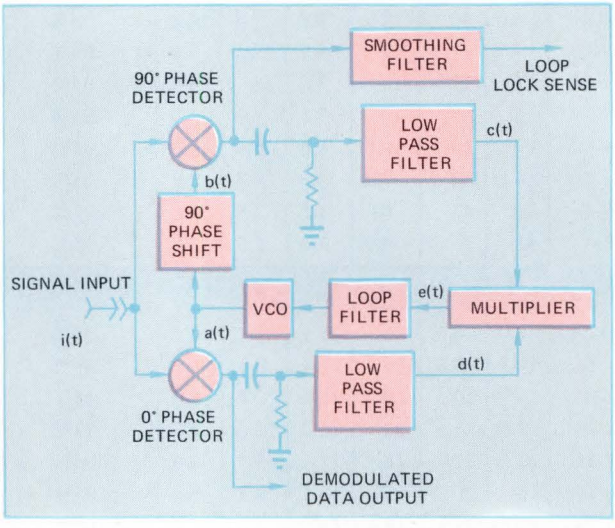

Fig. 1 – Block diagram of a Costas phase-lock loop (PLL) designed to extract phase information from a modulated signal. The synchronizing PLL can function only if the difference between the carrier-loop initial VCO frequency and the actual carrier frequency is of the order of the PLL noise bandwidth.

False locks may occur between two intermodulation products as the loop is swept over the incoming signal spectrum and generally have very large phase jitter and minimal lock-indication dc voltage. In proper lock, the dc indication from the residual carrier is approximately 20 dB greater than a false indication.

Since the sideband lock condition is ambiguous, some means must be used to resolve the demodulated data phase. Thus, it is desirable to employ the residual carrier, which may also be used for correct lock indication and sweep stop. The lock sense voltage will be either plus or minus depending upon which sideband lock is established. Thus, by multiplying the data stream by the lock voltage, the correct data phasing is provided.

Other design factors that have to be considered are: preconditioning agc to provide a reasonable range of signal levels into the loop during acquisition, controlling the loop search stop (if used), and controlling steady state tracking error.

Costas loop analysis

An analysis of the Costas loop operation, as shown in **Fig. 1**, is as follows:

If the incoming signal is

$$i(t) = \underbrace{A\cos(\omega t + \Theta)}_{\text{carrier}} \pm \underbrace{B\sin(\omega t + \Theta)}_{\text{modulation}};$$

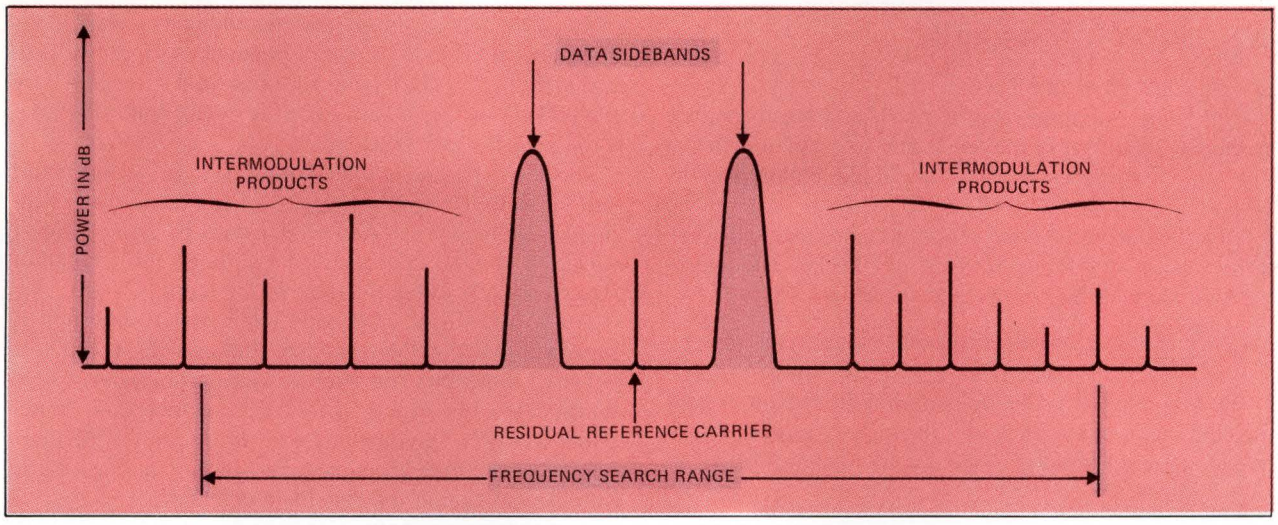

Fig. 2—Signal spectrum at the Costas PLL receiver. The signal is transmitted by a double-sideband suppressed-carrier (DSB-SC) modulation scheme, using differential phase-shift keying (DPSK). Note the desired modulation sidebands and other angle intermodulation products within the required frequency search range.

and the oscillator output $a(t) = \cos \omega_o t + \Phi$;

then oscillator output $b(t) = \cos (\omega_o + \Phi + \pi/2)$.

By the trigometric identity, $\cos (\alpha + \beta) = \cos \alpha \cos \beta - \sin \alpha \sin \beta'$

$$b(t) = -\sin (\omega_o t + \Phi),$$

where Θ and Φ are initial phase offsets.

Then,

$$d(t) = i(t)a(t) = A/2 \cos (\omega t + \Theta - \omega_o t - \Phi) + A/2 \cos (\omega t + \Theta + \omega_o t + \Phi) \pm B/2 [\sin (\omega t + \Theta + \omega_o t + \Phi) + B/2 \sin (\omega t + \Theta - \omega_o t - \Phi)].$$

When $\omega t \approx \omega_o t$ then the low-pass filter will provide;

$$d(t) = A/2 \cos (\Theta - \Phi) \pm B/2 \sin (\Theta - \Phi).$$

Similarly, $c(t) = i(t)b(t)$

$$= -A/2 \sin (\omega_o t + \Phi + \omega t + \Theta) - A/2 \sin (\omega_o t + \Phi - \omega t - \Theta) \pm [-B/2 \cos (\omega t + \Theta - \omega_o t - \Phi) + B/2 \cos (\omega t + \Theta + \omega_o t + \Phi)].$$

The low-frequency part of i(t) is

$$c(t) = -A/2 \sin (\Phi - \Theta) \pm [-B/2 \cos (\Theta - \Phi)]$$
$$= A/2 \sin (\Theta - \Phi) \pm [-B/2 \cos (\Theta - \Phi)];$$

since $-\sin (\Theta - \Phi) = \sin (\Phi - \Theta)$.

With inputs d(t) and c(t) ac coupled into the multiplier, the multiplier output is

$$e(t) = \frac{A^2 \mp B^2}{8} \sin (2\Theta - 2\Phi) \pm \frac{AB}{4} \cos (2\Theta - 2\Phi)$$

Thus, the multiplier output signifies an error difference which provides a loop correction in phase/frequency via the loop filter and the voltage controlled crystal oscillator.

Phase-lock loop design

If the signal level at the input to the receiver shown in **Fig. 3** is −87 dBm, with a noise power of −49 dBm in a 50-MHz bandwidth, an input signal-to-noise ratio (s/n) of −38 dB is provided. Due to the weak input signal, the modulation scheme (DSB-SC), and the negative s/n ratio, the receiver employs a Costas phase-locked demodulator.

The receiver uses a noncoherent agc signal which holds the 70-MHz i-f amplifier output level constant even when the signal is buried in the noise. After amplification and noise bandwidth reduction (50 to 4 MHz), the i-f signal of 70 MHz is then mixed with a 65-MHz local oscillator and down-converted to 5 MHz. The 5-MHz signal is then fed to a 5-MHz synchronous tuned amplifier with a gain of 20 dB and a bandpass of 200 kHz. Thus, the s/n ratio at the input to the phase lock demodulator is −14 dB.

To calculate the receiver's loop bandwidth, such factors as data rate, acquisition range, frequency drifts and doppler shifts must be considered. A provision for manual or automatic sweep acquisition can be inserted in the loop to enhance acquisition. This would enable the i-f bandwidths to be narrowed, thus improving the predetection s/n ratio, which in turn decreases acquisition time and, more importantly, increases the probability of lock. The sweep rate $\Delta\dot{\omega}$,[3] must not, however, exceed a maximum given by

$$\Delta\dot{\omega}_{max} = (1 - (\text{snr})_l^{-1/2})\omega_n^2 \text{ rad/sec}^2,$$

where $(\text{snr})_l$ is the loop s/n ratio and ω_n is the loop natural frequency.

A high probability of lock[3] will be obtained for a loop s/n ratio of +6 dB or better. We will calculate a loop bandwidth to provide a + 10 dB s/n ratio in the loop at threshold. Another important consideration is that the calculated loop bandwidth be at least an order of magnitude less than the signal data rate, otherwise the loop would track each data bit transition in addition to the phase error of the data subcarrier, thus never achieving demodulation of the data stream.

The s/n ratio in the 200-kHz second i-f bandwidth is −14 dB. We therefore need a 24-dB improvement, or a noise bandwidth (B_n) of 800 Hz in the receiver. Thus, B_n is obtained as follows:

200-kHz bandwidth = 53 dB
−24 dB
+29 dB = 800 Hz

Since $B_l = \frac{\omega_n}{2} (\delta + 1/4\delta)$ Hz (one-sided noise bandwidth)[2] where δ = damping factor and $B_n = 2B_l$,

then for $\delta = 0.707$, $B_l = 0.53\omega_n$. Thus $\omega_n \approx 800$ rad/sec.

Another approach to determining the loop bandwidth is as follows:

If the data sideband spectral density is given such that C/n_o = 39 dB-Hz, then for a +10 dB s/n_{loop} ratio,

s/n_{loop} ratio $= \dfrac{39 \text{ dB-Hz}}{B_n} = 10$ dB,

and $B_n = 29$ dB ≈ 800 Hz.

C/n_o^4 (carrier-to-noise ratio) is the ratio of the magnitude of the carrier to that of the noise after selection and before any nonlinear process such as amplitude limiting and detection.

A calculation of unaided pull-in time for maximum frequency offset of 700 Hz (0.001% of 70 MHz) and a loop natural frequency (ω_n) of 800 rad/sec gives

$$T_p \frac{(\Delta\omega)^{2\,(3)}}{2\delta\omega_n{}^3} \text{ (high gain-second-order loop)} \approx 27 \text{ msec.}$$

The loop gain K_v is determined from the maximum permissible static phase error, Φ_e, for a given maximum frequency offset or tracking range $\Delta\omega$, by the equation

$$K_v = \frac{\Delta\omega}{\Phi_e}.$$

A typical receiver specification is that agc must keep the output changes below 1 dB. Since for small angles, $\sin\Phi \approx \Phi$, a 1-dB change means that the static phase error must be held to within 0.125 radians. Computing the loop gain required to hold the static phase error to 5° or 0.087 radians where $\delta = 0.707$; $\Delta\omega$ (lock-in range, second-order loop) $\approx 2\delta\omega_n$ rad/sec$^{(2)} = 2(0.707)\ 800 = 1120$ rad/sec.

Thus, $K_v = 1.3 \times 10^4$.

The five elements in the Costas phase-lock loop that determine the loop gain K_v are: the phase detector, low-pass filter, multiplier, loop filter, and the voltage-controlled oscillator (see **Fig. 4**).

The phase-detector sensitivity, K_{pd}, can be measured by inserting an i-f signal at the desired operating level (below circuit distortion) and measuring the peak voltage of the low-frequency beat between the reference and i-f frequencies. This peak voltage is the volts/radian sensitivity of the phase detector. A typical K_{pd} for a passive mixer is 4 mV/radian.

The oscillator sensitivity, K_{vco}, can be measured by applying a dc control voltage and measuring the corresponding output frequency. A plot of frequency vs input voltage will yield K_{vco} in Hz/V, which is converted to radians/V by multiplying by 2π radians/cycle. A typical unit may have a $K_{vco} = 2.1 \times 10^4$ radians/V.

The low-pass active filter output, K_{lpf}, has a maximum gain of $\approx R_f/R1$, with a $f_{-3\ dB} \approx 2$ (data rate). The −3-dB point is primarily selected with regard to desired signal spectrum, overall loop-phase margin, and the amount of signal energy-to-noise tolerable in the loop.

For a 600-bit/sec data rate, the signal in the loop is passed through a low-pass/active filter with a 1200-Hz −3-dB bandwidth. The filter provides an output s/n ratio of about +9 dB. At this signal level, the loop noise bandwidth is 60 Hz, resulting in a +10 dB s/n ratio in the loop, which is more than adequate for acquisition and will cause little degradation in the data demodulation.

Also, as the i-f input, C/n_o, increases, the loop bandwidth will increase slightly as the signal level increases. The noncoherent agc restricts this increase to about 6 dB, resulting in a strong signal loop bandwidth of about 150 Hz. Since this increase in bandwidth occurs due to a better input s/n ratio, there will be no deleterious effects on demodulator operation. The output of the multiplier is $K_m = \dfrac{V_1 V_2}{10}$. Since one input to the multiplier is limited and large with respect to the second input, the multiplier output is approximately $\dfrac{1}{10}$.

The last loop element is the loop filter. The gain of this amplifier is set to make up the difference between the gain of the natural elements (phase detector, oscillator, multiplier, etc.) and the required loop gain. Thus, the loop dc gain should be equal to

$$K_{dc} = \frac{K_v}{K_{pd} K_{vco} K_{lpf} K_m}$$

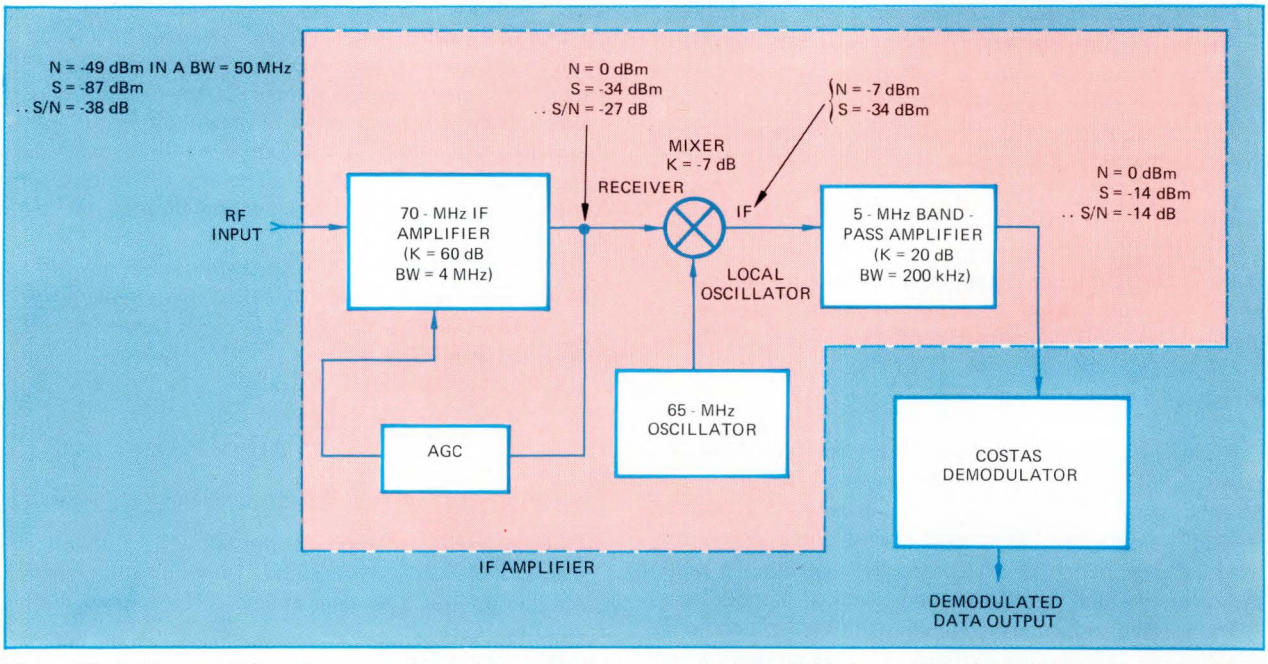

Fig. 3—Block diagram of the coherent receiver using a noncoherent agc signal that holds the 70-MHz i-f amplifier output level constant even when the input receiver signal is buried in noise. The receiver achieves a s/n ratio of −14 dB with the use of a Costas demodulator.

