16

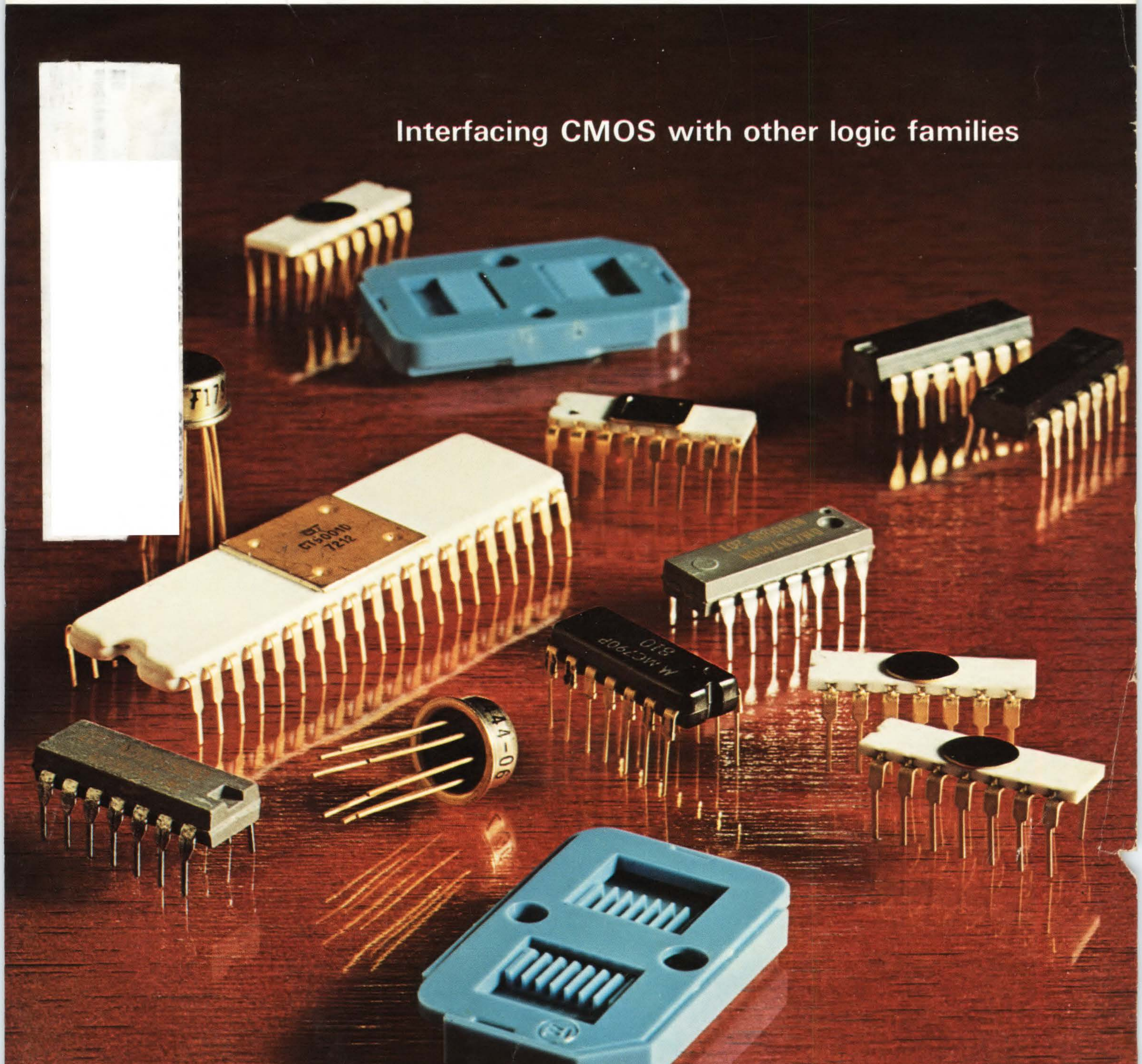
EXCLUSIVELY FOR DESIGNERS AND DESIGN MANAGERS IN ELECTRONICS

EDN

Yes, the transistor switching regulator can be quieted

Use generalized impedance converters in active filters

Interfacing CMOS with other logic families



A CAHNERS PUBLICATION

FEBRUARY 5, 1973

power supplies for op-amps . . . $14

These 2.3 x 1.8 x 1-inch modules have tracking outputs of ±15V with regulation of ±0.1% and ripple of 1 mv. The Model D15-03 (25 ma outputs) costs $14.00 in 1000 lots and only $24.00 for one. The Model D15-05 (50 ma outputs) is $39.00. For ±12V, the model numbers are D12-03 and D12-05. Same prices. Three-day shipment guaranteed.

Acopian

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

CHECK NO. 1

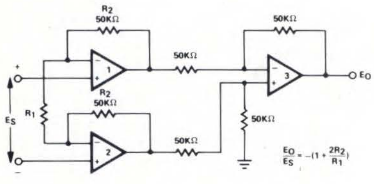
Here's a versatile new IC for
portable or battery-powered instrumentation

150 μWatts powers Triple Op Amp

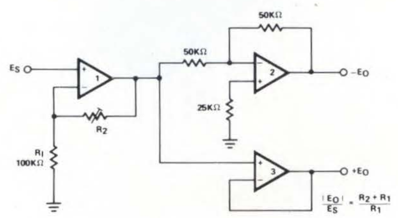
The Siliconix L144 is a *low-power* monolithic IC with three complete op amps and a common bias network on the same substrate. The circuit operates over a power supply range of ±1.5 to ±15 V, with a supply current set by an external bias resistor. With a ±1.5 V battery, only 50 μA is required for all three op amps!

Other features:

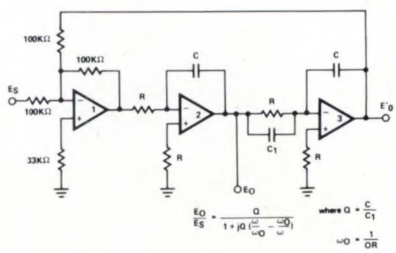
- Internal compensation provides stable operation for any feedback circuit—including capacitive loads >1000 pF
- 80 dB gain with 20KΩ load
- Typical slew rate 0.4 V/μsec
- Military or commercial versions available



Instrumentation amplifier for high input impedance with differential operation.



Precision phase splitter with good gain, high input impedance, low output impedance.



Active filter with high Q and excellent stability.

Applications? Above are three suggestions.
There are more: Low-drift sample-and-hold, inverting amplifiers, voltage comparators, and so on.
Call us if you have a specific design problem.

write for data

Applications Engineering: (408) 246-8905

Siliconix incorporated

2201 Laurelwood Road, Santa Clara, California 95054

CHECK NO. 5

CTS puts the squeeze on space wasters

CTS Cermet "Saver Pac" Resistor Networks
Increase Circuit Density . . . At Economical Prices

Space comes *high!* So you'll like how much a CTS 750 Series "SAVER PAC" network can save you, and your circuit. Less space . . . fewer components . . . greater system reliability . . . quicker, easier installation . . . reduced handling costs . . . and faster inspection. Consolidate up to 13 discrete resistors into one compact in-line resistor module. CTS can do it easily with twenty standard packages . . . available in .100", .125", or .150" lead centers. High power capabilities to 4.3 watts @ 70°C per module.

CTS 750 series cermet thick-film resistors assure proven performance—ultra high stability and reliability—backed by over 700,000,000 hours of test data. Hand install or use automatic assembly equipment . . . they're designed for either. Pick a SAVER PAC today. Large or small orders welcome. CTS of Berne, Inc., 406 Parr Road, Berne, Indiana 46711. Phone: (219) 589-3111.

CTS CORPORATION

A world leader in cermet resistor technology.

CHECK NO. 7

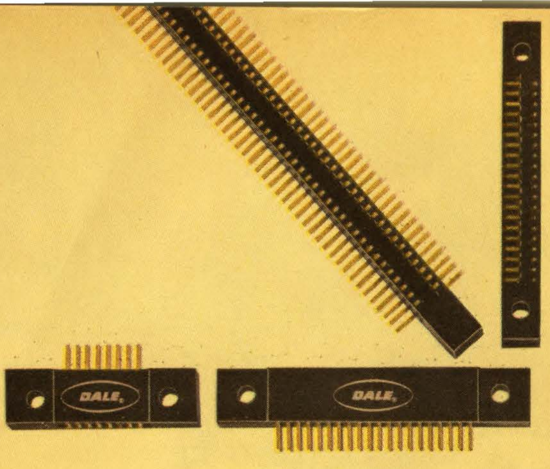
FEBRUARY 5, 1973
VOLUME 18, NUMBER 3

EDN with EEE
EXCLUSIVELY FOR DESIGNERS AND DESIGN MANAGERS IN ELECTRONICS

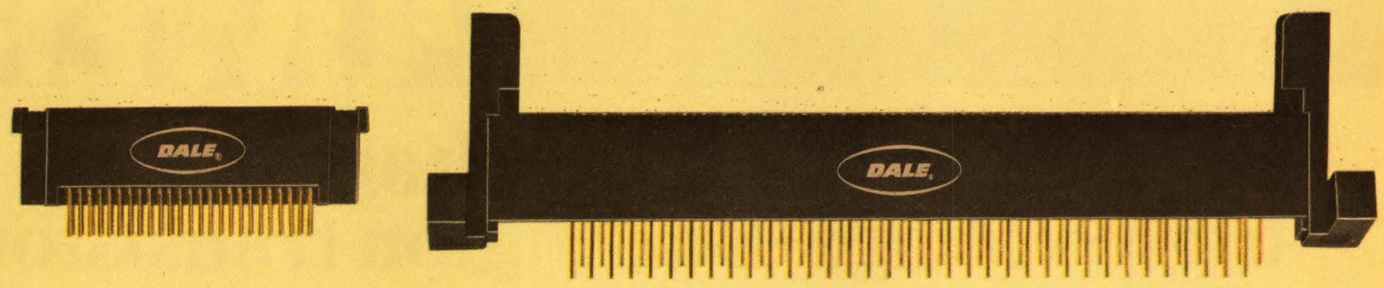
COVER

Interfacing CMOS ICs with other logic families in a mixed design is a major consideration for today's designer. For Part IV in EDN's CMOS design course, see pg. 38. Photo by Boston photographer Dick Norton.

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



digital readout connectors



...custom tailored to your case at standard prices

Don't let a connector dictate your case design. Dale *Customline* .050" and .100" edgeboards give you extra design flexibility to cope with case contours. They'll help you produce an easy-to-read product with lots of eye appeal whether you're working with a calculator, a panel meter, a counter ...or other digital display application. Our unique design and manufacturing process lets us deliver custom body and contact configurations *below* the price of conventional high density edgeboards. And, if you're talking about any volume at all, the tooling will be amortized in the bargain. This is no theoretical system. Dale *Customline* edgeboards are in use now mounting liquid crystal and LED displays in high volume calculator and panel meter applications. They're not limited to digital displays, either. They'll give you budget and design freedom wherever a low cost, reliable high density edgeboard is called for...the new leadless ceramic MOS packages, for example.

Make us prove it. Write for *Customline* Design Folder or call 605-665-9301 for Application Engineering Assistance.

DEPENDABLE DALE®

TO: Dale Electronics, Inc., East Highway 50, Yankton, S. D. 57078
Send ☐ Custom Edgeboard Design Outline
☐ Information on Standard Edgeboards ☐ Have Representative call.
NAME
TITLE
COMPANY
CITY
STATE
ZIP

EDITORIAL

When did you innovate last?

We saw recently where a General Electric engineer had 38 patent applications filed in his name during a 12-month period—a record, we suppose, not only for GE but for most other companies as well. By any measure, this is quite an achievement for both the individual and the organization.

We recognize, of course, that patent applications aren't the only measure of creative engineering. Some truly innovative design work is never patented, while other work of far less significance is often the subject of multiple patents.

True innovation and creativity are difficult to measure, especially in the field of electronics, where rapid change is the order of the day. So anything that provides even a small gauge of when people are being creative is worthwhile.

We would guess that one of the greatest obstacles to creativeness in design is the difficulty in recognizing and measuring it. There's no clear-cut way of knowing which approach to a design task will lead to an innovative solution—if indeed the innovativeness of the solution would be recognized. As a result, standard and proven approaches are all too often blindly followed and lead to what might be called "me too" engineering. The end item might not be the best or the cheapest, but it's competitive, and the project is completed essentially on time and within budget.

Companies aren't entirely blameless when it comes to "me too" engineering. In fact, consistent lack of design creativity and innovation is more the fault of the company and management than it is of the individual engineer. The company sets the goals and creates the environment in which the engineer works. If management wants "me too" products that just keep pace with the competition, that's what it will get. But if it wants to be a leader, it communicates this to its engineers and gives them the backing and support they need.

This is the type of company that maintained its R&D effort at a reasonable level during the economic squeeze of 1970 and 1971, and as a result was ready with significant new products when the turnaround came. The other type of company is just now coming out with its "me too" products to meet the competition.

Frank Egan
Editor

STAFF

Publisher
E. Patrick Wiesner

Editorial Staff
Frank Egan, *Editor*
Roy Forsberg, *Managing Editor*
Bob Cushman, *Special Features Editor*
Roger Allan, *Associate Editor*
John Bond, *Associate Editor*
Bill Furlow, *Associate Editor*
Jerry Moseley, *West Coast Editor*
Art Stapp, *West Coast Editor*

Art Staff
Dan Kicilinski, *Director*
Patricia Rawlins, *Illustrator*
Ezio Mattassi, *Illustrator*
Elizabeth Garrenton, *Illustrator*
Richard Pierro, *Illustrator*

Production Staff
Wayne Hulitzky, *Director*
William Tomaselli, *Manager*
Susan Kennedy, *Assistant*

Circulation
Ron Kinnes, *Manager*

Marketing Services
Ira Siegel, *Manager*

Editorial Consultant
John Peter

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

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

West Coast (415) 383-4220
23 Bayview Terrace
Mill Valley, CA. 94941

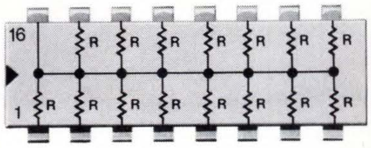
West Coast (213) 933-9525
5670 Wilshire Blvd.
Los Angeles, CA. 90036

191 FLAVORS OF BECKMAN DIPS

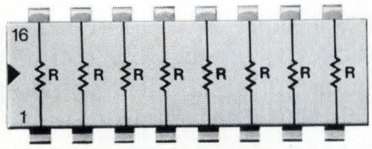
All 191 flavors of RESNET™ DIPs offer system compatibility because we use the same packages you use for I.C.s; plus you get ceramic dependability at plastic prices.

Whether you're inserting resistors automatically or by hand — call your local Beckman/Helipot representative and ask how you can save money using RESNET DIPs. He stocks locally for immediate delivery.

To request technical data, call your local Beckman/Helipot representative. Or write to Beckman Instruments, Inc., Helipot Division, 2500 Harbor Blvd., Fullerton, Calif. 92634.



898-1 (15 resistors)
Price (1,000-4,999) $.85

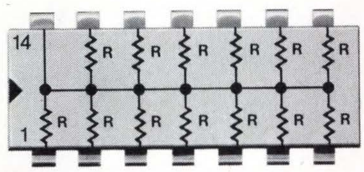


898-3 (8 resistors)
Price (1,000-4,999) $.76

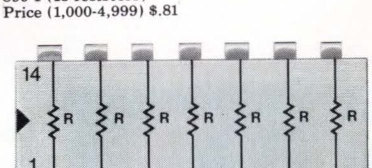
STANDARD RESISTANCE VALUES
(±2% or ±2Ω)

62*	110	330	1.0K	2.2K	6.0K	15.0K
68	150	470	1.5K	3.3K	6.8K	22.0K
100	220	680	2.0K†	4.7K	10.0K	

*Standard in 898-3 only.
†Standard in 898-1 only.



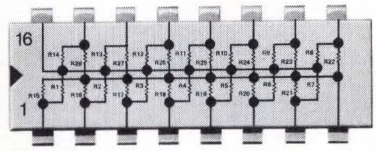
899-1 (13 resistors)
Price (1,000-4,999) $.81



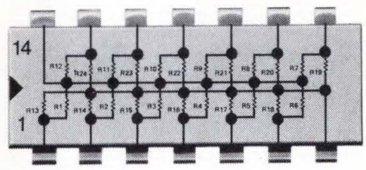
899-3 (7 resistors)
Price (1,000-4,999) $.72

STANDARD RESISTANCE VALUES
(±2% or ±2Ω)

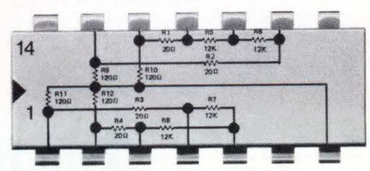
22	62	180	510	1.5K	4.3K	11K
24	68	200	560	1.6K	4.7K	12K
27	75	220	620	1.8K	5.1K	13K
30	82	240	680	2.0K	5.6K	15K
33	91	270	750	2.2K	6.0K	16K
36	100	300	820	2.4K	6.2K	18K
39	110	330	910	2.7K	6.8K	20K
43	120	360	1.0K	3.0K	7.5K	22K
47	130	390	1.1K	3.3K	8.2K	
51	150	430	1.2K	3.6K	9.1K	
56	160	470	1.3K	3.9K	10K	



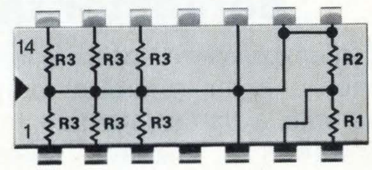
898-5-R220/330
Pulse squaring TTL terminator.
Price (1,000-4,999) $1.45



899-5-R220/330
Pulse squaring TTL terminator.
Price (1,000-4,999) $1.35



899-19
DIP interface network providing resistors for μA711 core sense amplifier configuration.
Price (1,000-4,999) $1.18



899-40
DIP network provides six line terminators and the threshold setting divider for the Intel 3208A sense amplifier.
Price (1,000-4,999) $1.35

Beckman®
HELIPOT DIVISION
CHECK NO. 13

The first flame-retardant polyester tape.

Now, a tough pressure-sensitive tape that combines a flame-retardant polyester backing with a flame-retardant thermosetting adhesive. "Scotch" Electrical Tape X-1284 meets the rigid flameout requirements outlined in UL subjects 492, 510, and 94. Provides functional temperature limit of 130° C.

"Scotch" Electrical Tape X-1284. Will not support combustion.

The tough "Scotchpar" polyester backing on "Scotch" X-1284 provides excellent electrical properties and tear resistance. Extremely flexible, it conforms to irregular surfaces and can be applied automatically. The unique flame-retardant adhesive delivers excellent electrolytic corrosion resistance.

"Scotch" X-1284 is ideal for coil holding and covering applications, high temperature harness wraps, color TV transformer insulation and yoke coil assemblies.

Ion implantation permits startling reduction of resistor areas in ICs

A technique for ion implantation of resistors in bipolar linear ICs was described recently by Ronald W. Lutz of Sprague Electric Co.

The process, developed at the Sprague Semiconductor facility in Worcester, Mass. uses an implantation system to bombard the semiconductor surface with Boron ions, as shown in **Fig. 1.** Resistors fabricated by implantation are less than one tenth the size of those made by standard diffusion methods. According to Mr. Lutz, in conventional IC designs with significant numbers of resistances, the use of implanted resistors can reduce total chip size by 20 to 30%, in some cases even 50%. The better controllability of implanted resistors and the reduced chip size can bring impressive improvements in yield, and in turn reduce costs.

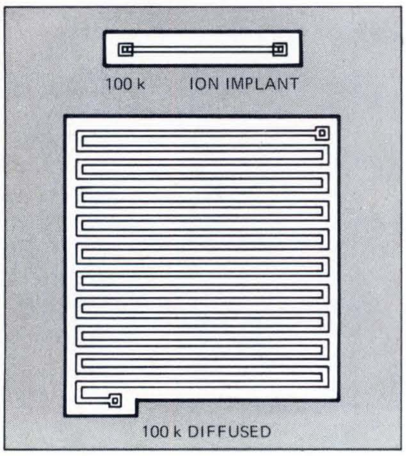


Fig. 1—Ion implantation of resistors permits precise control of the dopant concentration and yields uniform sheet resistance of up to 10k Ω/sq.

It is also of interest that the lateral component of conventional diffused resistors, known as out-diffusion or side-diffusion, which causes the resistors to swell to a width larger than that described by the photo mask, is essentially zero with implanted resistors. The doping ions do not spread because ion implantation is a low-temperature process. Accuracy and matching of the implanted resistors is determined mainly by photomask tolerances.

A scale drawing, **Fig. 2,** compares the relative surface areas of two 100kΩ resistors. The top resistor is fabricated by ion implantation, and the lower resistor by conventional diffusion techniques. The sheet resistivity of implanted resistors can be from 200 to 10kΩ per square, compared to the 135Ω per square which can be achieved in diffused resistors. In addition, the initial accuracy of implanted resistors is 5 to 10 percent, with matching possible to within one percent. Accuracy of diffused resistors is typically 20-30 percent and they can only be matched to within three percent.

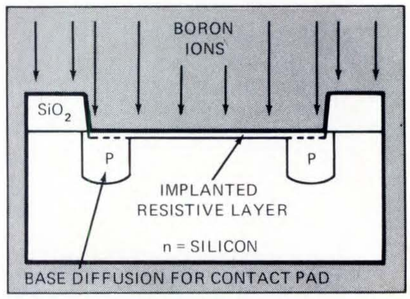


Fig. 2—Two 100kΩ resistors, drawn to scale, show the dramatic size difference between ion implanted (upper) and diffused (lower) types. This 10:1 reduction can reduce IC sizes up to 50 percent.

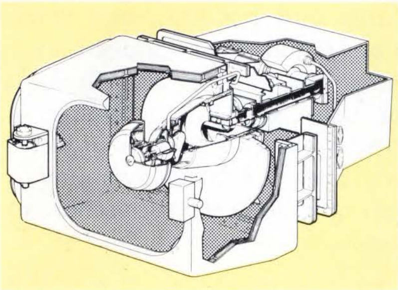
This technique was described in detail by Mr. Lutz in his paper, "The Impact of Ion Implantation on Consumer Electronics," presented at the IEEE Conference of Broadcast and Television Receivers.—BF □

Light scanner on Skylab to aid in study of Earth resources

When NASA's Skylab goes into Earth orbit later this year, it will include as part of the Earth Resources Experiment Package an optical scanning device for measuring the Earth's visible and infrared light.

Photo-like images made from the measured data will aid in the study of crops, water and air pollution and land-use mapping. The data may also be useful in determining new sources of gas, oil and coal.

The scanner, developed by



Cut away of the multispectral scanner shows the 24-in. spherical mirror (center) that will gather light energy from the Earth.

Honeywell's Radiation Center in Lexington, MA, will be mounted in the multiple docking adapter of Skylab in such a way that its light-gathering optical system will be pointed vertically toward the earth. Light energy reflected from the earth is gathered by the scanner's 24-in. spherical mirror, then passed through an additional system of mirrors and prisms that focuses the light, separates it into its spectral parts and directs it to a package of 13 cryogenically cooled mercury-cadmium-telluride detectors.

The detectors convert the energy received into electrical signals that are then stored on magnetic tape. The tapes will be returned to earth as each successive team of astronauts leaves the Skylab following its period in orbit. Computers will then convert the tapes into a format for scientific analysis, including color "photos" of the scanned areas.

Two angled scanning mirrors that are part of the scanner's optical system provide an instantaneous field of approximately one acre in area. Rotating at 6000 rpm, the mirrors rapidly transfer, an acre at a time, the light reflected from the 24-in. telescope through the optical system and to the detector package. Although the total radiant energy scanned is from a circular strip at the Earth's surface approximately 50 miles in diameter, only the forward 110° of the scanned circle is used for recording data, so that data is received continuously from an area 39 miles wide.

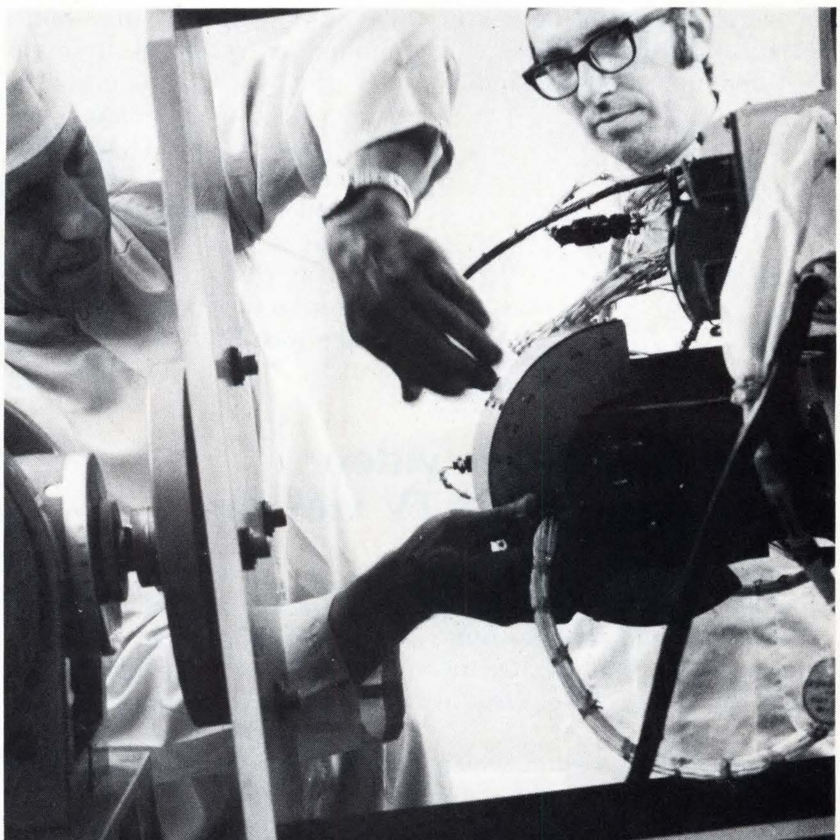
The remaining 250° portion of each scan cycle is used to (1) automatically calibrate the scan system by means of precision aligned light and thermal sources that are built into the scanning mechanism, and (2) to process the data into digital form for storage.

The scanner operates on the principle that all substances—animal, vegetable and mineral—reflect or emit light energy at known portions of the spectrum. Chlorophyll in plants, for example, reflects light energy in the 1μ range. Thus, the relative health of fields of grain or forests can be determined by measurement of their relative concentrations of chlorophyll.

Blue light (0.4μ) penetrates water more deeply than red (0.7μ). Simultaneous measurements of light at these portions of the spectrum can indicate how deep or how turbid a body of water is. Also, by comparing data in the infrared bands between 1 and 2μ with bands in the visible portion of the spectrum—0.4 to 0.7μ—it is possible to classify certain types of soil and rock outcroppings that are often associated with underground mineral sources.

The two main advantages of multispectral scanning from earth orbit are: First, orbital scanners can "look" at a broad portion of the Earth's surface in a given span of time. The Skylab's over-the-ground speed is 240 nautical miles per minute. This, multiplied by the 39-nautical-mile-wide field of view, enables the scanner to record data from a 9360-nautical-mile area each minute of operation.

Thus Earth-orbital scanning could be more efficient and less expensive than coverage of the



One of the detector packages for the multispectral scanner is shown being replaced. The detectors are cryogenically cooled, mercury-cadmium-telluride types.

same area using ground based or even aircraft based techniques. Early stages of insect infestation in large forest areas, for example, could be much easier to detect from images made of the orbit scanned area than by using ground based detection methods. This would enable foresters to take steps quickly to prevent its spread.

Second, orbital scanning techniques often can accomplish goals impossible to achieve on the Earth's surface. For example, maps of ocean surface temperatures and plankton concentration could be produced as a means of locating large schools of fish. Similarly, mapping of land areas and sources of water would enable land development giving greater consideration to ecological factors.—*FE* ▭

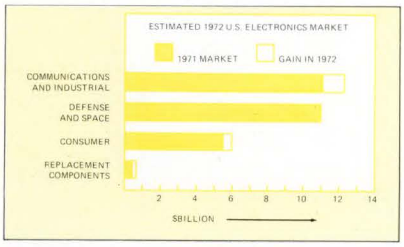
EIA figures point to 1972 electronics industry volume of $29.8 billion

According to figures released by the Electronic Industries Association the U.S. electronics industry experienced a significant business upsurge in 1972, and signs indicate a sustaining growth pattern over the next decade.

The estimated figures show a 1972 U.S. electronics market of $29.8 billion—compared with the $27.9 billion mark of 1971, for a 7% growth.

For the various segments of the overall market, the figures for 1972 breakdown as follows:

• Communications and industrial electronics sales are estimated at about $12.2 billion, compared with $11.1 billion in 1971. This growth rate of 10% is a major factor in the industry's overall expansion.



• Domestic label consumer item production approached $6 billion in 1972, up from $5.5 billion in 1971. This is the highest in the history of the consumer electronics industry.

• The defense and space electronics market for fiscal 1972 was $11 billion, the same amount as recorded in fiscal 1971. The fiscal 1973 defense and space electronics market has been projected at $12.2 billion. Another estimated $1.8 billion of electronics equipment and systems are sold to other government agencies.

• Replacement components market was $710 million, compared with $634 million for 1971, or a 12% rise.

Long-range EIA projections show that by 1975 the dollar volume of the U.S. industry is expected to reach $41.5 billion, climb to $56.9 billion by 1980 and reach $81 billion by 1985. The communications and industrial electronics market is projected to increase from $19.9 billion in 1975 to $29.3 billion in 1980 and to $45.5 billion by 1985. The consumer segment of the electronics market is projected at $6.5 billion in 1975, $8.8 billion in 1980, and $12.9 billion by 1985.

Government electronics is forecast at $15 billion for 1975, $18.8 billion by 1980 and $22.5 billion by 1985. Predictions for the electronic component market is $7.6 billion by 1975, $10.4 billion by 1980 and $14.2 billion by 1985.—*FE* ▭

Mylar disc stores video programming for TV viewers

The high-density video storage capabilities of a system using mylar discs and a laser-optic readout were demonstrated recently by MCA Disco-Vision, Inc.

The heart of the system, which is designed for home entertainment, is a 12-in. diameter metalized mylar disc and a 1-mW laser that reads information stored on the disc. Storage is done on one side of the disc in a spiral track at a density of 12,500 tracks per radial inch.

While the disc revolves at 30 revolutions per second, the laser beam is electronically guided to follow the track without making physical contact with the disc. Laser light, reflected off of the disc surface, is modulated by the information stored on the track and is converted to an electronic signal by a photodiode detector.

Storage capacity of a disc is claimed to be 40 billion bits on one side—enough for 40 minutes of uninterrupted programming or enough to store the social security number of every person in the United States. The system permits random access to information, program speed-up, slow-down, stills, reverse or picture-by-picture replay.

The Disco-Vision system, as well as a similar system announced by Philips this year, is designed for the consumer market and will tie in directly to commercial TV sets through the VHF antenna input.

Disco-Vision expects to offer a player/changer for under $500 and a single-disc player for under $400. Their discs will be in the range from $1.99 to $9.95, depending on content, length and subject. Philips' player is reported to be in the same price range as Disco-Vision's, but Philips' discs will be more expensive.

The laser in Disco-Vision's system is expected to have a useful life of approximately 9000 hours and a replacement cost of about $20. The discs should last indefinitely with proper care.

In addition to the commercial market, there are obvious applications for data storage in the areas of business and science. The expense of laser recording equipment precludes widespread use of this system in applications where data must be erased and rewritten frequently. However, there are many potential uses where a read-only capability is required. Some of the areas envisioned by Disco-Vision include library, catalog and archival storage, teaching machines and credit-card verification systems.—*AS* □

The Disco-Vision system, shown here sitting on top of the television receiver, plays back through any standard TV set. The system is connected to the VHF antenna input terminals and the television is then tuned to a channel not used for regular programming.

Liquid-crystal light valve acts as image intensifier

A new device for intensifying light images, with potential applications for television or other video-projection displays, has been constructed and operated by scientists at Hughes Research Laboratories in Malibu, CA.

The device, a type of light valve, uses a liquid crystal activated by a photoconductor to modulate a high-intensity light beam from a comparatively weak light image.

Disclosure of this light valve was made in a paper given at the International Electron Devices Meeting in Washington, DC. Authors of the paper are three Hughes scientists: Terry D. Beard, William P. Bleha and Shi-Yin Wong.

According to the authors, the light valve offers several advantages over currently used image intensifiers, including longer lifetime, higher brightness, simpler operation and lower cost. These factors give the device short-range potential in large-screen theater television systems, they said, and bring projection TV for the home a step closer.

The valve, which operates in a reflective mode, is a multilayer structure, as shown in **Fig. 1,** consisting of a thin-film photoconductor, a light-absorbing layer, dielectric mirror and liquid crystal sandwiched between transparent conductive

SCIENCE/SCOPE

An AWG-9 Phoenix weapon control system, normally used for launching missiles from the Navy's F-14 Tomcat fighter, has been installed and tested in a shipboard defense role aboard the USNS Wheeling, where it successfully detected and tracked multiple targets at both high and low altitudes from the ship's deck. In multiple target tests, five aircraft were flown in the target area and successfully tracked. The Hughes-built AWG-9 system is unique in its ability to acquire and track more than 20 targets at the same time, launch up to six Phoenix missiles, and guide them simultaneously.

A new electronics fabrication technique sandwiches a very thin dielectric supporting an etched stripline center conductor between two thin air-filled sheet metal ground planes stamped in a configuration that assures optimal support and bonding to the dielectric sheet and suppresses undesired parallel plate radiation modes. Used for the corporate feed of large antenna systems, air-filled strip transmission line has proved superior to dielectric-filled stripline in experiments recently completed by Hughes engineers. Air-filled stripline has better electrical characteristics and is lighter in weight and considerably less expensive to produce.

The Army's Advanced Attack Helicopter (AAH) program has designated the Hughes-built TOW anti-tank missile as primary armament. Hughes is offering major helicopter prime contractors competing for the award complete fire-control system integration for both missile and gun, gunner's and pilot's night vision equipment, laser target designator, and total ground support.

Hughes' Electron Dynamics Division needs engineers for R&D programs to meet projected future demand for transistorized microwave amplifiers; Gunn and Impatt diode sources; microwave and millimeter wave mixers, detectors, and ferrite devices; traveling wave tubes for space applications; and high-voltage, high-efficiency microwave power supplies. Write: B. E. Shryack, Hughes Aircraft Company, 3100 W. Lomita Blvd., Torrance, CA 90509. Hughes is an equal opportunity M/F employer.

A reliable lightweight, low-cost radar for air-superiority fighter planes is being developed by Hughes in a multimillion-dollar company-funded program. Initially, the system is to be designed for Northrop's P-530. It will have a look-up, look-down, clutter-free display capability. Designed for air-to-air and air-to ground missions, it will provide the fire control function for the Cobra's guns, missiles, rockets, and bombs. Special emphasis is being placed on minimum maintenance.

The government of Iran has made its second major purchase of Hughes-built TOW anti-tank missiles from the U.S. Army Missile Command, Huntsville, Ala. Iran plans to deploy TOW with armored infantry, helicopter, and infantry units. The Netherlands, West Germany, and Italy have also chosen TOW, and several other countries are evaluating it for both ground and helicopter applications.

Creating a new world with electronics

HUGHES

HUGHES AIRCRAFT COMPANY

CHECK NO. 17

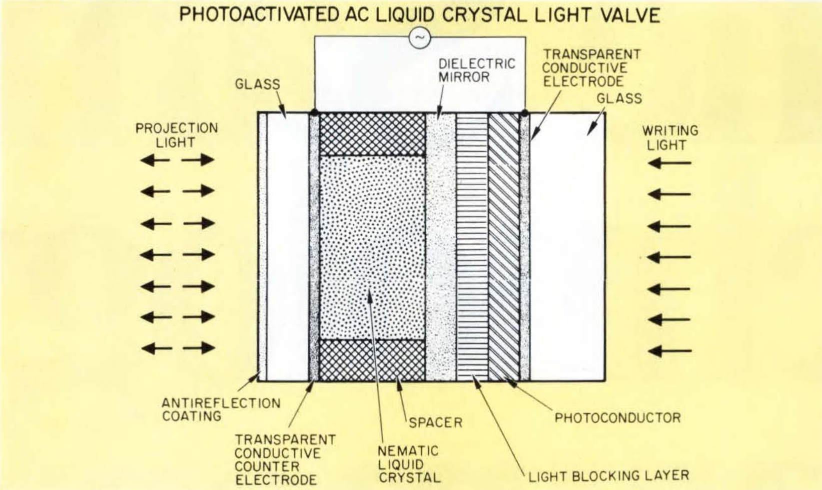


Fig. 1—Cross section of new liquid crystal valve, developed at Hughes Research Laboratories, shows various layers comprising the device. The light valve uses a liquid crystal activated by a photoconductor to modulate a high intensity light beam.

electrodes.