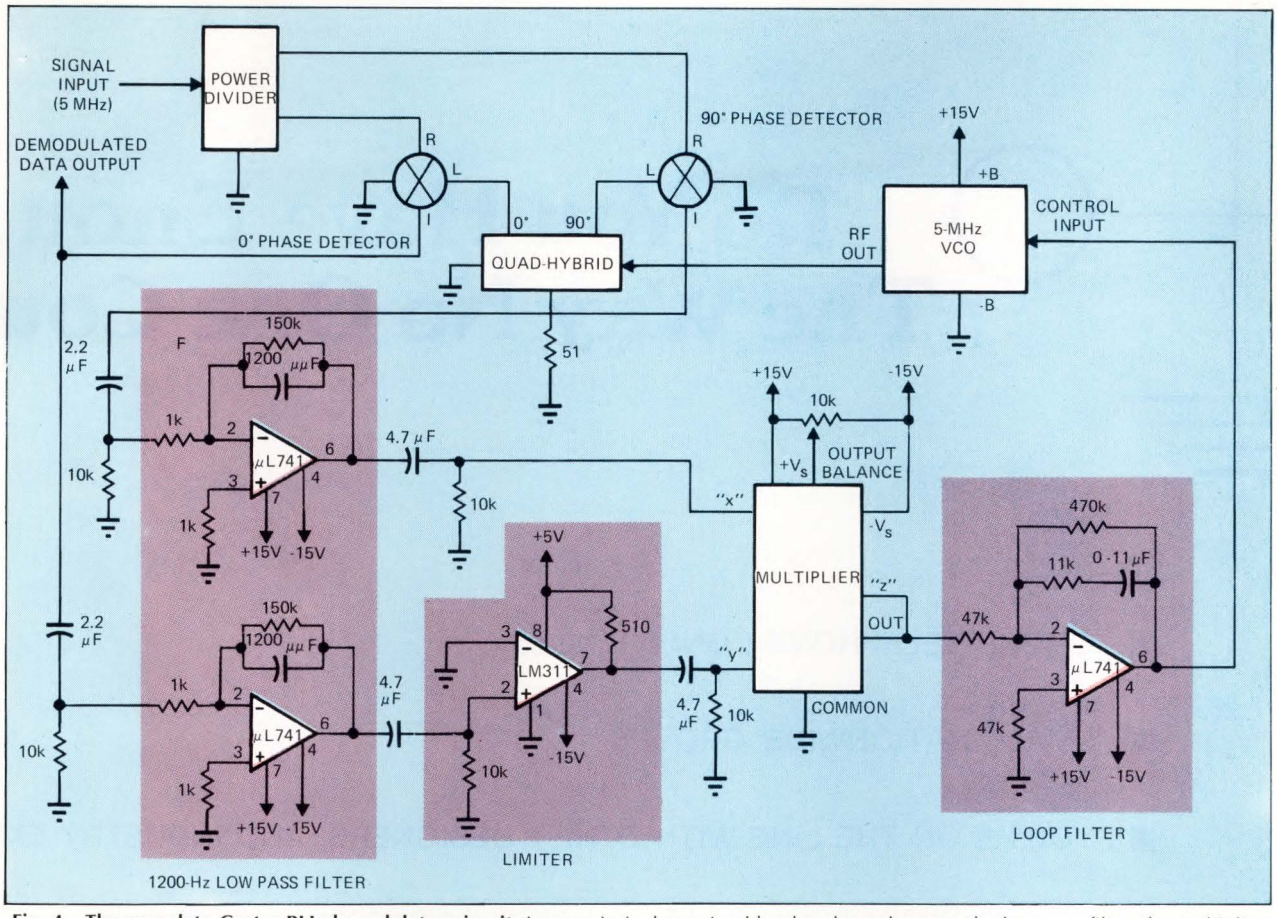

Fig. 4—The complete Costas PLL demodulator circuit. Loop gain is determined by the phase detector, the low-pass filter, the multiplier, the loop filter and the voltage-controlled oscillator. The power divider is RF Associates' Model H22, the quad-hybrid is Merrimac Research's Model QHT-2, the 0 to 90° phase detectors are both Relcom's Model M6A, and the multiplier is Analog Devices' Model 428J.

$$= \frac{1.3 \times 10^4}{(4 \times 10^{-3})(2.1 \times 10^4)(150)(1/10)} = 10.$$

The next step is to design the loop filter. So far we have two points from which to construct an open-loop Bode plot and to determine the loop filter components. The first two points to place on a sheet of semi-log paper are K_v = 84 dB at 1 radian and the cross-over point of 0 dB at 400 Hz (2500 radians), which will make the closed-loop noise bandwidth equal to 800 Hz, as determined earlier.

Loop damping is determined primarily by the placing of the breakout point (τ_2 = 830 radians) above the cross-over point. If τ_2 is set +6 dB above unity gain, a damping factor of 0.707 will result. Keep in mind that τ_2 should be set with some margin for loop-gain variations caused by temperature, aging, etc.

The design will proceed by moving from the crossover point at 2500 radians on a 6-dB/octave line to +10 dB loop gain, where τ_2 is marked for the breakout (lead network). The choice of 10 dB provides some margin and a damping factor of approximately 0.9. From this point, a 12-dB/octave line is drawn to intersect the initial voltage controlled oscillator slope. The intersection τ_1 = 19 radians gives the time constant for the lag network.

To obtain the desired lead-lag characteristic, the active filter configuration shown in **Fig. 4** can be used. We can assume that the 47-kΩ input includes the output impedance of the phase detector. Then, to get a dc amplifier gain of 10, a 470-kΩ feedback resistor is used. And since $\tau = 1/\omega$, $\tau_1 = RC = 470\ k\Omega \times 0.11\ \mu F = 0.052$ msec, and $C = 0.052$ msec/470 kΩ = 0.11 μF. Similarly, $\tau_2 = RC = 11 \times 10^3\Omega \times 0.11\ \mu F = 1.2$ msec yields R = 1.2 msec/0.11 μF = 11 kΩ. The input RC time constants of the oscillator are assumed to be well away from the 400-Hz cross-over point. □

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3. *"Phaselock Techniques,"* by F. M. Gardner, Wiley, 1966.
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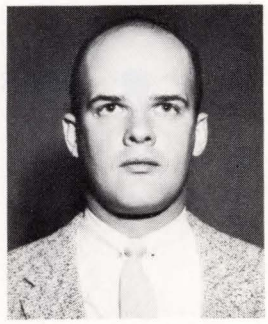
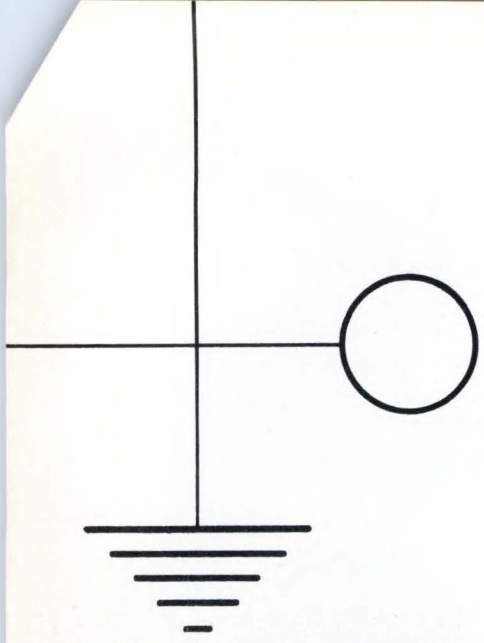
Author's biography



Robert P. Hennick is a senior design engineer at Bell Aerospace Company where he has been employed for 14 years. He is responsible for the design and development of communications systems. The particular design described in this article has been incorporated into a satellite air traffic control experiment for which Bell Aerospace is the prime contractor. Mr. Hennick holds a BSEE degree from Gannon College and is also a part-time instructor of electrical technology at Niagara County Community College.



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THE DISCUSSIONS YOU DIAL INTO

Dave Redick of Tymshare, Inc. speaks out on proper design choices for terminals

The challenge for designers of terminals is to match new ideas and new technology to the evolving needs of users. The right combination of product features and price in this rapidly-growing and fluid field can be an elusive target. But standards are emerging and the designer should be sensitive to these as they can make or break his design on the marketplace.

In my job as manager for selection of terminal equipment for one of the large time-sharing service houses (only GE and IBM are larger), I have sat between two groups: on the one side are hundreds of equipment vendors and their design engineers, trying to reach the marketplace; on the other side are customers—the end users of the service—who want reliable and effective terminal equipment so they can remotely access large powerful computer installations across the country.

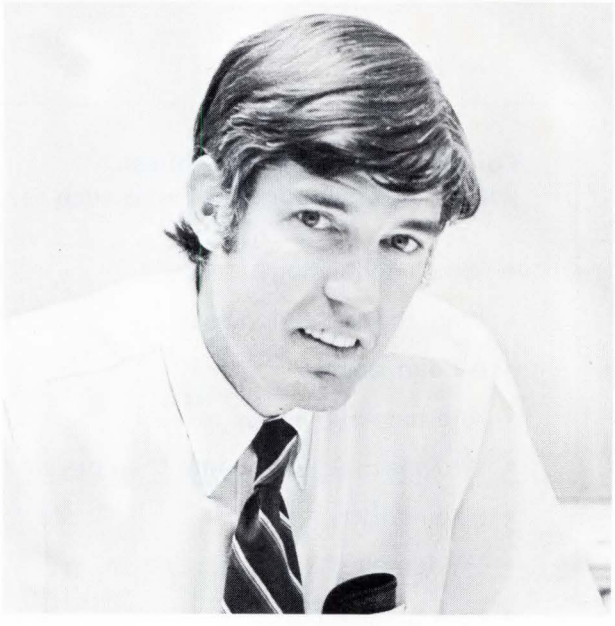
Since my company does not make terminals, we are vitally concerned that the terminal vendors design and produce good equipment. We are especially concerned that the equipment be reliable and maintainable because our revenues stop the minute a terminal goes down, and our customers quickly become disenchanted with our total service. Therefore, it has been my task to work closely with scores of current and prospective terminal equipment vendors to bring about good terminals. From my in-the-middle vantage point, I feel I've gained an overview of this new field that ought to help terminal designers.

A terminal to be used in time sharing is invariably operated by many different people in a wide variety of applications. Thus, the terminal should be as standard as possible.

Here are my opinions on basic general features that should be found in most terminals.

Selector switches for speed, parity, full/half duplex, and line/local options should be incorporated so that each user can quickly set up the terminal to suit the particular computer system he is tying into. These should be included whether the computer is an in-house installation or an outside commercial time-share service.

Code and interface specifications should adhere to main-stream standards. Fortunately, there is standardization on the use of ASCII (American Standard Code for Information Interchange). The U.S. government took the lead in standardizing on ASCII after it became clear that industry leaders such as IBM, Telex and Western Union were each going different ways, creating codes unique to their own equipment. There is also standardization on the EIA RS232C electrical interface (Electronic Industries Association). We can thank the Bell System for originating the de facto standard that become the basis for EIA's RS232C.



Keyboards present some problems. Here is one component that most manufacturers refuse to standardize. The teletype and common typewriter keyboard layouts are useful de facto standards, yet terminal designers insist on relocating various symbol keys and function keys such as "control," "carriage return," "break," "repeat" and "escape" to suit their whims. The poor customer must relearn the layout each time he uses a different terminal.

The lower-case mode is another area that could be handled better. Most users prefer a mode switch (upper/lower) which in the "upper" mode generates upper case for all alphabetic keys and only requires a shift for the symbols over the numerals. This is convenience for users communicating with the many time-share systems that only permit upper case letters (the IBM and G.E. networks for example). Otherwise the user is forced to go through the wasteful motion of hitting the upper-case shift key every time he hits a letter key. Just having an upper case locking shift as on a typewriter is not enough because you still want the ability to go straight to the numbers at the "bottom" of the numeric keys.

A keyboard adjunct of increasing utility is the 10-key numeric pad similar to the arrangement found on desk calculators. These can significantly increase the operator input rate for numeric data, whether on-line or in local key-to-tape mode.

Paper and magnetic tape both increase the power of any terminal for on-line and off-line work. These convenient memories may either be integral with the terminal or separate plug-in units.

Paper tape will remain popular for the time being because of its compatability with existing equipment, but I advise designers to consider magnetic tape for their new designs.

Magnetic tape contained in cassettes is more convenient to handle, has greater speed, and can be edited (erased and rewritten).

I've seen eight different classes of terminal equipment emerge on the marketplace. I think it will help designers new to the terminal field if I touch on each of these in turn, pointing out specific examples that I think deserve study, and making occasional comments about what I think are desirable features.

Portable Page Printers. This is one of the fastest-growing, yet still relatively least-developed classes of terminal equipment. The leading units in the higher-performance 30-characters-per-second category are, in my opinion, the Texas Instruments 725, the CTSI Execuport, and the Computer Devices 1030. All are thermal printers using special paper. T.I. uses its own thermal print head (of IC construction) and the others use an NCR head.

Terminals of this class should be under 35 lbs to be considered portable. Under 30 lbs is better yet. It is a matter of personal preference whether the case should be suitcase style (separate) or integral (removable top). I happen to think the integral case is more convenient. Of course all portable units should have an integral acoustic modem.

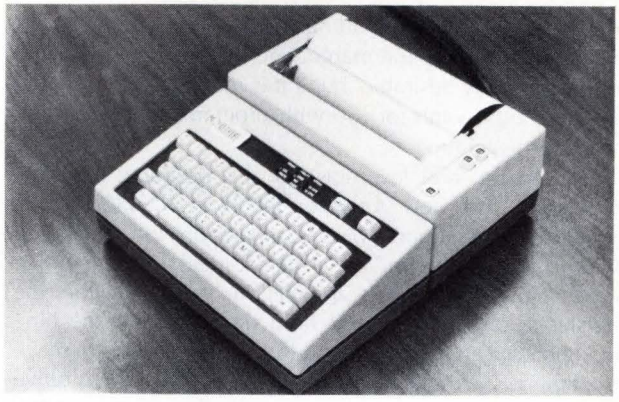
Portability is more important than some designers realize. It adds new dimensions to the time-share concept. The mobility not only aids the inter-city traveler—it allows a terminal to be shared within a company or department.

Texas Instruments 725

I see portable terminals soon being checked out of a central supply room, much like oscilloscopes and other portable tools are today.

Desk-Top Communications. The venerable Teletype Model 33 typewriter-like terminal is the cornerstone of this class. Its low cost and high reliability have served us all well. However, the market is crying for engineers to design faster and quieter machines.

The 30 character per second NCR Model 260 and the T.I. 720 are examples of "33 replacements." The NCR 260 rents for $80-110 a month and the T.I. 720 rents for $110-135 a month. Typical features found in these machines include 72-80 wide column print lines, and separate



NCR 260

modems. Although they can be moved by office staffs, they are not really intended to be portable.

Designers should understand that end users like to have these close by so they can readily make enquiries into the main computer, program the main computer, or have the computer make out small reports. They should operate quietly so they can be used in office or laboratory areas without disturbing neighboring workers. Gone are the days when terminals were banned to a dingy room "down the hall." The ideal desk top terminal would allow the user to work at his normal office area where he (or she) has access to personal files and can be conveniently reached by others. The market growth of these terminals will be related to traditional model 33 applications, but if designers can make them quieter, faster and perhaps even less expensive, they should expand to the point that they are almost as familiar as office typewriters (which they may indeed someday replace).

Wide-Carriage Report Generators. This is another dramatic growth area. Jobs that only a batch line printer in the computer room could do formerly, are now beginning to be performed in office areas by serial impact printers. Examples are the Univac DCT-500, the G.E. Terminet, and the Memorex 1240. The DCT-500 has become particularly popular because of its low price ($115-155 per month rental) and Univac's excellent field service.