The photoconductor is used to gate the applied alternating voltage across the liquid-crystal film in response to the "writing" light. The light-absorbing layer backing the dielectric mirror blocks any residual projection light. A nematic liquid crystal is used in the dynamic scattering mode.

The projection light source is focused into a diagonal mirror at the focal point of the projection lens, which collimates the light and reflects it off the light valve, as shown in **Fig. 2**. A blocking aperture is placed at the reimage point of the projection source to block light scattered by the dynamic scattering areas of the light valve. Writing is effected from the back side of the device.

The resolution achieved in a liquid crystal film cell is 50 lines per millimeter, providing greater than 1000 lines across a 2.5-cm cell aperture. Images written with an input light power of from 50 to 500 $\mu W/cm^2$ at a wavelength of 500 nm have been projected with 200 $lumen/cm^2$ of white light. Results of these tests have shown response times compatible with television frame rates and no interference in the image by the projection light.—*BF* □

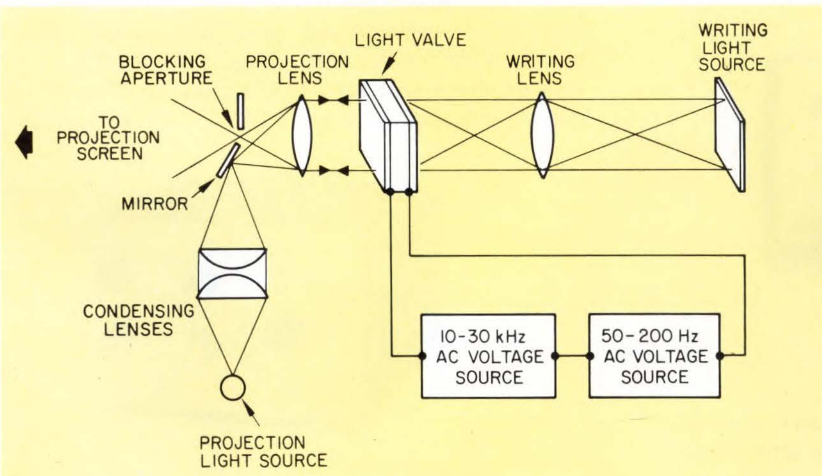


Fig. 2—Optical arrangement for projection display using new reflection light valve. The device holds potential for use in large-screen theater television systems, and eventually may be applicable to projection TV for the home and other video displays.

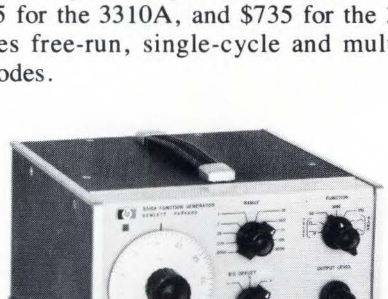
The Same Technology Instruments Makes Them

Take signal sources for example...

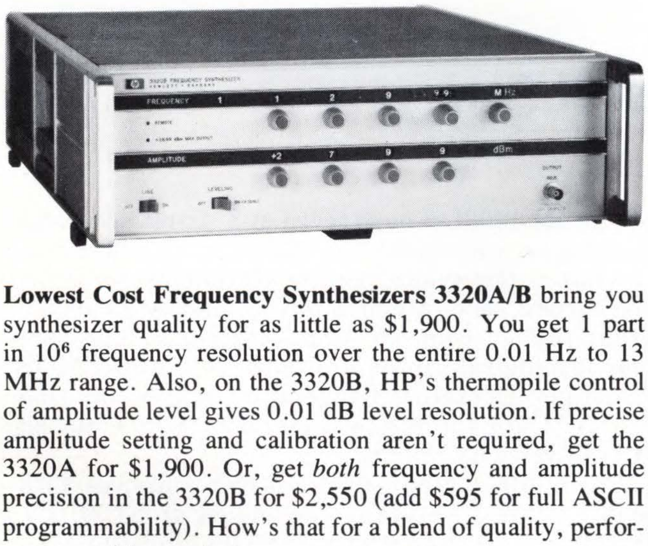
You can't see the automated testing and the other manufacturing advances that help lower the price of HP's quality signal sources. But you sure can see the versatility and extra performance you get for your money. From the simplest function generator to the most capable synthesizer, HP technology has brought the price of quality way down.

Brand New Function Generator 3311A shows what a performance plus you get from this technology in action. Priced at only $249, it adds sweep capability and a separate high-power pulse output to the usual sine, square and triangular wave outputs. Sweep it over any 10 to 1 span within its 0.1 Hz to 1 MHz range. The pulse output drives up to 20 TTL loads. Note that price again. It's 15% lower than its nearest major competition.

Wide Range Function Generators 3310A/B deliver general-purpose waveforms with extended low-frequency response. These 0.0005 Hz to 5 MHz instruments equip you with a linear very-low-frequency ramp, in addition to sine, square, triangle and pulse waveforms. Prices are a modest $595 for the 3310A, and $735 for the 3310B that also provides free-run, single-cycle and multiple-cycle operating modes.



HP That Makes Better...Now Cost Less

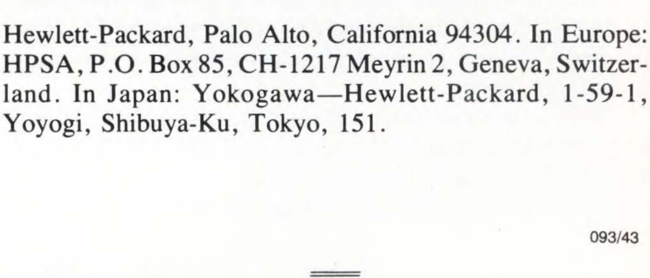


Lowest Cost Frequency Synthesizers 3320A/B bring you synthesizer quality for as little as $1,900. You get 1 part in 10^6 frequency resolution over the entire 0.01 Hz to 13 MHz range. Also, on the 3320B, HP's thermopile control of amplitude level gives 0.01 dB level resolution. If precise amplitude setting and calibration aren't required, get the 3320A for $1,900. Or, get *both* frequency and amplitude precision in the 3320B for $2,550 (add $595 for full ASCII programmability). How's that for a blend of quality, performance and low price!

Top-of-the-line Automatic Synthesizers 3330A/B have a built-in "brain" that lets you avoid tying up a computer. They're like the 3320A/B, only these can be programmed to automatically sweep their frequency spectrum (and, on the 3330B, its precision amplitude level). With the 3330B you're getting a synthesizer, a sweeper, a marker generator, a counter, a programmable attenuator, a built-in controller and a precision level generator—in other words a lab-in-a-box—for just $6,000. Or, cut that to $5,100 for the manual-amplitude-control 3330A.

CHECK NO. 18

Whatever your needs in signal sources, satisfy them with one of HP's technology-leader instruments. They're packed with more capability than ever before—and priced lower, too. For more information on the entire family of HP signal sources, contact your local HP field engineer. Or, write



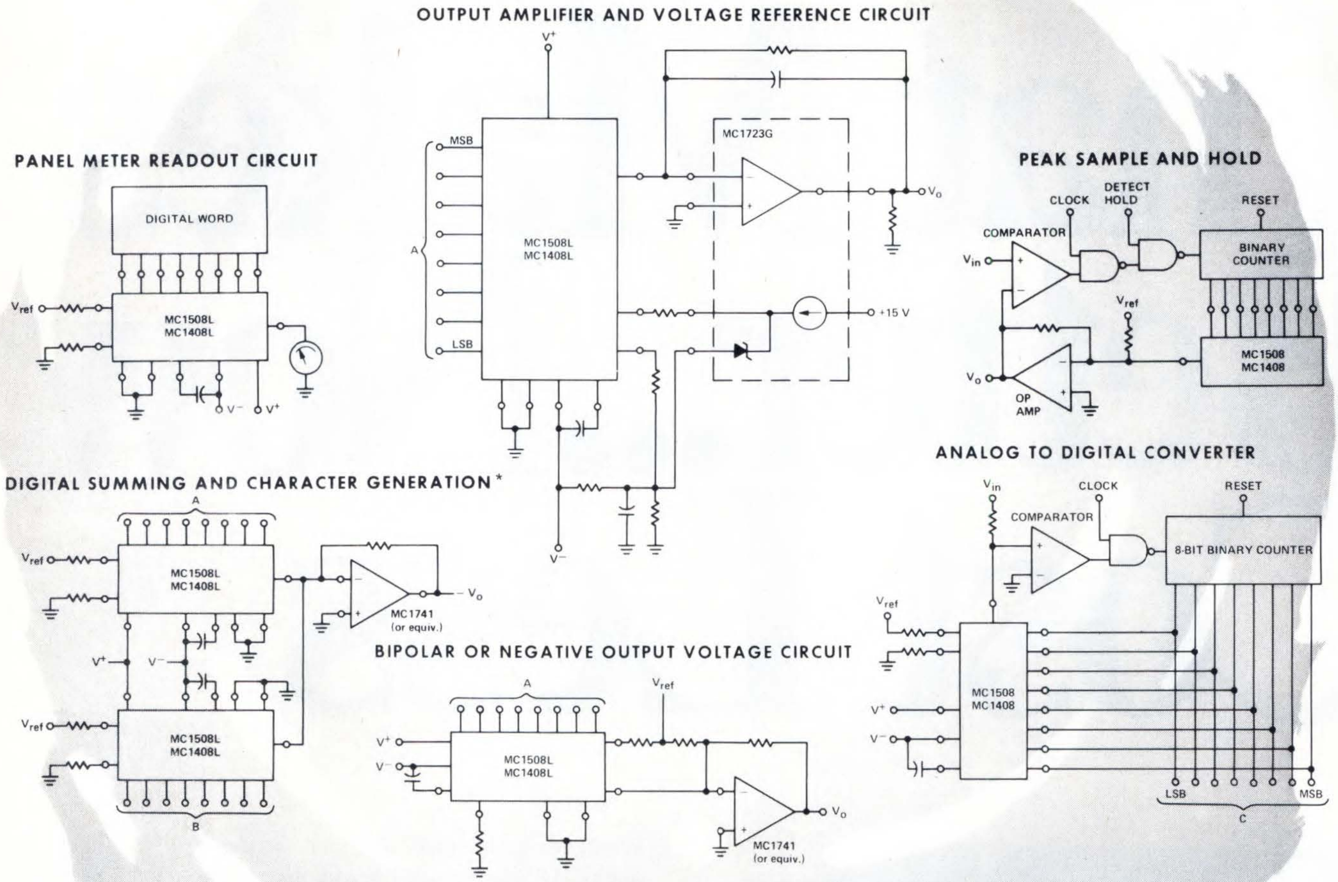
Hewlett-Packard, Palo Alto, California 94304. In Europe: HPSA, P.O. Box 85, CH-1217 Meyrin 2, Geneva, Switzerland. In Japan: Yokogawa—Hewlett-Packard, 1-59-1, Yoyogi, Shibuya-Ku, Tokyo, 151.

093/43

HEWLETT hp PACKARD

SIGNAL SOURCES

This Eight-Bit D/A Converter Does So Many Things . . . So Simply



Here Are Just A Few

Ever since we introduced the "basic" D/A converter, the MC1406 monolithic six-bit multiplying D/A, we've been getting requests to apply the same approach to an eight-bit type. By popular demand, then, here is the MC1508, a monolithic eight-bit multiplying D/A that's versatile, simple to use, and inexpensive.

The MC1508's flexibility is rooted in its simplicity. System requirements determine the voltage reference to be used, from simple zener to sophisticated IC. The op amp is chosen to meet the desired speed, accuracy and output range.

Choose among four variations covering a broad range of performance requirements. MC1508L-8 and MC1408L-8 provide worst case relative error of ±0.19% and full eight-bit accuracy. The MC1408L-7 and the MC1408L-6 have seven and six-bit accuracy, respectively, with eight-bit resolution. All four versions have a fast typical settling time of 300 ns, reference current slew rate of 4 mA/μs, and an extended output voltage swing of +0.5 V to −5 V. The non-inverting digital inputs are both TTL and CMOS compatible. Operating temperature ranges are −55 to +125°C for the MC1508 and 0 to +75°C for all MC1408 versions.

Prices (100-999) are in a class by themselves, with the MC1508L-8 naturally top priced at \$8.50, the MC1408L-8 in the middle at \$5.95, and the MC-1408L-6 carrying a low \$3.95 tag. Get full information by using the reader service number, or write to Motorola Semiconductor Products Inc., Box 20912, Phoenix, Arizona 85036.

MOTOROLA LINEAR

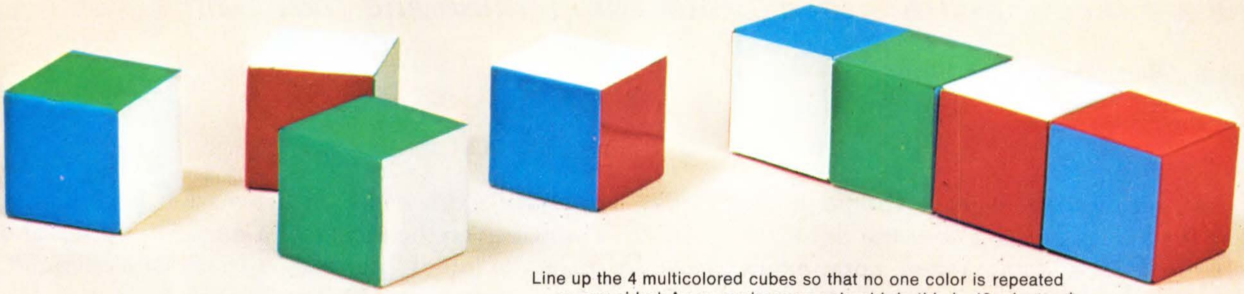
— Serving a greater range of analog designs

*This approach does not result in a 16-Bit D/A Converter.

CHECK NO. 19

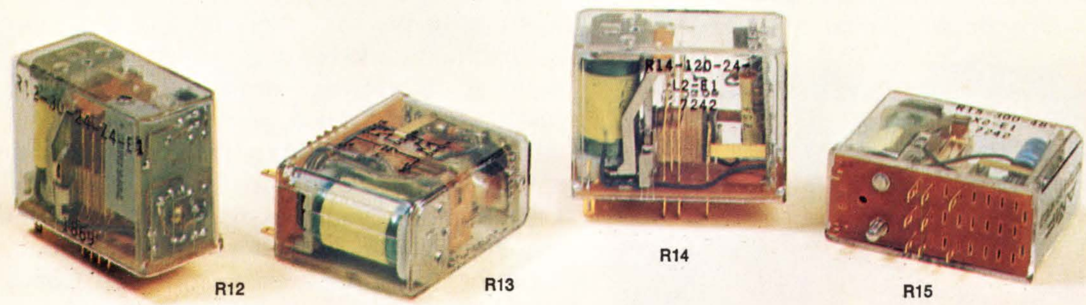
CHECK NO. 20 →

This problem should take you about 42 minutes to solve.



Line up the 4 multicolored cubes so that no one color is repeated on any side.† As an engineer you should do this in 42 minutes.*

With P&B's four new time delay relays you solve cost, accuracy and size problems. Immediately.



These new solid state time delays—each designed to solve different design problems—are built around our compact, widely accepted R10 relay. Each is available in 2 or 4 Form C contact arrangements and may be mounted directly to a chassis, printed circuit board, special mounting strip or in sockets having solder or printed circuit terminals.

R12 Series. A high resolution, 15-turn potentiometer provides delay on operate timing variations within ranges of 0.1 to 2.0, 1.0 to 30 and 5.0 to 120 seconds. Coils are for 12, 24 or 48V DC. Six contact styles cover a load range from dry circuit to 10 amperes.

R13 Series. These fixed, delay on operate time delays are available in 10 timing ranges from 1 to 300 seconds. They require less than 240 milliwatts of DC to operate. Operating voltages are 12, 24 and 48V DC. Contact ratings: dry circuit to 5 amperes.

R14 Series. Seven timing ranges provide delay on operate (R14) or interval timing (R14A) from .025 to 600 seconds. Available fixed or externally adjustable with coil voltages of 6, 12, 24 and 48V DC. Contacts may be specified from dry circuit to 10 amperes.

R15 Series. AC operated from 12, 24, 48 and 115V power sources, these compact time delays may be ordered fixed or externally adjustable in seven timing ranges from .025 to 300 seconds. Delay on operate (R15) or interval timer (R15A) modes are available.

Get complete specifications from your local P&B representative or call Potter & Brumfield Division AMF Incorporated, Princeton, Indiana 47670. 812-385-5251.

**Think you can readily solve the puzzle shown above? Ask your P&B representative for one.*

Solving switching problems is what we're all about.

AMF
Potter & Brumfield

†"Instant Insanity". Copyright Parker Brothers

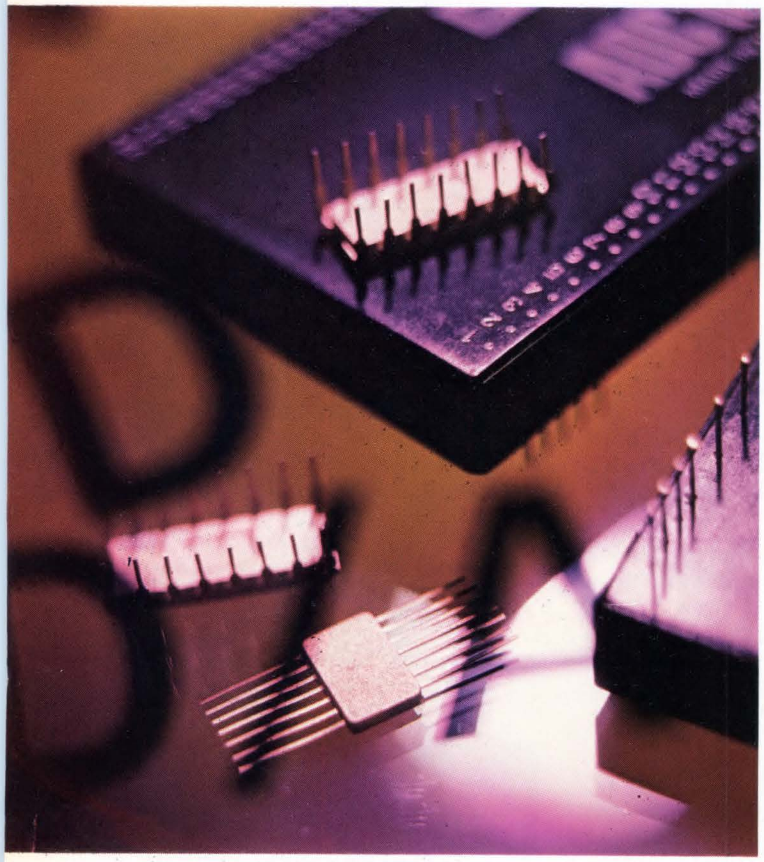
A/D and D/A converters: bridging the analog world to the computer

While prices and sizes are coming down, choosing the right converter is still a difficult task due to vigorous competition and rival claims.

Roger Allan, Associate Editor

Today, more than ever, it should be relatively easy for a designer to select the right D/A or A/D converter as a data system component, since there are literally dozens of manufacturers offering hundreds of converter types among them. The sad fact is, however, this is not so. A designer must not only know his design objectives thoroughly, but he must also be able to interpret specifically the performance capability of the device being offered to him.

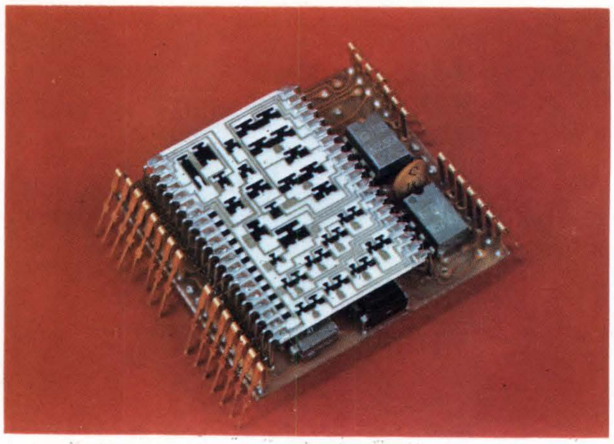
The first part—defining one's design goals—can be ideally accomplished. However, the sheer number of seemingly similar (but in reality different) converters on the market is certain to confuse even the most experienced designer, and make the job of interpreting spec claims difficult, if not impossible. Manufacturers spec their devices under certain assumed conditions. It is the designer's job to find out what these conditions are and to see if they are compatible with his application.



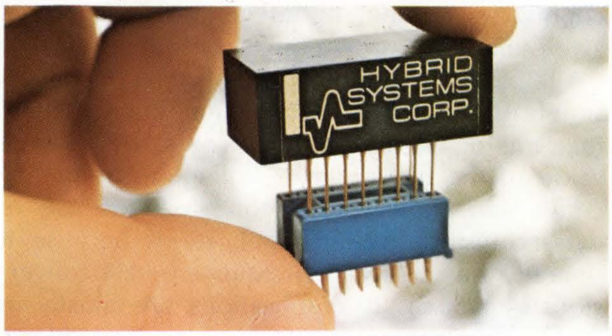
The low-cost building block approach to A/D and D/A converters using monolithic and thin-film DIP and flatpack elements. Introduced by Analog Devices in 1970, the μDAC network concept of monolithic quad switches and thin-film resistor ladder networks made stable and inexpensive converter designs feasible.

As if specifying is not difficult enough, one finds an up-and-coming monolithic converter technology with rival claims challenging hybrid devices in cost and performance. And to put the frosting on the cake, very little, if any, physical compatibility (and to some extent electrical) exists between converters from different manufacturers. In fact, some manufacturers' D/A converters are incompatible with their own A/D units.

With all this confusion, one point should be kept in mind. Quality is still a costly commodity, and higher-cost converters are, by and large, superior in performance to lower cost ones for the same resolution. This superiority of performance may include such unadvertised niceties as short- and long-term stability, infrequent need for recalibration, long-term immortality, immunity to power supply noise and variations, physical and electrical compatibility, monotonicity, inclu-



A modern day 12-bit D/A converter uses thick-film techniques to fit the entire converter function (switches, ladder, reference, range selection and output op amp) on a single pc board that fits into a 1.96×1.76×0.4-in. module. *(Zeltex ZD432)*



Miniaturization is exemplified by this 10-bit $19 D/A converter. It plugs nicely into a 16-pin dual-in-line socket; something space-conscious designers would be sure to appreciate. *(Hybrid Systems Model DAC 371I-10)*

sion of an output amplifier and an input register, deglitching circuitry and backup service from the manufacturer. These are the things that aren't spelled out completely in every data sheet.

This is not to say that low-cost converters are worthless. In fact, for some applications the opposite may be true. Experience has shown that, for many applications such as driving analog meters and strip-chart recorders and programming power supplies, designers tend to overspecify to be on the "safe" side. These applications do not, in general, require expensive converter components. Here, 8-bit D/A converters with 8-bit accuracy can do the job instead of 10- and 12-bit resolution units with much less accuracy. Since converter cost is proportional to resolution, large cost savings can be had.

In retrospect, it is easy to see why overspecifying tends to be common. Too many so-called 10- and 12-bit resolution D/A converters on the market are only good enough for 8 or 10 bits, respectively, once all operating conditions are considered. But there are units whose linearity is as good as, if not better than, their stated bit resolution under all types of operating conditions, and they can be purchased for a good price. The trick is to not only interpret the data sheet but also to have confidence in the manufacturer's reputation in order to fit the right converter to the application as closely as possible.

The modern world is largely a digital one. Digital methods afford us efficient and effective communications, and digital language is the language of the computer. By digitizing such real-world variables as pressure, temperature, speed and sound with A/D converters at the sensor source, and reconstructing these same signals with D/A converters at the terminal point, high-speed, noiseless, stable and low-cost communications are realized over long distances.

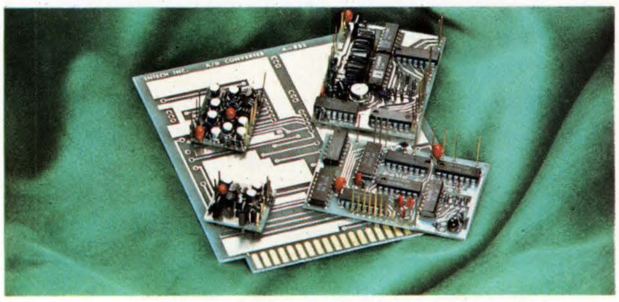
Until only a few years ago, literally shelf loads of components were needed to do this and at great costs and complexities. Today, with the advent of high-resolution, low-cost modular component converters that operate at high speeds yet cost but a fraction of what they used to, digital signal processing has come within the reach of nearly any designer needing it. This has been made possible due to advancements in thick- and thin-film and monolithic technologies which have integrated multitudes of components on one chip area. The result is much smaller sizes, improved performances in many cases, and of course, lower unit costs.

How D/A converters work

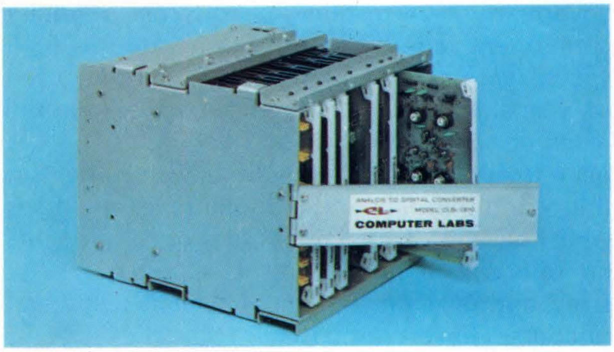
A D/A converter is a device that generates an analog voltage or current proportional to the value of the digital-input word. Basically, it consists of a stable reference (can be added externally), a set of binary weighted switches and a precision resistor ladder network. An input register and output op amp are sometimes included.

The most fundamental D/A conversion scheme is shown in **Fig. 1.** The input digital logic operates the switches, each contributing an appropriate amount of output current in binary weighted increments from a most significant bit (MSB) to a least significant bit (LSB), from left to right. The op amp converts the negative current to an output voltage. This approach is very simple and low in cost, but can only be used for medium- to low-resolution (10 bits or less) converters due to ladder network limitations.

Consider the design of 12-bit converters using this technique. Since the LSB resistor is 2^n times the MSB resistor value, it would have to be 4096 MΩ ($2^{12} \times 10^4\Omega$) for a 10 kΩ MSB resistor. This resistance range cannot be met by either the thick- or thin-film techniques which are used to obtain good resistor temperature tracking for sufficient accuracy. Discrete resistors are more expensive and simply do not have good enough tracking and stability characteristics to do the job. Switching speeds of the transistors and the output op amp also become limiting factors as resolution increases.



Thin-film technology together with discrete components join to make up this high-speed successive-approximation 12-bit A/D converter. It offers 4-μsec conversion time and is temperature stable to within $\pm$5 pp/°C. *(Intech)*



For high-speed systems applications, these A/D converters include track-and-hold amplifiers and allow the designer to use his own power supply and additional functions for added flexibility and economy. Shown is an 8-bit $5000 unit capable of 10-MHz word conversion rates. *(Computer Labs "Bare Bones" Series)*

One way to get around the large resistance range needed for high resolutions is to use the binary resistance quads as shown in **Fig. 2.** Each quad is essentially a 4-bit D/A converter with four different resistance values of R, 2R, 4R and 8R. By connecting two such quads along with an attenuating resistor in the current summing bus, an 8-bit unit is produced. The attenuating resistor used here reduces the LSB quad factor to the MSB quad by $2^4=16$. As more quads are added on, resolution is increased. One advantage of this method is that only the MSB quad resistors have the highest tolerance. Each successive quad can use resistors whose tolerance can be slightly less than the previous quad stage.

The most popular method, derived from the resistance quad method, is the R-2R ladder **(Fig. 3).** The beauty of this method is that it uses only two resistor values per bit in an R-2R relationship. The resistors must have close tolerances, however. This method is by far the most widely used one.

A/D converter circuits

Fundamentally, A/D converters either convert the input analog signal (either voltage or current) to a frequency or a set of pulses whose time is measured to provide a representative digital output or compare the input signal with a variable reference using an internal D/A converter to obtain the digital output.

Voltage-to-frequency, ramp and integrating-ramp methods are the three leading conversion processes that use a time-measurement principle. Successive approximation and parallel/modified parallel circuits rely on comparison methods.

Fig. 4 shows a typical voltage-to-frequency converter. Here, the input analog signal is integrated and fed to a comparator. When the comparator changes its state, the integrator is reset and the process repeats itself. The counter counts the number of integration cycles for a given time to provide a digital output.

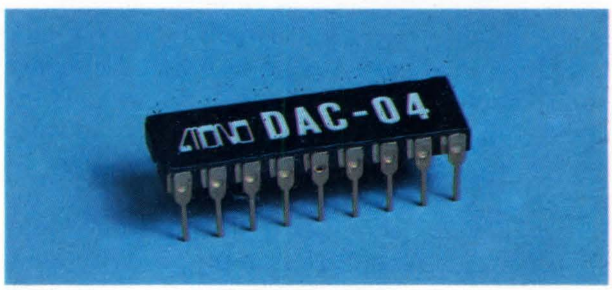
The principle advantage of this type of conversion is its excellent noise rejection due to the fact that the digital output represents the **average** value of the input signal. Voltage-to-frequency conversion, however, is too slow for use in data-acquisition system applications because it operates bit-serially (approximately 1000 conversions/sec max.). Its applications are mostly in DVMs using converters with resolutions of 10 bits or less.

Ramp conversion works by continuously comparing a linear reference ramp signal with the input signal (which is converted to a pulse) using a comparator **(Fig. 5).** The comparator initiates a counter when changing state, which counts proportionally the time the comparator is logically HIGH; the time itself being proportional to the magnitude of the input signal. The counter provides the digital representation of the input.

This method is slightly faster than the previous one, but it requires a highly linear ramp source in order to be effective. It does offer good 8- to 12-bit differential linearity for applications requiring high accuracy.

With the integrating ramp converter **(Fig 6),** or better known as the popular dual-slope converter, the input analog signal is integrated over a fixed period of time followed by the integration of a fixed reference voltage of opposite polarity bringing the output of the integrator network to zero. Since the time it takes to integrate the reference voltage is proportional to the magnitude of the input signal, measuring this integration time with a counter and a pulse source results in an accurate digital representation of the input signal.

While a relatively slow process, integrating ramp conversion offers high noise rejection and excellent stability with both time and temperature. It can be modified to increase its conversion speeds of approximately 2000 conversions/sec to more than 10,000 conversions/sec and is used



Complete 10-bit D/A conversion is available in this monolithic 18-pin dual-in-line package. The unit includes the reference, ladder network, switches and output op amp. In addition to obvious physical size advantages, monolithic construction allows for low power dissipation (only 300 mW) and low unit costs in OEM quantities. *(Precision Monolithics)*

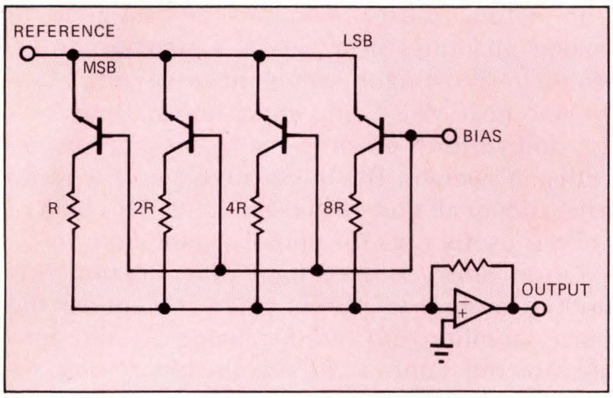


Fig. 1—The most fundamental D/A conversion scheme is straightforward and low in cost, but can only be used for low-resolution units due to resistor ladder limitations.

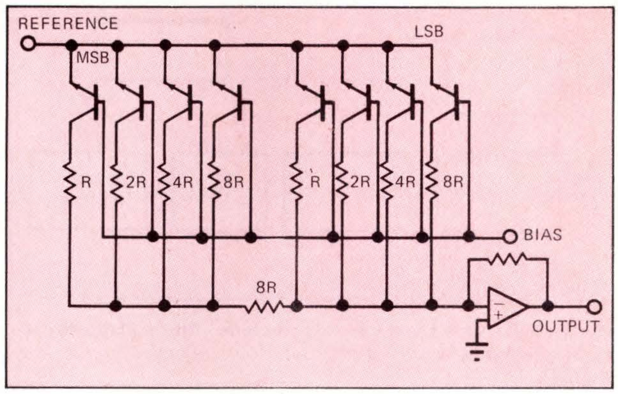


Fig. 2—The use of binary resistance quads alleviates the ladder network problem.

mostly in 8- to 12-bit converters for DVMs, DPMs and DMMs.

Successive approximation is a comparative method that uses a D/A derived reference, which is successively compared with the input analog signal **(Fig. 7).** A comparator adjusts the D/A converter's reference output to converge to the value of the input analog signal.

Speed is this method's largest advantage, with conversions up to 1,000,000/sec possible at up to 16-bit resolutions. However, its high susceptibility to noise does give it a major drawback. Because of its high speeds and resolutions, it is used widely in data-acquisition systems for interfacing to computers.

The simplest type of A/D converter is the parallel type **(Fig. 8).** It uses one comparator for each input quantization level (i.e., a 6-bit converter would have 6 comparators, and an 8-bit unit, 8 comparators). Conversion is straightforward; all that is required besides the comparators is logic for decoding the comparator outputs.

Because only comparators and logic gates stand between the analog inputs and digital outputs, extremely high speeds of up to 50,000,000 samplings/sec can be obtained at low resolutions of 6 bits or less. The fact that the number of comparator and logic elements increases with resolution obviously makes this converter impractical for resolutions greater than 6 bits.

Modified parallel designs, such as parallel-serial circuits, can provide a good tradeoff between hardware complexity and the resolution/speed combination at a slight addition in hardware and a sacrifice in speed. They can provide up to 100,000 conversions/sec for up to 14-bit resolutions.

Types of D/A converters

Basically, D/A converters are available with either a fixed internal (or external) reference or with an external variable reference (multiplying types). Fixed-reference D/A converters that do not include an internal reference source allow the user to utilize a more stable reference than he would otherwise obtain with a converter having its own built-in reference. In general, fixed-reference converters are more accurate than multiplying types because of the variable nature of the latter's reference.

Multiplying D/A converters produce outputs that are directly proportional to the product of the digital input, multiplied by a variable analog reference. They are used in programmable test equipment, resolver and CRT display applications, where output information must not only be produced but also must be positioned with respect to a set of coordinate references.

Functionally, D/A converters are available as current-output or voltage-output types. The former do not include output amplifiers and are not constricted by their bandwidth limitations. Settling times well under 1 μsec (as low as 25 nsec) can be obtained with output currents of approximately 10 mA or less (output voltage ranges from 1 to 2V).

Because the output amplifier is not included, current D/A converters tend to be a little less

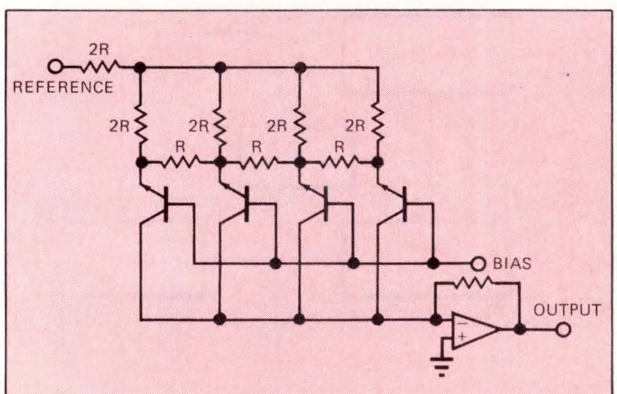


Fig. 3—The most popular D/A conversion method employs an R-2R ladder network.