Univac DCT-500

Any terminal in this class should accept standard 14-7/8 in wide sprocket-feed paper and produce a 118-132 column wide print line (the wider the better). Most offices like to use fan-folded paper with perforations every 11-in. so the completed reports can readily be torn into standard pages for easy handling. They also like to have extra layers with carbons so that multiple copies can automatically be generated. Programming of the "go-to-top-of-form" is essen-

tial to allow page formatting. A skip-perforation feature that allows a three-line margin and the beginning and end of pages is very desirable, but if it is included, there should be a disable switch for use with programs that have line-feeds for pagination.

High speed and low noise is also desirable for these machines). The new Anderson-Jacobsen AJ 630 thermal printer with its almost noiseless operation, fast speed and wide 132-column print line is almost ideal for use in office areas. However, for this application, it is likely that the noisier impact printers will hold their own for the time being because they can pound through to carbons to make multiple copies and have sprocket-fed paper for positive line registration and produce report-quality printing (rather than the dot-matrix fonts of thermal printers).

Another possibility in this class is to use an automated typewriter like the IBM "Selectric." The IBM 2741, the Datel, Dura and Novar units were early entries in this market that did use Selectrics. The Selectric prints at only 15 char/s, but it does provide lower-case letters as well as upper case, and has excellent printing quality.

Designers should appreciate that the quality of printing is becoming increasingly important as computers are being used to generate actual business correspondence.

A most interesting new impact printing mechanism has been announced by Diablo Systems, Inc. (now a part of Xerox). The Diablo printer appears to have the printing quality of the Selectric, but prints at twice the speed, and has fewer moving parts, costs less, and is quieter. It should be investigated by designers of this class of equipment.

Hazeltine 2000

Alpha-Numeric CRT's. These might be thought of as high-speed, soft-copy versions of page printers. The alpha-numeric CRT terminal has been the hero of the dedicated time-sharing systems used by stockbrokers and airlines, but it has yet to meet the rosy predictions made for it in general-purpose time-sharing applications. Designers must reduce its cost from the current $2,500-3,000 purchase price and $80-120 monthly rental prices. And in properly assessing the cost of CRT terminals, the designer must bear in mind that 99 out of 100 users will still want hard copy, so another $100-125 must be added to the monthly rental.

I sub classify alpha-numeric CRT's into two types:

a) Teletype replacements—these are simply faster, quieter versions of model 33's. No bells or whistles. The CCD 713 is an example.

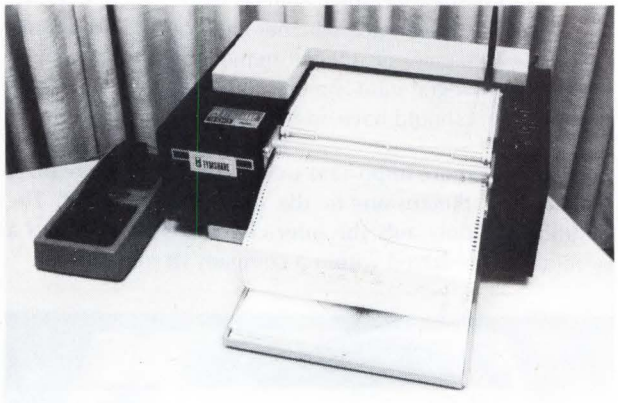
b) Editing types—these are more capable units that are intended to be used with minicomputers or time-sharing services with limited editing capability. They have built-in features that help the user clean up typing errors prior to transmission of a page (the full screen of the CRT) to the computer. The Hazeltine 2000 is an example.

The real advantage of the CRT is that it can go very fast. It is perfect for applications where the transmission line will permit high data rates and the user only wants to take a quick look at the data to make an on-the-spot decision. But real-world applications for CRT's are limited at this time by the slow (30 char/sec) speed of regular telephone lines and the fact that in most business environments users want hard copy. The sophisticated editing features of the editing type of CRT terminal are really redundant in many modern time-sharing systems, since these features are already provided by the central software package.

But when the terminal is also to be hardwired into a local computer—say the minicomputer of an intelligent terminal—then the CRT can truly come into its own, and give the user information from the local source at 120-480 char/sec.

The speed with which the operator can interpret the display becomes the limiting factor.

Full-graphic display. Pen plotters and full-graphic CRT's have been gaining steady acceptance with the more so-



Zeta Research Model 230B

phisticated users of time-sharing. However, high hardware cost and heavy reliance on elaborate software has limited this class of terminals in the "mass" markets. The designer's goal in this class of terminal is to help the user translate the voluminous amounts of data into easily-interpreted drawings and graphs.

In the case of the pen plotters, the goal is often also to produce accurate drawings that can be used for engineering purposes. Typically a relatively steep price must be paid for this accuracy. Accurate incremental plotters like the Zeta Research 230-B cost over $6,000. If the accuracy requirement can be relaxed, it is possible for the designer to reduce the cost while increasing the speed, as has been done with the Hewlett-Packard 7202 that sells for $3,300.

The CRT graphic displays are less accurate but much, much faster. A recent breakthrough, here, I feel, is the Tektronix 4010 which provides graphics and can be rented for $200-225 a month. Previously, CRT's with full graphic capability had to be outright purchased at prices as high as $9,000-20,000.

My main advice to designers with respect to this class of terminal is: "apply your creativity, and get the prices down."

Data entry. Here is an exciting new market. The idea is to make these terminals as small and as inexpensive as

possible by giving them modest, specialized keyboards and optional printing ability.

For the clever manufacturer, with the right price and features, I think there is a huge potential market for these "personal" micro-terminals. I see office workers, engineers, and managers having these little terminals much as they now have desk calculators.

As with calculators, an aggressive use of LSI circuitry is the key to low cost, high reliability, and small size. Future developments could include the use of local radio links to eliminate the need for having to be at a telephone. Another possibility will be the use of specialized "functional" keys to allow untrained operators, at the stroke of the key, to evoke the massive power of the central computer. This would be an extension of the functional keys on today's calculators that allow non-mathematicians to command difficult calculations, like obtaining square roots by tapping the button labelled with the symbol for that function.

Any person who now has to occasionally stop and jot down some record or request on a piece of paper, and

Datapet Model 5061

then remember to give that piece of paper to someone else for action, could use one of these micro-terminals. Doctors seeing patients on housecalls, housewives placing grocery orders, salesmen replenishing customer stocks . . . all could use this form of terminal.

Intelligent terminals. If an arithmetic processor and 4k or more words of storage is added to a terminal, it can be "intelligent." Essentially intelligent terminals are terminals with built-in minicomputers and enough peripherals (line printers and magnetic tape stations) to be small data processors in their own right. These intelligent terminals can be extremely cost effective. They allow the small to medium user to do his normal daily jobs in house at a minimum equipment cost, yet be able to at any time dial up an outside time share service for unlimited add-on power.

I predict the rapid acceptance of the intelligent terminal concept in the 70's. It is beginning to happen, now that the IBM 3725 and NCR 399 are on the market.

I think these intelligent systems will have far-reaching affects on all the other classes of terminals. Once a user has an intelligent terminal, he will be more motivated to add on smaller remote satellite terminals, such as portable page printers and data entry terminals. He'll have the in-house computing power to reduce the flood of data from these satellites, before he forwards the digested data

Modem

on to the time-share service's large central computers.

Modems. This is the one class of terminal equipment that has reached maturity. The large engineering investments in modems that followed the Carterphone decision (the court decision that made it legal to connect non-Bell System equipment to the phone lines) have resulted in a good selection of economical modems. Most of the modems handle 0-300 baud transmissions and these are now mass-produced at prices in the $250-325 range. There are modems that will handle transmissions up to 1,200 baud, but few of these have so far found wide use.

There is one new development in modems that ought to interest designers. This is the concept of transmitting and receiving at different speeds, or with asymmetrical data rates. Speeds of 30 char/sec or 300 baud are about the limit for the regular switched telephone network. But if the user will settle for a slower speed in one direction, he can have a higher speed in the other direction. For example, since he couldn't type faster than 15 char/sec anyway, the user might settle for a 15 char/sec transmit speed. Then, he could receive on the printer at 60 to 120 char/sec.

The tremendous growth in terminal technology and sales that we have seen in the last few years is only the beginning. Terminals will keep many design engineers busy in the 1970's. □

Who is Dave Redick?

Dave was manager for terminal equipment marketing at Tymshare, Inc., Palo Alto, Calif. Tymshare serves some 1,000 customer companies with four large computer installations scattered about the U.S., all interconnected by 40,000 miles of leased telephone lines. Because his company vitally needs terminals to sell its service, Dave has found himself intimately involved with more than one terminal design team, advising them on what features customers want. Tymshare has now become a major distributor of terminals. They account for 10% of Tymshare's $14 million annual revenues.

Dave received a bachelor's degree in mechanical engineering from the U. of Michigan, Ann Arbor, and a master's in business administration from the U. of Santa Clara, Santa Clara, Calif. He started as an engineer in aerospace but then progressively moved towards data system marketing, using disc memories as a bridge between his mechanical past and his electronic present. He has just accepted a job as marketing manager for Datapet, a new company bringing out a $900 data entry.

CIRCUIT DESIGN AWARDS

Analog arithmetic unit offers good accuracy

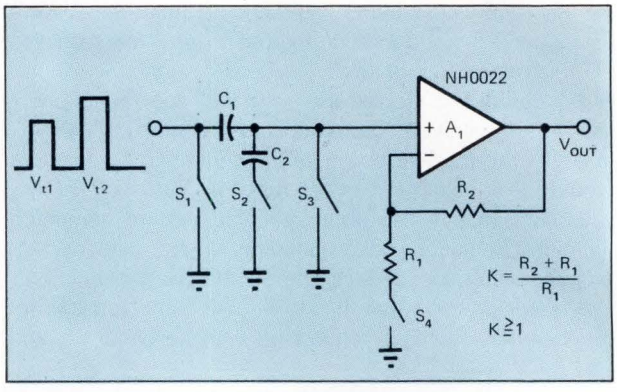
Charles F. Wojslaw,
National Semiconductor, Santa Clara, Calif.

In automated or computer-controlled test systems, it is often necessary to process several sequential analog signals prior to their being digitized and stored in memory. The analog circuit shown here offers the accuracy, speed and flexibility to perform sample-and-hold, divide, subtract, or amplify functions. The circuit can achieve a ± 1mV + 5μV/msec accuracy. If it is designed with J-FET analog switches, the circuit provides the necessary speed and reliability to operate in a computer test system.

The circuit can have gain by closing S_4 which configures A_1 as a non-inverting amplifier with gain equal to $(R_2 + R_1)/R_1$.

For the subtract function, the timed switch S_3 is opened during V_1 test time to store V_{t1} test time, again storing V_{t1} across C_1, and then closing S_1 to transfer the voltage. The output voltage, $V/_{out}$, is equal to K (V_{t1}).

Simple division for V_{tt} is achieved by closing S_2 and opening S_3. The output voltage V_o is equal to $K \frac{C_1}{C_1 + C_2}$. V_{tt}. □



Analog arithmetic unit can sample-and-hold, divide, subtract or multiply. Using FET analog switches in place of mechanical switches shown in the circuit can provide processing speeds compatible with computer test systems.

To Vote For This Circuit
Circle 150.

Divider circuit maintains pulse symmetry

Leslie A. Mann,
Radiation Inc., Melbourne, Fla.

It is often necessary, when generating clocks in a digital system, to divide the basic clock frequency by an odd number. In doing so, the 50/50 duty cycle possessed by the basic oscillator is lost. The circuit described here allows the designer to maintain a 50/50 duty cycle by the addition of only a few gates and 2 flip-flops.

The example shown in **Fig. 1** was designed as a divide-by-five counter to generate a 1-MHz, 50/50 duty cycle clock from the 5-MHz system reference. Two phases of a 1-MHz clock are generated as shown in **Fig. 2**. One phase is a decode of binary 4 from the counter while the other is a decode of 1, clocked at mid-bit time. The two phases are

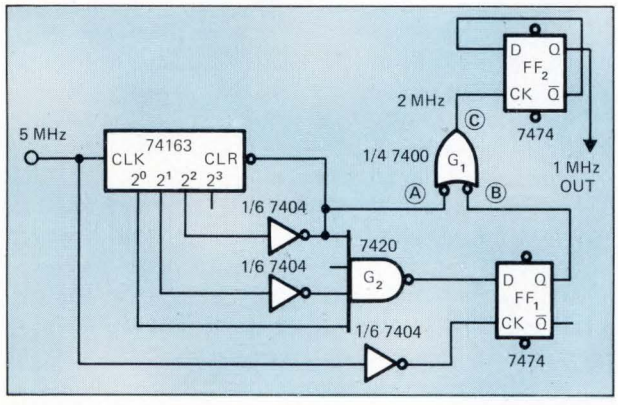


Fig. 1—Pulse symmetry, usually lost in odd modulo dividers, is maintained in this ÷5 circuit by first decoding through G_1, G_2 and FF_1 for a ÷2.5 count. This assymetrical pulse train is then divided by 2 at FF_2 for symmetry.

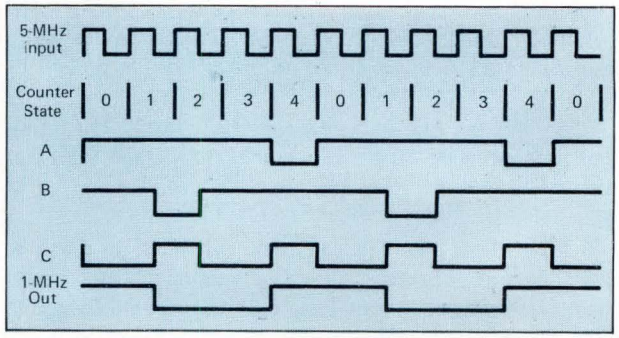


Fig. 2—NAND gate G_1 inputs are shown as waveforms A and B. Output (C) is then processed through FF_2. Similar techniques can be found for maintaining pulse symmetry in most odd-modulo dividers.

then recombined through gate G1 to give a 2-MHz clock. This clock is used to toggle FF-2, thus generating the desired 1-MHz, 50/50 duty cycle output.

By selecting the proper decodes off the counter, this same method may be used to generate a symmetrical square wave output through any odd number of divisions from the basic clock frequency. The only requirement is that this basic oscillator have a 50/50 duty cycle. □

To Vote For This Circuit
Circle 151.

Operational amplifier makes a simple delayed pulse generator

Dean T. Anderson,
Collins Radio, Cedar Rapids, Iowa.

It is often necessary to have a delayed pulse generated from a clock pulse, and use both pulses in gating circuitry. However, problems arise if the delayed pulse is generated as the clock pulse starts to fall before the clock is at its final state. This condition may generate an unwanted momentary output in the gate circuitry using these pulses.

A simple solution to this problem is to use an operational amplifier that will generate the desired delayed pulse from the clock pulse. Before the input pulse is applied to the circuit, the positive 1.1V bias on the operational amplifier, input C, keeps the output in its −15.5V state. As the clock or input pulse switches to +15.5V, both inputs B and C charge to 4.5 times larger than input C; the voltage on B will always be lower than C as long as the clock pulse stays positive. When the clock switches to −15.5V, input B and C will discharge to 0 and 1.1V respectively with C staying larger than B for 15μsec. After the 15μsec the voltage at input C will be less than at B for 1 msec and the output will switch to +15.5V for that time period. When the input voltage at B again drops below C, the output switches back to the −15.5V state.

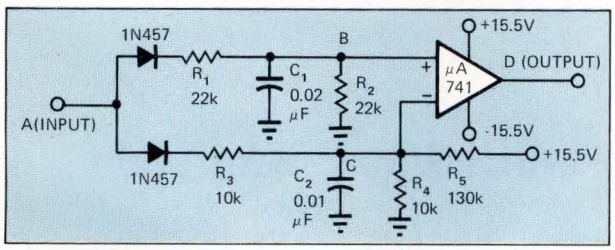


Fig. 1—Delayed pulse generator uses an op amp and is programmable for both delay time and pulse duration, by selection of the RC networks.

With the circuit values shown, the output pulse is 1 msec wide and delayed from the clock pulse by 15 mμsec. Furthermore, any number of time constants can be used to generate different pulse widths and delays. □

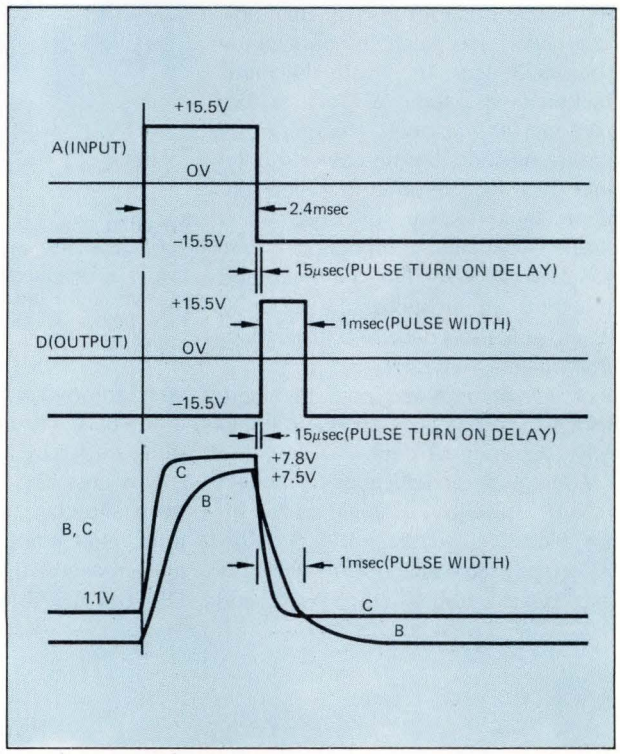


Fig. 2—Timing pulses obtained from component values given in Fig. 1 result in a 1 msec pulse output which is delayed 15μsec from the trailing edge of the input pulse.

To Vote For This Circuit
Circle 152

Rules & Announcements

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

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Readers have voted:

Herb Cohen winner of the March 1 Savings Bond Award. His winning circuit is "PUT oscillator has 4-decade frequency range." Mr. Cohen is with Electret Corp., New York, N.Y.

Alexander Liu winner of the March 15 Savings Bond Award. His winning circuit is "Low cost IR system detects intruders." Mr. Liu is with Fairchild Microwave & Optoelectronics Division, Palo Alto, Calif.

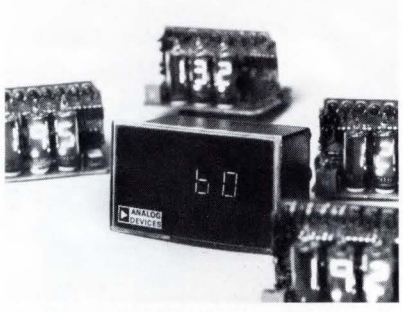
$50, 2-1/2-digit DPM heats up the competition with analog meters

PROGRESS IN INSTRUMENTATION

The lowest price for a 2-1/2-digit unipolar DPM has been announced by Analog Devices, Inc., with the introduction of its Model AD2002 at $50 each in 100 quantities. The unit operates from 5V dc (has no power supply) and uses RCA Numitron seven-segment incandescent displays. BCD output is available as an option.

Aimed at scientific, medical and industrial aapplications, the AD2002 at $50 starts to compete with analog-type meters, which offer up to 1% accuracy at best and cost anywhere from $25 to $75. The DPM is rated at 0.5% accuracy ±1 digit.

Additional specifications include 10-mV resolution, a single-ended input that accepts 0 to +1.99 V, 100-MΩ input impedance, 70-nA bias current, TC of 1/20th of a digit per °C and



Priced at only $50 in 100 quantities, this 2-1/2-digit DPM offers a low-cost alternative to analog meters. It requires 5V dc to operate and features 0.5% ±1 digit accuracy. Its overall dimensions are 1.8 by 3 by 1.5 in.

operation over a temperature range of 0 to+60°C. Aluminum case dimensions are 1.8 by 3 by 1.5 in.

Low-cost 2-1/2-digit DPMs have been showing up in recent months from other manufacturers. Datel Systems recently introduced the Model DM-100 at $75 in 100 quantities. This 5V DPM uses LEDs and has standard BCD output. Faratron Corp., has the Model 2501 (115V) or 2541 (+5V dc) that costs $65 in 100 quantities. This includes BCD output and a seven-segment incandescent display (LED optional). Another version, Model 2521, costs $58. Weston Instruments has a 115V 2-1/2-digit unipolar Model 1260 which costs $79.50 on 100 quantities. This one offers a Nixie display and optional BCD.

Analog Devices, Inc., Route 1 Industrial Park, Norwood, Mass. 02062. Phone (617) 329-4700. **270**

Datel Systems, Inc., 1020 Turnpike St., Canton, Mass. 02021. Phone (617) 828-6395. **271**

Weston Instruments, Inc., 614 Frelinghuysen Ave., Newark, N. J. 07114. Phone (201) 243-4700. **272**

Faratron Corp., 280 Green St., South Hackensack, N. J. 07606. Phone (201) 488-1440. **273**

Monolithic, high-frequency phase-lock loops offer wide flexibility

PROGRESS IN MONOLITHIC ICs

Two new very-stable monolithic phase-lock loops stretch guaranteed high-frequency operation up to 25 MHz and incorporate designs that allow expansion of the basic phase-lock loop applications. The two are Harris Semiconductor's HA-2820, a low-frequency unit, and the HA-2800 high-frequency device. The former is guaranteed to work over 0.01 Hz to 3 MHz, while the latter has a minimum upper frequency of 25 MHz.

Each PLL features a broken loop between the VCO (voltage-controlled oscillator) and the phase comparator with appropiate external connections, allowing for independent variation of loop and demodulation gains. Such a design makes each PLL useful for phase demodulation applications.

Also, the dc level of the demodulated output voltage and/or gain (from the low-pass filter) can be externally controlled.

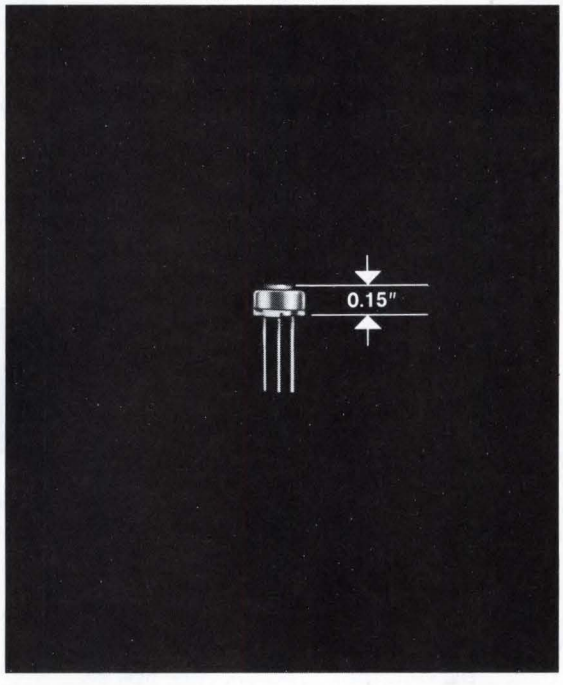
Both PPLs are specified to be stable in center frequency (f_o) to a maximum of 100 ppm/°C. Short-term stability of high-frequency PLLs has generally been about 600 ppm/°C, at best.

The new PLL duo is available in both military (−55 to 125°C) and commercial (0 to+75°C) temperature ranges. The low-frequency PPL can be supplied in a 14-pin hermetic DIP, while the high-frequency unit comes in a 16-pin hermetic DIP.

Quantity pricing (100 units) is $13.35 each for the low-frequency military version (HA-2820) and $6.35 for the low-frequency commercial unit (HA-2825). The high-frequency military version (HA-2800) costs $22.65 each while the high-frequency commercial version (HA-2805) lists for $9.85 each. Harris Semiconductor, Box 883, Melbourne, FL 32901. Phone (305) 727-5407. **274**

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

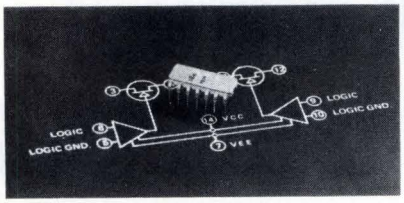
SHOWN ACTUAL SIZE



You can't do better than our Series 82 Trimmers for small size and low cost . . . and, of course, Helipot dependability. These ¼" single-turn, general-purpose cermet models have the lowest profile in the industry with a proven cermet resistance element that can be set to any voltage ratio within 0.05% of full scale. Sealed metal housings, solid stops, and essentially infinite resolution. They'll save you space—they'll save you money. (Our prices start at $1.40 list.) Two good reasons to write for specs and prices today.

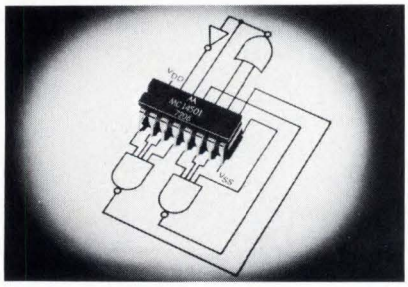
Beckman® INSTRUMENTS, INC.
HELIPOT DIVISION
2500 Harbor Blvd., Fullerton, Calif. 92634
HELPING SCIENCE AND INDUSTRY IMPROVE THE QUALITY OF LIFE

CIRCLE NO. 33



DUAL FET ANALOG GATE features "break-before-make" action. The CAG45 consists of two completely separate FET analog switch circuits capable of switching up to ±10V signals (ac or dc) and being controlled directly from most logic circuits. It features zero offset voltage and low on-resistance (50Ω maximum at normal temperatures). Unit prices are $19.60 (1-49) Teledyne Crystalonics, 147 Sherman St., Cambridge, MA 02140. Phone (617) 491-1670. **170**

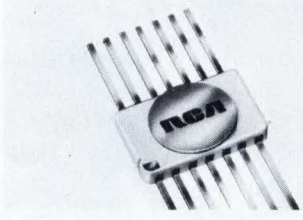
TRANSISTOR ARRAY ICS, LM3046 consists of five general purpose silicon NPN transistors on a common monolithic substrate. Two of the transistors are internally connected to form a differentially-connected pair. The LM3046 is supplied in dual-in-line plastic package with a temperature range of 0° to +70°C. Price: 100 pcs.—$1.10 ea. European Electronic Products Corp., 10180 W. Jefferson Blvd., Culver City, CA 90230. Phone (213) 838-1912. **171**



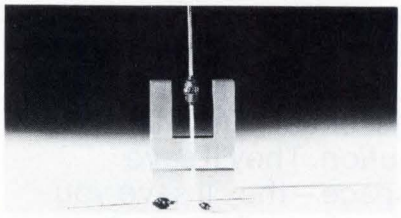
CMOS TRIPLE GATE offers both NOR/OR and AND/NAND functions in a single package. This CMOS logic device has both a 2-input NOR/invert gate and two 4-input NAND gates. They provide a high fanout, >50, and a typical noise immunity of 45% of supply voltage. The MC1451CL is priced at $1.99 ea in quantities of 100. Technical Information Center, Motorola Inc., Semiconductor Products Div., P.O. Box 20924, Phoenix, AZ 85036. Phone (602) 273-6900. **172**

CMOS LOW-POWER MONOSTABLE/ASTABLE MULTIVIBRATOR incorporates logic techniques to permit positive or negative edge-triggering. This device, designated CD4047A (Preliminary), has retriggering and external counting options available. The CD4047A (Preliminary) is currently available on a sample basis in a 14-lead dual-in-line ceramic package (CD4047AD). Price: $15 (1-24 unit-level). RCA Solid State Div., Route 202, Somerville, N J 08876. Phone (201) 722-3200. **173**

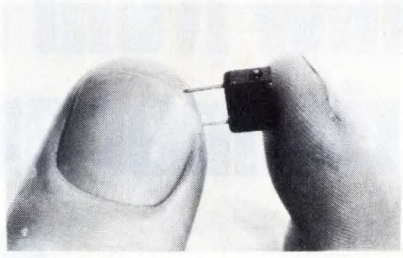
1500V TRANSISTOR is rated at 2.5A. The EEP EU105 is a high voltage NPN silicon power transistor rated at 0.75 μsec T_s, and packaged in a TO-3 metal case. The EU105 is intended for use in line deflection circuits of television receiver, voltage regulators and similar applications. Price: 1-24 pcs.—$4.98 ea., 100-up pcs.—$3.96 ea. European Electronic Products Corp., 10180 W. Jefferson Blvd., Culver City, CA 90230. Phone (213) 838-1912. **174**



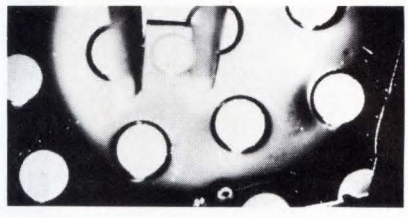
CMOS HIGH-CURRENT QUAD BUFFER, designated CD4041A, will typically sink 2 TTL loads at the true outputs and 1 TTL load at the complement outputs. The CD4041A is supplied in a 14-lead ceramic DIP (CD4041AD), a 14-lead plastic DIP (CD4041AE), or a 14-lead flat pack (CD4041AK). Price (1000-unit level): CD4041AD, $6.15 ea., CD4041AE, $3.00 ea., CD4041AK, $6.80 ea. RCA Solid State Div., Box 3200, Somerville, N J 08876. Phone (201) 722-3200. **175**



PIN MICROWAVE DIODES are rated at 100V. These diodes series UM4001B, UM7001B through UM7201B, and UM6001B through UM6601B offer a wide range of capacitance, resistance and carrier lifetime. All feature low distortion and low insertion loss for microwave applications such as TR switches, antenna selectors, switching matrices and attenuators. Prices are as low as 85¢ in 10,000 quantities. Unitrode Corp., 580 Pleasant St., Watertown, MA 02172. Phone (617) 926-0404. **176**



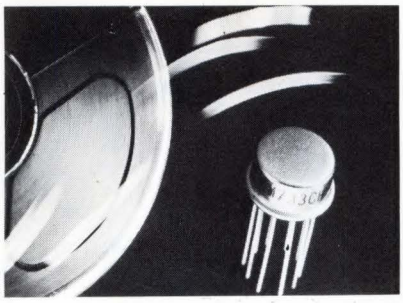
LEDS MOUNT IN DIP SOCKETS. The LD1 provides a single LED with built-in series resistors. LD1s can be stacked on 0.1-in. .1 inch centers and require only 3mA @ 5V. Price is $0.99 (1k qty). Unique Devices Co., P.O. Box 70, Bountiful, UT 84010. Phone (801) 295-4252. **177**



HIGH Q TUNING VARACTORS yield high reliability, uniformity. The VAT-200 series microwave tuning varactors feature PLESA™ passivation method, ultra-low leakage current, high Q (to 4000), high temperature operation, and controlled capacitance/voltage characteristics. Reverse breakdown voltages are 30/45/60V, leakage current, typical, at 25°C is 5 nA and at 150°C is 500 nA. Varian, Solid State Div., Salem Rd., Beverly, MA 01915. Phone (617) 922-6000. **178**

40W, 12.5V POWER TRANSISTORS for mobile communications, the RCDT 216 Series, available in the MT-72 case with stripline packaging withstand infinite VSWR at all phases at full-rated power and voltage. The units are functional tested to exact customer specifications and are immediately available from the factory. They are priced at $26.80 each in 1-99 quantities. Solitron/Microwave, Solid State Products Div., 1440 W. Indiantown Rd., Jupiter, FL 33458. Phone (305) 746-8311. **179**

CMOS HEX BUFFER/CONVERTERS, CM4009A/CM4010A, provide high current sinking capability, 8 mA minimum at V_{OL} of 0.5V, and V_{DD} of +10V. CM4009A is an inverting buffer/converter and CM4010A is non inverting. Conversion capability ranges from CMOS logic operating at +3V to +15V, to DTL or TTL logic operating at +3V to +6V. Solitron Devices, Inc., P.O. Box 23157, 8808 Balboa Ave., San Diego, CA 92123. Phone (714) 278-8780. **180**