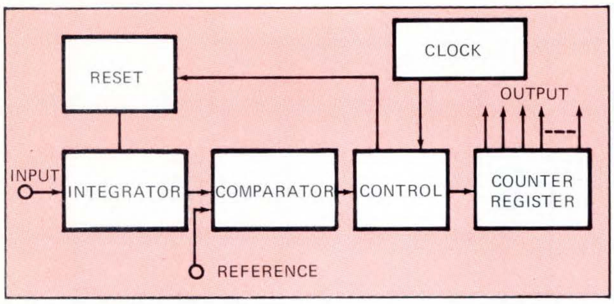


Fig. 4—A/D converter circuits include the voltage-to-frequency scheme, which offers high noise rejection but is slow in speed.

expensive than voltage types. However, they may not be as temperature stable since the output is directly influenced by the temperature stability of the converter's resistance ladder network. Their applications are in areas where speed is paramount, and that includes A/D converters and CRT deflection circuits.

Voltage-output converters do have output amplifiers. Because of this, their settling times tend to be above the 1-μsec range. However, a high-performance and high-speed output amplifier can be added to a high-speed current-output converter to make the output voltage a little faster in settling time, although this may cost quite a few additional dollars

Inputs and outputs

To a large extent, no D/A or A/D converter can be of much practical use to anyone without a knowledge of the type of digital input or output code utilized and the magnitude of both the digital and analog signals involved.

Converters work with either unipolar or bipolar digital codes. The former includes straight or natural binary and BCD. The latter includes offset binary, one's complement and two's complement. The Gray code can be used for both unipolar and bipolar applications.

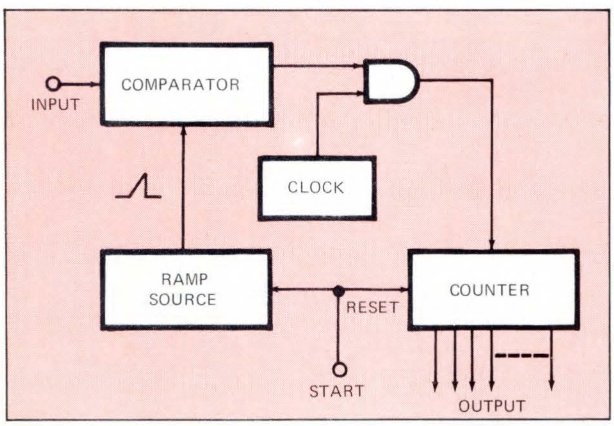


Fig. 5—Ramp conversion is a little faster and offers very good differential linearity, provided that the ramp signal employed is highly linear itself.

In natural binary, numbers are assigned to analog quantities in a natural systematic order, where the most significant bit has a weight of $1/2 = 2^{-1}$, the next MSB being equal in weight to $1/4 = 2^{-2}$, and so forth down to the least significant bit with a $1/2^n$ weight. The binary number value is the total sum of all non-zero bit weights. This type of code is useful only for unipolar operation.

Offset binary is used for bipolar circuits. It is nothing more than straight binary, except that the binary number zero and the analog quantity zero are not the same as in straight binary and are **offset** so that the maximum negative value of the analog quantity is coded at binary zero. This allows the MSB to be assigned a "0" for all negative analog values and a "1" for all positive analog values.

A complementary code is used basically where bipolar analog quantities must be quantized, but with the provision that the binary number zero be assigned to the analog quantity zero. This is done by simply inverting a binary code and inverting every "0" to a "1" and vice versa, for the MSB only. It is simply a binary code with an inverted MSB.

Differences in quantizing the zero analog level using a complementary code result in either one or two's complement codes. If the binary number zero is assigned to the analog range whose lower limit value is zero, a one's complement code results. In two's complement coding, the binary zero is assigned to an analog range whose zero value occurs in the center of the corresponding analog range.

The Gray code is another binary code. This code is similar to the natural binary code in that

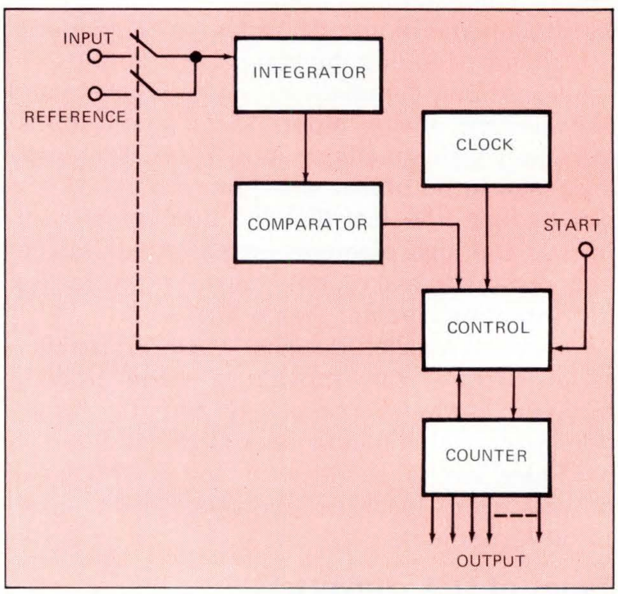


Fig. 6—The integrating converter provides excellent noise rejection and high time and temperature stability but is relatively slow in speed.

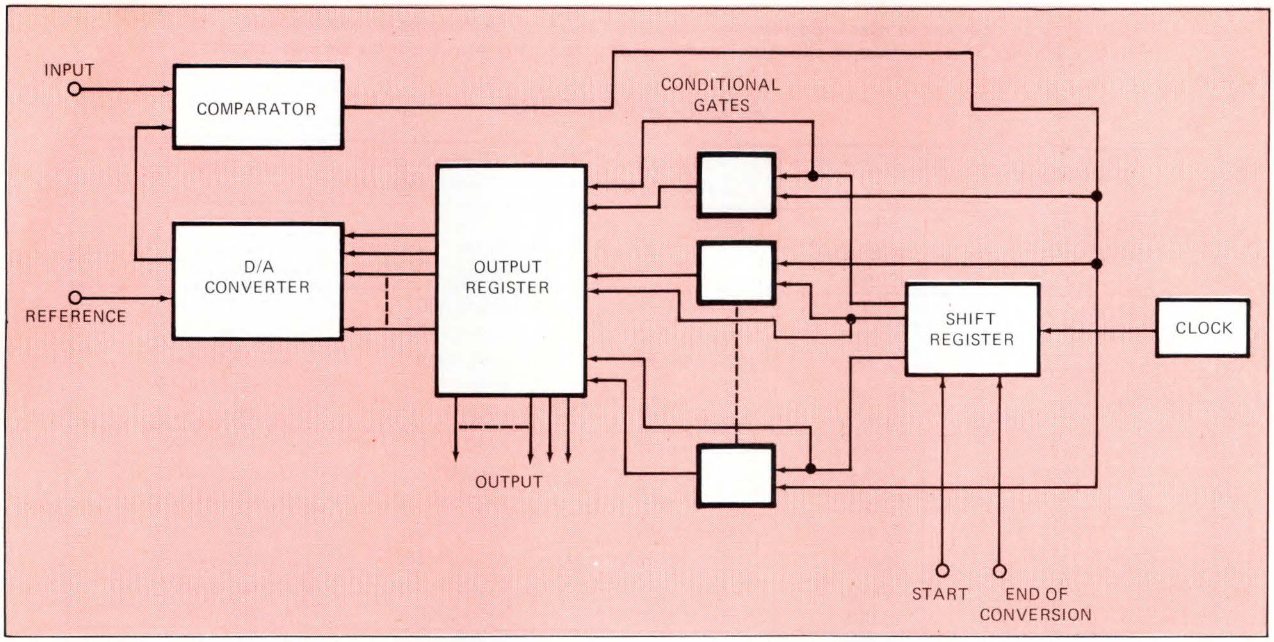


Fig. 7—Successive approximation is useful for high-speed and high-resolution designs, but is susceptible to noise.

each specific set of codes represent unique portions of the analog range. It does not, however, follow the same weighting rules as natural binary. In some applications such as shaft-angle encoders, this code is said to offer fewer errors than other codes.

The specific relationship between the natural binary code to the Gray code can perhaps be best illustrated, in going from the former to the latter, by the following example for the binary equivalent for the number 27, which is 11011. To convert this number to the Gray code, we proceed as follows: for the binary MSB, the Gray code MSB will always be the same, or "1" in this case. Each succeeding binary MSB will produce a "1" in Gray code for a change in binary (in going from "0" to "1" or vice versa in binary) or "0" in Gray code for no change in binary. Thus 11011 or 27 in straight binary is 10110 in the Gray code.

BCD of the 8-4-2-1 variety is a code in which each bit represents a binary quad. Taking the MSB of this BCD code, its LSB represents a weight of 0.1. The next MSB's LSB is 0.01, and the next one is 0.001, and so forth. Weight assignments from 0 through 9 can be given for each quad set. Such a code is widely used in digital-voltmeter and panel-meter inputs and is produced by the input A/D converter.

There are a few other codes, many of which are hybrids or combinations of these basic codes. However, the ones already mentioned cover most of the codes currently in use by A/D and D/A converters. **Table I** lists them all and shows how they differ for a hypothetical analog voltage range.

By far, TTL and some DTL levels are the most widely used for digital codes in A/D and D/A converters. A few converters are also CMOS compatible. The analog outputs of D/A converters vary, with popular outputs at 2.5, 5, 10, 10.24 and even 20V. The most widely-found outputs are 10 and 10.24V. Current-output units, as previously mentioned, provide up to 10 mA of output current, with typical outputs being 1, 1.2, 1.5, 2.4 and a popular 5 mA step.

Choosing a converter

There are generally two different classes of modular converters available: an economy low-cost, moderate-to-low-accuracy and low-resolution group for "cheap and dirty" and general-purpose applications that do not require high accuracies. Converters in this group sell for under $100 for 6 to 12 bits of resolution (less than $10 for some 8-bit D/A converters). The other group includes converters of 13-bit design and higher, whose application requires good to excellent accuracies. These cost a lot more—$300 or more in many cases.

In between, there are a few low-resolution, high-accuracy and high-resolution, low-accuracy converters at moderate prices. But no matter which group you purchase from, one important quality to look for besides the stated specifications is just how stable a particular converter will be with time and temperature six months or more from now. This will reflect the quality of design and of the components behind that converter; something not always apparent at the time of purchase.

(Text continued on page 34)

Specifications for conversion rates and settling times given here are not to be construed as absolute, but only as guidelines. This is because no two manufacturers specify these parameters under the same conditions.

A/D CONVERTERS

Company	Resolution	Range of word conversion rates	Range of costs (single quantity)	Technology
Adage, Inc., Boston, MA	8 Bits	1 MHz	$5700	Rackmount
	14 Bits		$6000	Rackmount
	15 Bits		$6000	Rackmount
Analog Devices, Inc., Norwood, MA	8 Bits	800nsec-18μsec*	$79-$1680	Modular/hybrid
	10 Bits	1μsec-22μsec*	$225-$1990	Modular/hybrid
	12 Bits	15μsec-85μsec *	$305-$950	Modular/hybrid
	14 Bits	40msec*	$259	Modular/hybrid
	16 Bits	400μsec*	$1350	Modular/hybrid
Analogic Corp., Wakefield, MA	8 Bits	2μsec-10μsec*	$149-$429	Modular/hybrid
	10 Bits	2.5msec-45msec*	$159-$525	Modular/hybrid
	12 Bits	4μsec-9msec*	$129-$59	Modular/hybrid
	13 Bits	10μsec-75μsec*	$345-$715	Modular/hybrid
	14 Bits	12μsec-111msec*	$249-$1400	Modular/hybrid
	15 Bits	17μsec*	$1500	Modular/hybrid
	16 Bits	670μsec-200msec*	$200-$250	Modular/hybrid
Biomation, Inc., Palo Alto, CA	6 Bits	10 MHz	$1850	Rackmount
	8 Bits	2 MHz-100MHz	$2950-$9500	Rackmount
Burr-Brown Research Corp., Tucson, AZ	8 Bits	20μsec*	$150-$170	Modular/hybrid
	10 Bits	30μsec*	$190-$220	Modular/hybrid
	12 Bits	30μsec-12.5msec*	$230	Modular/hybrid
	14 Bits	50msec*	$250	Modular/hybrid
	16 Bits	30msec-200msec*	$225-$250	Modular/hybrid
Computer Labs, Greensboro, NC	4 Bits	6 MHz-25 MHz	$3200-$5800	Rackmount
	5 Bits	5 MHz- 20 MHz	$3250-$6400	Rackmount
	6 Bits	4 MHz-33 MHz	$2800-$13,200	Rackmount
	7 Bits	3 MHz-20 MHz	$2900-$11,400	Rackmount
	8 Bits	2 MHz-15 MHz	$3000-$11,800	Rackmount
	9 Bits	1 MHz-5 MHz	$5550-$9660	Rackmount
	10 Bits	2 MHz-3 MHz	$4900-$6500	Rackmount
	10 Bits	100 Hz	$4900	Rackmount
Cycon, Inc., Sunnyvale, CA	8 Bits	2μsec-50μsec*	$49-$250	Modular/hybrid
	10 Bits	2.5μsec-100μsec*	$69-$350	Modular/hybrid
	12 Bits	100μsec*	$99-$149	Modular/hybrid
	14 Bits	10msec*	$89	Modular/hybrid
	16 Bits	200μsec*	$149-$199	Modular/hybrid
Data Technology, Santa Ana, CA	15 Bits	40 kHz		Rackmount
Datel Systems, Inc., Canton, MA	4 Bits	2.5 MHz-25MHz	$545-$1250	Modular/hybrid
	6 Bits	20 KHz-1.66 MHz	$22.95-$745	Modular/hybrid
	8 Bits	625 Hz-10 MHz	$59-$2495	Modular/hybrid
	10 Bits	500 Hz-1 MHz	$89-$995	Modular/hybrid
	12 Bits	200 Hz-250 kHz	$99-$450	Modular/hybrid
	13 Bits	20 kHz	$595	Modular/hybrid
	14 Bits	20 kHz	$695	Modular/hybrid
	15 Bits	20 kHz	$795	Modular/hybrid
	16 Bits	20 kHz	$895	Modular/hybrid
Dynamic Measurements Corp., Winchester, MA	9 Bits	4.5μsec*	$295	Modular/hybrid
	11 Bits	4.5μsec*	$325	Modular/hybrid
	12 Bits	6.5μsec*	$395	Modular/hybrid
	13 Bits	6.5μsec*	$395	Modular/hybrid
Function Modules, Inc., Irvine, CA	12 Bits	2msec-20msec*	$85-$95	Modular/hybrid
	14 Bits	750μsec-8msec*	$85-$95	Modular/hybrid
	15 Bits	10msec*	$115	Modular/hybrid
Gralex Industries, Farmingdale, NY	8 Bits	625μsec*		Modular/hybrid
	10 Bits	244μsec-2.5msec*		Modular/hybrid
	12 Bits	10msec*		Modular/hybrid
	14 Bits	2.44msec*		Modular/hybrid
Helipot Div. of Beckman Instruments, Fullerton, CA	8 Bits	1 MHz	$240	Modular/hybrid

Company	Resolution	Range of word conversion rates	Range of costs (single quantities)	Technology
Hybrid Systems Corp., Burlington, MA	8 Bits	3μsec-200μsec*	$59-$195	Modular/hybrid
	12 Bits	13μsec-20μsec*	$99-$220	Modular/hybrid
ILC Data Devices Corp., Hicksville, NY	4 Bits	16 MHz	$900	Modular/hybrid
	8 Bits	6 MHz	$3000	Modular/hybrid
	8 Bits	22μsec*	$200	Modular/hybrid
	9 Bits	11μsec-22μsec*	$225-$325	Modular/hybrid
	10 Bits	11μsec-22μsec*	$250-$350	Modular/hybrid
	11 Bits	11μsec-22μsec*	$275-$375	Modular/hybrid
Intech, Inc., Santa Clara, CA	12 Bits	4μsec*	$420	Modular/hybrid
Inter-Computer Electronics, Inc., Landsdale, PA	4 Bits	2 MHz-100 MHz		Rackmount
	5 Bits	20 MHz-50 MHz		Rackmount
	6 Bits	2MHz-30MHz		Rackmount
	7 Bits	20 MHz		Rackmount
	8 Bits	100 kHz-15 MHz		Rackmount
	9 Bits	1 MHz- 5 MHz		Rackmount
	10 Bits	100 kHz-2 MHz		Rackmount
	12 Bits	500 kHz		Rackmount
Lancer Electronics Corp., Norristown, PA	14 Bits	6μsec-35μsec*		Rackmount
	15 Bits	50μsec*		Rackmount
	16 Bits	100μsec*		Rackmount
	18 Bits	50μsec*		Rackmount
Micro Networks Corp., Worcester, MA	8 Bits	20μsec*	$150	Modular/hybrid
Phoenix Data, Inc., Phoenix, AZ	6 Bits	100nsec*	$3495	Modular/hybrid
	8 Bits	100nsec-8μsec*	$175-$3995	Modular/hybrid
	9 Bits	900nsec-9μsec*	$195-$735	Modular/hybrid
	10 Bits	1μsec-10μsec*	$215-$785	Modular/hybrid
	11 Bits	1.5μsec-12μsec*	$240-$890	Modular/hybrid
	12 Bits	2μsec-15μsec*	$260-$995	Modular/hybrid
	13 Bits	8μsec-35μsec*	$310-$585	Modular/hybrid
	14 Bits	10μsec-80μsec*	$345-$695	Modular/hybrid
	15 Bits	5μsec-250μsec*	$725-$1495	Modular/hybrid
Preston Scientific, Inc., Anaheim, CA	8 Bits	750 kHz-10 MHz	$5710	Rackmount
	9 Bits	500 kHz-10 MHz	$6340	Rackmount
	10 Bits	400 kHz-5 MHz	$6930	Rackmount
	11 Bits	300 kHz-3 MHz	$7210	Rackmount
	12 Bits	150 kHz-2 MHz	$7540	Rackmount
	13 Bits	125 kHz-1 MHz	$7840	Rackmount
	14 Bits	110 kHz-760 kHz		Rackmount
	15 Bits	100 kHz-750 kHz		Rackmount
SRC Div. of Moxon, Inc., Irvine, CA	12 Bits	5μsec*	$500-$760	Rackmount
Teledyne-Phibrick, Dedham, MA	8 Bits	6μsec-50μsec*	$69-$265	Modular/hybrid
	10 Bits	7μsec-100μsec*	$89-$295	Modular/hybrid
	12 Bits	10μsec-6μsec*	$98-$345	Modular/hybrid
Tustin Electronics Co., Santa Ana, CA	8 Bits	3μsec*	$420	Modular/hybrid
	10 Bits	4μsec*	$470	Modular/hybrid
	12 Bits	5μsec-8μsec*	$300-$500	Modular/hybrid
	15 Bits	9μsec-18μsec*	$1000-$1200	Modular/hybrid
	8 Bits	170nsec-1.5μsec*	$2360-$3200	Rackmount
	9 Bits	250nsec-2μsec*	$2600-$3600	Rackmount
	10 Bits	300nsec-3.5μsec*	$2840-$4000	Rackmount
	11 Bits	400nsec-3.5μsec *	$3080-$4400	Rackmount
	12 Bits	500nsec-4μsec*	$3320-$4800	Rackmount
	13 Bits	700nsec-4μsec*	$3560-$5000	Rackmount
	14 Bits	900nsec-5μsec*	$3800-$5600	Rackmount
	15 Bits	1.1μsec-5μsec*	$4040-$6000	Rackmount
Zeltex Inc., Concord, CA	8 Bits	3μsec-50μsec*	$49-$415	Modular/hybrid
	10 Bits	4μsec-100μsec*	$69-$435	Modular/hybrid
	12 Bits	6μsec-200μsec*	$99-$450	Modular/hybrid
	13 Bits	52μsec*	$495	Modular/hybrid

D/A CONVERTERS

Company	Resolution	Range of settling times	Range of costs (single quantities)	Technology
Analog Devices Inc., Norwood, MA	8 Bits	40nsec-10μsec	$140-$220	Modular/hybrid
	10 Bits	40nsec-5μsec	$49-$495	Modular/hybrid
	11 Bits	1μsec	$150	Modular/hybrid
	12 Bits	3μsec-15μsec	$79-$295	Modular/hybrid
	14 Bits	250μsec	$395-$820	Modular/hybrid
	16 Bits	250μsec	$745-$1170	Modular/hybrid
Analogic Corp., Wakefield, MA	8 Bits	100nsec-12μsec	$59-$305	Modular/hybrid
	10 Bits	120nsec-12μsec	$33-$350	Modular/hybrid
	12 Bits	200nsec-12μsec	$39-$475	Modular/hybrid
	13 Bits	200nsec-6μsec	$275-$585	Modular/hybrid
	14 Bits	1μsec-6μsec	$350-$695	Modular/hybrid
	16 Bits	3μsec-6μsec	$595-$895	Modular/hybrid
	4-Digit BCD	2μsec	$375	Modular/hybrid
Burr-Brown Research Corp., Tucson, AZ	8 Bits	1.5μsec-7μsec	$90-$140	Modular/hybrid
	10 Bits	1.5μsec-7μsec	$100-$150	Modular/hybrid
	12 Bits	2.5μsec-7μsec	$125-$185	Modular/hybrid
	16 Bits	10μsec-50μsec	$325	Modular/hybrid
	3-Digit BCD	2μsec-5μsec	$125-$185	Modular/hybrid
Computer Labs Greensboro, NC	4 Bits	30nsec-90nsec	$1480	Rackmount
	5 Bits	30nsec-90nsec	$1530	Rackmount
	6 Bits	30nsec-90nsec	$1580	Rackmount
	7 Bits	30nsec-90nsec	$1630	Rackmount
	8 Bits	30nsec-90nsec	$1690	Rackmount
	9 Bits	30nsec-90nsec	$1760	Rackmount
Cycon Inc., Sunnyvale, CA	8 Bits	2μsec-20μsec	$19-$109	Modular/hybrid
	10 Bits	2μsec-20μsec	$29-$129	Modular/hybrid
	12 Bits	2μsec-20μsec	$49-$139	Modular/hybrid
	14 Bits	2μsec-20μsec	$99-$179	Modular/hybrid
	2-Digit BCD	2μsec-20μsec	$19-$59	Modular/hybrid
	3-Digit BCD	2μsec-20μsec	$39-$89	Modular/hybrid
	4-Digit BCD	2μsec-20μsec	$69-$149	Modular/hybrid
Datel Systems Inc., Canton, MA	8 Bits	25nsec-25μsec	$9.95-$199	Modular/hybrid
	10 Bits	25nsec-25μsec	$39-$250	Modular/hybrid
	12 Bits	150nsec-25μsec	$59-$295	Modular/hybrid
	13 Bits	250nsec	$325	Modular/hybrid
	14 Bits	250nsec	$350	Modular/hybrid
	15 Bits	250nsec	$395	Modular/hybrid
	16 Bits	250nsec	$495	Modular/hybrid
	2-Digit BCD	150nsec-20μsec	$9.95-$109	Modular/hybrid
	3-Digit BCD	150nsec-5μsec	$39-$149	Modular/hybrid
Dynamic Measurements Corp., Winchester, MA	8 Bits	400nsec-5μsec	$75-$125	Modular/hybrid
	10 Bits	300nsec-5μsec	$95-$155	Modular/hybrid
	12 Bits	300nsec-5μsec	$115-$195	Modular/hybrid
	13 Bits	300nsec-1.2μsec	$145-$195	Modular/hybrid
	3-Digit BCD	300nsec-5μsec	$120-$165	Modular/hybrid
Function Modules Inc., Irvine, CA	8 Bits	300nsec-20μsec	$19	Modular/hybrid
	10 Bits	300nsec-20μsec	$29	Modular/hybrid
	12 Bits	300nsec-20μsec	$47-$49	Modular/hybrid
	3-Digit BCD	300nsec-20μsec	$37-$39	Modular/hybrid
Harris Semiconductor Melbourne, FL	8 Bits	1.5μsec	$27.95**	Monolithic
Helipot Div. of Beckman Instruments, Fullerton, CA	8 Bits	25μsec	$39.75	Modular/hybrid
	11 Bits	5μsec	$95-$155	Modular/hybrid
	13 Bits	5μsec	$180-$240	Modular/hybrid
Hybrid Systems Corp., Burlington, MA	8 Bits	400nsec-30μsec	$9.90-$190	Modular/hybrid
	10 Bits	1μsec-30μsec	$19-$200	Modular/hybrid
	11 Bits	30μsec	$150	Modular/hybrid
	12 Bits	50nsec-300μsec	$39-$220	Modular/hybrid
	15 Bits	1μsec	$500	Modular/hybrid
	2-Digit BCD	50nsec-30μsec	$115-$150	Modular/hybrid
	3-Digit BCD	950nsec	$9.90	Modular/hybrid

*Conversion time. Conversion rate is not available
**For quantities of 100 units or more

Company	Resolution	Range of settling times	Range of costs (single quantities)	Technology
Hycomp Inc., Maynard, MA	8 Bits	50nsec-5μsec	$125-$200	Modular/hybrid
	10 Bits	50nsec-30μsec	$150-$225	Modular/hybrid
	12 Bits	30μsec		Modular/hybrid
ILC Data Devices Corp., Hicksville, NY	8 Bits	70nsec-5μsec	$95-$270	Modular/hybrid
	9 Bits	5μsec	$110	Modular/hybrid
	10 Bits	70nsec-5μsec	$139-$350	Modular/hybrid
	11 Bits	500nsec-5μsec	$159-$270	Modular/hybrid
	12 Bits	500nsec-2μsec	$290-$350	Modular/hybrid
	13 Bits	2μsec	$310	Modular/hybrid
	13 Bits	Optimized for 400 Hz	$260-$310	Modular/hybrid
	14 Bits	5μsec	$340	Modular/hybrid
	3-Digit BCD	7μsec	$225-$250	Modular/hybrid
Lancer Electronics Corp., Norristown, PA	12 Bits	10μsec		Modular/hybrid
	14 Bits	7μsec-10μsec		Modular/hybrid
	16 Bits	8μsec-25μsec		Modular/hybrid
Micro Networks Corp., Worcester, MA	6 Bits	3μsec		Modular/hybrid
	8 Bits	100nsec-15μsec		Modular/hybrid
	10 Bits	100nsec-5μsec		Modular/hybrid
	12 Bits	500nsec-5μsec		Modular/hybrid
	2-Digit BCD	3μsec		Modular/hybrid
	2-½-Digit BCD	3μsec		Modular/hybrid
	3-Digit BCD	500nsec		Modular/hybrid
Motorola Semiconductor Phoenix, AZ	6 Bits	200nsec	$3.95**	Monolithic
Perkin-Elmer Corp., Norwalk, CT	11 Bits	25μsec		Modular/hybrid
Phoenix Data Inc., Phoenix, AZ	12 Bits	10μsec	$175-$195	Modular/hybrid
	13 Bits	10μsec	$225-$245	Modular/hybrid
	14 Bits	10μsec	$275-$295	Modular/hybrid
	15 Bits	15μsec-20μsec	$445-$735	Modular/hybrid
	16 Bits	15μsec-20μsec	$575-$845	Modular/hybrid
Precision Monolithics Inc., Santa Clara, CA	6 Bits	1.5μsec	$8.25**	Monolithic
	10 Bits	225nsec-1.5μsec	$16-$45**	Monolithic
	11 Bits	1.5μsec	$35-$45**	Monolithic
Preston Scientific Inc., Anaheim, CA	12 Bits	2.5μsec		Rackmount
	13 Bits	3μsec		Rackmount
	14 Bits	3.5μsec		Rackmount
	15 Bits	4μsec		Rackmount
Sprague Electric Co., Worcester, MA	8 Bits	1.5μsec-18.5μsec		Modular/hybrid
	10 Bits	1.8μsec-20μsec		Modular/hybrid
	12 Bits	15μsec		Modular/hybrid
SRC Div. of Moxon, Inc., Irvine, CA	9 Bits	2μsec	$760(basic chassis) + $225	Rackmount
	12 Bits	5μsec	$760(basic chassis) + $260	Rackmount
	15 Bits	10μsec	$760(basic chassis) + $300	Rackmount
Teledyne-Phibrick Dedham, MA	4 Bits			
	8 Bits	300nsec-25μsec	$19-$179	Modular/hybrid
	10 Bits	300nsec-25μsec	$29-$229	Modular/hybrid
	12 Bits	100nsec-5μsec	$69-$370	Modular/hybrid
	13 Bits	100nsec-200nsec	$225-$395	Modular/hybrid
	14 Bits	100nsec-2μsec	$305-$485	Modular/hybrid
	16 Bits	300nsec	<$500	Modular/hybrid
	1-Digit BCD			Modular/hybrid
	3- Digit BCD	300nsec-5μsec	$64-$97	Modular/hybrid
Tustin Electronics Co., Santa Ana, CA	8 Bits	1μsec	$190	Modular/hybrid
	10 Bits	1μsec	$200	Modular/hybrid
	12 Bits	1μsec	$220	Modular/hybrid
	15 Bits	1μsec	$500	Modular/hybrid
Zeltex Inc., Concord, MA	8 Bits	1μsec-25μsec	$11.90-$195	Modular/hybrid
	10 Bits	2μsec-20μsec	$19.00-$39	Modular/hybrid
	12 Bits	10μsec-20μsec	$49.00-$225	Modular/hybrid
	2-Digit BCD	20μsec	$19.00	Modular/hybrid
	3-Digit BCD	20μsec	$39.00	Modular/hybrid

For example, one can purchase a 12-bit D/A converter for only $29. Such a unit will have a temperature coefficient of 100 ppm/°C. Another 12-bit unit costing $125 has 10 ppm/°C TC. A mere 1°C temperature change in the former (hardly significant) will cause its accuracy to change by a full LSB, whereas the higher cost one's accuracy will only be degraded 1/10 that of the lower cost unit. A change of 10°C would have to take place (in general, not very likely) before inaccuracy of a LSB is reached in the latter. The difference in cost may have been about $100 between these two units, but the real cost to the user can be hundreds of dollars in the long run once the converter is packaged into a circuit if the designer is not careful.

When interpreting data sheet specifications, great care must be taken to find out under what conditions a particular parameter is defined, and parameters are certainly defined differently. For example, some manufacturers give their specifications at a 25°C temperature. Others over 0°C to +70°C. Still others give no temperature at all.

One very important D/A-converter specification, settling time, is stated under many conditions—to different percentages of full scale, as a maximum or as a typical figure, and for a given input voltage step (which isn't always the same for different manufacturers), just to name a few.

When trying to compare A/D converters, a designer is immediately confronted with a problem: Is its speed of operation better characterized by conversion time as some manufacturers specify, or word conversion rate as other insist as being more meaningful? Most modular A/D converter makers state only conversion time in their data sheets, and it must be assumed that it is the same as the reciprocal of the converter's word conversion rate.

Actually, both conversion time and word conversion rate, as specified by all rackmount A/D converter manufacturers, are important to the designer. Not only does he want to know in how fast a time a particular conversion can take place from input to output (conversion time), but also how many conversions he can make for a given period of time (conversion rate).

Also remember, a high-speed A/D converter module needs a sample-and-hold amplifier, and sometimes buffer amplifiers, to work properly within a system. So an advertised 1-μsec A/D converter module is no longer 1 μsec in conversion speed when these other system components are taken into consideration but may be only 10 μsec or worse from system input to system output.

Temperature coefficient is sometimes given as a single figure, or specified more than once for offset, gain and range, to name a few. To make life a little more hectic, TC is given in ppm/°C or as a percentage per °C. So it becomes a little difficult to compare converters effectively. But a keen observation of the published specs can be a little helpful for product evaluation.

One other important point—Know the manufacturer you are dealing with. Does he deliver on time? Does he provide decent field applications assistance? What is his reputation? These factors can save a designer much valuable time and money.

TABLE I. The most popular types of digital codes used by A/D and D/A converters. A hypothetical analog voltage range of 0 to 1024 mV is quantized using these different codes at a 3-bit level.

Unipolar codes Analog voltage	Straight binary	8-4-2-1 BCD (3-digit weighting)
0 to 128 mV	000	0001 0010 1000
128 to 256 mV	001	0010 0101 0110
256 to 384 mV	010	0011 1000 0100
384 to 512 mV	011	0101 0001 0010
512 to 640 mV	100	0110 0100 0000
640 to 768 mV	101	0111 0110 1000
768 to 896 mV	110	1000 1001 0110
896 to 1024 mV	111	not permitted above 0.999
Bipolar codes Analog voltage	**Offset binary**	**One's complement**
−512 to −384 mV	000	100
−384 to −256 mV	001	101
−256 to −128 mV	010	110
−128 to 0 mV	011	111
0 to +128 mV	100	000
+128 to +256 mV	101	001
+256 to +384 mV	110	010
+384 to +512 mV	111	011
Analog voltage	**Two's complement**	**Gray code**
−576 to −448 mV	100	000
−448 to −320 mV	101	001
−320 to −192 mV	110	011
−192 to − 64 mV	111	010
− 64 to + 64 mV	000	110
+ 64 to +192 mV	001	111
+192 to + 320 mV	010	101
+ 320 to + 448 mV	011	100

Compatibility

Most A/D and D/A converters are not physically compatible universally, and some aren't compatible electrically. Physically, package sizes differ, with the more popular configurations being 2×2×0.4 in. and 2×4×0.4 in. Pin layouts are often not the same, so a user has to configure his pc board to accept several different pin layouts for multiple sourcing. One manufacturer blames this incompatibility on a fast-changing and size-competitive converter industry that forces makers to change designs, which gives rise to second-sourcing problems.

However, there is some trend towards physical compatibility. That trend is towards dual-in-line pin spacing and eventually dual-in-line packaging. Many converters can be purchased with at least one second-source manufacturer.

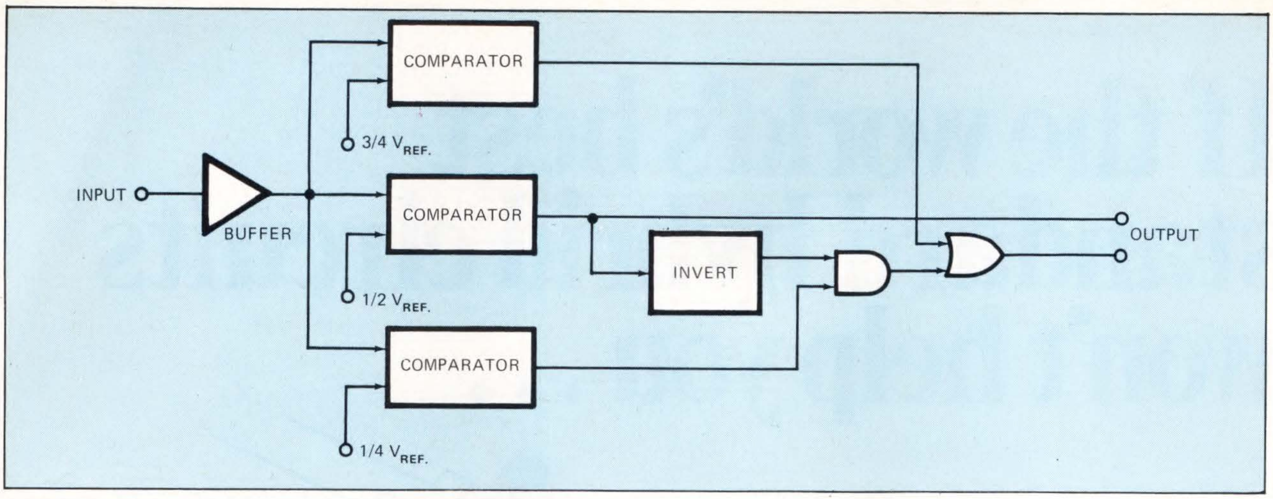


Fig. 8—The fastest and simplest conversion method is the parallel comparator technique (2-bit design shown), which requires modification (to serial-parallel circuits) for use in the medium- and high-resolution A/D converters.