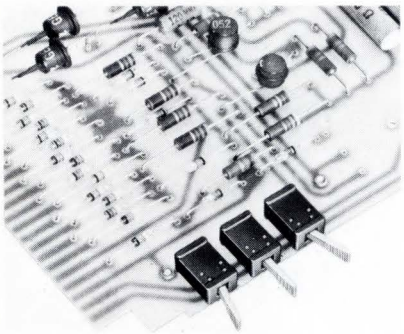
DIFFERENTIAL AMPLIFIER'S bandwidth is 120 MHz. The LM733, a high gain monolithic video amplifier, features selectable gains of 10, 100 and 400. Input resistance is 250 kΩ, and output resistance is only 10Ω. Supply range is ±3 to ±8V with a ±5V differential input capability at maximum supply voltage. 100-piece prices: LM733H-TO-5 is $5.35; LM733CN-molded DIP is $2.45. National Semiconductor Corp., 2900 Semiconductor Dr., Santa Clara, CA 95051. Phone (408) 732-5000. **181**

VOLTAGE COMPARATOR, the LM311 is now available in an 8-pin mini-DIP package. The new configuration, called the LM311N, offers the same performance as the LM311 at a lower price. The LM311N is designed to operate from a single 5V supply or ±15V supplies. In quantities of 100, the LM311N is priced at $3.15 ea. National Semiconductor Corp., 2900 Semiconductor Dr., Santa Clara, CA 95051. Phone (408) 732-5000. **182**

1024-BIT MOS DYNAMIC RAM can serve as a pin-for-pin replacement for the 1103 MOS RAM, while eliminating the critical precharge and chip-enable overlap timing requirement. Designated the 3534/1103, it is a 1024 × 1-bit dynamic RAM constructed with conventional P-channel, silicon gate technology. It is available in an 18-lead hermetically sealed DIP. The 100-999 price is $14. Semiconductor Components Group, 464 Ellis St., Mountain View, CA 94040. Phone (415) 962-3816. **183**

55-GHZ MICROWAVE MIXER DIODE features ultra-low noise. Featuring overall double sideband noise figures of 6.0, 6.5 and 7.0 dB at 55 GHz, the new line of gallium arsenide, Schottky barrier, mixer diodes for radiometry applications is designated the SSV-44040 Series. They are available in single units and matched pairs (the conversion loss for matched pairs is within 0.3 dB). Sperry Electronic Tube Div., Dept. 9002, Waldo Rd., Gainesville, FL 32601. Phone (904) 372-0411. **184**

UNIVERSAL ACTIVE FILTER SECTION is available in a standard 8-pin TO-5 package. Model μAR1800 Active Filter Section has a pin layout compatible to standard IC op amps and can be used to form virtually any second-order transfer function by the addition of external circuit components. The unit can be programmed for Q and center (cut off) frequency. Price is $4.25 each in quantities of 100. Integrated Electronics, Inc., 16845 Hicks Rd., Los Gatos, CA 95030. Phone (408) 265-2410. **185**



MOLDED TOGGLE SWITCHES, Series T8200, fit 0.062 in. to 0.093 in. printed circuits boards. Integral wire leads are 0.130 in. long. Weighing only 0.05 oz, the units measure 1.1 in. by 0.39 in. by 0.27 in. including toggle. Contacts are rated for a minimum of 100,000 operations on resistive loads of 1A, 6 & 12V dc; 0.5A, 28V dc and 120V ac. Control Switch Inc., 1420 Delmar Drive, Folcroft, PA 19032. Phone (215) 586-7500. **186**

MINIATURIZED TRIMMER CAPACITORS are offered in either side or top tuned versions in eight standard max. values from 5.5 pF to 40 pF. The dielectric is glass. They are "O" ring sealed to provide 40 PSI. protection against dust, moisture, flux, solder, cleaning fluids and encapsulents. Typical prices are $3.50 each for 1000 of the 10 pF units. Voltronics Corp., West St., E. Hanover, N J 07936. Phone (201) 887-1517. **187**

SINGLE-DIODE STRIPLINE-SWITCH MODULES, series A9S160, are designed for low and intermediate power switching from 100 MHz to 12.4 GHz. A9S161 and A9S162 are designed for fast switching. A9S163 and A9S164 are designed for general-purpose switching and attenuation with anode ground. A9S165 and A9S166 are for general-purpose switching and attenuation with cathode ground. Aertech Industries, 825 Stewart Dr., Sunnyvale, CA 94086. Phone (408) 732-0880. **188**

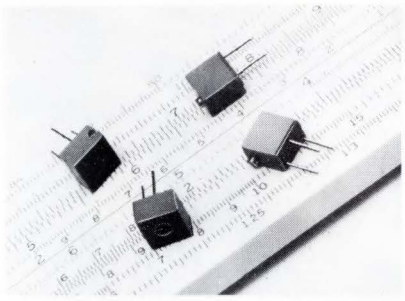
VARIABLE RESISTOR SLIDE SWITCH ASSEMBLY, catalogued as LPP type, incorporates a push-pull switch mounted on a 0.890-in. diameter variable resistor as is common on on-off applications for TV sets. The assembly carries a TV-1 rating. Both single-pole, single-throw and single-pole, double-throw switches are available. Stackpole Components Co., P.O. Box 14466, Raleigh, NC 27610. Phone (919) 828-6201. **189**

SEVEN-SEGMENT-DIGITAL READOUTS, the FE SERIES is introduced. This incandescent-filament readout offers many cost-saving features such as long life, over 100,000 hours; high brightness, up to 7000 ft. L; low current, 8 to 16 mA per segment; and low drive voltage. Three models are available: FE-630, 3V; FE-640, 4V; FE-650, 5V. Price is $3.15 each in 1000 quantities. Pinlites, P.O. Box 453, Caldwell, N J 07006. Phone (201) 226-7724. **190**

MULTI-LAYER CERAMIC CAPACITOR MATRIX provides improved performance over single-layer types. Monolithic construction of the unit eliminates the need for installing individual multi-layer chips, thereby reducing assembly costs by as much as 50%. Range is to 16 capacitors from 50 pF to 0.1 μF. Price: from $1.00 each. Delivery: 6 to 8 weeks. The Potter Co., 500 W. Florence Ave., Inglewood, CA 90301. Phone (213) 678-2651. **191**

LOCKING CIRCUIT-BOARD SUPPORT features a new arrow-type locking head which inserts into a 0.187 in. hole in the chassis where it expands to lock permanently into position. A squeeze of the fingers permits removal of the board from the support. Made of nylon, the LCBS supports are available in seven spacing heights from 3/16 in. to 7/8 in. FOR FREE SAMPLES, and literature, contact Richlok Corp., 5825 N. Tripp Ave., Chicago, IL 60646. Phone (312) 539-4061. **192**

PALLADIUM/SILVER-RESISTOR PASTES, Series 7000B, for consumer electronic devices, overcome some of the previous shortcomings of palladium/silver resistor systems. The pastes are relatively insensitive to variations in firing temperatures. They are available in resistivities to 5 MΩ. Price per ounce is $18.50 to $48, depending on quantity. Electro-Science Lab., Inc., 1601 Sherman Ave., Pennsauken, N J 08110. Phone (609) 663-7777. **193**



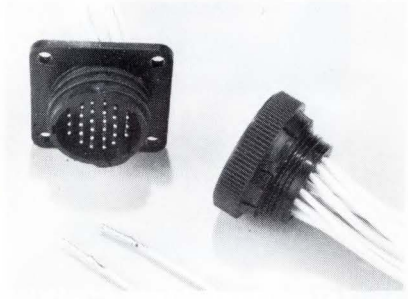
TRIMMER RESISTOR, Model 1240, has maximum T.C. of 10 ppm/°C. Containing a resistance element of bulk metal film set on ceramic, this trimmer features excellent stability. Resistance range is from 2Ω to 5 kΩ non-measurable inductance; no dc offset; no thermal noise; 20-turn adjustment; and max. noise of 10Ω ENR. Typical price is $5 each in 100 lot quantity. Vishay Intertechnology, Inc., 63 Lincoln Highway, Malvern, PA 19355. Phone (215) 644-1300. **194**

PROGRAMMABLE ENCODING-SWITCH KEY, the CES Series switch, can hold within the switch body up to 9 diodes for ASCII or any binary coding. There is no weldering, soldering or clamping of diode leads. To insert diodes, replace a faulty diode, or change codes, the customer unsnaps the diode matrix, re-positions the diode, and closes the switch. Less than 40¢ in large quantities. Industrial Echelon, Inc., P.O. Box 313, Huntingdon Valley, PA 19006. **195**

ZERO-INSERTION-FORCE RECEPTACLES for leadless substrates accommodate 2.000 in. × 0.578 in. side-metallized-leadless-ceramic substrates. The high normal-contact force (averaging 120 grams) provided by the stainless steel contacts is in part responsible for the low (5 to 9 MΩ) contact resistance. Contact "tails" are arranged in two rows of 20 on 0.100 in. spacing with 0.600 in. between rows. Amp Inc., Harrisburgh, PA 17105. Phone (717) 564-0101. **196**

FIXED ATTENUATORS from 0.5 dB to 40 dB are offered in 50, 75, 100 and 600Ω impedances. The units are manufactured with 1% precision film resistors and are designed in Pi networks. Frequency range is extremely flat from dc to 100 MHz. Standard units, available from stock, are produced in 3/4 in. diameter brass enclosures with BNC connectors on each end. Allen Avionics, Inc., 224 E. 2nd St., Mineola, NY 11501. Phone (516) 248-8080. **197**

NUMERIC READOUT, the "Mono-bit," provides rapid access to all parts. Molded, mirror surfaced light pipes permit illumination levels in excess of 500 ft. L with contrast ratios of 3 to 1. Custom-color combinations for special applications are also available. Symbolic Displays, Inc., P.O. Box 4322, Irvine, CA 92664. Phone (714) 546-0601. **198**



ALL-PLASTIC CIRCULAR CONNECTOR, the "O" Series, combines the desirable features of metal cylindricals with the cost and weight advantages of plastic-bodied commercial connectors. The stamped-and-formed crimp-type contacts accept wires from AWG #20 to #28 and either pins or sockets snap readily into either plug or receptacle housings. AMP Inc., Harrisburg, PA 17105. Phone (717) 564-0101. **199**

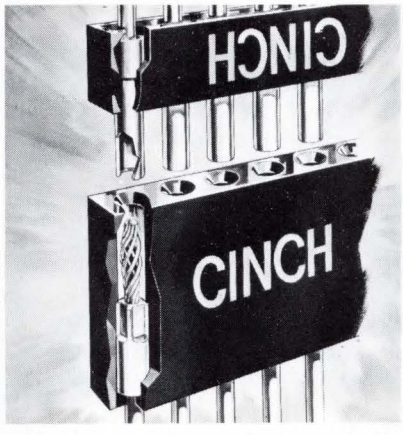
MINIATURE PRECISION WIRE-WOUND RESISTORS, "miniohms," are offered in any of 44 standard values from 10Ω to 300 kΩ. MiniOhms are available with accuracies of ±0.01%, ±0.025% and±0.1%. General Resistance, Inc., 500 Nuber Ave., Mt. Vernon, NY 10550. Phone (914) 699-8010. **206**

ACTIVE BAND-REJECT FILTER, Series 9000, provides a precisely controlled ratio of 3 dB and 40 dB bandwidths. Series 9000 filters use ±15V dc power, are encapsulated for printed-circuit mounting, and are available from 0.01 Hz to 100 kHz. Model 9060, (60 Hz) costs $120 (1 to 4 pieces). Polyphase Instrument Co., E. 4th, Bridgeport, PA 19405. Phone (215) 279-4660. **207**

DRY REED TRANSFER SWITCHES feature low insertion loss, low VSWR and long operating life. Models 4908 and 4910 provide fast switching times, 2 msec typical, low VSWR at all ports and high isolation, 100 dB min. for Model 4908 and 45 dB min. for Model 4910. Narda Microwave Corp., Plainview, L.I., NY 11803. Phone (516) 433-9000. **208**

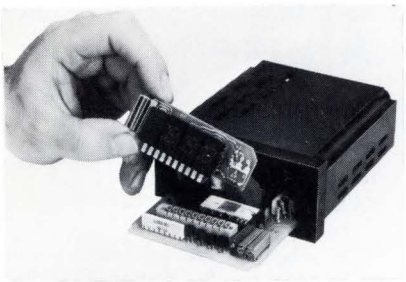
DELAY LINES available in 0.220-in. high DIP package. Series LC-250 delay lines afford savings in printed circuit board packaging density. Series LC-250 is available with standard delay times from 5 to 200 nsec, standard rise times from 2 to 40 nsec, and with standard impedances of 50, 100, 200 and 360Ω. Arcidy Associates, 370 Commercial St., Manchester, NH 03101. Phone (603) 668-2111. **209**

ON-OFF-ON SPDT SWITCH features momentary action in both ON positions. The flatted handle toggle is a new option and 3 new terminal styles are available as options for all switches. These include 3/4-in. long or 1-1/16-in. long wirewrap terminals and a 3/16-in. long configuration for direct insertion into printed circuit boards. American Switch Corp., 24 Mill Lane, Arlington, MA 02174. **212**



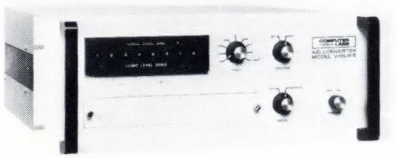
MINIATURE CONNECTOR SYSTEM, the Dura-Con, provides a size 24 contact for use on 0.050 in. centers, in a "strip" connector with 20-contacts on a 1 in.-long insulator. Operating temperature range is −65°F to +275° F, and they will withstand 20 shocks at 500g with no discontinuity. Contact resistance is 8 MΩ maximum after 500 mating cycles. Cinch Connectors, TRW Electronic Components, 1501 Morse Ave., Elk Grove Village, IL 60007. Phone (312) 439-8800. **213**

PC BOARD JUMPERS, Series 405, are specially prepared lengths of flat cable with Kapton on one side and polyester insulation on the other. High-production infra-red-soldering techniques can be utilized directly through the Kapton. Standard lengths: 1 in., 2 in. and 3 in. Number of conductors: 10 to 100. Price: from 50¢ each. Ansley Electronics Corp., Old Easton Rd., Doylestown, PA 18901. Phone (215) 345-1800. **214**



DPMs OFFER PLUG-IN LEDs AND MOS/LSI CHIPS. One MOS/LSI chip contains digital logic, polarity-sensing logic, comparator-to-sense-threshold crossing, overrange-sensing logic and display-strobing and storage-register synch. Model 1295 (under $100 in OEM quantities) is a full bipolar 3-1/2-digit unit; Model 1296 is a limited bipolar 3-1/2-digit DPM; and Model 1297 is a full bipolar 2-1/2-digit instrument. Weston Instruments, Inc., 614 Frelinghuysen Ave., Newark, N J 07114. Phone (201) 243-4700. **215**

PANEL METER USES SLIDE-IN SCALES. Model 7025, 2-1/2-in. panel meter features slide-in scales. It allows a relatively small basic stock of meters to be modified with a larger number of slide-in scales for a variety of requirements. It offers 1% tracking as standard for many popular ranges and 1/2% tracking upon specification. Several front-plate colors, sizes and mounting styles are offered. LFE Corp., Process Control Div., 1601 Trapelo Rd., Waltham, MA 02154. Phone (617) 890-2000. **216**

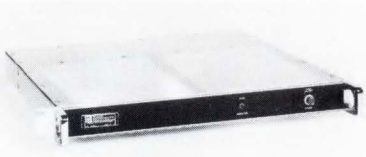


7- AND 8-BIT A/D CONVERTERS OPERATE AT 20 AND 15 MHz. Model VHS-720 is the 7-bit unit that operates at 20 MHz. Model VHS-815, the 8-bit unit, operates at 15 MHz. Both units are self-contained and include track-and-hold circuits, power supplies and built-in test circuits. All normal calibration is done at the front panel of each converter. Computer Labs, 1109 S. Chapman St., Greensboro, NC 27403. Phone (919) 292-6427. **217**

NEW COMPUTER CONTROLLED TEST SYSTEM designated COMPAC is an extended minicomputer that communicates with external-process circuitry and data transducers via interface hardware. The basic COMPAC system for $16,500 includes a 300-point two-wire-analog-input multiplexer, a high accuracy A/D converter, 64 digital I/O channels, a program data display, a 16-bit minicomputer with 8k of core memory, a teletypewriter and a complete software system. Non-linear Systems, Inc., Box N, Del Mar, CA 92014. Phone (714) 755-1134. **218**

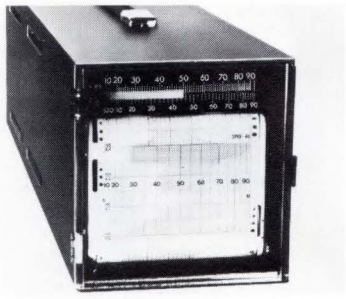
REAL-TIME ANALYZER HAS BUILT-IN COMPUTER COMPATIBILITY for automatic control of noise and vibration studies. The SD301C analyzer has an option that permits both remote control and sensing of its critical functions. Both remote control and sensing of switch positions are provided for the input voltage range (10 and 1-dB attenuator switches); the frequency range (10 ranges from 10 Hz to 50 kHz); and the post-filter output gain (0, 10, 20 and 26 dB). Spectral Dynamics Corp., Box 671, San Diego, CA 92112. Phone (714) 278-2501. **219**

A "BUILD-AS-YOU-NEED" STRAIN-GAGE-DATA-ACQUISITION SYSTEM. The V/E-20 Series of strain-gage instrumentation can read and/or automatically record up to 100 channels of inputs from gages bonded to a structure or from load cells. A test engineer can start with the moderately priced V/E-20A digital-strain indicator and, with the other V/E-20 Series modules available, gradually build up to a fully automatic System, complete with automatic printout. Vishay Instruments, Inc., 63 Lincoln Highway, Malvern, PA 19355. Phone (215) 647-5115. **220**



TWO NEW FREQUENCY SYNTHESIZERS digitally control the frequency of the tuning heads in Watkins-Johnson's RS-160 PAN/MAN receiving system. The FS-101 operates from 2 to 300 MHz and the FS-102 operates from 2 to 1000 MHz. Control of the synthesizer is either through a TTL-compatible parallel or serial digital-frequency-command word input. Watkins-Johnson Co., 6006 Executive Blvd., Rockville, MD 20852. Phone (301) 881-3300. **221**

BIDIRECTIONAL-PRESET COUNTER ACCEPTS UP TO 24 RELAY OR SOLID-STATE OUTPUTS. Model CB1245 is a hand wired, readily modified counter with a maximum capacity of five decades, indicating up to 99,999. It is designed for programming industrial processes and will display inches, feet, turns, meters or any other unit of measure. Electronic Counters & Controls, Inc., 33 Baker Rd., Lake Bluff, IL 60044. Phone (312) 362-8910. **222**



DUAL-INPUT RECORDER measures humidity, moisture and/or temperature. Designated Model SMT, the line-operated instrument employs a continuous-balance ac Wheatstone bridge with the range of each input established by its own plug-in unit. An internal timer automatically switches the inputs, each of which can be independently set between 15 sec and 15 min of cycle time. Beckman Instruments, Inc., Cedar Grove Operations, 89 Commerce Rd., Cedar Grove, N J 07009. Phone (201) 239-6200. **223**

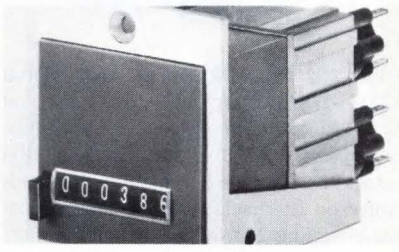
TWO-AND FOUR-PHASE PULSE GENERATORS are designed particularly for test and evaluation of MOS four-phase logic and dynamic RAMs. Their output frequency is adjustable from 10 Hz to 12 MHz. Each phase is independently adjustable in amplitude (+12 to −30V), rise and fall times (10 nsec to 100 μsec) and baseline offset (+5 to −5V). Rise and fall times are completely independent. The $2500 Model 601 is a four-phase generator, and the $1600, 610 is a two-phase unit. Comaltest, Inc., Commerce Dr., Danbury, CT 06810. Phone (203) 792-3777. **224**

26-RANGE, 4000-COUNT DMM COSTS $475. Model DV357A features 5 dc voltage ranges covering 400 mV to 1000V fullscale and 5 ac voltage ranges from 200 mV to 1000V fullscale (50 Hz to 150 kHz). It also has 5 dc current ranges from 400 μA to 2A fullscale, 5 ac current ranges from 200 μA to 2A fullscale and 6 resistance ranges from 400Ω to 40 MΩ fullscale. Dc and ac voltage accuracies are ±0.05% of reading ±1 digit and ±0.2% (to 10 kHz) and ±0.5% (to 20 kHz) ±1 digit, respectively. Traco, Inc., 509 Rolling Hills Rd., Somerville, N J 08876. Phone (201) 725-5333. **225**

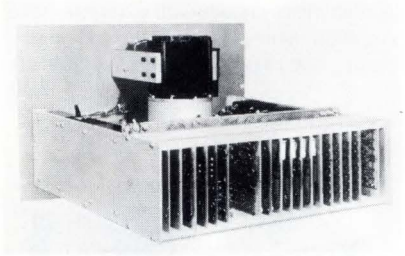
A PORTABLE 8-CHANNEL COLD-JUNCTION COMPENSATOR. The MARK VIII compensator, for use in thermocouple circuits, operates on self-contained energizers. It provides the physical and electrical equivalent of an ice-bath reference for thermocouples at 0°C and 32°F for any one of eight different selected thermocouple calibrations. Omega Engineering, Inc., Box 4047, Stamford, CT 06907. Phone (203) 322-1666. **226**

BUILDING-BLOCK DATA-ACQUISITION A/D SUBSYSTEM, known as MODAC 1600, is designed for those whose measurement and control applications require a small number of A/D inputs and outputs. The subsystem provides interface capability for up to seven I/O modules, each of which handles 32 bits. Each analog input module accepts 16 inputs and each analog output module produces up to eight outputs. The subsystem operates with either computer of the MODCOMP I, II AND III family and has a base price of $1300. Modular Computer Systems, 2709 N. Dixie Highway, Fort Lauderdale, FL 33308. Phone (305) 563-4392. **227**

PORTABLE 15-KV-DC DIELECTRIC TEST SET is designed for testing the insulation of power systems and rotating machinery. The instrument includes an optional input-voltage stabilization circuit which allows testing from fluctuating 115V supplies often encountered in field testing. Other features include oil-free design, low ripple, and guarded meter circuits with complete surge protection. James G. Biddle Co., Plymouth Meeting, PA 19462. Phone (215) MI6-9200. **228**



DIFFERENTIAL COUNTER DOESN'T JAM ON SIMULTANEOUS INPUTS. The bi-directional counter, Model GO 431, is designed to accept positive and negative pulses separately or simultaneously without jamming or missing a pulse count. It will operate on 6 to 220V, ac or dc, at a power consumption of 3.7W. Speeds are from 10 to 25 counts/sec. Price for a 6-digit dc-operated unit in quantity is under $40. Hecon Corp., 31 Park Rd., New Shrewsbury, N J 07724. Phone (201) 542-9200. **252**



DISC SYSTEM FOR D-112 AND PDP-8 COMPUTERS. Each DU-1 disc) 1 disc unit has a maximum storage capacity of 4 megabits or 264k individually addressable 13-bit words (12 bits plus one parity bit). Data is stored on 128 tracks, with each track capable of storing 2048 words in serial format. average access time for the disc is 8.4 msec with a maximum 2-megabit transfer rate. Price for DC-1 controller and one DU-1 disc is $11,000. Digital Computer Controls Inc., 12 Industrial Rd., Fairfield N J 07006. Phone (201) 227-4861. **229**

SERIAL IC MEMORY SYSTEM STORES 20k BITS PER PC CARD. System in-60 is built with N-channel MOS-shift registers and operates from +5V. Large systems storing more, or words longer than 6-10 bits, are made by interconnecting additional 8 × 10 1/2 in. cards. Clock rates are from 1 MHz to 25 kHz, and the memory has a guaranteed access time of 500 nsec at 1 MHz. Cost is less than 1/2¢/bit. Intel, 3065 Bowers Ave., Santa Clara, CA 95051. Phone (408) 246-7501. **230**

FERRITE CORES REQUIRE NO TEMPERATURE COMPENSATION. The new temperature-independent (TIN) core material permits a full operating range from −25°C to +100°C without temperature compensation. TIN cores eliminate most thermal sensing devices, heat sinks, and blowers. A core stack's optimum operating point remains constant and the operating envelope is unchanged despite temperature variations. Ampex Corp., 13031 W. Jefferson Blvd., Marina del Rey, CA 90291. Phone (213) 821-8933. **231**

NON-IMPACT PRINTER PUTS OUT 500 LINES/MINUTE. The Matrix LP-1150 is a 132-column printer which prints high-contrast 7 × 9-dot-matrix characters at 500 lines/min. (1100 cps) on 11 in. wide paper. It uses an electrostatic writing technique. Twenty-three controllers for interfacing with most popular mini- and midi-computers are also available. $4300. Versatec, Inc., 10100 Bubb Rd., Cupertino, CA 95014. Phone (408) 257-9900. **232**

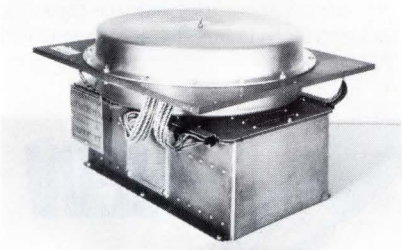
MODEM WORKS ON ALL TYPES OF PHONE LINES. The Series 348 Astroset MODEM, with interchangeable equalizers, can tackle just about any phone line in the world and run smoothly at 4800 bps with a low error rate. When operated on dedicated or switched C4 lines, C1 and C2 conditioned lines or type 3002 unconditioned circuits, the series 348 is a highly stable 4800 bps modem. $5000. Astrocom Corp., 15012 Minnetonka Industrial Rd., Minnetonka, MN 55343. Phone (612) 933-2208. **234**

TAPE CONTROLLER FOR NOVA MINIS. Series 1X20 tape controller is available as a complete tape-memory subsystem or as a controller interface. The controller provides control of data flow between the NOVA and up to four transports (7- or 9-track compatible). It controls generation of tape format for compatible information interchange. I/O driver subroutines and diagnostics are supplied with the controller. $3040. Information Products, Inc., 4202 Directors Row, Houston, TX 77018. Phone (713) 688-3423. **235**

HI-SPEED MULTIPLEXER REDUCES LINE COSTS. The TDX-4, a 4-channel time division multiplexer is designed to reduce line requirements in high-volume data-transmission systems. It will multiplex 2, 3, or 4 medium speed data channels (1200, 2400, 4800 bps) into a single higher speed composite channel (3600 to 9600 bps). The unit is transparent to all data formats; input channel rates can be intermixed; self-checking diagnostics are provided. Rixon Electronics, 2120 Industrial Parkway, Silver Spring, MD 20904. Phone (301) 622-2121. **236**

DATA-COMMUNICATIONS TERMINAL STORES 100k CHARACTERS. The Model 330 consists of a solid-state keyboard and 30 cps printer mounted on a base which houses the electronics including two buffers, a communications-control unit, and a high-speed modem. The buffers can store 50k characters each, and are capable of simultaneous input and output at different speeds. Wiltek, Inc., 59 Danbury Rd., Wilton, CT 06897. Phone (203) 762-5521. **237**

COLOR ADDED TO COMPUTER DISPLAY SYSTEM. Model 6600 television-display system is a multi-channel disc refreshed display system that uses RGB color TV monitors. Separate channels to drive the three primary electron guns give flexibility for 15 colors plus black by combining 4 channels up to 4095 colors plus black from 12 channels. Price for 4-channel system is $30,590. Data Disc, Inc., 686 W. Maude Ave., Sunnyvale, CA 94086. Phone (408) 732-7330. **238**

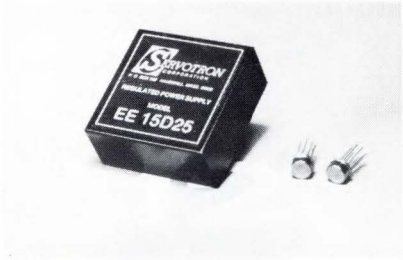


FIXED-HEAD DISC MEMORY PROVIDES 6.4 MEGABIT CAPACITY ON 128 TRACKS. Model 7128 has access times of either 8.3 or 16.5 msec. The system uses phase modulation and a self-clocked detection system with electronic circuits packaged on plug-in pc boards. Packing density is 1350 bpi. Interface signals are at TTL levels, and serial transfer rate is 1.5 or 3.0 MHz depending on drive speed. $6450. Information Data Systems, Inc., 7550 Walnut Lake Rd., Walled Lake, MI 48088. Phone (313) 624-5525. **239**

PROGRAMMABLE ROM PERMITS CUSTOM MICRO-PROGRAM CONTROL STORE. The bi-polar, ROM is available in modules of 256 × 40 words and is expandable in 256 word increments up to 1024 words. Each module is priced at $2500. The programmable ROM provides all the features of a standard, software-supported computer plus the capability to add and alter microprogramming tailored to specific applications. Modular Computer Systems, 2709 N. Dixie Hwy., Ft. Lauderdale, FL 33308. Phone (305) 563-4392. **240**

CIRCLE NO. 25

CIRCLE NO. 28

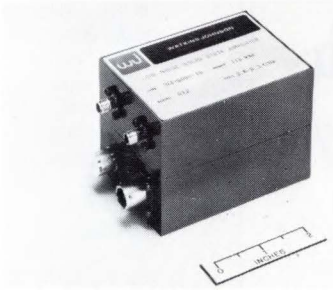


REGULATED POWER SUPPLY MODULES FOR ONLY $12 (1 to 99). Models EE12D25 and EE15D25 provide outputs of ±12 and ±15V dc, respectively, at 25 mA and sell for only $9.97 (1000 quantities). Model EE5S200 provides 5V dc at 200 mA and costs $14 (1 to 99) and $11.75 (1000 units). All supplies have 0.25% line and load regulation, 2 mV rms ripple and noise and 0.02%/°C TC. They measure 2 x 2 x 0.875 in. and work from 105 to 125V ac, 50 to 440 Hz. Servotron Corp., Box 292, Haverhill, MA 01830. Phone (617) 374-0777. **241**

NEW DIP PULSE TRANSFORMERS are offered in 14 and 16-pin configurations with up to four transformers per package. Primary inductance ranges from 5 to 2000 μH in a 1:1 turns ratio, and from 5 to 200 μH in a 2:1 turns ratio. T-case transformers are also available in 6-pin configurations. DIP transformers cost $2 per unit in production quantities; T-case transformers cost $1.50 per unit in production quantities. Vanguard Electronics, 930 W. Hyde Park Blvd., Inglewood, CA 90302. Phone (213) 678-7161. **242**

BROADBAND AMPLIFIER COVERS 30 TO 300 MHZ. PAM-300 Series amplifiers cover the entire vhf band and feature a 5.5-dB noise figure and an output of up to +10 dBm at 1-dB compression. Gain is 24 dB while gain variation is only ±0.5 dB. For two −20-dBm input signals, the second-order intermodulation products are −40 dB down and the third-order intermodulation products are −65 dB down. Input VSWR is 1.7:1 and VSWR output is 1.3:1. American Electronic Laboratories, Inc., Box 552, Lansdale, PA 19446. Phone (215) 822-2929. **243**