Electrically, the picture is a lot brighter. While not all manufacturers provide the same D/A converter output and A/D converter input levels, many do. These include popular 2.5, 5 and 10V bipolar and unipolar D/A converter outputs and 5 and 10V bipolar and unipolar A/D converter inputs. Most converters are powered by ±15V and are TTL/DTL input compatible. Some recent ones are CMOS compatible.

Monolithic converters

Monolithic converters are certainly here and are fast establishing themselves a niche in the marketplace, their principle advantage being lower unit prices in OEM quantities.

Since modular converters are not as price sensitive in large OEM quantities as monolithic units, the latter tend to be very competitive in cost. For example, a 10-bit monolithic A/D converter can be bought for as low as $16 (in 100 quantities).

However, price need not be the only answer. The claim that monolithic units offer better performance than modular ones is not altogether true. If accuracy is to be maintained over wide temperatures and long periods of time, then low-drift modular converters using the most stable resistors and switching elements are the answer, and they usually contain discrete components.

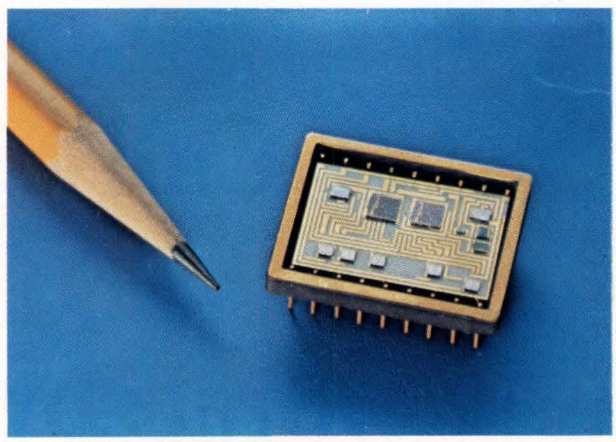
Monolithic technology may be winning the price battle, but it has yet to win the high-performance war.

Currently, there are three monolithic-converter manufacturers—Precision Monolithics the leader, with 6-, 10- and 11-bit D/A converters; Harris Semiconductor with an 8-bit D/A converter; and Motorola Semiconductor with a 6-bit D/A converter. These are the only ones making **complete** converter products. Several other manufacturers who make components for converters are poised to jump in.

An interesting aspect of the monolithic converter business is the availability of monolithic components to make low-cost converter kits for do-it-yourselfers. Harris Semiconductor offers its monolithic 8-bit D/A converter along with a monolithic A/D encoder and a monolithic analog comparator for an 8-bit successive approximation A/D converter kit.

IC current sources, switches, registers, comparators, ladder networks and op amps are all available from most IC companies for low-cost construction of D/A and A/D converters.

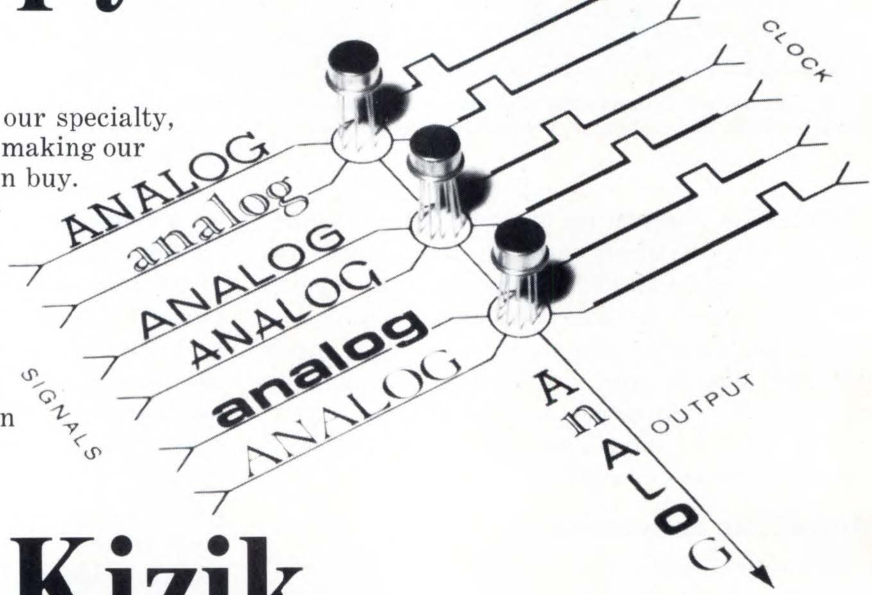
Presently, no complete monolithic A/D converter is available. However, a 12-bit successive approximation A/D converter is on the drawing boards at Precision Monolithics and should be available shortly after this report is published. The LSI unit will reportedly be introduced in a 40-pin dual-in-line package. □



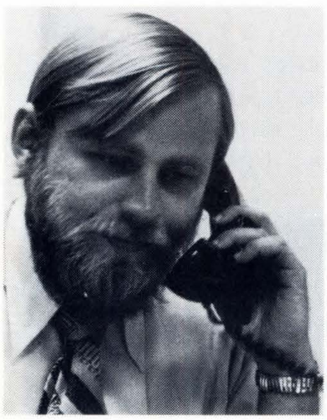
Four-quadrant 8-bit-plus-sign D/A multiplication in a single dual-in-line compatible package. The hermetically sealed 18-pin unit utilizes thin-film technology and contains two amplifiers—an output one and an additional one to allow for straight or offset-binary and two's complement operation. *(Micro Networks)*

If the world's best standard hybrid circuits won't help you . . .

Solid state signal switching is our specialty, and we've spent nearly 14 years making our analog switches the best you can buy. We offer more than 100 standard hybrid switch circuits . . . including the fastest, the most versatile, and (value-for-value) some of the most economical analog switches in the world. Chances are good that we have what you need on our shelves.



. . . Greg Kizik will.



If you have a custom hybrid requirement, Greg and his associates can bring years of applications experience to bear on your needs. These men are backed by a unique facility capable of supplying thick film or thin film circuits and semiconductors, all to MIL-STD-883 Level A. We supply circuits ranging from simple analog functions to multi-layer MSI assemblies for many MIL and NASA programs.

We will work closely with you to give you best value, whether you're buying custom or standard circuits. For the added convenience of our western customers, Greg has opened our new regional office in Marina Del Rey, California. You can reach him at (213) 821-5069.

Call (617) 491-1670

TELEDYNE CRYSTALONICS

147 Sherman St., Cambridge, Mass. 02140

CHECK NO. 21

NOW! BETTER VOLTAGE TRANSIENT PROTECTION IN A MINI SIZE

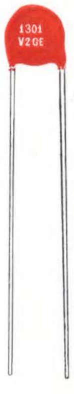
MIGHTY MINI-MOV™ VARISTORS

Designed for PC board use, these new "aspirin-size" GE-MOV varistors are rated at 1-4 joules and for both AC and DC operation. They are the latest addition to GE's growing line of superior metal oxide suppressors which provide better performance . . . better than selenium, silicon carbide, zeners or other older methods.

MODEL	MAXIMUM VOLTAGE		SUGGESTED RESALE PRICES			
	AC	DC	1-99	100-999	1000-9999	10,000
V130LA1	130	175	$1.44	$ .96	$ .72	$.48
V130LA2	130	175	1.53	1.02	.77	.51
V150LA1	150	200	1.65	1.10	.83	.55
V150LA2	150	200	1.77	1.18	.89	.59
V250LA2	250	330	2.76	1.84	1.38	.92
V250LA4	250	330	2.94	1.96	1.47	.98

The final numbers (1-4) designate the maximum energy rating in joules (watt-seconds)

For a FREE EVALUATION SAMPLE, call your local authorized GE semiconductor distributor . . . or write to General Electric Company, Semiconductor Products Department, Building 7, Mail Drop #49, Electronics Park, Syracuse, N.Y., U.S.A.



Actual size
As low as $.48 in quantity lots.

GE-MOV™ VARISTORS
ASSURE YOUR EQUIPMENT WILL ENDURE

GENERAL ELECTRIC

CHECK NO. 22

EDN Design Course

CMOS—Part IV

Interfacing CMOS with other logic and display devices

Bill Furlow, Associate Editor

If your CMOS design only had to communicate with other CMOS systems, life would be beautiful. But let's be realistic. There are a lot of other popularly used logic families around, and there is always the man/machine interface to consider. Actually, because of the wide range of acceptable power-supply voltages, CMOS interfaces easily with most other logic forms.

Basic interface elements are available

The schematics of four CMOS 4000 Series devices that were specifically designed for interfacing chores are shown in **Fig. 1.** These are the 4009, 4010, 4049 and 4050. All are hex-element devices, of which only one segment is shown. The 4049 and 4050 are preferred replacements for the 4009 and 4010, respectively, in all applications

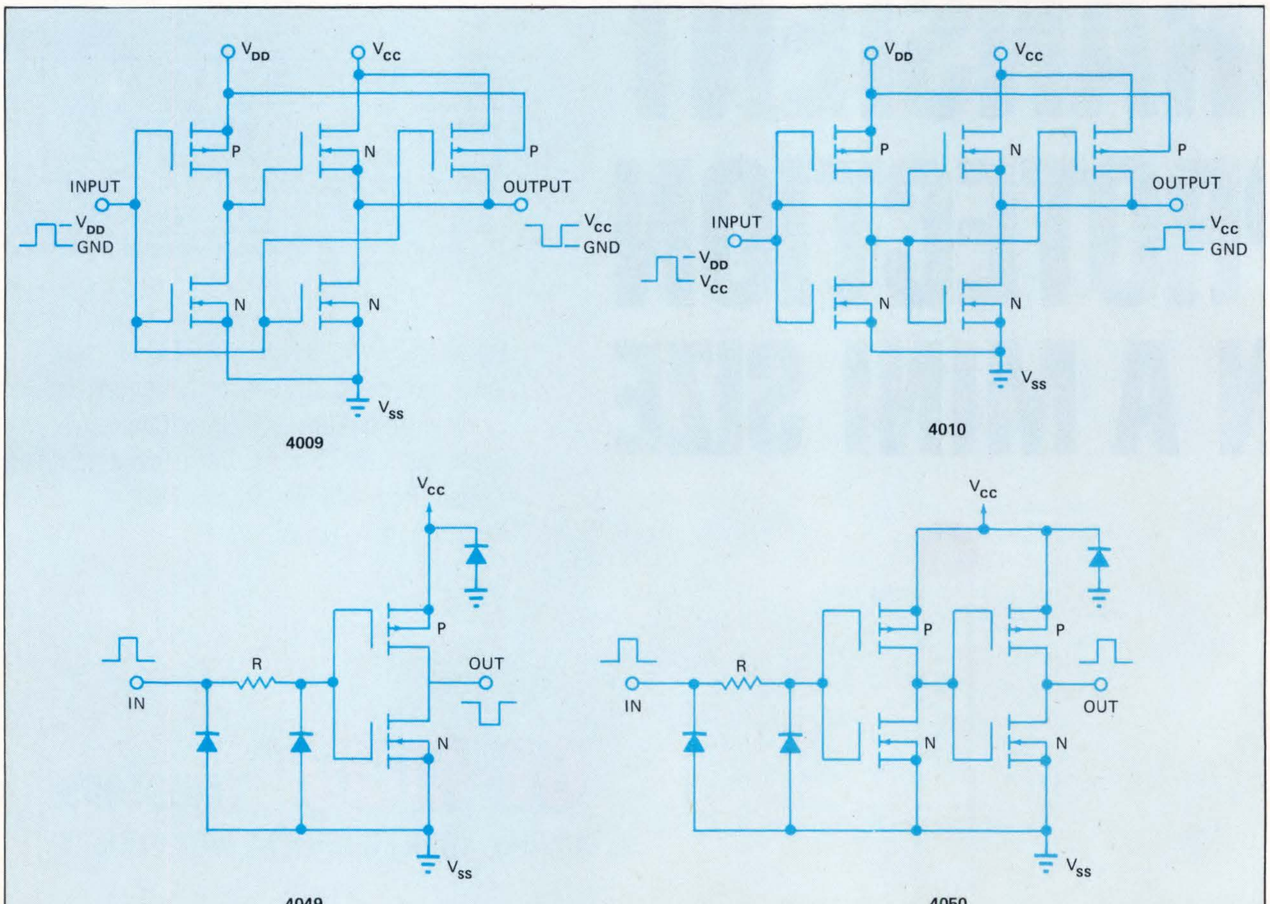


Fig. 1—CMOS circuits specifically designed for TTL interfacing. All are hex-element devices of which only one circuit is shown. Types 4009 and 4010 are not recommended for new designs.

except multiplexers. The reason for replacing the 4009 and 4010 is that, frankly, there were some inherent weaknesses in the designs that didn't show up until the parts were in the field. It happens that in normal layouts a PNPN lateral junction is created within some CMOS devices. By definition, a PNPN junction is an SCR. That SCR can't be fired in normal CMOS circuits because access to the gate (of the SCR) is not available. Under certain *improper* operating conditions the dual power-supply voltage feature of the 4009 and 4010 will allow the SCR to fire. If you are using 4009 or 4010 devices, then, it is *imperative* that these precautions be observed:

1. V_{cc} voltage must be equal to or less positive than V_{DD}.
2. Capacitive loads must be less than 200 pF when using supply voltages greater than 10.5V.
3. Power supply turn-on time must be greater than 10 μsec.
4. Input signals must not be applied before both power supplies are "up" and cannot exceed the supply levels.
5. These precautions apply to 4009 and 4010 devices *only* and do not apply to types 4049 and 4050.

The 4049 and 4050 are inverting and noninverting (respectively) hex-buffers and can provide logic-level conversion using only one supply voltage. The 4049 and 4050 should be used in place of the 4009 and 4010 in all inverter, current driver and logic-level conversion applications. They are pin compatible with the 4009 and 4010, and the V_{DD} contact (pin 16) is not connected internally, so connections to this terminal have no effect on circuit operation. This means that 4009s and 4010s in existing hardware can be easily replaced with 4049s or 4050s.

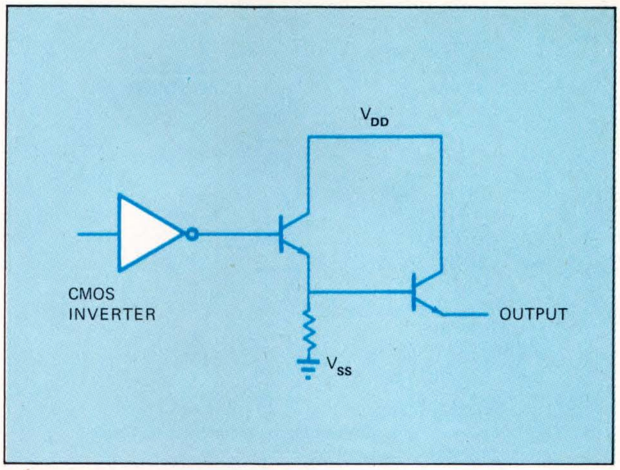


Fig. 2—Bipolar Darlingtons on the CMOS chip offer greater output drive capacity for interfacing and display applications

One inconsistency in the 4000 family which can be of considerable importance in interface circuits is that there is some variation of the guaranteed minimum output-current capabilities of similar devices from different manufacturers. This only indicates that slightly different device geometries or processes are used, but it makes the designers job a little tougher when he must use several suppliers. To be really safe, you must dig through all of the data sheets from each manufacturer you plan to use and use the lowest guaranteed output currents in your calculations.

CMOS families for easy interface

National's 54C/74C family of CMOS circuits are designed to be pin compatible with 54L/74L low-power TTL circuits (LPTTL), and fan-out

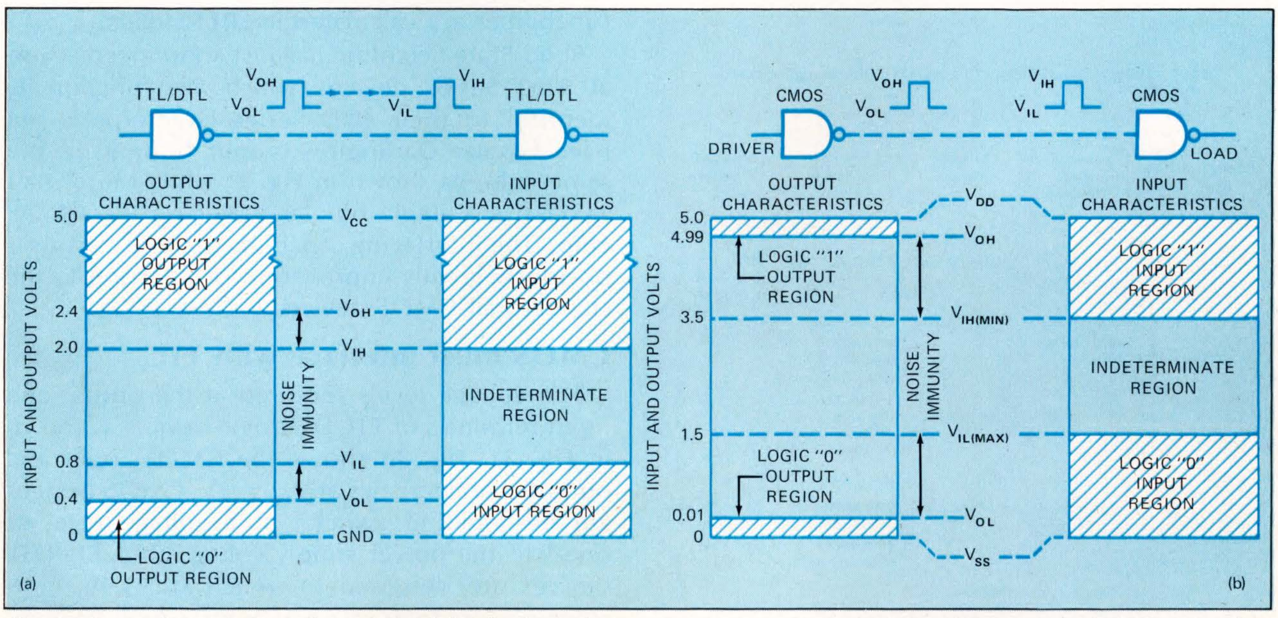


Fig. 3—Comparison of TTL and CMOS logic levels shows that they are nearly compatible when operating at the same supply voltage. It's only the ONE output from a TTL gate which does not meet the input ONE requirements of a CMOS gate; other levels are acceptable for TTL-to-CMOS or CMOS-to-TTL.

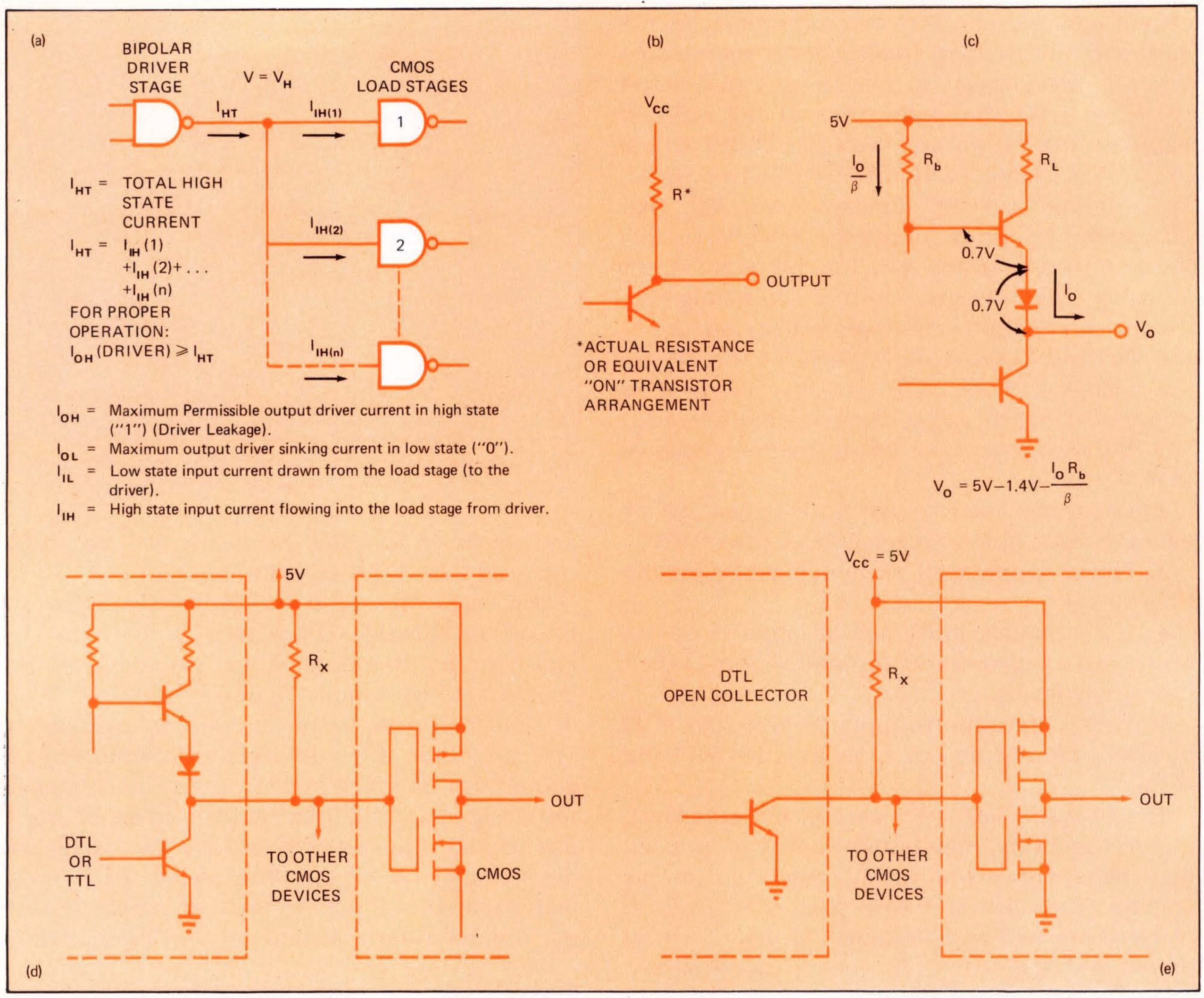


Fig. 4—Bipolar-to-CMOS interface requirements (a) depend on the output configuration of the bipolar devices. Gates using resistor pull-up **(b)** may interface directly. Active pull-ups, such as the transistor-diode arrangement shown in **(c)**, may require an external pull-up resistor **(d)**. Open collector outputs **(e)** also require external pull-up resistors.

Table I – Comparison of CMOS, TTL and DTL Interfacing Parameters

Family	Supply Voltage (Volts)	Logic Swing/Output Drive Capability	Dc Input Current	Noise Immunity	Propagation Delays
CMOS	3.0 to 15	V_{SS} to V_{DD} (driving CMOS) Output drive is type dependent see text	10 pA (typical) 1 and 0 state	1.49 at V_{DD} = 5V The switching point occurs from 30% to 70% of V_{DD} which is 1.5V to 3.5V at V_{DD} = 5V	35nsec (typical) for inverter C_L = 15 pF
DTL and TTL	5	0 State: 0.4V max. at I_{sink} = 16 mA 1 State: 2.4V min. at I_{load} = −400μA	0 State: −1.6 mA max. 1 State: 40μA max.	at V_{CC} = 5V 0.4V guaranteed. The switching point occurs from 0.8V to 2V	20nsec (typical) for inverter C_L = 15 pF

capabilities are calculated in LPTTL loads.

Solid State Scientific has just announced several 4400 Series devices which are functionally identical to their 4000 Series counterparts but have bipolar Darlington output buffers on the same chip, as shown in **Fig. 2** while Motorola's 14511 has a single bipolar driver on the CMOS chip. The interfacing capability of these circuits is obviously greatly improved in comparison to the standard all-CMOS devices.

CMOS must interface with TTL

The voltage levels required at the output and input terminals of TTL/DTL logic devices is shown in **Fig. 3a. Fig. 3b** shows the CMOS input and output characteristics at V_{DD} = 5V. CMOS devices are designed to switch at a voltage level of one-half the power supply voltage, but TTL/DTL devices are designed to switch at +1.5V, considerably less than one-half of the supply voltage.

When you interface any two logic families, you must carefully consider the logic swings, output drive capability, dc input current, noise immunity and delay times of each. **Table I** compares these parameters for CMOS and TTL/DTL. Since both can operate at a supply voltage of 5V, they are directly compatible, within certain restrictions.

When driving a CMOS input as in **Fig. 4a** with a TTL output ZERO, the voltage levels and currents are totally compatible. However, there are three types of TTL outputs (resistor pull-up, active pull-up and open collector) which must be considered when driving a CMOS input with a TTL output ONE. When using devices where a resistor pull-up device ties the output pin to V_{cc}, as in **Fig. 4b,** the total load shouldn't draw enough current to reduce the output voltage below the required ONE input for the CMOS.

When an active pull-up is used, such as the transistor plus diode arrangement shown in **Fig. 4c,** there can be a problem in the ONE state because the minimum output level (2.4V) cannot assure an acceptable ONE state input for the CMOS device. The 2.4V minimum TTL/DTL output level is often specified at a load current of 400 μA. However, negligible current is being drawn by the CMOS device, so the minimum TTL/DTL high-output level would typically be 3.4 to 3.6V under these conditions. You have no noise immunity in such a configuration. Therefore, it is recommended that a pull-up resistor be added from the output terminal of the bipolar device to V_{CC}.

When driving a CMOS device from such an active pull-up output arrangement (as shown in **Fig. 4d),** the driver should not fan out to TTL/DTL circuits, only to other CMOS devices.

Selection of a pull-up resistor for a circuit requires consideration of fan out, maximum allowable collector current in the low state (I_{OL} max.), collector-emitter leakage current in the high state (I_{CEX}), power consumption, power-supply voltage and propagation delay times. The minimum value of the external pull-up resistor is:

$$R_{X(min)} = \frac{V_{DD} - V_{OL(max)}}{I_{OL} \quad (M)I_{IL}}$$

where M is the number of CMOS load stages. The maximum value of the external pull-up resistor is determined by:

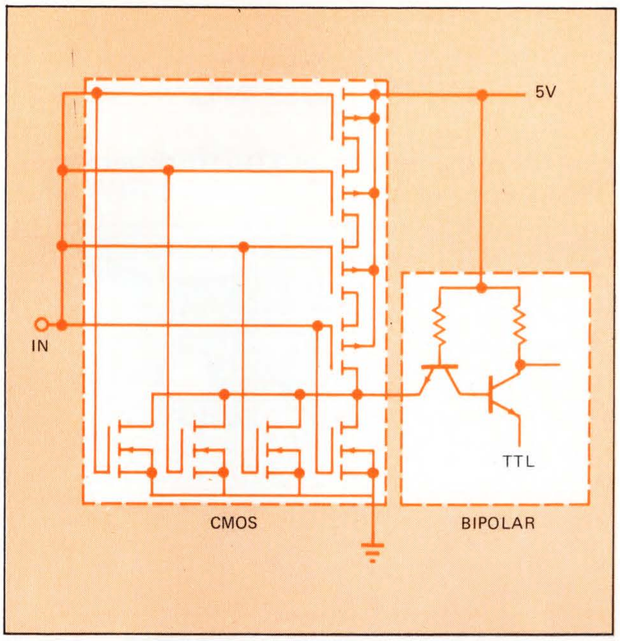


Fig. 5—Paralleling all inputs of a 4002 NOR gate can provide current sourcing of 3.2 mA. This is enough to drive one standard TTL load.

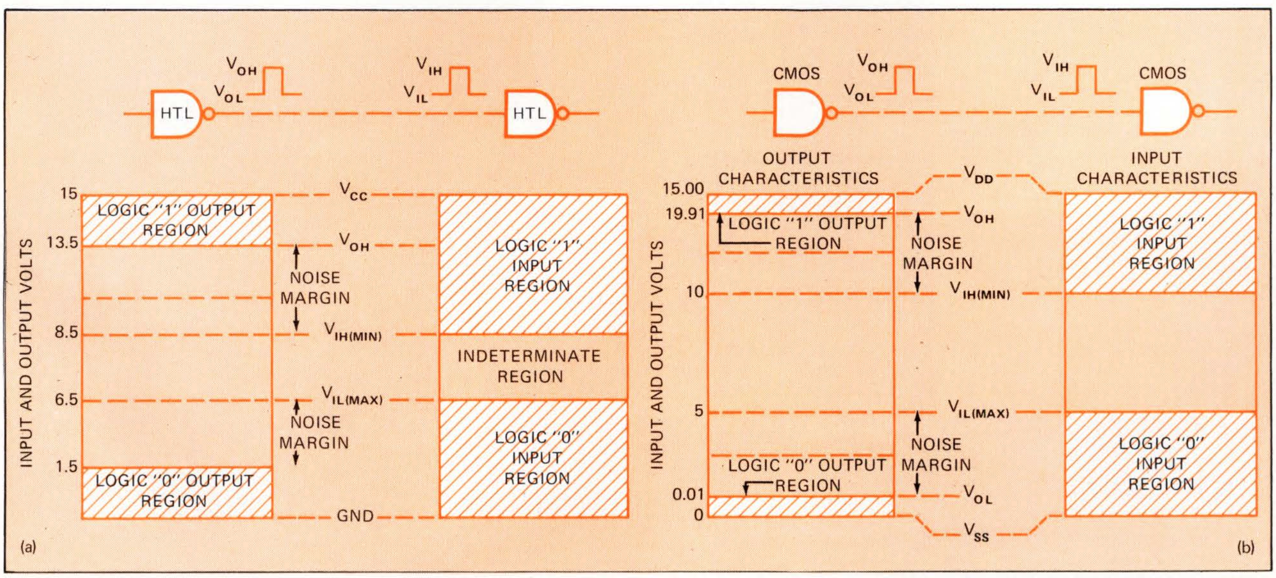


Fig. 6—Comparison of output and input levels of HTL and CMOS operating at 15V shows close correlation. These families complement each other for industrial control or similar designs. HTL logic elements may become very popular as power drivers for CMOS circuits.

$$R_{X(max)} = \frac{V_{CC} - V_{IH}}{I_{CEX} + (M)I_{IH}}$$

where N is the number of TTL/DTL driver stages.

The values of I_{IH} and I_{IL} for the CMOS input

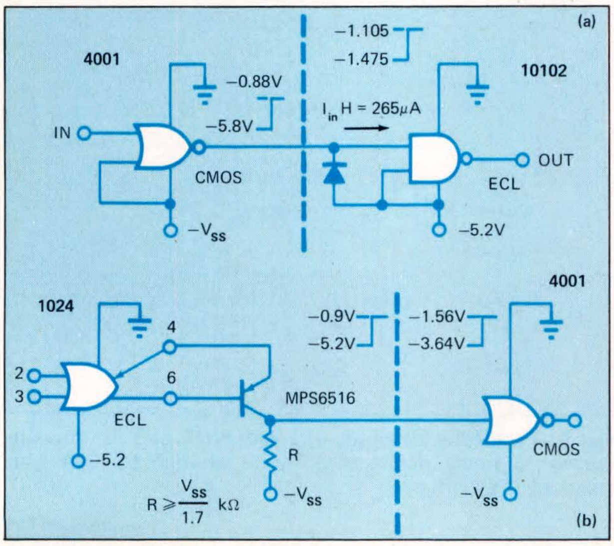


Fig. 7—Driving ECL with CMOS gates **(a)** requires operating CMOS with a negative supply voltage. A clamping diode must be used on the ECL input if the CMOS supply is more negative than −5.2V. CMOS cannot be driven directly from an ECL output because the voltage swing is too small. Special considerations for driving CMOS **(b)** are described in the text.

currents in both high- and low-level states are approximately 10 pA and are neglected because their value is insignificant when compared with the value of the bipolar currents. Therefore, the equations for bipolar-to-CMOS interface using a pull-up resistor can be reduced to:

$$R_{X(min)} = \frac{V_{DD} - V_{OL(max)}}{I_{OL}}$$

$$R_{X(max)} = \frac{V_{CC(min)} - V_{IH(min)}}{I_{CEX(max)}}$$

(V_{IH} is the value for the CMOS device)

Devices with open collectors also require an external pull-up resistor, as shown in **Fig. 4e.** The selection of the external pull-up resistor is the same as previously described. It is recommended that when driving a CMOS device from an arrangement such as the one shown (with both V_{DD} and V_{CC} supply voltages at 5V), the driver should not fan out to any other TTL/DTL gates but can be fanned out to other CMOS devices.

Actually the calculations for these pull-up resistors give quite a range of acceptable values, and most designers have found that a standard 2 kΩ (for TTL/DTL) or 3 kΩ (for LPTTL) is always

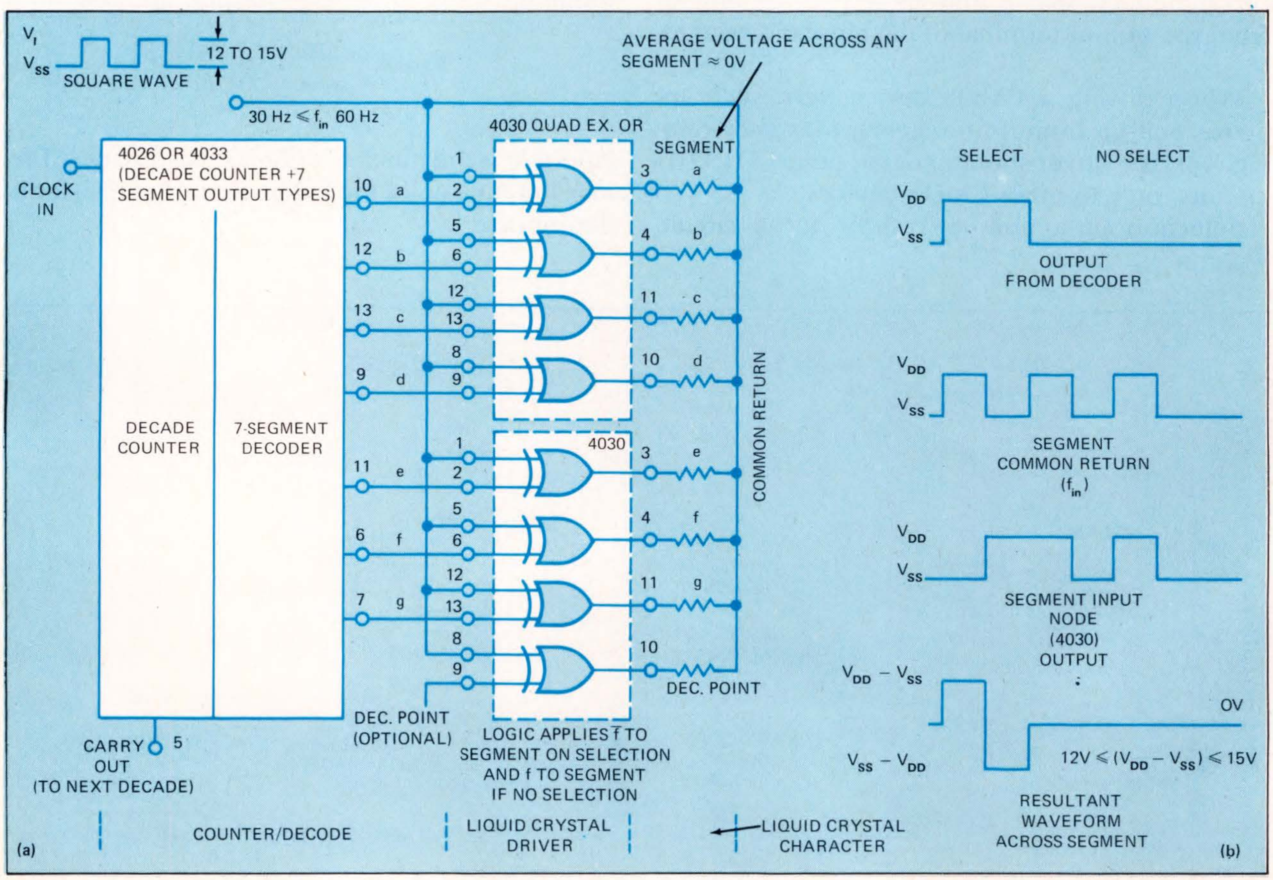


Fig. 8—Liquid crystal displays are ideally suited to CMOS systems because of their ultra-low-power requirements. The exclusive-OR driver circuit **(a)** maintains an effective ±ac voltage across the circuit segments of the displays with only a positive pulse input. Circuit waveforms are shown in **(b)**.

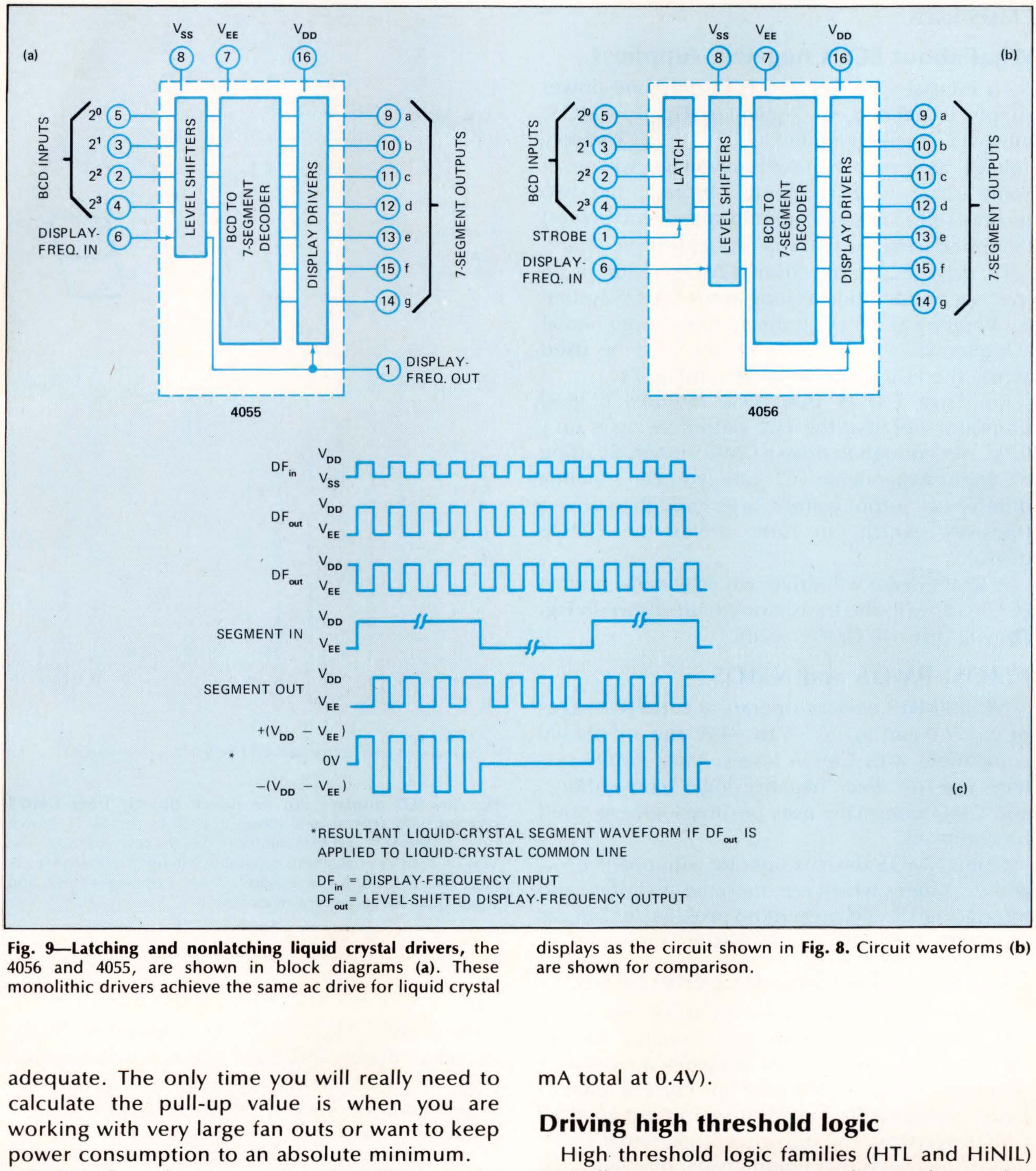


Fig. 9—Latching and nonlatching liquid crystal drivers, the 4056 and 4055, are shown in block diagrams **(a)**. These monolithic drivers achieve the same ac drive for liquid crystal displays as the circuit shown in **Fig. 8.** Circuit waveforms **(b)** are shown for comparison.

adequate. The only time you will really need to calculate the pull-up value is when you are working with very large fan outs or want to keep power consumption to an absolute minimum.

Going the other way, most CMOS gates can drive one low-power TTL gate, but many of the MSI counters, registers, etc., have a limited drive capability. In cases where the CMOS output must drive a larger fan out or standard TTL inputs, the 4049- or 4050- type buffers must be used. Connecting a 4002 4-input NOR gate as shown in **Fig. 5** will provide a maximum sink-current capability of 3.2 mA, which allows a fan out of two standard TTL gates at 0.8V or one TTL gate at 0.4V.

The 54C/74C CMOS family is designed to operate with LPTTL systems. Input levels from LPTTL to 54C/74C are compatible, and 54C/74C outputs will drive two standard LPTTL loads (0.36 mA total at 0.4V).

Driving high threshold logic

High threshold logic families (HTL and HiNIL) typically operate from 15V supplies, and since this is the upper limit of most CMOS devices, they are easily interfaced with each other. Actually Motorola's MHTL family has a maximum supply voltage rating of 18V, and this is one reason that their 14000-AL CMOS series is specified for supply voltages up to 18V.

As you can see from **Fig. 6,** the voltage levels of CMOS and HTL are nicely attuned to each other. Should the slow rise times of the HTL driver be unacceptable when driving CMOS, a 2.5 kΩ pull-up resistor can be used to speed things up.

A standard CMOS gate will drive one HTL load. A standard HTL gate will drive more than 50

CMOS loads.

What about ECL's negative supplies?

To interface CMOS and ECL, only one power supply is needed, as shown in **Fig. 7.** CMOS, however, is speed limited at 5.2V (the ECL supply voltage) and, even at maximum voltage, will never come close to ECL speeds. In fact, the two technologies are so far apart in speed (and power) that interfacing the two will probably be very rare.

To drive ECL gates from CMOS requires no special consideration as long as the CMOS system is operating at −5.2V. If the system is operated at a higher voltage, a diode clamp must be used across the ECL input, as shown in **Fig. 7a.**

To drive CMOS from ECL requires a level translator because the ECL output swing is only 0.7V, not enough to drive a CMOS input. By using a 2-input expandable ECL gate, you can obtain a differential output voltage large enough to drive a transistor which, in turn, drives the CMOS device.

A CMOS gate will drive two ECL loads, and an ECL load, with the translator circuit shown in **Fig. 7b,** will drive 50 CMOS loads.

CMOS, PMOS and NMOS

Most PMOS devices operate at supply voltages of $V_{DD} = 0$ and $V_{SS} = -6$ to -15V and are readily compatible with CMOS levels. Most PMOS systems use so-called "negative-logic" conventions, and CMOS normally uses positive logic, so don't be confused.

Some NMOS devices operate with positive V_{DD} and V_{SS} ranges which are the same as CMOS, and interfacing should present no problem, as long as the CMOS and NMOS supplies are the same.

Liquid crystals—almost a perfect match

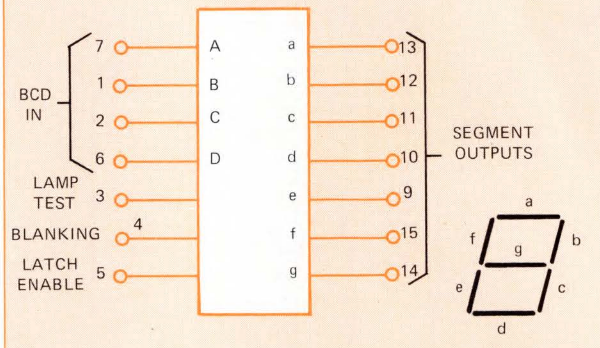
Many of the advantages of CMOS, like ultra-low power consumption and portable battery operation are seriously limited when a readout is required. The phenomenally low current drain of liquid crystal displays makes them almost ideal for CMOS systems. The only drawback, and it's very minor, has been that liquid crystal displays need an ac drive for a reasonable display life. One method of achieving this is shown in **Fig. 8,** along with the circuit waveforms. Two CMOS devices designed specifically for driving liquid crystal displays, the 4055 and 4056, are shown in the functional block diagrams in **Fig. 9a and b,** and their system waveforms in **Fig. 9c.**

LED and incandescent displays

Even though LED readouts consume more power than liquid crystal displays, they are very attractive, and it's not realistic to think that you can avoid using them, even in low-power systems. Several new CMOS circuits, notably Motorola's MC 14511 BCD-to-7 segment latch/ decoder/ driver and Solid State Scientific's SCL 4426 and 4433 decade counters with 7-segment display outputs are designed to provide LED drive capabilities for CMOS systems.

The 14511, shown in **Fig. 10,** can source up to 25 mA of current per segment, which means that it can't drive MAN-1 type displays but could easily handle MAN-3 size or smaller readouts. The 4426 and 4433, as mentioned earlier, incorporate bipolar driver transistors on the CMOS chip and are rated at 15 mA per segment, indicating that they too can drive MAN-3 sized LED displays.

The Microelectronics Div. of Hughes Aircraft has achieved MOS drivers which can handle 240V in their research labs, but so far no CMOS devices exist which can drive high voltage displays, so your only option is to interface from your CMOS system to one of the TTL compatible drivers or discrete transistors. ▭



LE	BI	LT	D	C	B	A	a	b	c	d	e	f	g	DISPLAY
X	X	0	X	X	X	X	1	1	1	1	1	1	1	8
X	0	1	X	X	X	X	0	0	0	0	0	0	0	Blank
0	1	1	0	0	0	0	1	1	1	1	1	1	0	0
0	1	1	0	0	0	1	0	1	1	0	0	0	0	1
0	1	1	0	0	1	0	1	1	0	1	1	0	1	2
0	1	1	0	0	1	1	1	1	1	1	0	0	1	3
0	1	1	0	1	0	0	0	1	1	0	0	1	1	4
0	1	1	0	1	0	1	1	0	1	1	0	1	1	5
0	1	1	0	1	1	0	0	0	1	1	1	1	1	6
0	1	1	0	1	1	1	1	1	1	0	0	0	0	7
0	1	1	1	0	0	0	1	1	1	1	1	1	1	8
0	1	1	1	0	0	1	1	1	1	0	0	1	1	9
0	1	1	1	0	1	0	0	0	0	0	0	0	0	Blank
0	1	1	1	0	1	1	0	0	0	0	0	0	0	Blank
0	1	1	1	1	0	0	0	0	0	0	0	0	0	Blank
0	1	1	1	1	0	1	0	0	0	0	0	0	0	Blank
0	1	1	1	1	1	0	0	0	0	0	0	0	0	Blank
0	1	1	1	1	1	1	0	0	0	0	0	0	0	Blank
1	1	1	X	X	X	X				*				*

X = Don't care
*Depends upon the BCD code applied during the 0 to 1 transition of LE.

Fig. 10—LED displays can be driven directly from CMOS systems with several new devices, such as the 14511 shown here, or the 4426 and 4433 mentioned in the text. Although the 14511's 25 mA per segment capability will not drive displays as large as a MAN-1, it can handle a MAN-3 or smaller LED, and some small incandescent readouts.

Peak holder stretches narrow video pulses

Many of the problems encountered in video pulse work can be minimized by first conditioning such pulses before they are processed.

Bert Pearl, Lockheed Missiles and Space Co.

The processing and recording of narrow video pulses is a difficult task because of the large bandwidth required. Such pulses also have poor visibility when displayed. These problems are eased considerably if the signal is conditioned first by a peak holder, which preserves peak amplitude and prf information while stretching the pulse sufficiently to alleviate the signal handling problem. Such a peak holder is shown in **Fig. 1**.

The peak holder accepts negative-going pulses (it can be connected for positive inputs) of from 50 mV to 5V peak amplitude and as narrow as 50 nsec. It produces, in conjunction with timing and control circuits, stretched output pulses of up to 300 μsec at the same peak amplitude as the input signal. The specific application to be described is for unity gain operation; but the circuit may easily be modified for higher gain.

The basic approach is to place the peak detection diode within the loop of an operational amplifier whose closed-loop gain is unity. This technique effectively divides the diode knee-voltage by the open-loop gain of the amplifier, virtually eliminating the knee-voltage as a source of error.

If a very high-gain operational amplifier were used, slew rate and recovery time would limit effective speed. For this reason, a wideband but relatively low-gain amplifier is employed here. Its input stage is a CA3006 integrated differential amplifier, which includes a matched differential pair and a temperature compensated constant-current source. The CA3006 gain and noise figures are specified up to 100 MHz; maximum offset voltage is 1 mV at 25°C. The CA3006 drives a common-emitter stage, which in turn feeds the peak detector portion of the circuit.

Diodes CR_7 and CR_8, resistor R_{21} and capacitor C_{15} shunted by the input impedance of source follower Q_7 comprise the actual peak detector. Stages Q_7 and Q_8 provide high input impedance and low output impedance, with resultant good drive capability. The output may be grounded through the 200Ω isolating resistor, R_{24}, with no effect on operation. Resistor R_{16} is made equal to R_{11} to give the unity inverting gain required for this application. Capacitor C_{14} is used to set the closed-loop high-frequency roll-off; too high a value degrades output rise time, while too low a

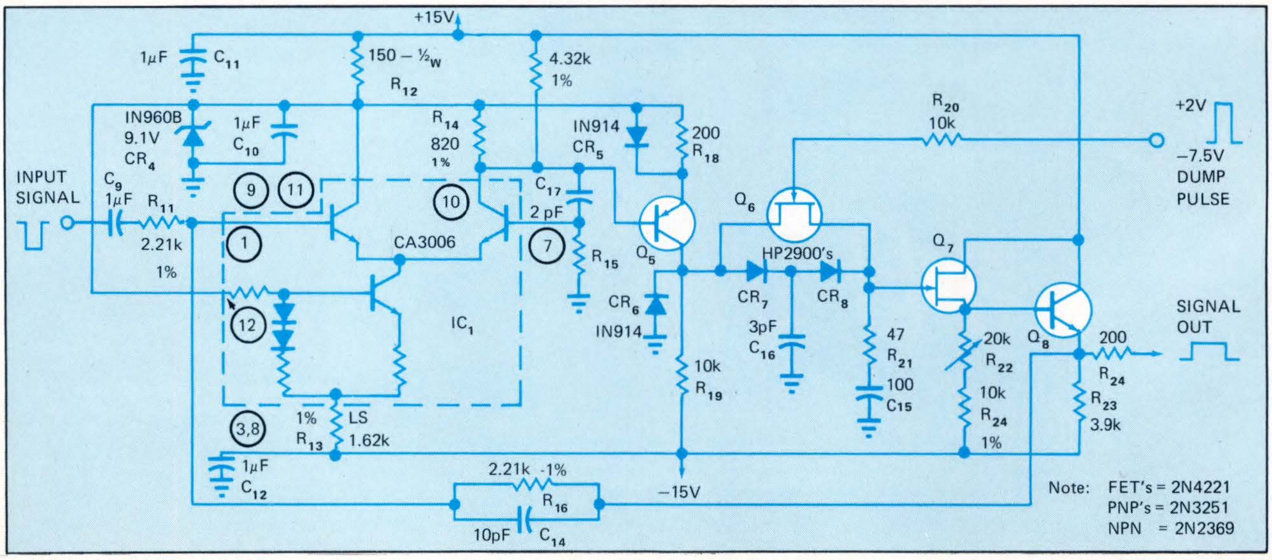


Fig. 1.—The basic peak holder circuit consists of peak detection diodes CR_7 and CR_8 connected within the feedback loop of a unity-gain operational amplifier.

value causes an overshoot, which produces an erroneously high output for low-level signals.

Open-loop compensation is provided by C_{17}, connected between the collector and base of the common-base section of IC_1. Resistor R_{13} may be used as a zero set, to achieve precisely 0 mV dc at the output of the peak holder with no signal. Diode CR_5 in the emitter circuit of Q_5 provides a low impedance to high-level signals to aid in achieving fast rise time. At low signal levels, R_{13} predominates to provide emitter degeneration and increased stability.

At the end of an input pulse, C_{15} holds the value of the signal level, and the loop is broken at the series diodes (CR_7 and CR_8). The resultant positive output voltage is coupled back through IC_1 and cuts off Q_5. Without some provision to compensate for it, the collector of Q_5 would go sharply negative to −15V. This negative step would divide between the capacitance of the reverse biased series diodes and C_5, causing a negative step at the start of the hold period. The condition can be further aggravated if stray capacitance in the layout adds to the diode capacitance.

When operating at a 50 mV signal level, only a small portion of the 15V step would cause appreciable error at the gate of Q_7. Since the loop is open, this more negative value would be retained during the hold period. To minimize this effect, two low-capacitance diodes are used for CR_7 and CR_8, with further capacitance isolation provided by C_{16}, connected from the junction of CR_7 and CR_8 to ground. In addition, diode CR_6 limits the negative swing of the Q_5 collector to one diode drop below ground.

The required negative excursion of the collector of Q_5 is that for no signal. Since the output of the peak holder is essentially 0V for no signal, the Q_5 collector quiescent voltage is determined by the series diode drops, the gate-to-source rise in Q_7, and the base-to-emitter drop in Q_8. The primary variation between units is in the Q_7 FET characteristics. This is compensated for by adjusting R_{22} for a quiescent Q_5 collector voltage between +0.2V and −0.3V.

Control circuits required

If no timing and control circuitry were used in conjunction with the peak holder, C_{15} would discharge very slowly through the OFF resistances of CR_7, CR_8, Q_6 and Q_7, causing extremely long stretching, with output pulses overlapping and never reaching zero amplitude. In order to achieve predictable termination times for the stretched pulses, the sections in the block diagram of **Fig. 2** must be added. In simplest form, a μA710 can be used for the threshold limiter; a 9602 dual monostable for the delay-pulse and dump-pulse timing generators; and a discrete stage for the dump-pulse output stage.

With these additional blocks, operation of the peak holder is as follows: between input pulses and for the delay period after the start of an input pulse,

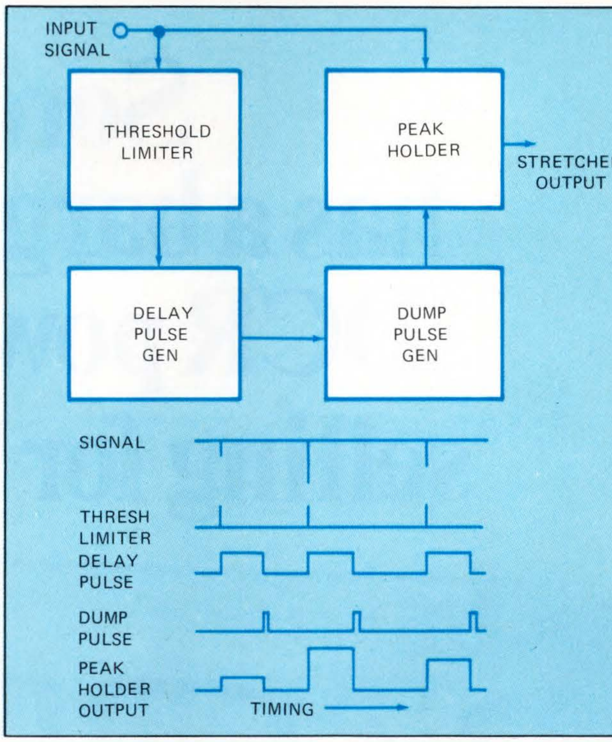


Fig. 2.—Additional timing and control circuits must be added to the basic peak holder for practical operation.

Q_6 is cut off by a gate voltage of −7.5V, supplied by the dump-pulse generator. After the delay, a 2-μsec positive dump pulse applied to the gate of Q_6 turns it on, closing the loop and permitting C_{15} to discharge rapidly through the closed-loop output impedance of Q_5.

The peak holder's output dc sensitivity to supply voltages is dependent on the forward conductance of the differential input stage and is typically 14 mV per volt for the positive or negative 15V supply.

If it is desired to use a positive input pulse, the bottom end of R_{15} is lifted off ground and the signal applied there, with the inverting input to C_9 grounded. The peak holder may be converted to a sample-and-hold circuit by elimination of CR_7, CR_8 and C_{16}, and increasing the value of C_{15}. The sample period occurs when Q_6 is turned on; the hold period, when it is cut off. ▭

Author's biography

Bert Pearl is a research specialist with Lockheed Missiles and Space Co., Sunnyvale, CA, where he is involved in the design of digital and analog data processing equipment. Bert holds a BSEE from Purdue Univ. He lives with his wife and three sons in Sunnyvale, CA.

Sorensen has a bargain for you: DCR power supplies selling for $360-$4200.

Sorensen's DCR power supplies offer you the lowest cost per watt in the industry. More power output for each dollar you invest.

And DCR's comprise the broadest lab/systems line available anywhere: 37 models in 10 voltage ranges, 7 power levels.

Features? All silicon solid-state electronics. Precision regulation. Remote voltage, current or resistance programming — and remote sensing at distances to 200 feet. Operation in either voltage or current modes.

For complete data and prices, write Sorensen, a unit of Raytheon Company, 676 Island Pond Road, Manchester, N.H. 03103. Telephone (603) 668-1600. Or TWX 710-220-1339.

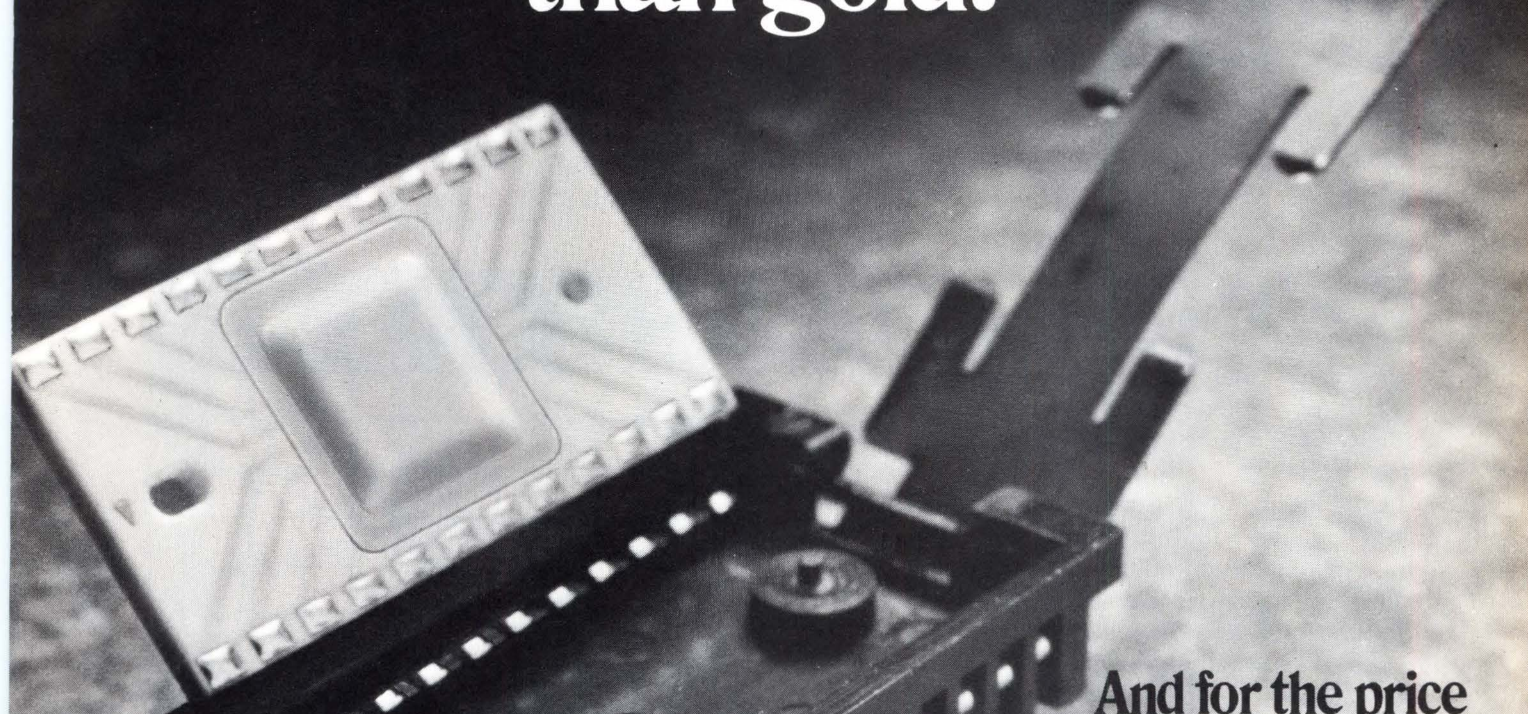
Sorensen POWER SUPPLIES

Key Data

- 37 models available.
- 10 voltage ranges from 20 to 30,000 Vdc.
- 7 power levels from 400 to 20,000 W.
- Low output ripple.
- Voltage and current regulation with automatic crossover.
- Typical efficiencies to over 80%.
- Fits standard 19″ rack (except 20 kW models).
- Optional overvoltage protection for all models (except 20 kW).
- Series or parallel operation.
- MTBF greater than 25,000 hours.

CHECK NO. 25

Now tin makes better pluggable IC connections than gold.



And for the price of a stamp HYPOINT will prove it.

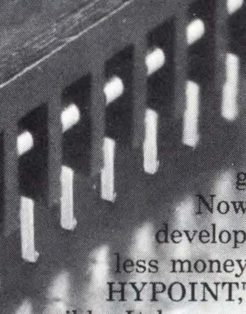
For years the only way to make reliable IC connections has been the expensive way—with gold. But not anymore.

Now after 3 years of research and testing we've developed a way to make better IC connections for a lot less money—with tin plating.

HYPOINT,™ a totally new termination concept makes it possible. It has no leads to bend. Now tiny chisel points in the receptacle penetrate metal targets in the ceramic package to make a perfect gas-tight, corrosion-free contact. This low profile terminator is easy to connect (zero entry), the ceramic can be disconnected and reconnected easily for field servicing and each connection is as reliable as the first.

Hard to believe? Take 8¢ and mail us your coupon. We'll send you the proof.

Please send me detailed information on your new HYPOINT tin IC terminators. Please include, too, your complete test data on its performance as compared to gold.



Name ______________________ Title ______________

Company ______________________________________

Street ____

City ______________ State ______________ Zip ______

Burndy Corporation
Norwalk, Connecticut 06856

BURNDY CONNECTS

International Sales Headquarters & Manufacturing Facilities: Canada/England/Belgium/Mexico/Brazil/Australia/Japan. Sales Offices in major cities.

Approximate analog functions with a low-cost multiplier/divider

Such a device, capable of computing nonintegral exponents, can be useful in inexpensive and accurate approximations of many trigonometric functions.

Daniel H. Sheingold, Analog Devices, Inc.

Nonlinear function fitting has been until recently a costly undertaking involving the use of elaborate circuitry. However, the present availability of modular components that can multiply, divide, take the square root of and even exponentiate functions has changed this picture drastically, in terms of both cost and flexibility.

Components that combine the computation of products, ratios and exponents in the form $Y\ (Z/X)^m$ have revolutionized nonlinear function fitting, especially the analog representation of such trigonometric functions as sin θ, cos θ and tan θ, through the use of nonintegral exponents. This is useful in such applications as resolver and coordinate transformations (especially Cartesian-to-polar) and time-function generation.

In addition to the applications mentioned, other applications such as linearizing the outputs of transducers having nonlinear characteristics (thermocouples and strain gages) and the generation of arbitrary functions having no discontinuities (as compared to functions simulated by piecewise-linear approximations) are also possible.

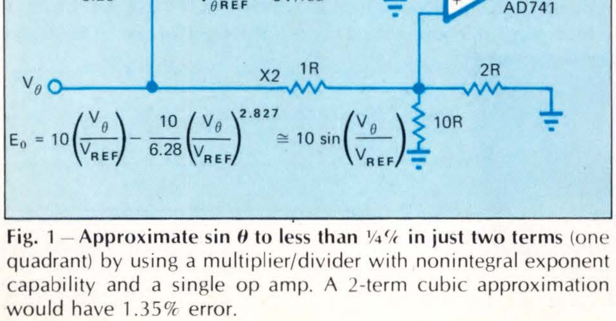


Fig. 1—Approximate sin θ to less than ¼% in just two terms (one quadrant) by using a multiplier/divider with nonintegral exponent capability and a single op amp. A 2-term cubic approximation would have 1.35% error.

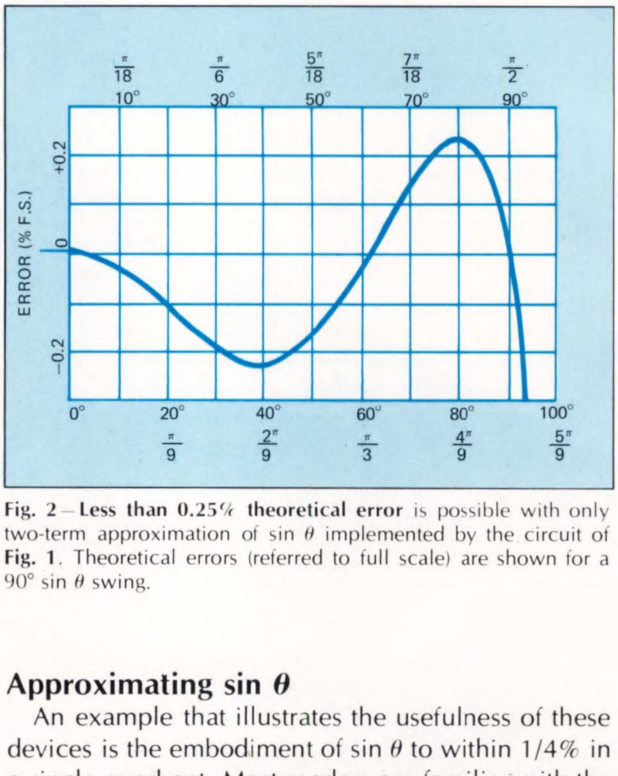


Fig. 2—Less than 0.25% theoretical error is possible with only two-term approximation of sin θ implemented by the circuit of **Fig. 1**. Theoretical errors (referred to full scale) are shown for a 90° sin θ swing.

Approximating sin θ

An example that illustrates the usefulness of these devices is the embodiment of sin θ to within 1/4% in a single quadrant. Most readers are familiar with the infinite series for sin θ:

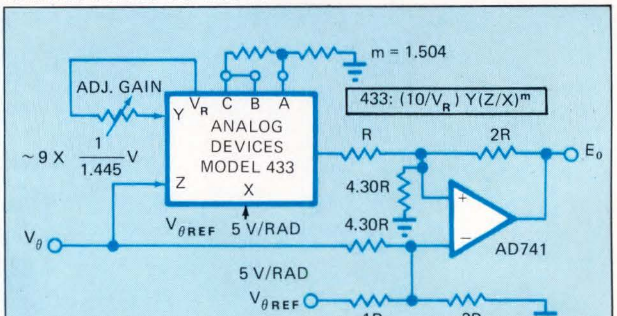


Fig. 3—Approximate cos θ to better than 1% with the use of a multiplier/divider that computes nonintegral exponents and one op amp. The approximation uses an arbitrary exponent as one term of cos θ plus a linear and a constant term.

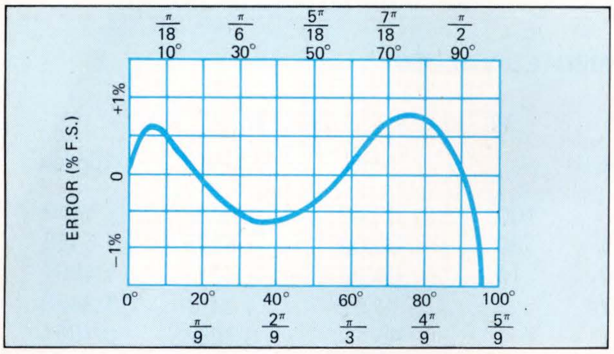


Fig. 4 – Better than 1% theoretical error is possible with a three-term approximation of cos θ, as shown in **Fig. 3**. These theoretical errors are referred to full scale and are shown for a 90° swing of the cos θ function. With 2 op amps, sin $(\pi/2 - \theta)$ will give less than 0.25% error.

$$\sin\theta = \theta - \frac{\theta^3}{3!} + \frac{\theta^5}{5!} - \cdots\cdots. \quad \textbf{(1)}$$

Approximations using modified coefficients allow truncation of the series to (e.g.) 2 terms with less than 1.35% error[1]. However, using a multiplier/divider module having nonintegral exponent capability in addition to modified coefficients, one can obtain less than 0.25% error (one quadrant) with just two terms. A reasonably close approximation is

$$\sin\theta \cong \theta - \frac{\theta^{2.827}}{6.28} \text{ (0 to } \pi/2 \text{ radians).} \quad \textbf{(2)}$$

It can be implemented with a simple circuit composed of the multiplier/divider module and a single op amp. A circuit and a plot of the theoretical errors can be found in **Fig. 1** and **Fig. 2**, respectively.

For "round-number" scaling, one might typically choose either 5V/radian or 1V/10 °. Voltage equivalents for both are given in **Table I**.

Approximating cos θ

For approximating cos θ to reasonable accuracy, two terms are generally inadequate. However, by using arbitrary exponents and a linear third term, we can get a better-than-1% approximation using only a single-power term embodied by one multiplier/divider and one op amp. A reasonably close approximation is

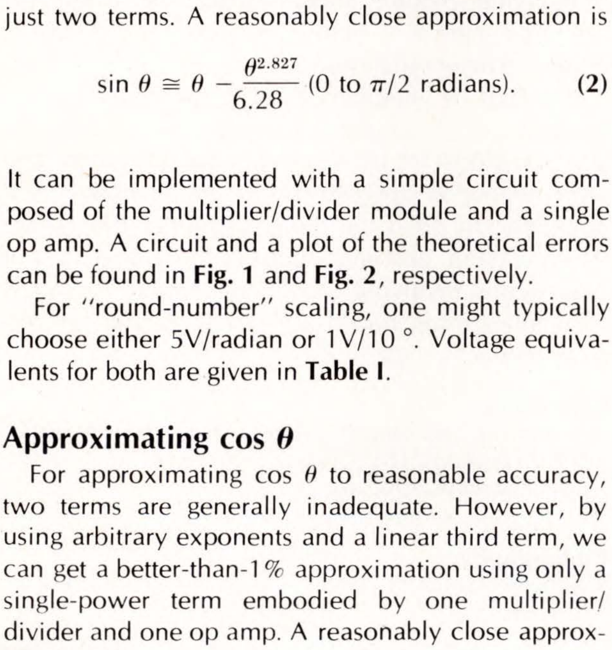


Fig. 5 – Approximate tan^{-1} θ to 0.75% using this simple circuit of a multiplier/divider, capable of computing $Y(Z/X)^m$ where m is nonintegral.

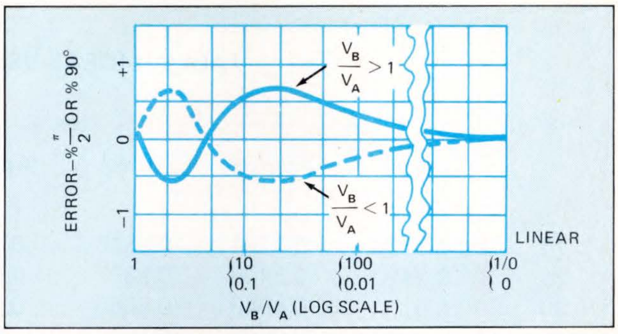


Fig. 6 – Less than 0.75% theoretical error is possible when approximating tan^{-1} θ using the circuit shown in **Fig. 5**. The error percentage is plotted as a function of the arc tangent ratio (shown logarithmically).

$$\cos\theta \cong 1 + 0.235\,\theta - \frac{\theta^{1.504}}{1.445}. \quad \textbf{(3)}$$

A circuit and a plot of the theoretical errors can be found in **Fig. 3** and **Fig. 4**. For a better fit (with 2 op amps), use $\pi/2 - \theta$ in the sine approximation.

Calculating tan^{-1} (V_B/V_A)

The arc tangent is inherently one of the most difficult functions to fit because of the wide dynamic range that the input ratio ideally must cover. "Building-block" approximations generally have limited usefulness because the ratio must appear explicitly as the result of a division. This function, however, is a useful one. It provides the angular information in the transformation of (R,θ) where $R = \sqrt{V_A^2 + V_B^2}$ and $\theta = \tan^{-1}(V_B/V_A)$.