MULTIPLE-OUTPUT HV CRT SUPPLIES ARE LOW IN COST. Designated LU-15, these $60 (500 quantities) solid-state units are proportional dc-to-dc converters providing an anode output of +3000 to +15,000V dc for a +3 to +15V dc input; a +600V at 1 mA focus voltage and a −150V dc at 1 mA cutoff voltage. Output ripple is 0.1% pk-pk at full load (250 μA) and load regulation is 2% for 1/2 to full-load variations. Venus Scientific Inc., 399 Smith St., Farmingdale, NY 11735. Phone (516) 293-4100. **244**



SOLID-STATE AMPLIFIERS EXHIBIT 1 dB PULSED DISTORTION UNDER OVERDRIVE. Designated WJ-780-20 for the 1 to 2.6-GHz frequency range and WJ-5090-11 for the 2 to 4.5-GHz frequency range, these units provide small-signal amplification as well as flat-limiting output. Small signal variation is ±1.0 dB and saturated output power variation is 3 dB. Watkins-Johnson Co., 3333 Hillview Ave., Stanford Industrial Park, Palo Alto, CA 94304. Phone (415) 326-8830. **245**

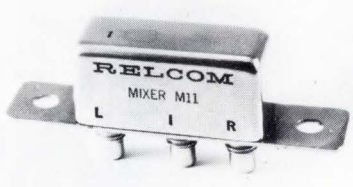
A NEW DUAL AC/DC REFERENCE SWITCH is comprised of three planar epitaxial monolithic chips—a dual switch and two amps. Each switch can operate independently with either an ac or dc reference voltage. The UHC-023 switch features 5 mV dc offset voltage, 0.1Ω dc series resistance and 40-μsec dc switching time. It is packaged in a modified 10-lead hermetically sealed flatpack and is rated for continuous operation over the temperature range of −55 to +125°C. The UHC-023 costs $29.97. Sprague Electric Co., Marshall St., N. Adams, MA 01247. Phone (413) 664-4411. **246**

NEW MICROWAVE AMPLIFIERS cover the frequency range of 600 MHz to 3.1 GHz. The MRA Series of MICroAMP power devices offer full gain and power output over bandwidths up to 50%. Fifteen devices offer power outputs from 1.5 to 18W. Since each device's input circuit is designed to provide 50Ω, it is necessary only to construct an easily realized output circuit to obtain a broadband amplifier. Amplifier stages can be constructed as 50/50Ω building blocks. TRW, Inc., 14520 Aviation Blvd., Lawndale, CA 90260. Phone (213) 679-4561. **247**

NEW VIDEO DELAY MODULES accept wide-band video signals directly and delay them a nominal 64 μsec with no significant signal loss. This makes image-enhancing circuits feasible even in economical cameras like those used in cable or closed-circuit television. BASE modules can also be used in video-cable equalizing and other video-signal applications. In small quantities, they cost $800 to $950. Corning Memory Products, Corning Glass Works, 3900 Electronics Dr., Raleigh, NC 27602. Phone (919) 828-0511. **248**

MULTIFUNCTION MODULE HAS 0.3% DIVIDER ACCURACY. Model 433 can perform a wide range of computations including multiply, divide, square and exponentiate, in the 0 to +10V range. Requiring only two external resistors for programming the expression $Y(Z/X)^m$, it multiplies, divides or exponentiates up to the 5th power or root. It may also be used to develop rms or vector sums using external amps. The 433 is priced at $75. Analog Devices, Inc., Route 1 Industrial Park, Norwood, MA 02062. Phone (617) 329-4700. **249**

LOW-COST SOLID-STATE CIRCUIT BREAKERS combine the advantages of an electromechanical circuit breaker with the speed and reliability of a solid-state unit. The SY series breakers are simple and easy to install, having only four connections—two for the load and two for the programming transistor—which allows the user to adjust the trip point from 500 mA to 1.5A. Inrush inhibit is also included at no extra cost. Flight Systems, Inc., Box 25, Mechanicsburg, PA 17055. Phone (717) 697-0333. **250**



DOUBLE-BALANCED MIXER LOWERS NOISE FIGURE TO 5 dB over 960 to 1215 MHz. The M11 has a guaranteed LO noise rejection at the I-port of 30 dB minimum across its entire frequency span. Maximum guaranteed VSWR at the R and I-ports is 2:1 and 1.5:1, respectively. The M11 comes in a miniature package with miniature connectors and is guaranteed to meet its specifications over a temperature range of −54 to +125°C. Relcom Dept., Watkins-Johnson Co., 3333 Hillview Ave., Stanford Industrial Park, Palo Alto, CA 94304. Phone (415) 326-8830. **251**

Switching, plain and not so plain

The hybrid time delay relay featured below (at d) is a business-like combination of modern electronics with a reliable, inexpensive electromagnetic relay. A single package wraps up the whole deal. It is for places where you want a switching delay of from 1 to 120 sec. repeatably accurate to ±3%, fixed or variable; and prefer not to provide the timing elsewhere. The idea is neither original nor recent. Sigma does it more compactly, reliably and *cheaper*.

10,000 volt switching doesn't sound like a subject that belongs on this page. It wouldn't under common circumstances, but item c is an elegant means of grounding the high voltage in an office copier when somebody has to reload it. Would you believe it's an internally illuminated photoconductive element dropping open circuit resistance of 10^{12} ohms to 100k?

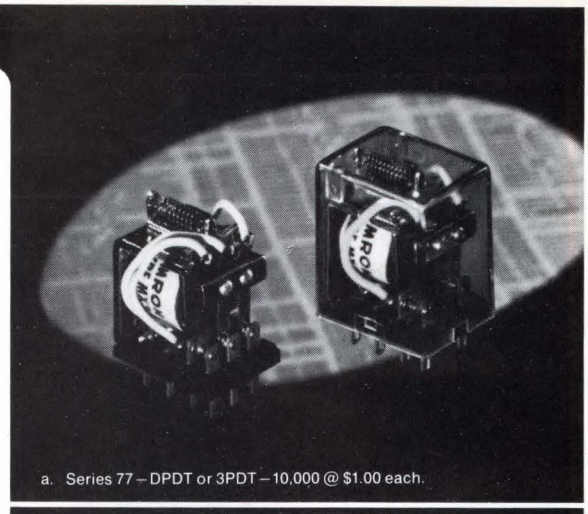
Light controlled photoconductor relays in standard packages were brainchildren of a Sigma division specializing in solid state photoconductors. Great merit and flexibility results from use of these Datacels® as we call them; viz. total isolation of input from output or outputs (1 to 4)—with outputs passive and nearly as compatible as resistors. The latest variety was invented by our lady physicist and is imaginatively known as a "Ladybug."

A Ladybug-relay combination solved a recent delayed alarm problem for a Sigma customer. By using a Neon light source for control, the Ladybug imposed *no load* on the timing circuit, operated directly from 120 volts with lock-on alarm. It makes quite a time delay device—up to 60 sec. after *opening* a control circuit. Ladybugs and Datacels® have the flexibility of three alternative internal light sources: Incandescent, Neon and LED.

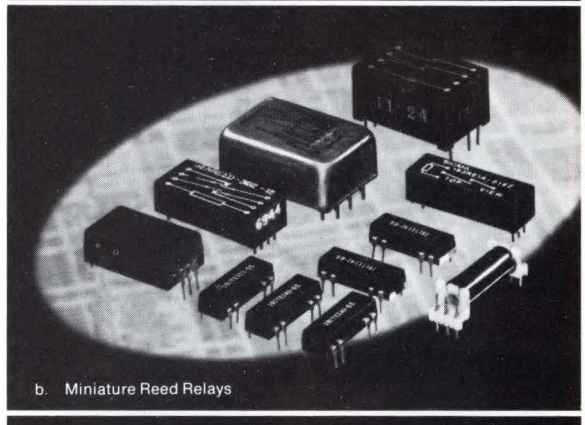
Savvy switching is a worthwhile specialty to know about when you can use it. Sigma has it and has had it since the late thirties.

If you'll circle No. on the beano card, you'll get a fistful of poop. If you write on a specific question, we'll answer it carefully along *with* the poop; and if you make it a personal letter to relay marketing chief, Stu Knapp, with your problem and project laid bare, the action will be sudden and substantial. Write Sigma Instruments, Inc., 170 Pearl St., Braintree, Mass. 02185. Telephone 617-843-5000.

SIGMA
INSTRUMENTS INC

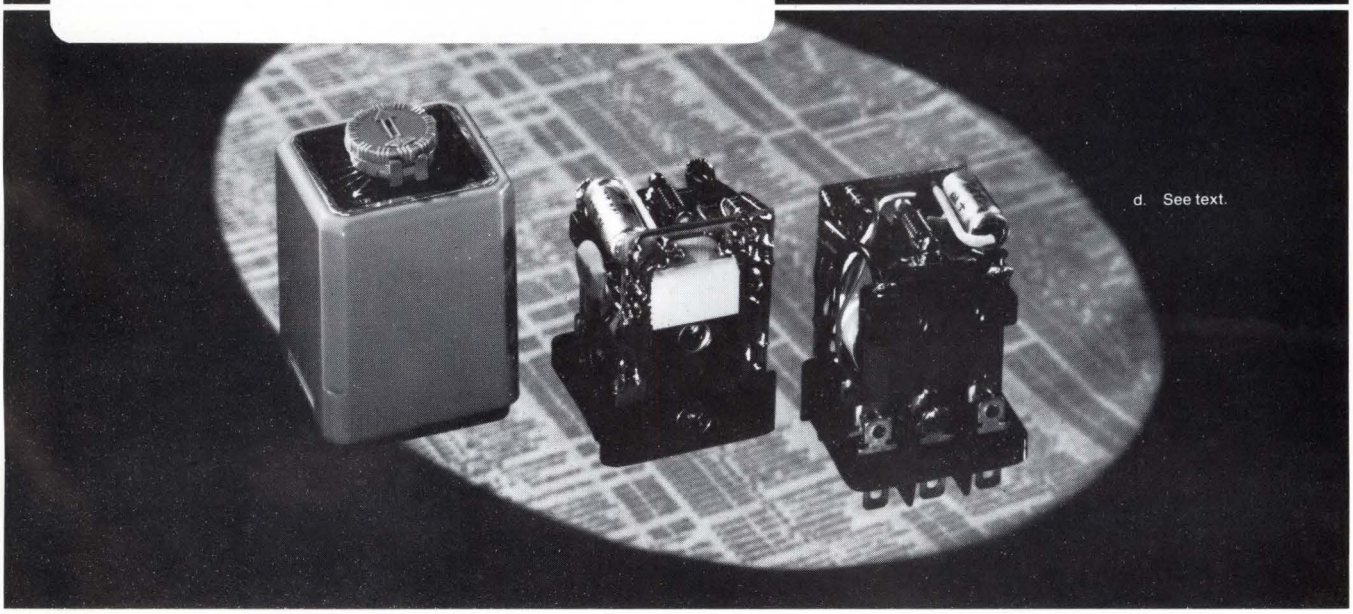


a. Series 77—DPDT or 3PDT—10,000 @ $1.00 each.



b. Miniature Reed Relays

c. See text.



d. See text.

LITERATURE

ULTRA-HIGH-SPEED D/A CONVERTERS offering the user state-of-the-art output settling time are described in a 4-page brochure. Electrical and mechanical specs and operating and application data are listed. Datel Systems, Inc., 1020 Turnpike St., Canton, MA 02021. Phone (617) 828-6395. **258**

CIRCUIT-BOARD-TEST SYSTEMS are shown in a 16-page brochure. The booklet discusses hardware and software aspects of the Teradyne L100 test system, as well as general economic considerations involved in board testing. Teradyne, Inc., 183 Essex St., Boston, MA 02111. **257**

OEM POWER SUPPLIES are detailed in a new catalog. A full line of more than 150 standard supplies with complete specifications, prices and delivery schedules are listed. Custom power supply capabilities are also included. Powertec, Inc., 9168 DeSoto Ave., Chatsworth, CA 91311. Phone (213) 882-0004. **263**

IBM 1130 REPLACEMENT. An 8 page brochure, "Instant Relief for Your IBM Throughput Problems" describes G.A.'s 18/30 DMS system, a direct, lower cost, improved performance replacement for the IBM 1130. It also provides a comparison chart of the two systems, user comments, and background information about the company. General Automation, Inc., 1055 S. East St., Anaheim, CA 92805. **253**

COMMUNICATIONS CABLE PRODUCTS described in new catalog. A complete line of telephone cables and other communications products is described in detail in a comprehensive catalog which offers complete physical and electrical data for a full line of plastic-insulated telephone cables. Anaconda Wire and Cable Co., 605 Third Ave., New York, NY 10016. Phone (212) 867-8000. **259**

LOCK-IN PHOTOMETER, Model 20, is described in a new bulletin. The instrument is a synchronous-detection system used in photomultiplier applications where the signal is a chopped-light beam. How individual customer needs can be met, low cost and ease of operation are detailed. Pacific Photometric Instruments, 5745 Peladeau St., Emeryville, CA 94608. **264**

PRODUCT GUIDE describes line of linear ICs including D/A converters, precision comparators, op amps, and monolithic chips. Also described are high-performance modular A/D and D/A converters. Facilities, capabilities, and the "Triple Passivation" IC process are detailed, along with a preview of new products to be released during 1972. Precision Monolithics Inc., 1500 Space Park Dr., Santa Clara, CA 95050. Phone (408) 246-9225. **254**

MICROMINIATURE INDICATORS for a wide range of commercial, military and industrial applications are described in a short form catalog. Features of the indicators include mounting on 0.225 in. centers and front-panel-lamp replacement. Incandescent Brite-Eye indicators and transistorized Trans-Eye indicators use a variety of 15 standard T-1 lamps and have seventy different caps available in seven styles and ten colors. Datatron Co., 1562 Reynolds Ave., Santa Ana, CA 92711. **260**

MAGNETIC FLUIDS BROCHURE available. These fluids are ultra-stable colloidal suspensions of magnetic particles in any of a variety of liquid carriers. The fluid behaves as a Newtonian liquid with the added feature that it can react with an external magnetic field. The brochure covers technical specifications, an explanation of the basic phenomenon and many suggestions for product application. Ferrofluidics Corp., 144 Middlesex Tpk, Burlington, MA 01803. Phone (617) 272-5206. **265**

A COMBINED X-Y AND STRIP-CHART RECORDER BROCHURE describes Houston Instrument's Omnigraphic 200 x-y and 3000 one- and two-pen Strip-Chart Recorders. The 16-page brochure includes characteristics of the recorders' signal-handling, time-base and point-plotting modules. Houston Instruments, Div. of Bausch & Lomb, 4950 Terminal Dr., Bellaire, TX 77401. Phone (713) 667-7403. **255**

IBM REPLACEMENT MEMORY. A revised brochure describes operation and specifications of the Ampex Model ARM-30 mainframe core memory which replaces and expands IBM 360/30 mainframe memory. Request brochure C-165/6 from Ampex Corp., Marketing Communications (M-15), 13031 W. Jefferson Blvd., Marina del Rey, CA 90291. **261**

DRANETZ ENGINEERING'S full line of instruments and test systems for measuring impedance, phase angle, voltage and current, transfer function, and real and imaginary power are described and illustrated in a 12-page catalog. Dranetz Engineering Laboratories, Inc., 2385 S. Clinton Ave., S. Plainfield, N J 07080. Phone (201) 755-7080. **266**

MINICOMPUTERS AND MICROPROGRAMMING are the subjects of three papers presented at the 1972 IEEE International Convention. Papers reprinted in the free brochure are "Static and Dynamic Control Memory in Micro-Programmable Computers," "The Dedicated Minicomputer In Industrial Applications," and "Micro-Programming: Real Applications In Minicomputers." Brochure, "Technological Leadership." Interdata, 2 Crescent Place, Oceanport, N J 07757. **256**

SELF-SCAN ALPHANUMERIC PANEL DISPLAYS are explained for the OEM and the end user in a new brochure. The brochure describes the display panel at a technical level for the manufacturer considering its use in his equipment. At a more basic level, the brochure can be used by the OEM to describe the display panel to his customer. Burroughs Corp., Electronic Components Div., Plainfield, N J 07061. Phone (201) 757-5000. **262**

TOGGLE & PUSHBUTTON SWITCHES for printed circuits are covered in new bulletin. Line includes 2- and 3-position toggles and a pushbutton switch that provides momentary or latch-in operation. All switches are rated for 100,000 operations with loads up to 1A at 6 to 12V dc. Currently in mass production, the switches are for applications in appliances, instruments, office equipment, and other commercial applications. Control Switch Inc., 1420 Delmar Dr., Folcroft, PA 19032. Phone (215) 586-7500. **267**

signals and noise

Watch those watch specs

Dear Sir:

The April 1 issue of EDN/EEE carries a story about the Motorola quartz watch components. It's a fine article, and we appreciate your attention. But on one point it has proven confusing to your readers.