A circuit that embodies the approximation is shown in **Fig. 5**, while the theoretical errors are plotted in **Fig. 6**. The equation fundamentally provided by the scheme is

$$\theta = \frac{\pi}{2}\,\frac{W^{1.2125}}{1 + W^{1.2125}} \cong \tan^{-1} W, \quad \textbf{(4)}$$

TABLE I - VOLTAGE EQUIVALENTS

Radians	Degrees	Volts	Degrees	Radians	Volts
0	0	0	0	0	0
0.1	5.73	0.5	10	0.1745	1
0.2	11.46	1.0	20	0.3491	2
0.3	17.19	1.5	30	0.5236	3
0.4	22.92	2.0	40	0.6981	4
0.5	28.65	2.5	45	0.7854	4.5
0.6	34.38	3.0	50	0.8727	5
0.7	40.11	3.5	60	1.047	6
0.8	45.84	4.0	70	1.222	7
0.9	51.57	4.5	80	1.396	8
1.0	57.296	5.0	90	1.5708	9
1.1	63.03	5.5	100	1.745	10
1.2	68.75	6.0			
1.3	74.48	6.5			
1.4	80.21	7.0			
1.5	85.94	7.5			
1.6	91.67	8.0			
1.7	97.40	8.5			

TABLE II-IDEAL VS. COMPUTED VALUES

$\theta°$	$\sin\theta$		$\cos\theta$		W	$\tan^{-1}$W		
	Ideal	Approx.	Ideal	Approx.		Ideal°	Ideal(r)	Approx.
0	0.	0.	1.	1.	100	89.43	1.5608	1.5649
10	0.1736	0.1734	0.9848	0.9905	30	88.09	1.5375	1.5458
20	0.3420	0.3409	0.9397	0.9390	10	84.29	1.4711	1.4801
30	0.5	0.4980	0.8660	0.8602	3	71.57	1.2490	1.2428
40	0.6428	0.6405	0.7660	0.7591	1	45.	0.7854	0.7854
50	0.7660	0.7643	0.6428	0.6389	0.5	26.57	0.4636	0.4735
60	0.8660	0.8658	0.5	0.5015	0.2	11.31	0.1974	0.1954
70	0.9397	0.9412	0.3420	0.3485	0.1	5.71	0.0997	0.0907
80	0.9848	0.9871	0.1736	0.1810	0.05	2.86	0.05	0.0405
90	1.	1.	0.	0.	0.	0.	0.	0.

where $W = V_B/V_A$.
The circuit solves the implicit equation

$$\theta = \left[\frac{\pi}{2} - \theta\right]\left[\frac{V_B}{V_A}\right]^{1.2125} \tag{5}$$

with a maximum theoretical error of less than 0.75%.

The circuit of **Fig. 7** computes the square root of the sum of the squares by solving the implicit equation[2]

$$V_C = \frac{V_A^2}{V_C + V_B} + V_B. \tag{6}$$

Its solution is

$$V_C = \sqrt{V_A^2 + V_B^2}.$$

Some practical considerations

The numbers presented in the trigonometric approximations have all been worked out to about four places to determine the limits of performance with ideal circuitry. However, since performance depends critically on the analog circuit elements, care must be observed to take into account component tolerances and provide "tweaks" for an empirical fit. In the case of the arc tangent approximation, care may be necessary to avoid oscillation at large values of the ratio. For example, large values of feedback capacitance around the amplifier will be helpful but can slow down the circuit's response.

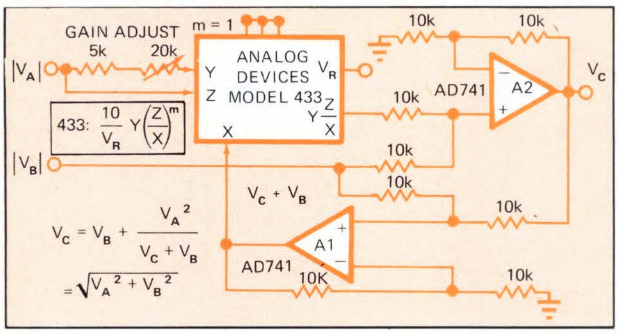


Fig. 7—Compute the value of vector sums efficiently, with only a multiplier/divider and two op amps. This circuit computes the square root of the sum of the squares.

Table II presents ideal and computed values of the functions discussed for the typical coefficient values listed. Although there may be coefficient values that would give somewhat better fit, they are perhaps best determined empirically in view of the multiplier/divider module tolerances and the resistor ratios. The table will help in making these kinds of empirical determinations.

It should be intuitively evident that series sums or products of nonintegral exponent terms may be used for closer fits to these and other functions. The aforementioned approximations are intended as a beginning to open the topic for further discussion. At some point, one must consider the relative cost of expressions involving increased complexity versus techniques using digital computations and conversion interfaces. ☐

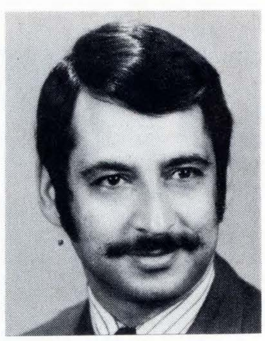
References

[1]Abramowitz and Stegun, Editors, *Handbook of Mathematical Functions*, U.S. Dept. of Commerce, National Bureau of Standards, 1968, pg. 76.
[2]*Ibid.*

Bibliography

Sheingold, Daniel H., Editor, *Analogue Dialogue*, Vol. 6, No. 2, pg. 2.

Author's biography



Daniel H. Sheingold is the technical marketing manager for Analog Devices, Inc., where he has been working since 1969. Previous to that, he spent 19 years with George A. Philbrick Researches, Inc., developing his expertise in analog function modules and op amps. Mr. Sheingold holds a BSEE from Worcester Polytechnic Institute and an MSEE from Columbia University.

C-LINE SCRs

WE PUT 14 YEARS OF THYRISTOR EXPERIENCE INTO EVERY UNITRODE SCR.

Unitrode Corporation
Dept. 3 Z , 580 Pleasant St., Watertown, Mass. 02172

☐ Please send SCR information kit containing detailed specs and application notes.

NAME____________________

TITLE____________________

CO.____________________

ADDRESS____________________

CITY________ STATE________ ZIP________

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

And that means a better industrial product. Our performance record proves it. In industrial/commercial applications, the use of Unitrode SCRs doubled last year and has doubled again this year. For the military, Unitrode supplies more lead-mounted SCRs than everyone else combined. Unitrode is the only SCR supplier with Military Qualification Approval on all TO-5 and TO-18 mil. specs. Why this kind of acceptance? Our experience. It means a lot to people who've had experience with less.

Our broad line of SCRs including plastic and hermetically sealed metal types offers a wide range of choices for literally hundreds of applications. The Unitrode SCR product line ranges from our very popular, rugged 0.8 amp TO-92 plastic package and TO-18 hermetically sealed series to our 1.6 amp TO-5 and TO-39 series and 5 amp TO-59 stud series. Some series are available to 600 volts.

It's what you would expect from a company that makes thyristors a major part of its effort—not just a sideline.

For fast action, call Sales Engineering collect at (617) 926-0404
Unitrode Corporation, 580 Pleasant St., Watertown, Mass. 02172.

UNITRODE quality takes the worry out of paying less.

Yes, the noisy transistor switching regulator can be quieted

By adjusting impedances of internal and external noise loops and using EMC approaches, noise reduction is possible.

Peter W. Grant, IBM Corp.

When designing power supplies requiring lightweight and small physical size, the transistor switching regulator (TSR) is an increasingly popular approach. In such a design, prime power entering the TSR **(Fig. 1)** is rectified, stored in the bulk capacitor C_x, and then switched by transistors across the transformer primary winding. Several hundred volts (at high currents) are switched at kilohertz rates, creating both audible and electronic noise. This unwanted electronic noise often spills into adjoining circuitry causing severe interference problems.

The reason why noise is generated in a TSR lies in the method of voltage regulation. The high degree of regulation obtained is achieved by adjusting the switched current's pulse width instead of the former method of quiet, dissipative series regulator circuits. But switching high voltages and currents creates electonic noise.

The usual "brute-force" shielded-enclosure method of containing electrical noise consists of totally surrounding the noise source with a metal shield **(Fig. 2).** E (electrical) and H (magnetic) field radiation is reduced but feedthrough capacitors must be used on all wires entering or leaving the enclosure, thus increasing the shield's cost. The capacitors can also put prime power voltages on the shield if the shield is not securely grounded.

There are other methods, though, by which noise in a TSR can be controlled. These include lowering the impedance of internal circuit noise loops, increasing the impedance of external circuit noise loops and other electromagnetic-compatible (EMC) circuit approaches. Before describing these approaches in detail, let's take a look at just how the noise is generated.

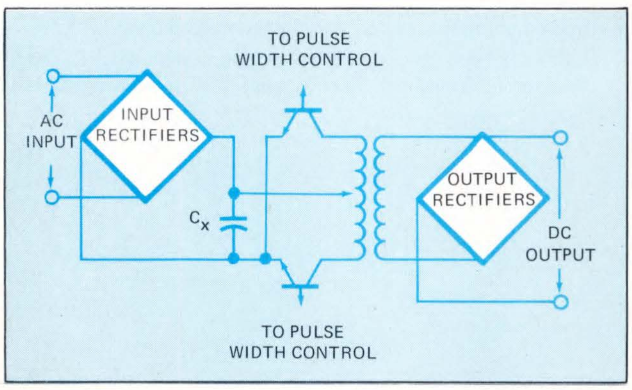


Fig. 1—A fundamental transistor switching regulator circuit. Ac power is rectified, stored in bulk capacitor C_x, and then switched across the transformer primary winding by the transistors.

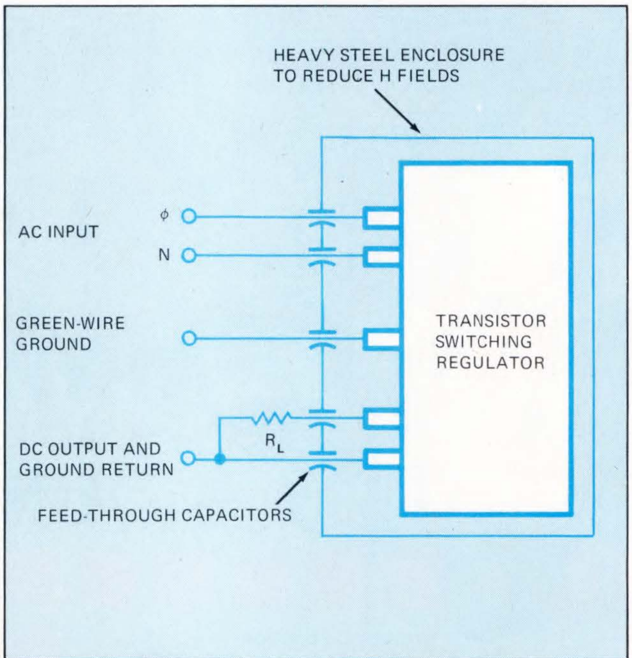


Fig. 2—Brute-force shielding of a transistor switching regulator is a common method of containing the regulator's electrical noise. It consists of totally surrounding the noise source with a metal shield to reduce E and H fields, and requires the use of feedthrough capacitors on all wires entering or leaving the enclosure, thus adding greatly to the cost of the regulator's design.

Noise source

The main source of noise in the TSR is the sudden charging and discharging of the parasitic capacitances of the transformer winding, the transistor-to-heat-sink space, and the wiring by the basic TSR action of switching high currents and voltages. The charging source is the bulk capacitor; so with the capacitor, transformer, transistors, and wiring making a complete circuit (small loop) there seems little reason for charging current to enter the outside world. However, the impedances of this small loop are irregular and some components have grounded heat sinks or cases through which current is dissipated to the entire TSR (larger loop) and thus to the outside world.

Noise from the TSR that could interfere with an associated system must leave and re-enter by four ports in the TSR's case. Referring to **Fig. 3,** they are **(1)** prime power entry, **(2)** green-wire ground, **(3)** remote load grounding and **(4)** the capacitive coupled drain wire. This fourth and last port consists of the path of noise as it radiates to the case (spacecharge).

In reducing noise from the TSR, an understanding of the terms "differential mode" and "common mode" is required. Differential mode (DM) refers to a system of conductors, usually a pair, having a signal contained in their voltage difference. In a simple single ended DM system, the return line and the transmission line form a differential pair which contains the total signal. Also, the sum of conductors carrying current in one direction and the sum for the opposite direction could be called a DM pair.

In most cases, if the return current is divided among elements of a common return, the signal line and one element of the common return would not make a DM pair. The grounding or common return elements would constitute a common mode (CM) system, referred to as a system of conductors where a signal is common to two or more conductors.

If currents going past an observation point on the transmission line have their direction in common, they are common mode. If their directions are different, they are differential mode. That is, for differential mode the currents must be equal and exactly opposite in phase. For common mode the currents must be evenly divided among the impedances of the various conductors and exactly in phase.

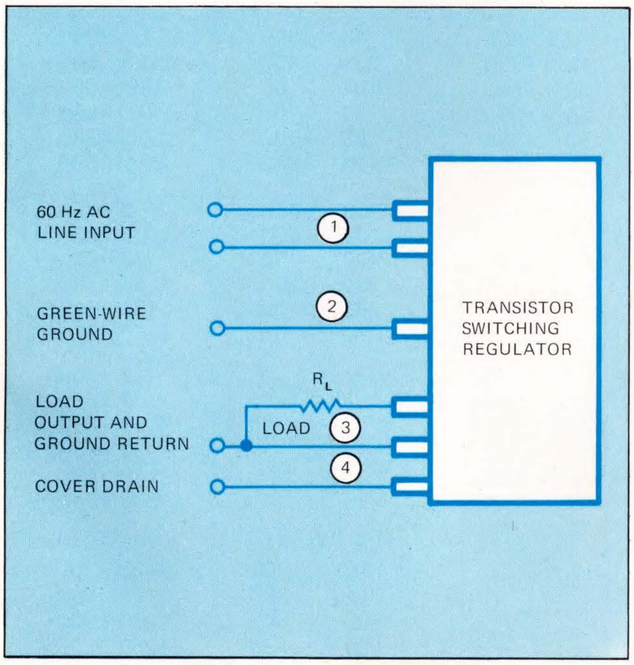


Fig. 3—Noise from a transistor switching regulator leaves or re-enters the regulator's case by four ports: (1) prime power entry, **(2)** green-wire ground, **(3)** remote load grounding, and **(4)** the capacitive coupling drain wire.

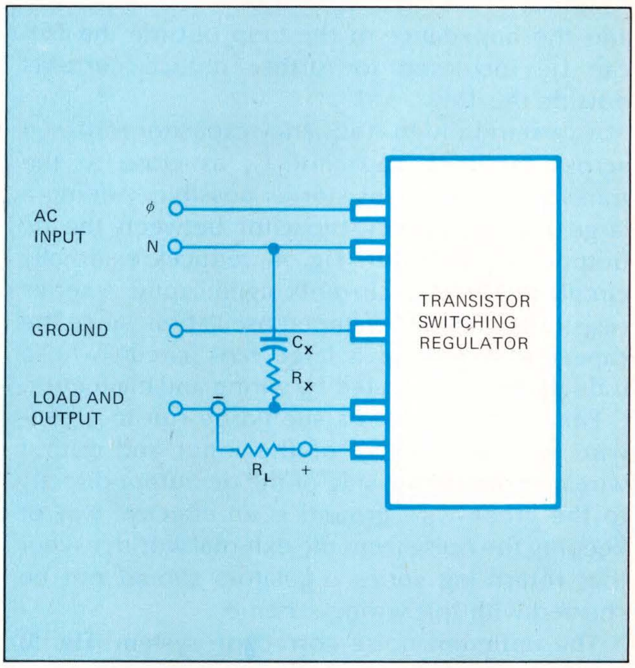


Fig. 4—Noise can be "shorted" in a transistor switching regulator by placing a high-frequency capacitor C_x between the ac neutral and output. A series resistor R_x is added to dampen tank-circuit oscillations.

The small charging circuit (small loop) in the TSR becomes part of a common-mode circuit when the current in the circuit finds a common-mode return. This return is found via the transformer secondary, out through the dc bus, through logic ground, to prime-power ground, and back through prime-power wires through the rectifiers to the bulk capacitor, and also via radiated paths. These paths can be traced with a current probe and scope; i.e., a particular spike can be seen leaving by the power line and returning by the ground wire.

Design considerations

It would be ideal to design the small loop in the TSR so that the generated noise could be contained in the loop. However, since parasitic capacitance exists and energy escapes through transistor cases, heat sinks, etc., current is transmitted to the larger loop, which consists of the entire TSR. It would be difficult, if not impossible, to design the small loop in such a manner that no energy would be converted to a common mode and allowed to escape. But, the larger loop (entire TSR) can be "noise shorted" so that the noise mainly circulates inside the TSR, and the impedance of the loop outside the TSR can be increased to further reduce currents outside the TSR.

As a start, a high-frequency capacitor is placed across the bulk capacitor C_x as close to the transformer and transistor as possible. Adding a large high-frequency capacitor between the dc output and ac input **(Fig. 4)** reduces externally circulating ground currents significantly. A series resistor is added to dampen oscillation, since the capacitor is part of a large tank circuit whose inductances are created by wiring and magnetics.

For safety, capacitors should be run to green-wire ground from all of the input and output wires. Shorting one side of the dc output directly to the green-wire ground is an effective way of keeping the noise from the external world, except that return-leg series regulators should not be shorted with this wiring scheme.

The optimum noise correction system **(Fig. 5)** meets external circuit requirements and shunts a large amount of external noise current. A large, UL approved, high-frequency capacitor and series resistor is placed between the ac neutral wire and green-wire ground. Since a large capacitor from ground to ac neutral is used, another capacitor to the phase wire is, in effect, only paralleled to the neutral one. Also, since both wires of a pair are sufficiently high-frequency coupled, only one wire of a pair is needed for noise shorting. The loop is closed to the dc output with a resistor that damps the oscillation without allowing ripple current and without seriously shunting any external series regulator.

If small spikes of ground current remain, they can be reduced in amplitude and frequency by winding the ac wires and green-wire ground around ferrite cores (common-mode impedances). Six turns of the twisted-pair ac wires around an X-30 ferrite core will reduce the spikes by a factor of 10. The core has to be used with twisted-pair wires since each wire carries large amounts of prime current that would saturate the core, making it useless. (See **Table 1** for ferrite impedances.) Since the sum of ac currents in the twisted pair is zero, the core only sees common-mode noise. Both wires of a pair (each of the ac wires or the positive and negative wires of a dc output) are sufficiently high-frequency coupled so only one wire of a pair is needed for noise shorting, as previously described. Since a large capacitor to ac neutral is used, another capacitor to the phase wire is, in effect, only parallel to the neutral one.

Noise energy that leaves the TSR by capacitive coupling must return by another port. A five sided metal box enclosing the TSR would simulate capacitive coupling. Such a box simulates a machine's frame and the fourth TSR port. Noise is capacitively coupled to this box and must be dealt with. The ungrounded box supplies a nice Gaussian shield, but safety requires grounding it. Grounding the box to the frame allows an increase in high-frequency energy to circulate

	Frequency(MHz)	X-30	P-30	Tube	Wire only
One turn 5 inch wire	0.5	10 +80Ω	3.5 +80Ω	48 +86Ω	1 +30Ω
	1.5	30 +40Ω	10 +80Ω	295 +40Ω	1.5 +60Ω
	4.5	26 +10Ω	33 +70Ω	107 − 6Ω	4 +80Ω
	14	37 +30Ω	60 +25Ω	82 −10Ω	10 +88Ω
	35	40 +50Ω	50 +20Ω	68 +10Ω	30 +88Ω
	108	110 +70Ω	85 +60Ω	125 +45Ω	90 +88Ω
Two turns 14 inch wire	0.5	50 +80Ω		200 +85Ω	2 +75Ω
	1.5	130 +30Ω		1200 +35Ω	6 +83Ω
	4.5	100 0Ω		420 −10Ω	17 +88Ω
	14	100 +20Ω		320 −20Ω	52 +88Ω
	35	135 +35Ω		250 −10Ω	145 +88Ω
	108	400 +40Ω		400 − 6Ω	1750 +82Ω
Six turns 14 inch wire	0.5	400 +82Ω	115 +90Ω		2 +70Ω
	1.5	1120 +28Ω	360 +85Ω		6 +80Ω
	4.5	900 0Ω	1250 +65Ω		17 +88Ω
	14	800 −10Ω	2000 −20Ω		50 +88Ω
	35	800 −25Ω	940 −55Ω		140 +88Ω
	108	450 −65Ω	400 −70Ω		1600 +84Ω
Six turns 32 inch wire	0.5			1850 +84Ω	8 +84Ω
	1.5			13K 0Ω	23 +90Ω
	4.5			10K −35Ω	70 +90Ω
	14			1600 −60Ω	220 +90Ω
	35			800 −70Ω	1250 +90Ω
	108			108 −88Ω	280 −90Ω

Table 1—Ferrite impedances. The comparison is made here for X-30 cross core, P-30 pot core and a tube ferrite 2-in. long by 1-in. in outside diameter and 1/4-in. in inside diameter.

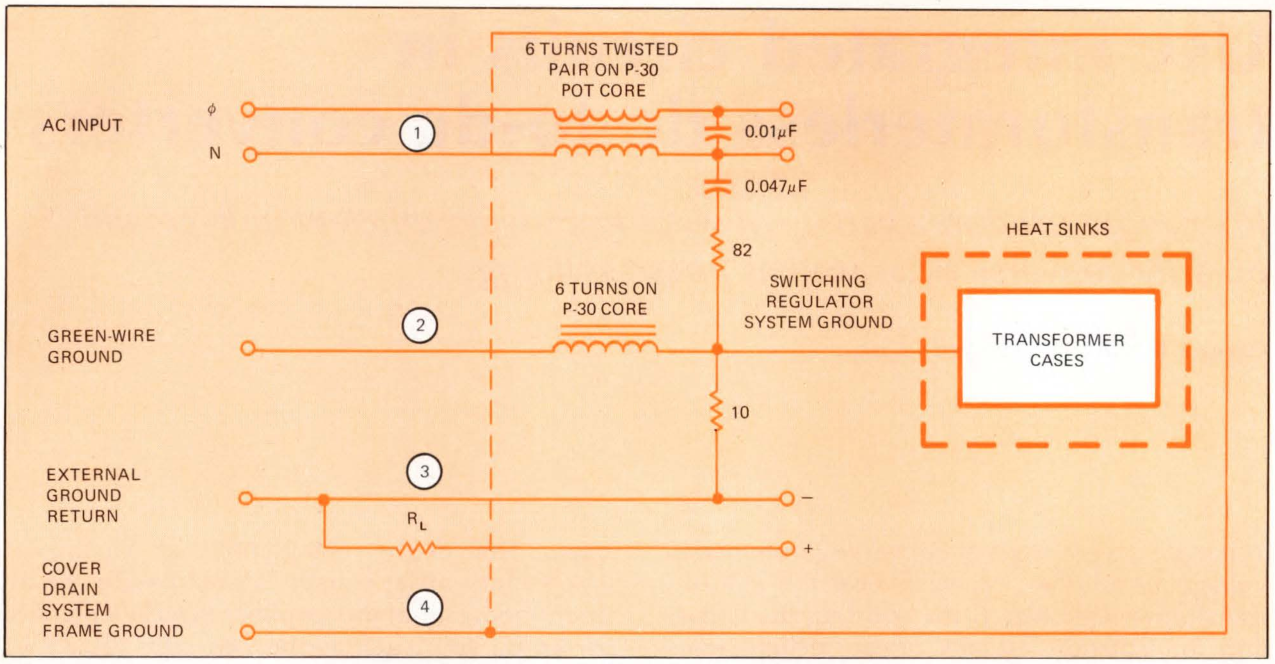


Fig. 5—This optimum noise-correction system meets external circuit requirements and can shunt a large amount of noise current from external circuitry. The ferrite cores add even more protection by increasing external noise path impedances.

through the system ground back through the dc output. Grounding the box to TSR ground and system ground bvpasses the high green-wire ground impedance and raises the noise level considerably.

Diode noise

Another source of noise common to most power supplies is diode reverse-recovery noise.

Electromagnetic Compatability

EMC is the present term covering a wide range of undesirable elements of electronics including inteference to radio reception, computer errors caused by noise and some of the effects of lightning.

EMI, electro-magnetic interference, is part of EMC. This term covers radiated noise and is usually measured in terms of volts per meter or ampere-turns per meter. If the noise is broad-band, it is measured in complex terms such as dB/μV/m/MHz (decibels above one microvolt per meter per megahertz).

RFI, radio frequency interference, is the outdated term for EMI

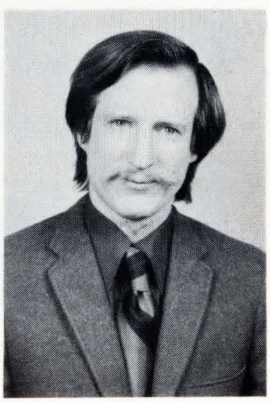
PLT, power line transients, is one kind of conducted noise generally caused by switching inductive loads and is measured on the power line.

Because diode current does not shut off exactly as the diode voltage crosses zero, it takes a little reverse current to clear out the carriers. Depending on the types of diodes used, this reverse-recovery current comes in different amounts and different turn-off speeds result when the carriers are cleared.

Fast-recovery diodes do not allow the reverse current to reach very large levels and soft-recovery diodes shut off slowly at the end of recovery. Hard-recovery diodes shut off very rapidly, creating a current step function that causes adjacent circuitry to ring. So the choice is for both fast- and soft-recovery diodes.

One final point. Circuit analysis of electric noise paths and currents can never be total or complete since the impedance of noise paths are extremely complex. The engineer must rely strongly on past experience, developing a "feel" for impedances of open wires and interframe capacitances. ▭

Author's Biography



Peter Grant received his BSEE from the University of Maryland in 1965. Prior to joining IBM in 1967, Mr. Grant was involved in design work for Litton Industries. At IBM he has been responsible for several electromagnetic compatibility projects. Mr. Grant is presently engaged in designing power systems.

Use integrated circuits in transformerless dc-to-dc converters

ICs can be used in a variety of ways to provide efficient voltage and polarity conversion, as well as phase splitting.

Eugene R. Hnatek, Signetics Corp.

There are several ways of converting from one dc voltage to another. Many involve the use of a transformer (see **Fig. 1**) for boosting the voltage and for isolation reasons (these include transformer-rectifiers; dc/dc converters, etc.). Other methods involve the use of a high-efficiency voltage regulator (**Fig. 2**) to obtain a voltage change.

For many applications integrated circuits now offer an attractive and transformerless alternative to conventional conversion methods. They can perform a variety of functions and have cost and reliability advantages. Three basic application areas will be discussed: precision rectifiers, op amp dc converters and voltage splitters.

Precision rectifiers

The basic precision rectifier circuit is shown in **Fig. 3.** In this circuit the diodes act as perfect rectifiers because each diode's forward voltage drop is effectively divided by the op amp's open-loop gain at the input signal frequency of interest. This circuit, however, does have some drawbacks. One of the most serious is that the op amp's input offset voltage is amplified by the dc open-loop gain of the amplifier (50,000 minimum for an op amp such as the 741). This causes an error output voltage because one of the diodes is always ON; and the other, OFF. The error occurs when the input signal multiplied by the open-loop gain at the frequency of interest is less than the input offset voltage multiplied by the dc gain.

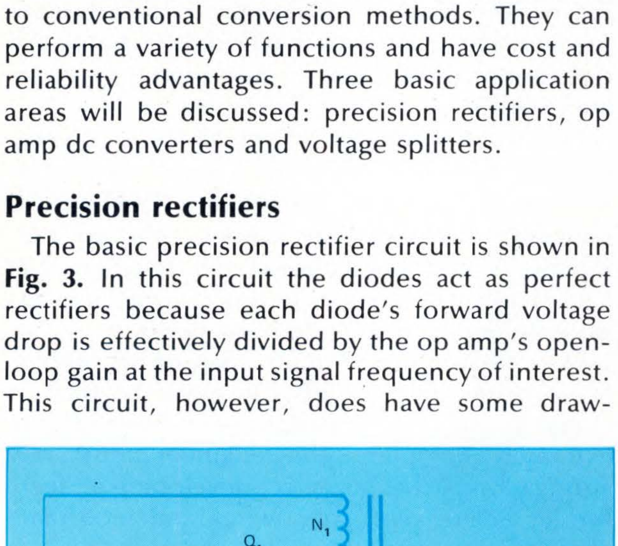


Fig. 1—In a typical single-transformer dc-to-dc converter, the oscillator transistors convert the input dc to ac, which is boosted by the transformer and rectified by the diodes.

A second serious problem is that, with a very low input signal, the amplifier's input noise voltage is amplified by the open-loop gain. If the level of input noise is high enough, the diodes turn on, causing a dc error to be present at $+E_{out}$ and $-E_{out}$.

The op amp used in the circuit of **Fig. 3** should have a high gain-bandwidth product. Devices like the LM301A and 308A, with feed-forward compensation, and the NE531 are ideally suited for this application.

Fig. 3 can be modified to overcome the above disadvantages, as shown in **Fig. 4.** The addition of C_2, R_4 and R_5 brings the dc closed-loop gain of the circuit to unity. Thus, the op amp's input offset voltage is only amplified by 1. The addition of C_3 reduces the gain-bandwidth product when the diodes are not conducting. This reduces the gain available to amplify the input noise voltage. However, C_3 should be chosen with care, since it also affects the circuit's gain-bandwidth product with the diodes conducting.

Another variation of the precision rectifier is shown in **Fig. 5.** In this circuit, the addition of R_6, C_4 and R_7, C_5 serves two purposes: these components reduce the peak rectified voltage at $+E_{out}$ and $-E_{out}$ to an average dc voltage, and they cause the circuit to act as a voltage doubler.

The time constant of R_6C_4 and R_7C_5 in **Fig. 5** should be set at 1/10 of the single sine-wave period of the highest frequency to be rectified. As a minimum, the values of R_B and R_L are at least ten times R_A; then, the discharge time of C_4 and C_5 is at least ten times as long as the charge time.

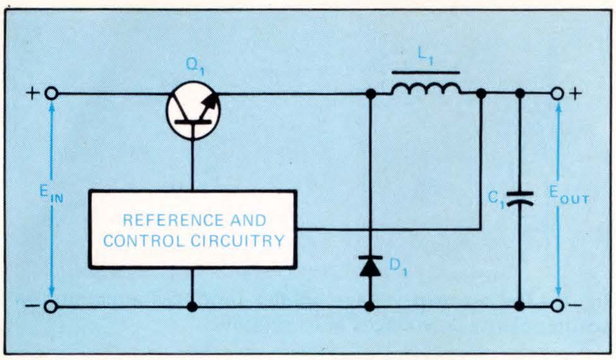


Fig. 2—Switching-voltage-regulator converters have normally been used for converting high-input dc voltages to lower output dc voltages.

Another method of improving circuit performance is to use hot-carrier or Schottky diodes for the rectifiers. These diodes have much lower forward voltage drops as a function of forward current, which increases the available circuit gain.

Op amp dc converters

Conventional switching regulators are capable of converting from a high input dc voltage to a lower output voltage at high efficiency. A problem develops, however, if a higher output voltage than the input is desired. Additionally, if an output voltage with opposite polarity to the input voltage is desired, the design gets complicated. Traditionally, both requirements have been satisfied by the use of a transformer. This can be avoided with the type of switching regulator conversion circuit shown in **Fig. 6.** It is a switching regulator circuit for a +5V to a −15V converter of the type that has application as a power supply for MOS memories in a logic system where only +5V is available.

The method by which the regulator of **Fig. 6** generates the opposite polarity is as follows (see simplified diagram of **Fig. 7**): Transistor Q_2 is turned on and off with a given duty cycle. If the base drive is sufficient, the voltage across the inductor is equal to the supply voltage minus V_{sat}. When the transistor turns off, the inductor current has a path through the diode, D_2, which

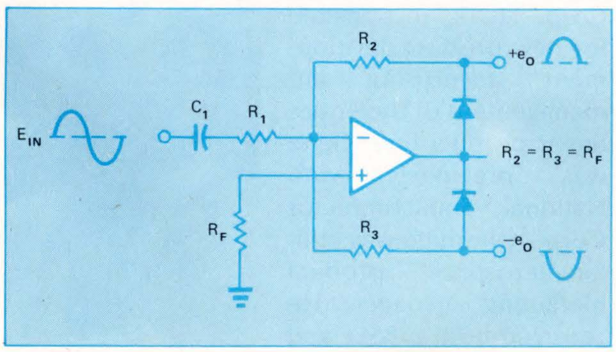


Fig. 3—The basic precision rectifier circuit suffers from errors in its dc output.

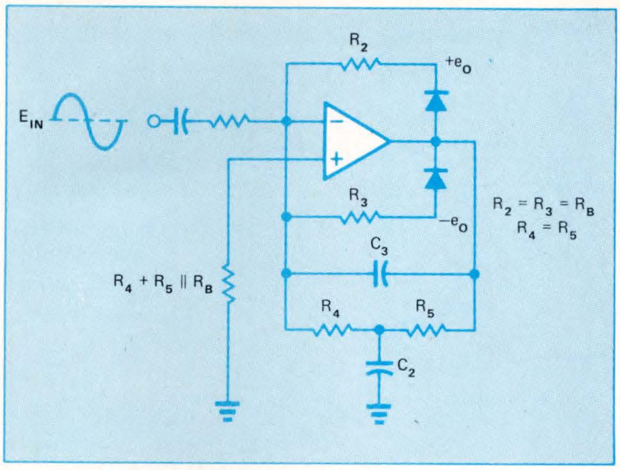


Fig. 4—Improved performance in the basic precision rectifier is achieved with the addition of R_4, R_5, C_2 and C_3.

builds up a negative voltage across R_L. Capacitor C_2 prevents the voltage from dropping to zero during the transistor ON time.

Referring to the entire circuit, **Fig. 6,** the LM311 voltage comparator is chosen because it operates from a single 5V supply and has high current capability. An op amp, such as the LM301A, could be used, but in that case another transistor would be required in conjunction with Q_2, and this would reduce the circuit's efficiency.

The LM311 operates as a high-duty-cycle, free-running oscillator. A high duty cycle is required to start the oscillator (for high current and voltage). Then, once oscillating, the regulator takes over at an approximately 50% duty cycle. The high duty cycle is also necessary to get the required output voltage. However, with a high duty cycle, the oscillator has the potential of not starting—i.e., stalling in a dc mode. If it stalls for a few seconds, Q_2 gets "wiped out"—there is a dc path to ground due to excessive current flow.

A large amount of dc negative feedback, along with R_4, is used to set the output of the LM311 in the center of its active region to ensure starting

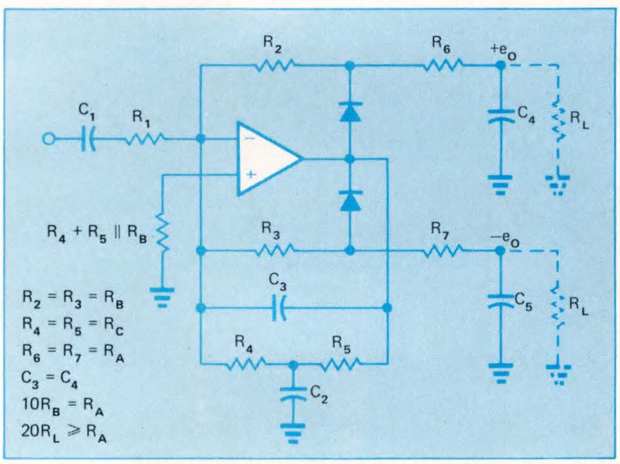


Fig. 5—This version of the precision rectifier circuit also acts as a voltage doubler.

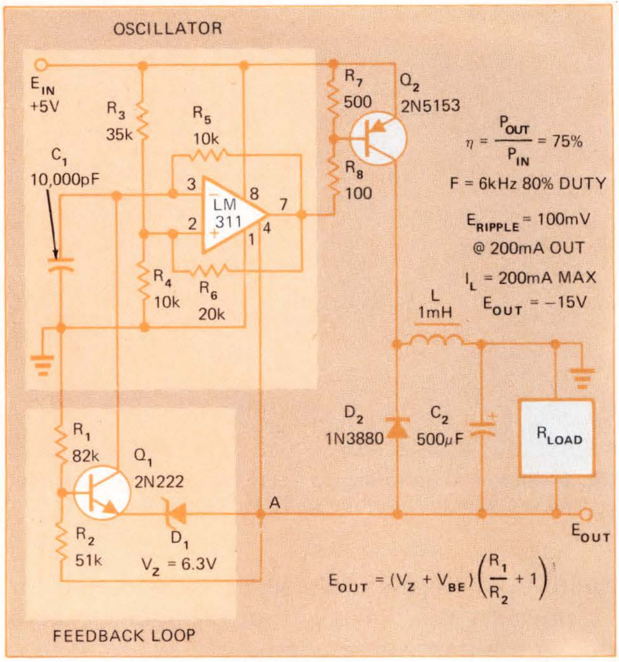


Fig. 6—Switching-regulator dc-to-dc conversion circuit converts a +5V input to a −15V output.

and reasonable symmetry in the output waveform. Capacitor C_1 reduces the negative feedback at high frequencies, giving net positive feedback and oscillation. A feedback loop is used to regulate the oscillator's duty cycle. The voltage that is sensed at point A is used by means of voltage divider R_1 - R_2 to regulate the current through Q_1 and thus control the duty cycle.

In the circuit, R_5 provides positive feedback; R_3 and R_4 set the duty cycle; R_3, R_4 and R_6 provide the hysteresis; and D_2 provides drive voltage.

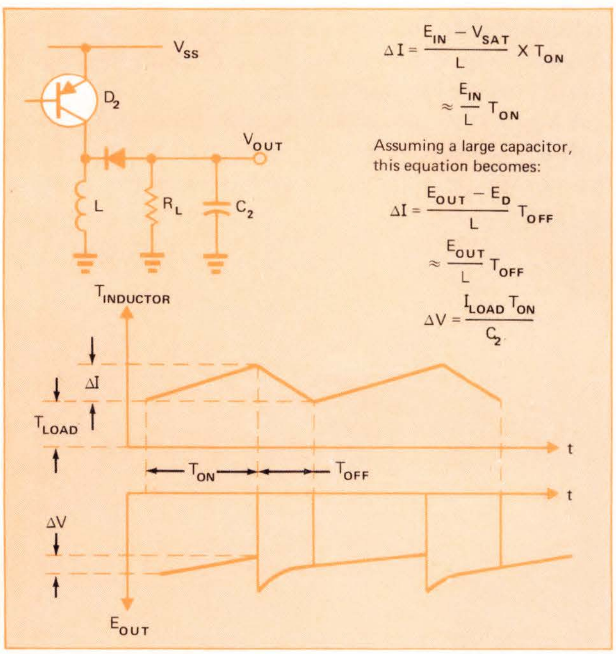


Fig. 7—The negative output voltage is developed when Q_2 cuts off and the field around inductor L drives current to ground through R_L.

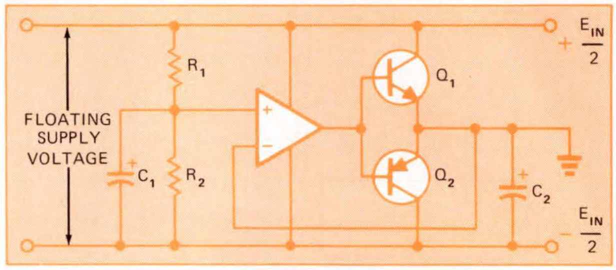


Fig. 8—The op map voltage splitter produces equal but opposite polarity dc voltages at its outputs.

Op amp voltage splitter

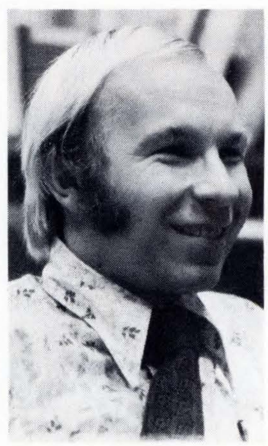
In some instances a split voltage is desired when a single supply voltage is available. A circuit that performs this function is shown in **Fig. 8.**

Resistors R_1 and R_2 divide the voltage on the floating input. The control circuit essentially is a low-output-impedance follower with complementary current boosters in the feedback loop. Current flows into or out of ground when the outputs are unbalanced; the differences in positive and negative feedback drive the outputs back toward balance.

Good balance is maintained because small output variations result from a large current flow. Transistors Q_1 and Q_2 must dissipate power equal to $\frac{1}{2}$ (IV), where V is the input voltage and I is the source and sink current. Capacitor C_1 reduces noise and prevents oscillation. C_2 absorbs current transients. ☐

This article was written while Mr. Hnatek was with National Semiconductor Corp.

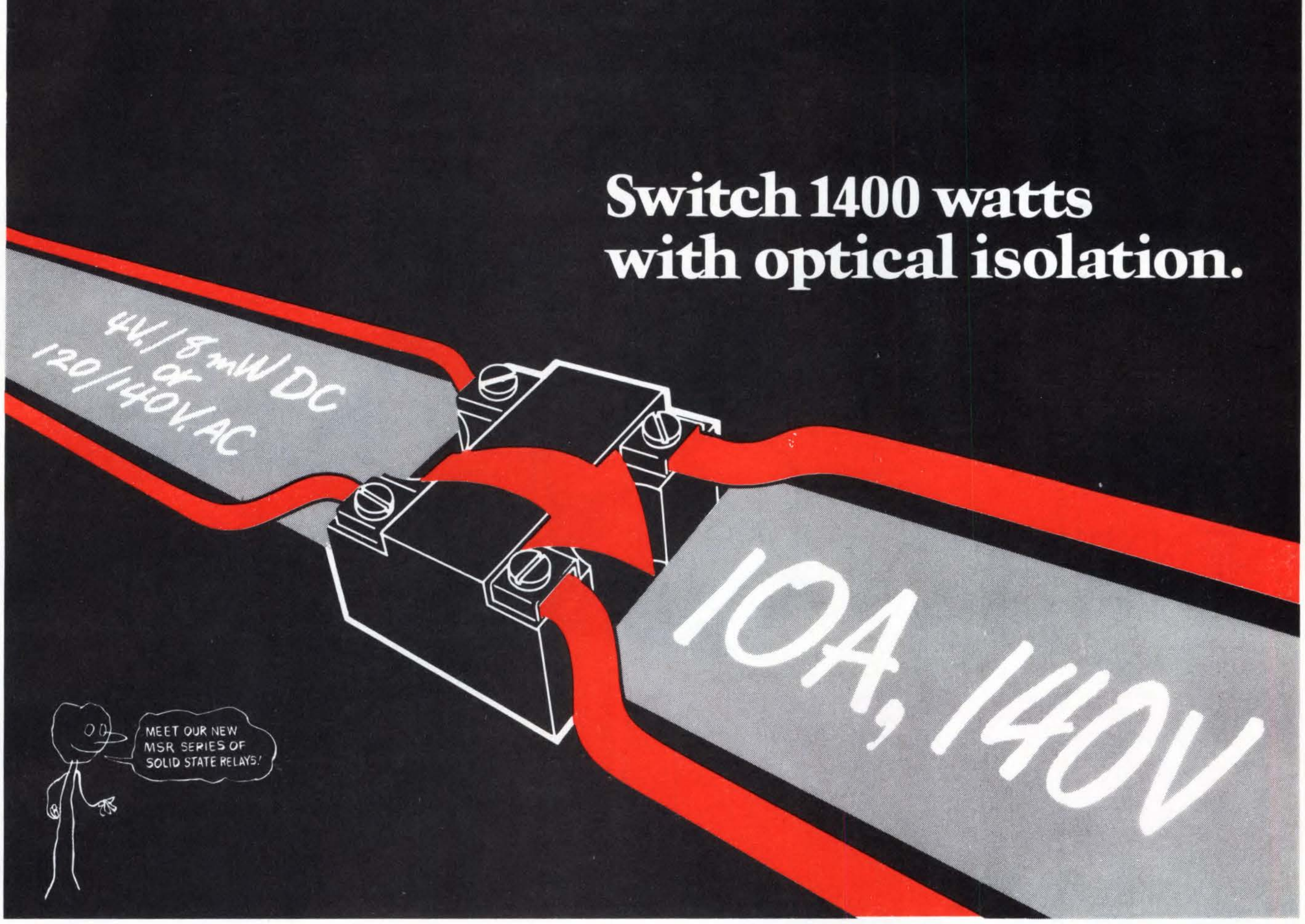
Author's biography



Eugene R. Hnatek is presently linear marketing manager at Signetics Corp. He is responsible for new product development, advertising and management of the entire linear product line. Gene was previously with National Semiconductor Corp., where he was military/aerospace product marketing manager. He received both a BSEE and MSEE from Bradley University.

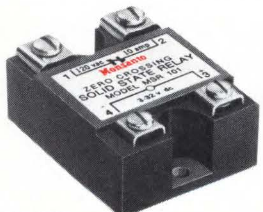
Putting innovation to work.

Switch 1400 watts with optical isolation.



These solid state switches offer normally-open or normally-closed contacts that are compatible with TTL, DTL, or MOS inputs (8mW at 4 volts). That's for DC. For AC applications, they'll handle 120 or 240 VAC input. The output of either variety switches 140 volts AC at 10 amps.

There are many more features: **zero voltage turn-on; zero current turn-off;** they eliminate electrical noise from arcing contacts, transients from contact bounce, high voltage transients with inductive loads, and derating because of inductive or lamp loads.



MSR100
DC input, N.O. contacts

MSR101
DC input, N.C. contacts

MSR102
AC input, N.O. contacts

MSR103
AC input, N.C. contacts

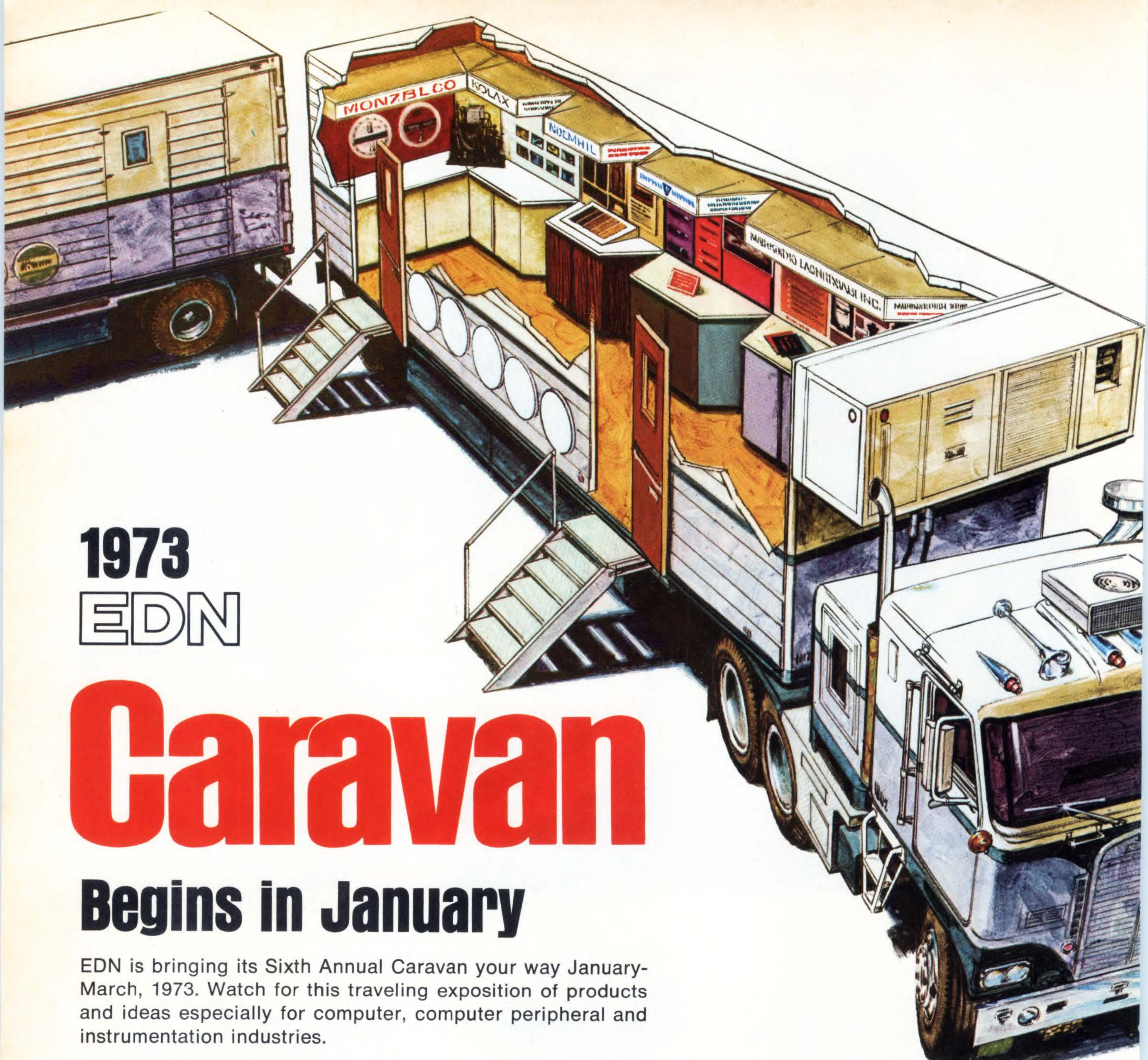
They also have high noise immunity; they're protected from false actuation; they don't need electromagnetic shielding, coil-suppression diodes, transistor buffers or magnets.

And they're small (2¼" x 1¾" x 1⅞"), 4 ounces, with rugged screw terminals and a wide operating range. Ask for our new data sheet on the MSR Series of solid state relays from **Monsanto Commercial Products Co.,** Electronic Special Products, 10131 Bubb Road, Cupertino, California 95014. Phone (408) 257-2140.

Distributed by: Alta Electronics, Elmar Electronics, Hammond Electronics, Kierulff Electronics, Kierulff/Schley, Liberty Electronics, Schweber Electronics, Semiconductor Specialists, Wesco Electronics, Western Radio; Canada: Canadian Dynamics, Ltd., Cesco Electronics, Ltd.

Monsanto

CHECK NO. 26



1973 EDN

Caravan

Begins in January

EDN is bringing its Sixth Annual Caravan your way January-March, 1973. Watch for this traveling exposition of products and ideas especially for computer, computer peripheral and instrumentation industries.

Don't miss this unique opportunity.

ANALOG DEVICES INCORPORATED
ANSLEY ELECTRONICS CORPORATION, DIVISION OF THOMAS & BETTS CORPORATION
BELDEN CORPORATION
BURNDY COMPONENTS GROUP, BURNDY CORPORATION
BURROUGHS CORPORATION, ELECTRONIC COMPONENTS
TRW CINCH DIVISION OF TRW INC.
CORNELL-DUBILIER ELECTRONICS
I-T-E IMPERIAL CORPORATION, DISTRIBUTION & CONTROLS GROUP
NORTH AMERICAN PHILIPS CONTROLS CORPORATION
THE SUPERIOR ELECTRIC COMPANY
UNION CARBIDE CORPORATION, DEMET DEPARTMENT
WESTON INSTRUMENTS, INC., A Schlumberger Company

EDN 221 Columbus Ave / Boston, Mass. 02116

We may be visiting your city — or perhaps your own plant site.
Watch for the detailed tour schedule in our next issue.

EDN CARAVAN JANUARY 31 - FEBRUARY 26 ITINERARY

DATE	TIME	SITE
January 31 A.M.	Wednesday 9:00-11:30	Electronic Memories & Magnetics, 12621 Chadron, Hawthorne, CA
January 31 P.M.	Wednesday 2:00-4:30	Northrup Aircraft, 2301 W. 120th, Hawthorne, CA (Parking: East Lot)
February 1 A.M.	Thursday 9:00-11:30	TRW - Data Systems, 19900 S. Normandie, Torrance, CA (Parking: Behind Main Plant on Chadron)
February 1 P.M.	Thursday 2:00-4:30	Xerox Data Systems, 701 S. Aviation Blvd., El Segundo, CA
February 2 A.M.	Friday 9:00-2:00	Ampex 13031 W. Jefferson, Marina Del Rey, CA (Parking: front of "Employment Lobby Parking Lot")
February 5 A.M.-P.M.	Monday 9:00-2:00	Hughes Aircraft Co., Centinela & Teale, Culver City, CA (Parking: Building 604, NW corner)
February 6 A.M.	Tuesday 9:00-11:30	RCA, 8500 Balboa Blvd., Van Nuys, CA (Parking: along side of fence at entrance)
February 6 P.M.	Tuesday 2:00-4:30	Litton Industries, 8000 Woodley St., Van Nuys, CA (Parking: Building 45)
February 7 A.M.	Wednesday 9:00-11:30	Singer - General Precision, 833 Sonora, Glendale, CA (Parking: check with Guard Captain at Main Gate)
February 7 P.M.	Wednesday 2:00-4:30	Bell & Howell, 300 Sierra Madre, Pasadena, CA
February 8 A.M.	Thursday 9:00-11:30	Burroughs, 460 Sierra Madre, Pasadena, CA
February 8 P.M.	Thursday 2:00-4:30	Burroughs, 14800 E. Proctor, City of Industry, CA (Parking: between the two buildings)
February 9 A.M.	Friday 9:00-11:30	Hoffman Electronics, 2343 N. Arden Dr., El Monte, CA (To Be Confirmed)
February 9 P.M.	Friday 2:00-4:30	Hughes Aircraft, 651 N. Gilbert, Fullerton, CA
February 12 A.M.-P.M.	Monday 9:00-3:00	North American Rockwell, 3370 Miraloma, Anaheim, CA
February 13 A.M.	Tuesday 9:00-11:30	Century Data Systems, 1270 N. Kramer Blvd., Anaheim, CA (To Be Confirmed)
February 13 P.M.	Tuesday 2:00-4:30	Northrup Corp., 500 E. Orangethorpe, Anaheim, CA
February 14 A.M.	Wednesday 9:00-11:30	Varian Data Machines, 2722 Michelson Dr., Irvine, CA (To Be Confirmed)
February 14 P.M.	Wednesday 2:00-4:30	Philco Ford, Ford Road, Newport Beach, CA (Parking: at the gate outside fence)
February 15 A.M.	Thursday 8:30-10:30	Control Data Corp., 4455 East Gate Mall, La Jolla, CA (Parking: rear door of building)
February 15 P.M.	Thursday 2:30-4:30	Cubic Corp., 9233 Balboa Ave., San Diego, CA (Parking: parking lot, west side of building)
February 16 A.M.	Friday 9:00-11:30	Honeywell, 8611 Balboa Ave., San Diego, CA
February 16 P.M.	Friday 2:00-4:30	Stromberg Datagraphix, 1895 Hancock St., San Diego, CA
February 19	Holiday	Washington's Birthday
February 20 A.M.	Tuesday 9:00-11:30	Honeywell Info Systems, 13430 N. Blacks Canyon Highway, Phoenix, AZ (Parking: North Gate)
February 20 P.M.	Tuesday 2:00-4:30	Sperry Rand, 21111 N. 19th Ave., Phoenix, AZ (Parking: inside gate, south end of building)
February 21 A.M.	Wednesday 9:00-11:30	General Electric, 2255 W. Desert Cove, Phoenix, AZ
February 21 P.M.	Wednesday 2:00-4:30	Motorola Inc., 8201 E. McDowell Road, Scottsdale, AZ (Parking: at Receiving Gate)
February 26 A.M.	Monday 9:00-11:30	Texas Instruments, 13500 N. Central Expressway, Dallas, TX (Parking: East of S/C building Guest Lot)
February 26 P.M.	Monday 1:00-4:00	Recognition Equipment, 2701 Grauwyler, Irving, TX

BALANCE OF CALENDAR TO BE RELEASED LATER

There's plenty more where these came from.

Literally, thousands more.

Actually, the odds are in your favor that we have the unlighted pushbuttons you need, right-off-the-shelf.

Our secret is interchangeable parts. Pushbutton modules. Switch modules (including hermetically sealed units and high/low temperature versions). Facenuts. Even a selection of colored buttons.

We also give you a choice of momentary or alternate action. Or a combination of both. And finally, a pick of one, two, three or four pole circuitry.

Which gives you the opportunity to customize your panel—front and back. To make it the way you want it. And to do it economically.

For more information, call your MICRO SWITCH Branch Office or Authorized Distributor (Yellow Pages under "Switches, Electric"). Or write for Catalog 51.

MICRO SWITCH
FREEPORT, ILLINOIS 61032
A DIVISION OF HONEYWELL

MICRO SWITCH products are available worldwide through Honeywell International.

CHECK NO. 24

CHECK NO. 53 →

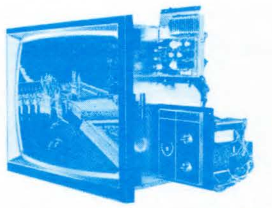
FREE

NEW '73 HEATHKIT® CATALOG

Over 350 electronic kits... world's largest selection

- Easy, fun to build
- Savings of up to 50%
- Designed for first time kit builders
- Kits for every interest — amateur radio, color TV, test & automotive instruments, marine electronics, radio control, home appliances, short-wave, stereo hi-fi, electronic organs, education, photographic . . and more!

Radio equipment kits for every interest — Shortwave, Amateur Radio, AM & FM Broadcast, including new VHF 8-Channel Scanning Monitor for automatic listening of police, fire, weather, and marine calls.



Color and B & W TV Kits — consoles, table models, portables, in a selection of screen sizes and cabinets, including the incomparable GR-900 offering 25 inches (diagonal) of glorious color, UHF and VHF power detent tuning, full remote control.

Test instruments for hobbyists and professionals — including new 2½ digit VOM, generators, frequency counters, oscilloscopes, meters of all kinds.

Automotive instrument kits — like the new Portable Engine Analyzer, new Capacitive Discharge Ignition System, tachometer, battery charger, and ignition analyzer timing lights.

Kits for music lovers — such as the new AR-1214 50-Watt Stereo Receiver, a new Dolby® cassette deck, 2 and 4-channel equipment, speakers and turntables, new Spinet electronic organ, guitar amplifiers.

Exciting kit ideas for the home — like the timely new Solid-State 6-Digit Electronic Clock-Alarm, 8-Digit Calculator, garage door openers, intercoms, microwave oven and more.

HEATH COMPANY
Benton Harbor, Michigan 49022

Please send my FREE Heathkit® Catalog

Name (Please print) ______________________

Address ______________________

City ______________________

State ______________ Zip ______________

SEND FOR YOUR FREE COPY TODAY!
...World's largest electronic kit catalog. A kit for every interest... every budget. Easy credit terms.

Please send my FREE Heathkit® Catalog

Name (Please print) ______________________

Address ______________________

City ______________________

State ______________ Zip ______________

SEND FOR YOUR FREE COPY TODAY!
...World's largest electronic kit catalog. A kit for every interest... every budget. Easy credit terms.

FREE

NEW 1973 EDITION
HEATHKIT CATALOG

HEATH COMPANY
DEPARTMENT 57-2
BENTON HARBOR, MICHIGAN 49022

PLACE
STAMP
HERE

FREE

NEW 1973 EDITION
HEATHKIT CATALOG

HEATH COMPANY
DEPARTMENT 57-2
BENTON HARBOR, MICHIGAN 49022

PLACE
STAMP
HERE

YOUR FREE

Heathkit Catalog is ready and waiting

Join the millions who have experienced the creative satisfaction and savings of a Heathkit hobby — Mail your card for one today. If the postcards at left have been removed, use the handy coupon below.

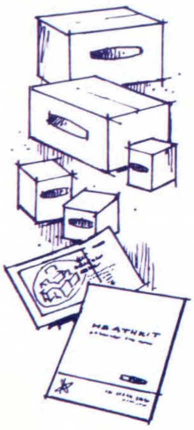
EVERY HEATHKIT PROJECT GIVES YOU –

Creative Enjoyment. A totally different, totally rewarding experience. And each easy-to-follow assembly manual has an appendix that's loaded with information, so you can learn how your kit works, even how to service it yourself. No special skills or experience needed—we show you how to do it — and there are rafts of experts at the factory and each Heathkit store ready with free consultation to assure your success.

Quality Performance. Every kit in our catalog is the result of 25 years of kit design experience to give you guaranteed performance specifications. Quality design, quality components, quality performance. Ask an electronics expert. He'll tell you about Heathkit quality.

Unmatched Value. Every Heathkit product is designed to give you unusual performance and features for its price. And many will save you up to 50% of the cost of comparable ready-made products.

EVERY HEATHKIT PRODUCT INCLUDES –



Complete Kitbuilder's Guide. A comprehensive beginner's booklet that shows you how to unpack your kit, how to identify parts and install them — even how to solder correctly.

Famous Heathkit Assembly Manual. In simple, non-technical language, it shows you step-by-step how to build your kit. We always assume you know nothing about electronics. That way everyone in the family can take part in your Heathkit project.

All The Parts — both electronic and mechanical, plus chassis, circuit boards (many even include the cabinet) and every kit includes all the solder you need. No self-fabricating for you to do, no searching for parts sources — everything included, ready to assemble.

GET STARTED TODAY — SEND FOR YOUR FREE HEATHKIT CATALOG

HEATH COMPANY, Dept. 57-2
Benton Harbor, Michigan 49022

☐ Please send FREE Heathkit Catalog.

Name________________________________

Address______________________________

City______________State____________Zip________

CL-451

Active filter design using generalized impedance converters

This technique simplifies the design of low-sensitivity active filters. See how a GIC works and how to use them when designing active filters.

Dr. L. T. Burton, University of Calgary
David Treleaven, Microsystems International Ltd.

In contrast to some better known impedance converting or inverting networks, generalized impedance converters (GICs) are easy to understand, and equip the circuit engineer with a unified and very versatile approa h to designing low-sensitivity active filters. As outlined in the box, a GIC network has a driving point impedance of

$$Z_i(s) = K(s)Z_L(s) \quad \textbf{(1)}$$

Current-conversion type GIC networks[1, 2, 3] can be realized in at least four different ways as shown in **Fig. 1,** all using differential input, single ended output operational amplifiers. Analysis of all these networks, assuming ideal amplifiers, gives identical driving-point impedances in the form of **Eq. 1** of

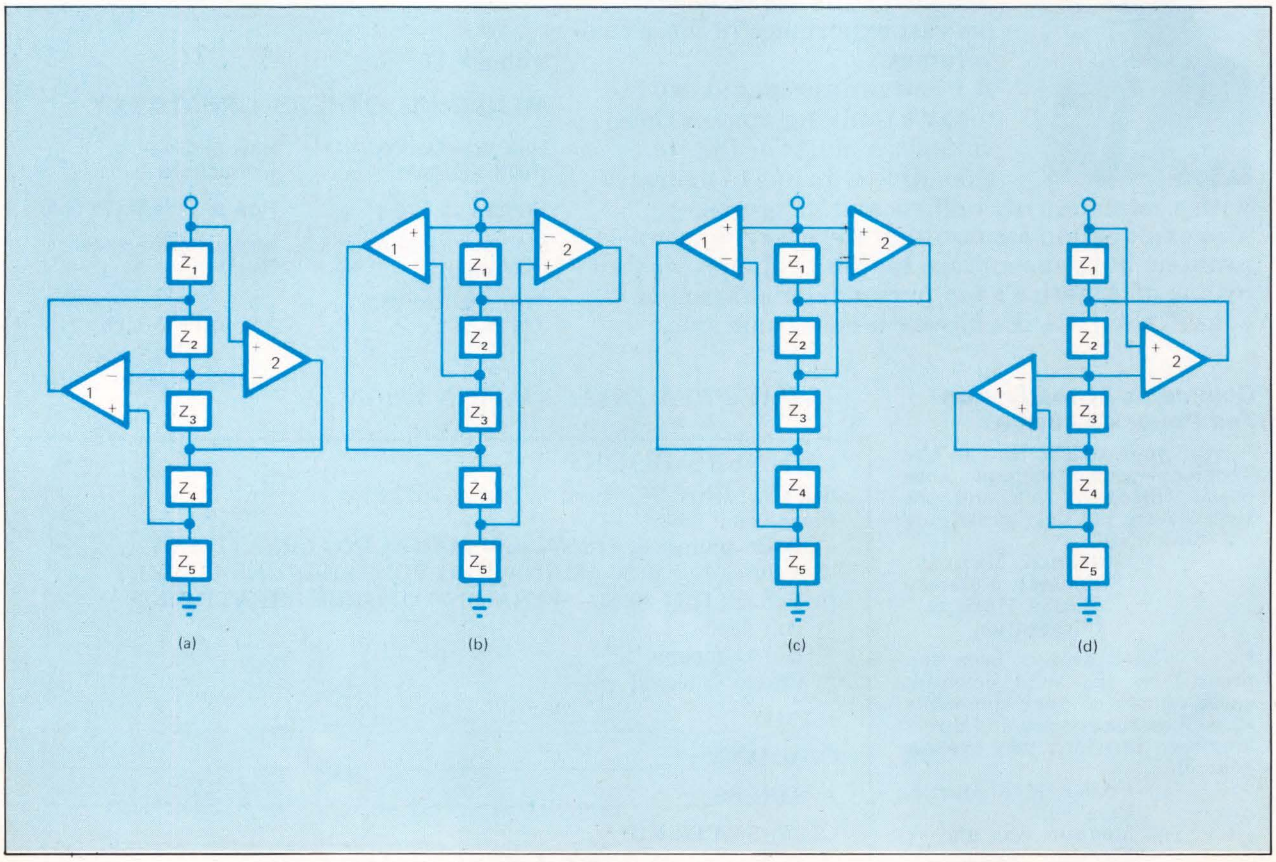


Fig. 1—Four ways of obtaining a generalized-impedance converter (GIC) using operational amplifiers.

$$Z_i = \left(\frac{Z_1 Z_3}{Z_2 Z_4}\right) Z_5 \quad \textbf{(2)}$$

which can be rewritten more generally as

$$Z_i = \frac{Z_1 Z_3 Z_5}{Z_2 Z_4} \quad \textbf{(3)}$$

The versatility of GICs as a design tool is evident from the preceding expression. An input impedance proportional to s (a grounded inductance) can be obtained by making either Z_2 or Z_4 a capacitor, with all other impedances resistors. Similarly, an input impedance proportional to $1/s^2$ (a D element[4]) can be simulated by making any two of $Z_1 - Z_3 - Z_5$ capacitive, with all other impedances resistive. If desired, impedances proportional to $1/s$, $\underline{s}^2$, and so on can also be obtained. A GIC connected to obtain an impedance proportional to s corresponds to an inductance simulated by a capacitively terminated gyrator. In fact, GIC configuration (c) with Z_2 as a capacitor is known as the Riorden gyrator.[5, 6] Not all the four GIC realizations of **Fig. 1** are equally attractive in practice. Configuration (a) and (b) provide superior stability[3] over configurations (c) and (d). Assuming ideal amplifiers, configurations (a) and (b) are unconditionally stable for all $Z_1 - Z_5$ RC combinations containing up to two capacitors. Of the two stable configurations, (a) offers markedly superior high-frequency performance over (b)[3].

GIC networks are particularly attractive for the design of low-sensitivity active filters. The sensitivity of a filter circuit's transfer function to circuit

IMPEDANCE CONVERTERS AND INVERTERS

A number of different impedance-converter networks are widely used in active network synthesis including: negative-impedance converters, positive-impedance converters, generalized-impedance converters and gyrators.

An ideal impedance converter is a two-port network which, when terminated at one port by an impedance $Z_L(s)$, presents at the other port an input impedance proportional to $Z_L(s)$ for all frequencies. Hence, as shown diagramatically below,

$$Z_i(s) = K(s) Z_L(s). \quad \textbf{(a)}$$

A negative-impedance converter is obtained if K(s) is a negative real constant. A positive-impedance converter is obtained if K(s) is a positive real constant.

A generalized-impedance converter (GIC) has the general form of **Eq. a** which can be rewritten as

$$\frac{V_1}{I_1} = K(s) \frac{V_2}{(-I_2)} \quad \textbf{(b)}$$

Eq. b can in turn be interpreted as either

$$V_2 = V_1/K(s) \quad \textbf{(c)}$$
$$-I_2 = I_1$$

or

$$V_2 = V_1 \quad \textbf{(d)}$$
$$-I_2 = K(s) I_1$$

Two special types of GIC there exist **with Eq. c** defining a voltage-conversion GIC and with **Eq. d**, a current-conversion GIC. An ideal impedance inverter has a defining equation of

$$Z_i(s) = K(s) \frac{1}{Z_L(s)} \quad \textbf{(e)}$$

A gyrator is a positive-impedance inverter with K(s) in **Eq. e** a positive real constant.

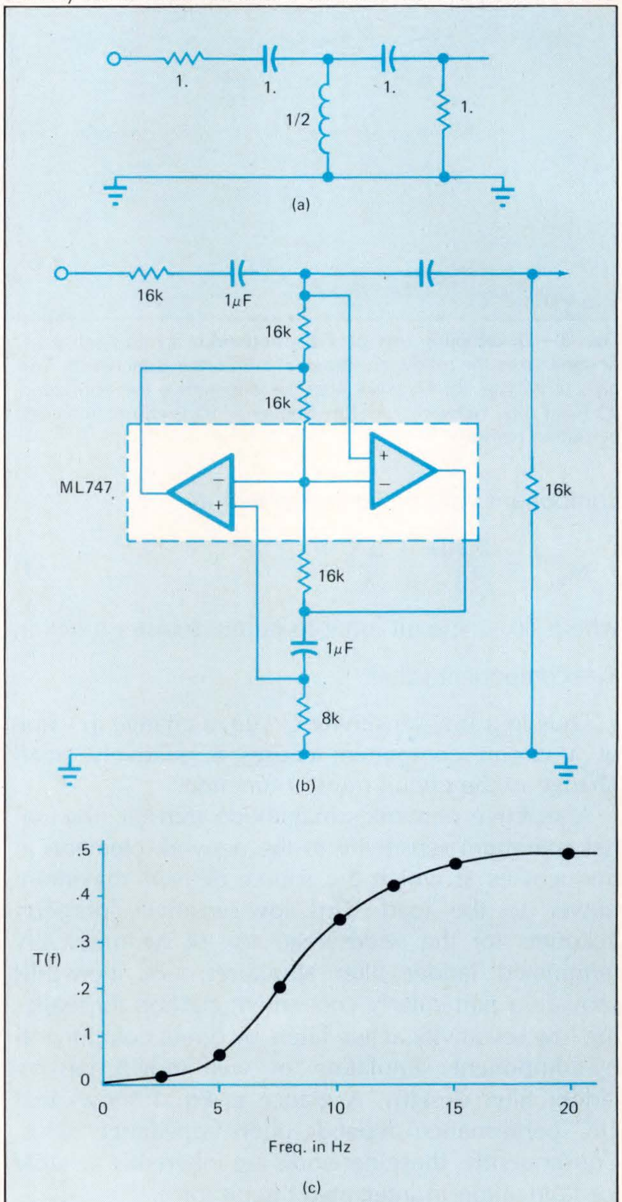


Fig. 2—Realization of highpass Butterworth active filter includes: (a) Third-order highpass prototype, (b) RC-active realization of (a), (c) Frequency response of (b).