The stumbling block is in the very first paragraph: Under a headline that says, "Accuracy to within a few minutes per year . . .," in the next breath it states, "Stabilities of 4.32 seconds a day . . . for a 0 to 60°C temperature range are achievable with wristwatches made from Motorola's three matched-set timepiece components." Without a little more information, 4.32 seconds a day variation must seem something less than phenomenal, and about equivalent to what you might expect from a conventional timepiece. Where's the great quartz-crystal accuracy?

The explanation lies in the aforementioned "0-to-60°C" temperature range. What you have said is perfectly correct, but in the real world of application, how often will a wristwatch encounter 60°C, or 140°F, temperatures? The answer, of course, is seldom or never. More commonly, the temperature range will vary, under the worst conditions, no more than from about +10 to +40°C. This temperature range accounts for a variation, or timing error, of less than 1 second per day if the watch is operated within these temperature extremes for 24 hours. At 28°C (the turnover temperature of the crystal) the timing error can approach zero.

This is the order of accuracy that can be associated with the quartz watch, and which is, in fact, obtainable from the Motorola matched components (quartz-crystal, silicon-gate CMOS integrated circuit and miniature stepping motor).

Very truly yours,
Chuck Johnson
Manager
World Marketing
Motorola, Inc.

A word about cost

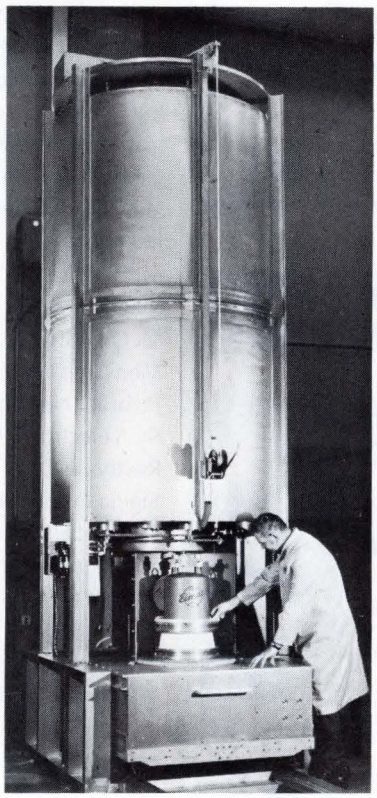
Dear Sir:

Although you touched on cost when you mentioned wasteful efforts and finishing projects on time in your editorial of March 1, 1972, you did not make a direct statement regarding cost.

At Westronics our profile of a good engineer includes a strong statement concerning cost consciousness.

If our engineering staff did not concern itself with the need to minimize cost, we would find it difficult to compete in the free market.

Sincerely,
D. L. Clarke
General Manager
Westronics, Inc.
Fort Worth, Texas



Try this for size

How would you like this in your HAM radio rig? It's the world's most powerful radio transmitting tube—a two-million-watt-output tetrode built by the EIMAC Div. of Varian. You can use it for medium—or high-frequency broadcast service, or as a 1000A, 60 kv switch. The price? $20,000 each.

He says we missed the point

Dear Sir:

Your editorial in the April 1 issue of EDN (*The Government Sprints Ahead*) misses the point. The nation needs technology—what it doesn't want is the technologists. They think overly much and are a disturbing influence to society. The only answer is strong unionism. Perhaps if engineers are paid somewhat better than garbage collectors, they will feel they have a stake in better engineering. Otherwise, we can look forward to bigger and better Edsels, Spectra 70's, etc.

Sincerely,
James Erons
Stamford, Conn.

Let's give credit

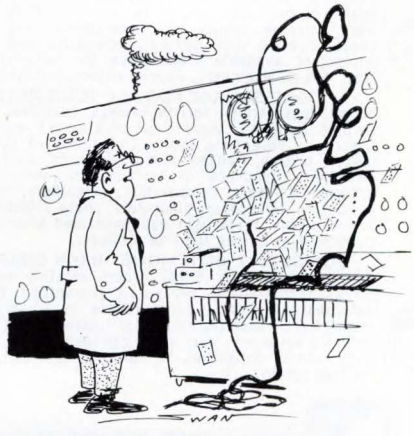
In the article, "Multiplexing doesn't have to be limited to communications applications," EDN, April 1, 1972, we neglected to add the following credit line: "The effort expended in the development of the EMUX system for the B-1 strategic bomber is funded by North American Rockwell, prime contractor for the B-1. This program is sponsored by the Aeronautical Systems Division, Wright Patterson AFB, Ohio (ASH)."

Here are some additional manufacturers of miniature switches not listed in the March 15, 1972 issue of EDN.

Licon, Div. of Illinois Tool Works
6615 West Irving Park Road
Chicago, Ill. 60634

The ASM Corp.
P.O. Box 860
Smithfield, NC 27577

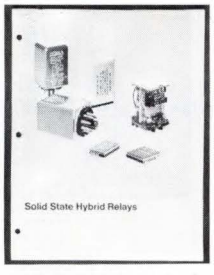
Roy Forsberg
Associate Editor



"I take it this means you're leaving the firm?"

ADVERTISERS INDEX

Application Notes



A HYBRID RELAYS APPLICATIONS FOLDER is available to help the potential user in matching the right hybrid relay to his particular application requirements. Six relay models are presented, with appropriate terminal-wiring diagrams, general input and output parameters and detailed application information. Potter & Brumfield, Princeton, IN 47670. Phone (812) 385-5251. **275**

THERMOCOUPLE SYSTEM CALIBRATOR literature describes a calibrator's application in test and calibration of thermocouple systems, without disturbance of the system under test. It is said to be applicable to nearly all thermocouple materials. General Resistance, Inc., 500 Nuber Ave., Mt. Vernon, NY 10550. Phone (914) 699-8010. **278**

HYBRID MICROCIRCUITS DESIGN MANUAL, is an informative 24-page manual that presents useful information for engineers using or designing circuits in hybrid form. It covers thick-film component characteristics, partitioning and design rules, the process, packaging and comparison with monolithic circuits. Numerous schematics and photographs illustrate typical circuits and process information. Airpax Electronics/Control Div., 6801 W. Sunrise Blvd., Ft. Lauderdale, FL 33313. Phone (305) 587-1100. **276**

HALL EFFECT IC application note provides output loading considerations for ULN-3000 series switches. Interfacing procedures are described for driving transistor, DTL, TTL, MOS, SCRs and Triacs. In all cases application note 27402.2 shows that the internal 2kΩ resistor or simple external resistor networks are sufficient for this interface. Sprague Electric Co., Semiconductor Div., 115 Northeast Cutoff, Worcester, MA 01606. Phone (413) 664-4411 **279**

CUSTOMIZED COMPUTER SYSTEMS. Xerox Corp's capabilities for designing customized computer systems to meet a user's total information requirements are described in a new eight-page brochure. It also summarizes typical applications of such systems in the areas of communications, data gathering and processing, flight test and spacecraft telemetry, laboratory operation, industrial monitoring and control, simulation, and business data processing. Pub. #64-60-77A. Xerox Corp., (A3-05), 701 S. Aviation Blvd., El Segundo, CA 90245. **277**

IMPACT PRINTERS. A 9-page technical article outlines the principles of serial impact printers. It also explains the principles of the dot matrix printing method, compares the "print-on-the-fly" approach with it and discusses pros and cons and application considerations of both types. The article then relates the characteristics and speed limitations of dot matrix and "print-on-the-fly" principles to line-at-a-time printers, as well as serial character-at-a-time printers. Printer Technology, Inc., Sixth Rd., Woburn Industrial Park, Woburn, MA 01801. **280**

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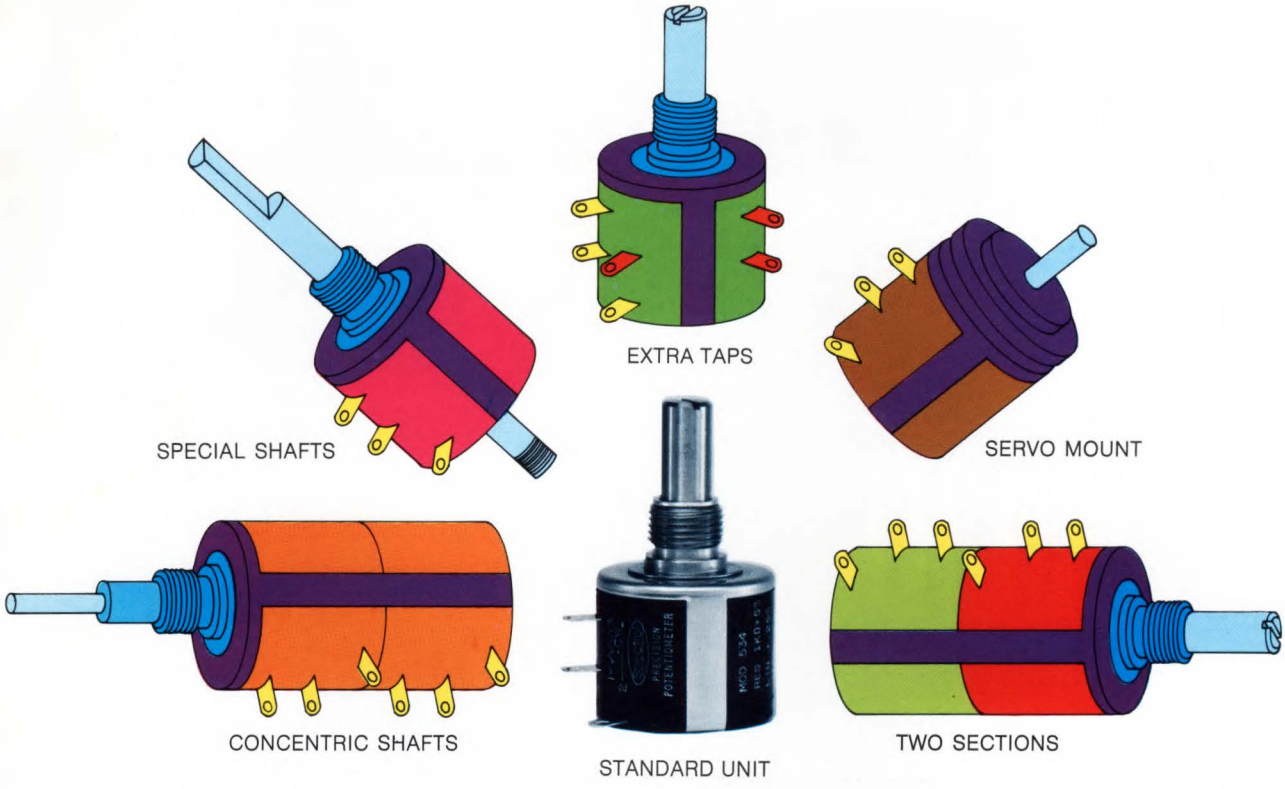

A 10-TURN WIREWOUND POT ONLY 3/4" LONG THAT'S PRICED WITH THE LOWEST AND SPEC'D WITH THE HIGHEST!

The new Spectrol Model 534 potentiometer takes the pain out of the compromise between price and quality. This ⅞-inch diameter, ¾-inch long, 10-turn, wirewound pot is packed with standard quality features you wouldn't expect in a low-cost industrial model—a rugged integrated construction with no glued joints, superior stop strength, higher power rating, and a design that permits ganging two sections into a unit that's almost as short as conventional ten-turn singles.

But if you want still more, you're looking at the most versatile low-cost pot on the market. Just look at these optional extras—extra taps, special shafts, special linearities, special resistances, non-linear elements, non-turn pins, 3-turn and 5-turn units, and a special sealing and humidity proofing process.

But for all its high quality and versatility, the standard Model 534 is priced right down there with the competitive units. It's a lot of pot for very little money. If you want to know how little, give us a call. For a data sheet, just use the reader service card.

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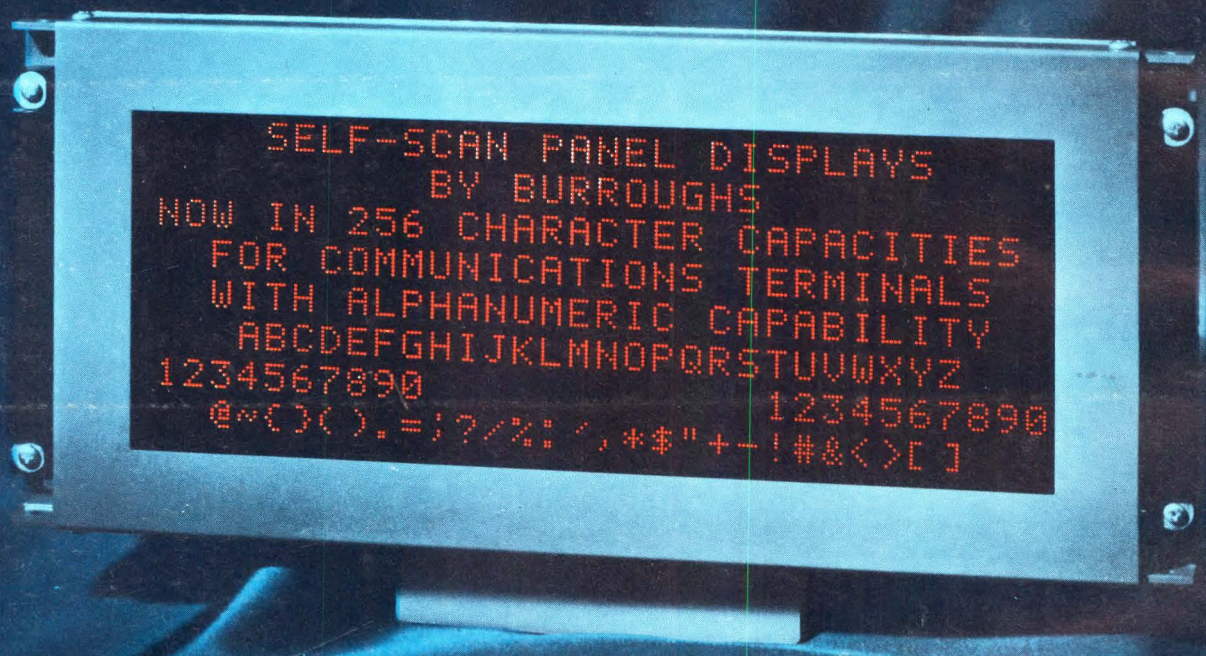
UNITED KINGDOM: **Spectrol Reliance Ltd.,** Drakes Way, Swindon, Wiltshire, England, Swindon 21351 • TELEX: 44692
ITALY: **SP Elettronica spa,** Via Carlo Pisacane 7, 20016 Pero (Milan) Italy, 35 30 241 • TELEX 32242

SELLS ON SIGHT



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One look at an operating SELF-SCAN® panel display and you will know why you should be featuring one in your system. SELF-SCAN displays are a new solution to the operator machine interface that provides advantages to the system builder, to the system user, and to the system operator.

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The 0.2" high characters are in the popular 5x7 dot matrix format and are made up of dots on .040" centers. The unit is ASCII compatible and displays a modified 64-character ASCII character set.

256-character display subsystems are available from stock for immediate delivery. Call or write Burroughs Corporation, Electronic Components Division, Box 1226, Plainfield, New Jersey 07061, Phone: (201) 757-3400. Ask to have a Burroughs sales engineer stop by your office and show you his 256-character SELF-SCAN panel, keyboard, and power supplies packaged in a standard Samsonite® briefcase.

Burroughs

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