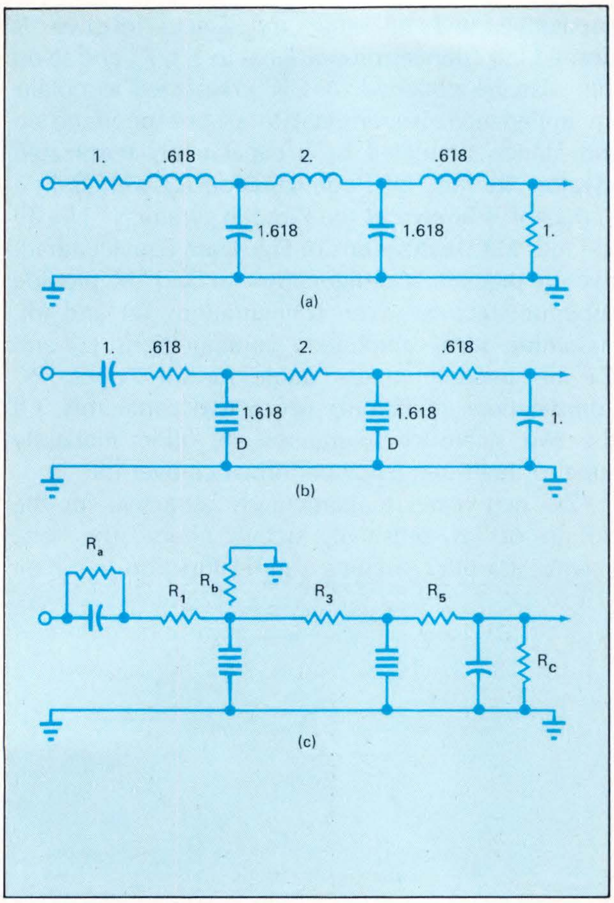


Fig. 3—Developing use of GIC networks for low-sensitivity designs takes the following steps: (a) Fifth-order Butterworth lowpass prototype, (b) Network after 1/s impedance transformation, (c) Final filter network with low-frequency transfer function compensation resistors.

component values can be defined as

$$S_{X_i}^{T(f)} = \frac{\Delta\, T(f)}{T(f)} \Big/ \frac{\Delta X_i}{X_i} \tag{4}$$

where T(f) = circuit input-to-output transfer function

X_i = component value.

Thus in a low-sensitivity circuit, a change in value of a circuit component causes a relatively small change in the circuit transfer function.

A reactive network's magnitude transfer function has minimum sensitivity to the network elements at frequencies at which the source delivers maximum power to the load. This low-sensitivity property accounts for the widespread use of symmetrically terminated ladder filter structures. GIC networks provide a particularly convenient method for realizing low-sensitivity active filters by direct component-by-component simulation of well-known passive ladder filter designs. A glance at **Eq. 3** shows that GIC performance depends upon impedance ratios. Consequently, these networks are inherently suitable for fabrication in integrated circuit form.

Highpass Butterworth filter

A straightforward example of a GIC realized active filter is illustrated in **Fig. 2.** It is desired to simulate the equiterminated Butterworth highpass ladder structure of **Fig. 2a** and to obtain a corner frequency of 10 Hz. The inductor will be realized in RC-active form by GIC configuration (a) of **Fig. 1. Eq. 3** indicates that the inductor can be simulated by making either Z_2 or Z_4 a capacitor, with all other impedances resistors.

The completed active filter circuit is shown in **Fig. 2b** with the normalized component values transformed to an impedance level of 16 kΩ and a frequency of 10 Hz. The two operational amplifiers are a matched pair in a single package. Measured frequency response of the filter is shown in **Fig. 2c.**

Lowpass Butterworth filter

As a second example of the use of GIC networks in low-sensitivity active filter designs, the fifth-order Butterworth lowpass ladder filter of **Fig. 3a** will be obtained in RC-active form. Note the nongrounded inductors in the passive prototype. The need for direct simulation of these floating inductors will be avoided (actually, postponed until the bandpass case) by using the versatility of the GIC network and a simple impedance transformation. The filter design will utilize the frequency dependent negative resistance (FDNR)[4] technique, employing a 1/s transformation of all impedances in the LCR prototype. The network of **Fig. 3a**, after the 1/s impedance transformation, is shown in **Fig. 3b**. Inductors have been replaced with resistors; resistors with capacitors; and capacitors with FDNR D elements,[4] where the D element driving-point impedance is given by

$$Z_D = \frac{1}{D\, s^2} \tag{5}$$

The transformed network has the same voltage and current transfer functions as the original[4].

The network of **Fig. 3b** is not complete in that it is necessary to provide a resistive path from the D element inputs to ground. Consider a D element realized by GIC configuration (a). Any two of $Z_1 - Z_3 - Z_5$ must be capacitors with all other impedances resistors. The resistive path to ground is required to supply input bias current to the noninverting input of amplifier 2. A large valued shunt resistor in the position of R_b in **Fig. 3c** will provide the required bias current.

However, this resistor (which corresponds to a large valued shunt inductance in the LCR prototype) causes a transmission zero at the origin of the s plane, and true direct coupled lowpass operation cannot be achieved. This low-frequency rolloff may not be a problem if it occurs below the frequency range of interest. A complete method of low frequency compensation for the circuit of **Fig. 3b** is to replace R_b by large valued resistors R_a and R_c, as shown in **Fig. 3c**. The low-frequency transfer function is then

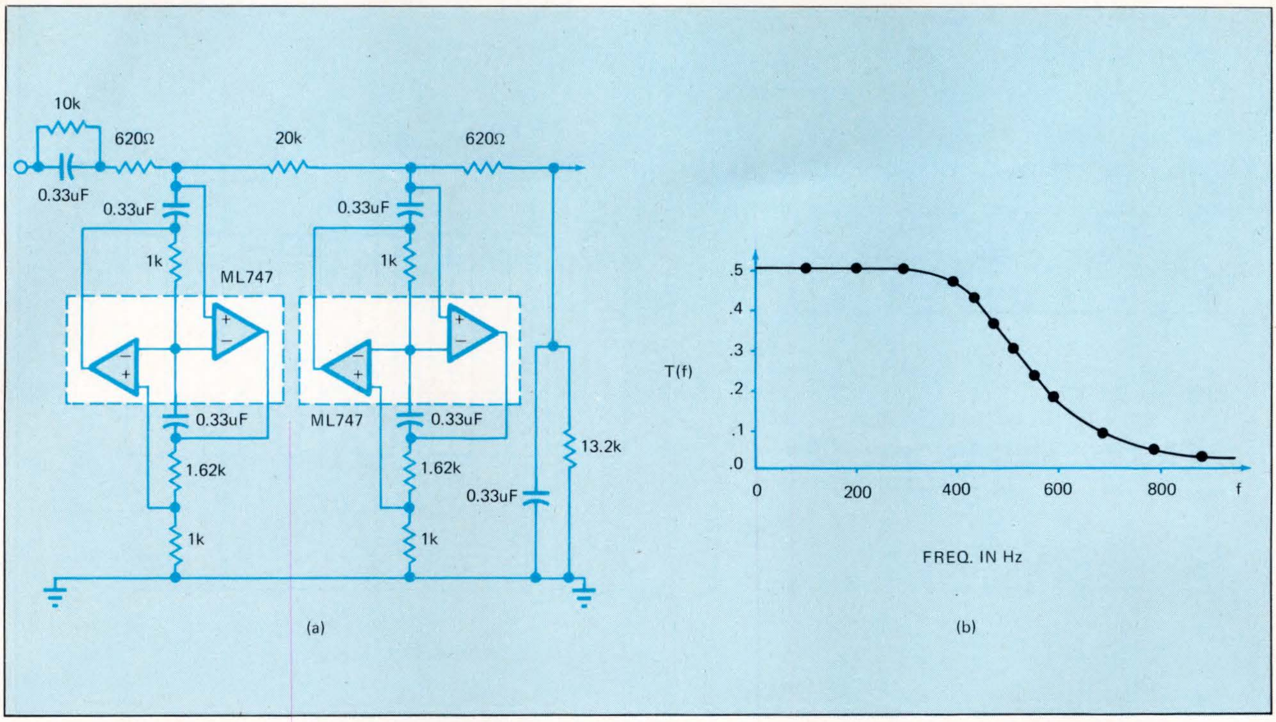


Fig. 4—Realizing a lowpass Butterworth active filter. (a) RC-active realization of **Fig. 3c**, (b) Frequency response of (a)

$$\text{Lim } T(f) = \frac{R_c}{R_a + R_1 + R_3 + R_5 + R_c}, \quad R_b = \infty \quad \text{as } f \to 0 \tag{6}$$

Since the passband transfer function magnitude is ideally 0.5, and since R_1, R_3, R_5 are all predetermined, R_a and R_c must be selected so that

$$\text{Lim } T(f) = 0.5 \quad \text{as } f \to 0 \tag{7}$$

$$\text{Thus, if } R_c = R_a + R_1 + R_3 + R_5 \tag{8}$$

$$\text{and } R_a, R_c \gg R_1 + R_3 + R_5 \tag{9}$$

the transfer function is adequately compensated at low frequencies. The complete filter circuit is shown in **Fig. 4a**. Prototype component values have been transformed to an impedance level of 1 kΩ and a frequency of 480 kHz. Dual operational amplifiers have again been used to hold the active device package count down to two. The measured frequency response is shown in **Fig. 4b**.

Bandpass requires ungrounded inductors

The design of lowpass and highpass filters is relatively straightforward because the active elements (L elements for highpass and D elements for lowpass) are grounded. This is not the case for the bandpass structure. For example, the fourteenth order symmetrical bandpass structure in **Fig. 5a** contains seven inductors, three grounded and four ungrounded. Direct RC-active simulation requires a technique for simulating the ungrounded inductors. The corresponding FDNR version of the filter, obtained by multiplying all branch impedances by 1/s, is given in **Fig. 5b**, and it will be observed that there are seven active D elements, four of which are ungrounded. Consequently, the FDNR bandpass structure has the same disadvantage as its LC counterpart in that four of the active simulated elements are ungrounded.

GIC—Embedding for ungrounded elements

A suitable technique for designing the ungrounded active elements is GIC-Embedding[1, 8]. This method consists of embedding a grounded 3-terminal network N between two identical GICs, as shown in **Fig. 6a**. The branch impedances of the GICs are Z_1, Z_2, Z_3 and Z_4; the network N has a transmission matrix

$$T_N = \begin{bmatrix} a & b \\ c & d \end{bmatrix} \tag{10}$$

$$\text{defined by } V_1 = aV_2 - bI_2, \quad I_1 = cV_2 - dI_2 \tag{11}$$

The transmission matrix of the complete structure of **Fig. 6a**, including the two GICs, is given by multiplying the transmission matrices of the three two-ports of the GIC-N-GIC cascade. It is easily shown that the GIC transmission matrices are

$$T_{GIC} = \begin{bmatrix} 1 & 0 \\ 0 & \dfrac{Z_2Z_4}{Z_1Z_3} \end{bmatrix} \text{ for GIC no. 1} \tag{12}$$

and

$$T_{GIC} = \begin{bmatrix} 1 & 0 \\ 0 & \dfrac{Z_1Z_3}{Z_2Z_4} \end{bmatrix} \text{ for GIC no. 2} \tag{13}$$

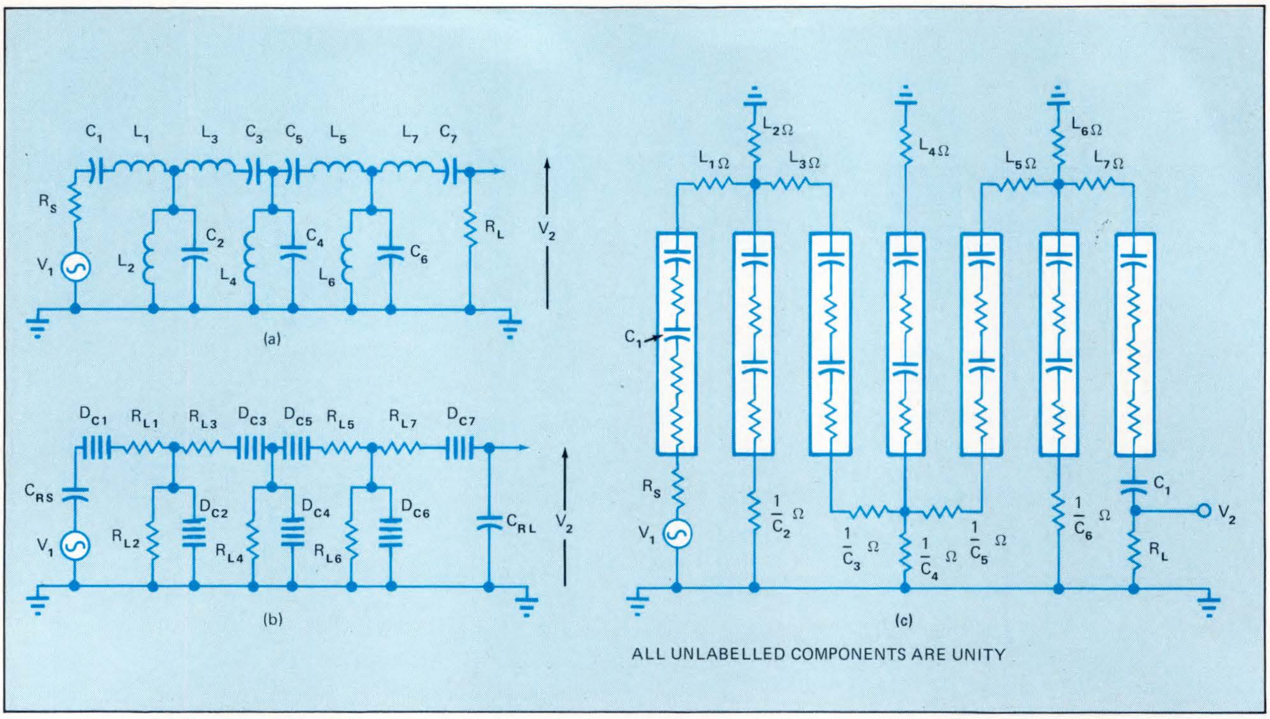


Fig. 5—Steps taken in developing a bandpass filter. (a) Fourteenth-order bandpass prototype, (b) Network after 1/s impedance transformation, (c) Efficient FDNR realization.

Thus, the transmission matrix for the cascade of **Fig. 6a** is given by

$$T = \begin{bmatrix} 1 & 0 \\ 0 & \dfrac{Z_2Z_4}{Z_1Z_3} \end{bmatrix} \begin{bmatrix} a & b \\ c & d \end{bmatrix} \begin{bmatrix} 1 & 0 \\ 0 & \dfrac{Z_1Z_3}{Z_2Z_4} \end{bmatrix} = \begin{bmatrix} a & b\dfrac{Z_1Z_3}{Z_2Z_4} \\ c\dfrac{Z_2Z_4}{Z_1Z_3} & d \end{bmatrix} \quad \textbf{(14)}$$

This is exactly the same transmission matrix as is obtained by multiplying the impedance of every branch of the network N by $\dfrac{Z_1Z_3}{Z_2Z_4}$.

Thus, **Fig. 6a** is equivalent to a network N′ that is obtained by impedance scaling each branch of N by $\dfrac{Z_1Z_3}{Z_2Z_4}$ as indicated in **Fig. 6b**. This result is most useful. For example, each ungrounded inductor can be replaced by an ungrounded resistor R (corresponding to network N) embedded between two GICs designed such that $\dfrac{Z_1Z_3}{Z_2Z_4} \propto s$; that is, with either Z_2 or Z_4 as capacitors and all other impedances as resistors. More generally, a complete subnetwork of resistors may be impedance scaled by $\dfrac{Z_1Z_3}{Z_2Z_4} \propto s$ to behave as a complete subnetwork of inductors, or a subnetwork of resistors may be impedance scaled by $\dfrac{Z_1Z_3}{Z_2Z_4} \propto s^{-2}$ to behave as a subnetwork of FDNR D elements. Consider the bandpass filter circuit of **Fig. 5a**. This structure can be simulated directly by using one GIC for each grounded inductor and two GICs for each ungrounded inductor by the method of embedding described above. A total of 11 GICs are required. Alternatively, consider the FDNR bandpass filter of **Fig. 5b**. It will now be shown that this configuration can be obtained with a considerably reduced active package count. Firstly, the grounded D elements in **Fig. 5b** require one GIC each.

The series D-C combinations at the terminations can be obtained by noting that

$$\frac{Z_1Z_3Z_5}{Z_2Z_4} = \frac{\left(\frac{1}{s}C_1\right)\left(\frac{1}{sC_3} + R_3\right)R_5}{R_2R_4} = \frac{R_5}{s^2C_1C_3R_2R_4} + \frac{R_3R_5}{sC_1R_2R_4} \quad \textbf{(15)}$$

which is of the required form to simulate a grounded series D-C branch using a single GIC.

Finally, the ungrounded D elements D_{C3} and D_{C5}, in conjunction with the grounded elements D_{C4} and R_{L4}, may be considered as a network N′ to be realized. This realization is obtained by impedance scaling all elements of network N′ by s^2, and then embedding the resulting network N between two GICs with $\dfrac{Z_1Z_3}{Z_2Z_4} \propto s^{-2}$, as shown in **Fig. 6c**. The grounded element with impedance s^2R_{L4} is realizeable using one GIC. Thus the required network N′ of

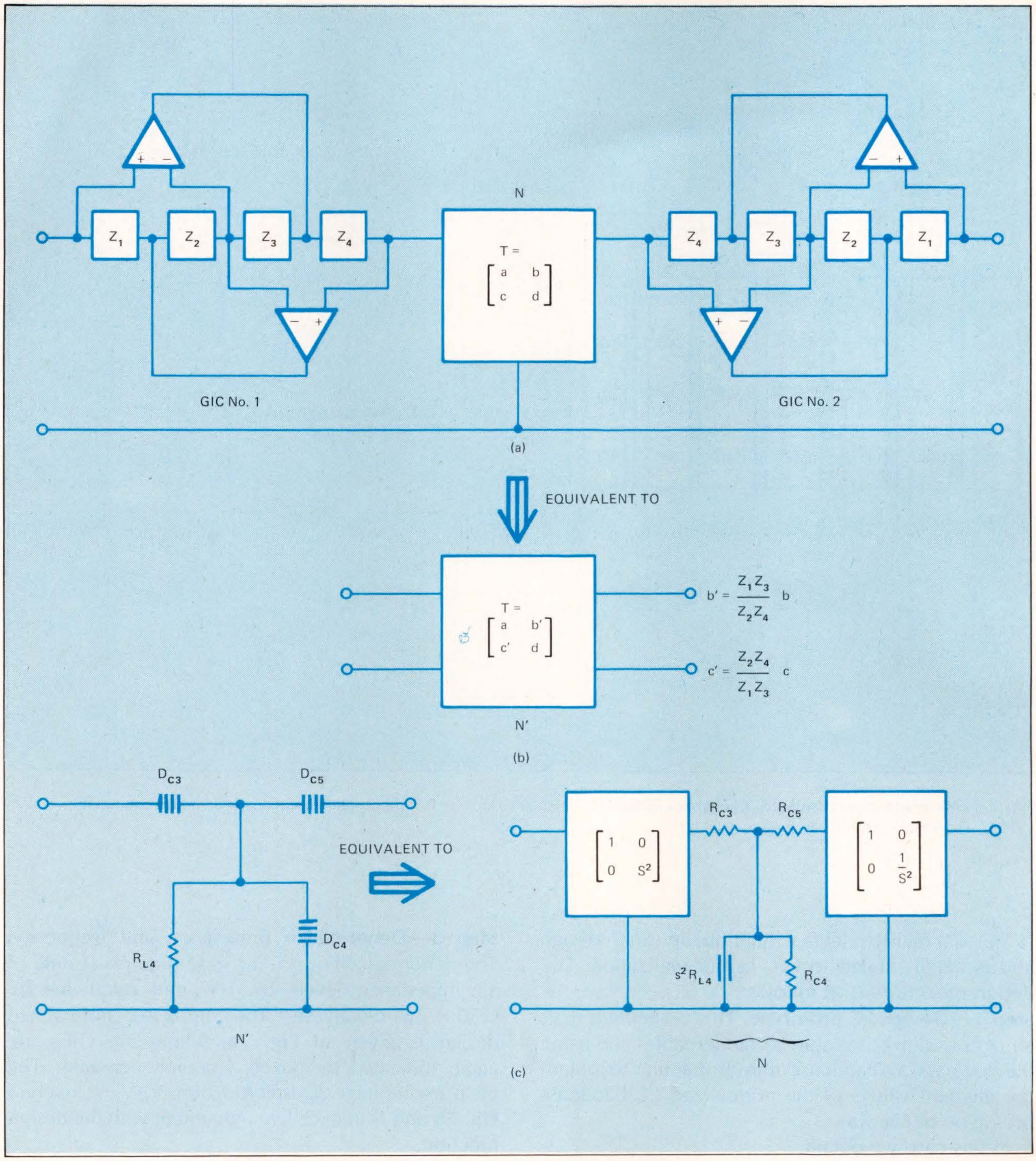


Fig. 6—Technique of GIC-Embedding is used for designing ungrounded active elements.

Fig. 6c is obtained using only three GICs.

The complete realization of the circuit of **Fig. 5b** is given in **Fig. 5c** for a normalized design. Seven GICs are required, corresponding to an active package count of seven if dual amplifiers in a single package are assumed. The GICs are not shown in detail but as boxed 4-branch networks with the branches corresponding to Z_1, Z_2, Z_3 and Z_4 of the GIC in **Fig. 1a**. Note that most of the element values are unity and that the nonunity values correspond directly to element values in the LC prototype of **Fig. 6a**. The extension of this work to a ladder of arbitrary length will be obvious from a direct comparison of the topologies of **Fig. 5a** and **5c**.

Designing a bandpass Chebychev filter

Let's go through a filter design step-by-step to see how the GIC technique works. A design example will use the following specs:

CHEBYCHEV	14th order, 0.5 dB ripple
CENTER FREQUENCY	150 Hz
BANDWIDTH	150 Hz
TERMINATION R_S, R_L	1000Ω

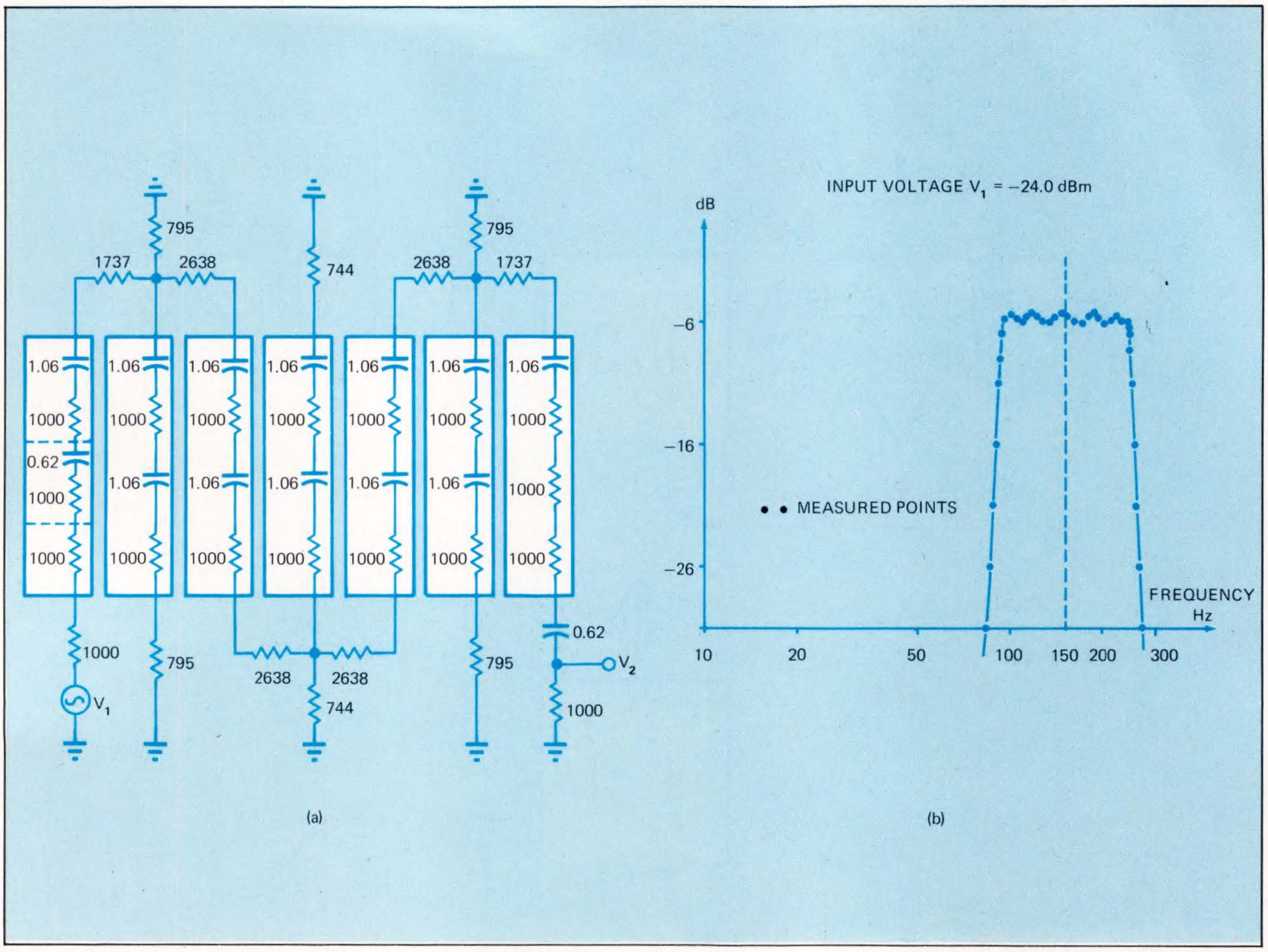


Fig. 7—Fourteenth-order bandpass Chebychev filter (a). Passband ripple = 0.5 dB, center frequency = 150 Hz, bandwidth = 150 Hz. Frequency response is shown in (b).

This is a highly selective high-quality filter design and is ideally suited to GIC ladder realization. The design procedure is as follows:

Step 1—Design LC prototype. This is simply a matter of consulting available LC ladder tables and using the lowpass-to-bandpass transformation[9] to obtain the element values of the normalized LC bandpass prototype of **Fig. 5a**.

In this case we obtain:

$R_S = R_L = 1\,\Omega$
$C_1 = C_7 = 0.575$ F $\qquad (1/C_1 = 1/C_7 = 1.737)$
$L_1 = L_7 = 1.737$ h
$C_2 = C_6 = 1.260$ F $\qquad (1/C_2 = 1/C_6 = 0.795)$
$L_2 = L_6 = 0.795$ h
$C_3 = C_5 = 0.379$ F $\qquad (1/C_3 = 1/C_5 = 2.638)$
$L_3 = L_5 = 2.638$ h
$C_4 = 1.340$ F $\qquad (1/C_4 = 0.744)$
$L_4 = 0.744$

Step 2—Substitute element values into normalized FDNR design. Direct substitution of the above numerical values into **Fig. 5c** gives the complete normalized FDNR design.

Step 3—Denormalize impedance and frequency. The denormalization in this case requires scaling of all impedance levels by 10^3 and frequency by $(150 \times 2\pi)$ radians/sec. The complete denormalized design is given in **Fig. 7a,** where the GICs are again indicated by boxed 4-branch networks. The measured voltage transfer function, V_2/V_1, is given in **Fig. 7b** and is in excellent agreement with the design function.

Wrapping up the details

For the type of high-quality bandpass filter that is given here, it is often necessary to compensate for component tolerances by a simple alignment procedure. This is performed by disconnecting each GIC and performing a simple tuning test. For example, consider removal of the middle GIC and two 744Ω resistors as shown in **Fig. 8a**. This subcircuit corresponds to a series connection of L_4 and C_4 in the LC prototype and thus should resonate at the center frequency of the filter. Therefore, tune the GIC by adjusting one of the GIC 1000Ω resistors so that V_2 exactly peaks at 150 Hz when a sinusoid V_1 is ap-

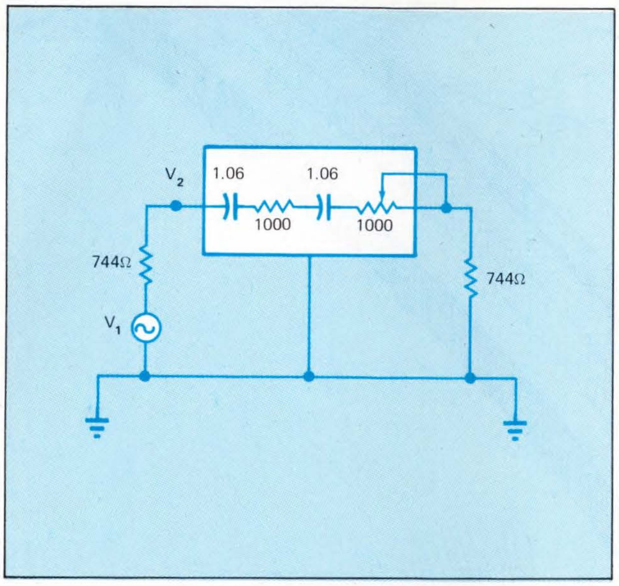


Fig. 8—GIC section alignment procedure used to compensate for component tolerances.

plied as shown. Repeat the procedure for each GIC. The completed FDNR filter circuit in **Fig. 7a** contains fourteen capacitors, the minimum number for a fourteenth order network. Furthermore, 12 of these capacitors will always be identical in value. In general, for an Nth order design, (N-2) capacitors will be identical in value. This is a distinct advantage in the fabrication process. Also note from **Fig. 7a** that all GICs have resistive connections to ground to conduct bias currents to the amplifiers. The sensitivity performance of this type of ladder structure is extremely good because it is basically a direct simulation of the inherently insensitive LC ladder.

GIC methods of simulating inductorless filters are particularly recommended for the high-quality designs in which Q factors are typically in excess of 20. Furthermore, it is interesting to note that the elliptic highpass and elliptic lowpass are easily realized, producing stopband zeros of transmission, by simply introducing extra shunt-arm capacitors for the highpass and extra shunt-arm resistors for the FDNR lowpass. ☐

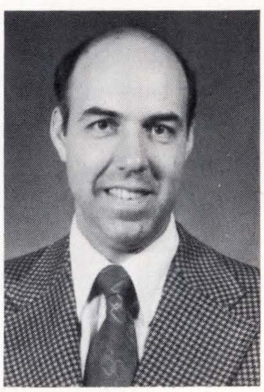
References

1. J. Gorski-Popiel, "RC-active synthesis using positive-immittance converters", Electronics Letters, vol. 3, no. 8, pp. 381-382, August 1967.
2. A. Antoniou, "Realization of gyrators using operational amplifiers, and their use in RC-active-network synthesis", Proc. IEE (London), vol. 116, pp. 1838-1850, November 1969.
3. L. T. Bruton, "Nonideal performance of two-amplifier positive-impedance converters", IEEE Trans. Circuit Theory, vol. CT-17, no. 4, pp, 541-549, November 1970.
4. L. T. Bruton, "Network transfer functions using the concept of frequency-dependent negative resistance", IEEE Trans. Circuit Theory, vol. CT-16, pp. 406-408, August 1969.
5. R. H. S. Riordan, "Simulated inductance using differential amplifiers", Electronics Letters, vol. 3, no. 2, pp. 50-51, February 1967.
6. H. J. Orchard and D. F. Sheahan, "Inductorless bandpass filters", IEEE J. Solid-State Circuits, vol. SC-5, no. 3, pp. 108-109, June 1970.
7. H. J. Orchard, "Inductorless filters", Electronics Letters, vol. 2, pp. 224-225, June 1966.
8. L. T. Bruton, "Circuit techniques for use in microelectronic communication and control systems", Ph.D. dissertation, University of Newcastle upon Tyne, England, November 1969.
9. P. R. Geffe, *Simplified modern filter design,* Iliffe Books Ltd., 1963.

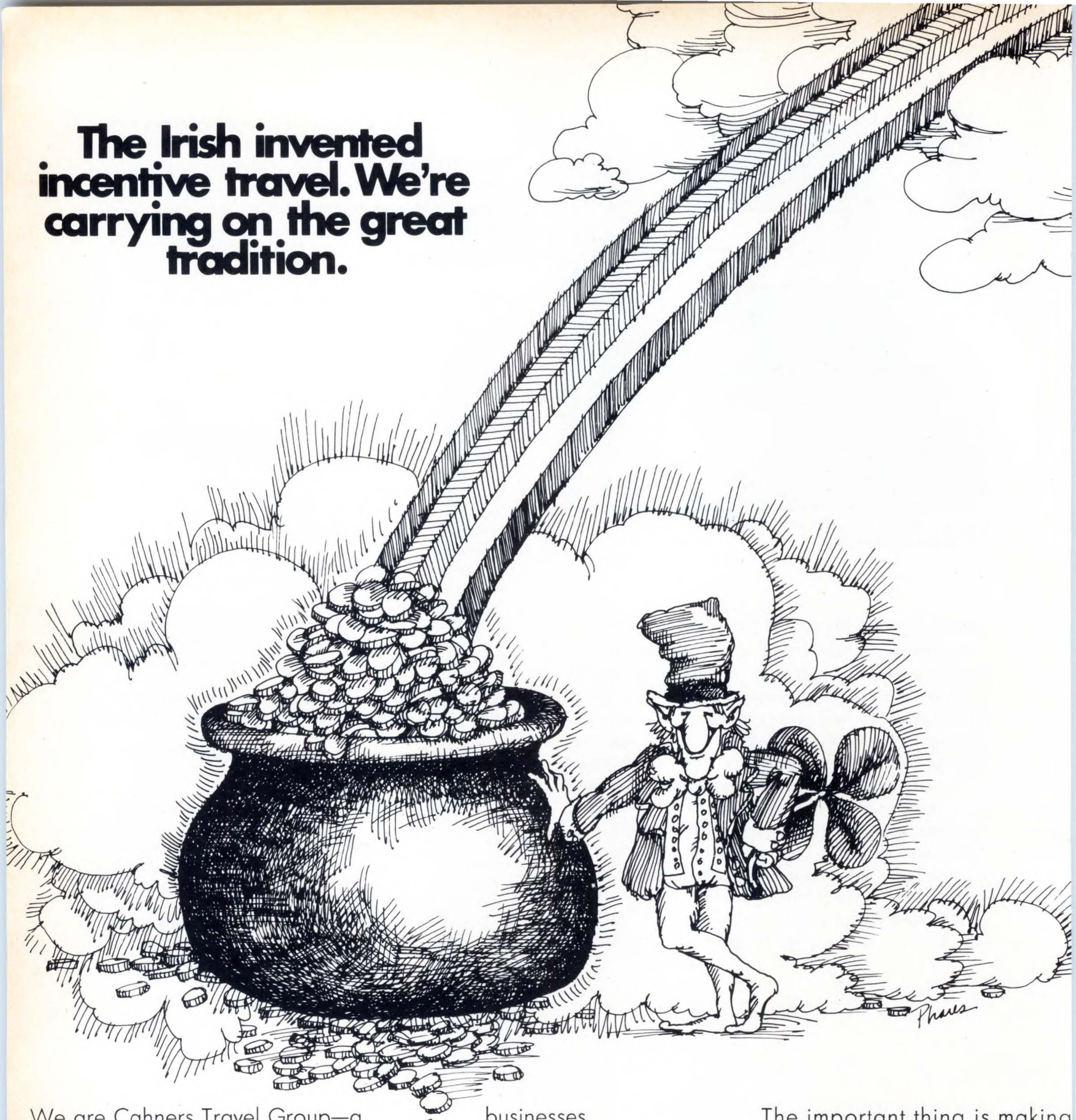
Author's biography

Dr. Len Bruton is associate professor in the Department of Engineering, Univ. of Calgary, Alberta, Canada. He taught previously at the Univ. of Newcastle upon Tyne, England. Len received his B.S. from Univ. of London, England; his M Eng from Carleton Univ., Canada, and his PhD from Newcastle Univ., England.

Dave Treleaven is a linear IC development engineer for Microsystems International, Ottawa, Canada. His chief responsibility is design and development of ICs for communications. Dave had previous stints at Canadian Westinghouse and TRW Semiconductor. He received his BASc from Univ. of British Columbia.



The Irish invented incentive travel. We're carrying on the great tradition.



We are Cahners Travel Group—a division of Cahners Publishing, publishers of this magazine and 28 other leading business journals.

We're one of the largest travel organizations in the country, with some 30 offices in the U.S. and Canada.

Cahners Publishing specializes in business information, Cahners Travel specializes in business travel. In particular, in incentive travel programs for small, medium and large businesses.

We handle these programs from inception, working out the details of the incentive system, its implementation, the travel plan, the trip itself (we go right along to make sure things go smoothly)—all the way to follow-up programs that set the stage for your next year's sales goals.

We do all this a little better because we know business and we know travel.

The important thing is making certain the award winners get to the end of their rainbow—Paris, Rome, Spain, the Caribbean, Hawaii, wherever it is—and have a whale of a time while there.

When you call us we can't promise that a leprechaun will answer—but a Cahners business travel expert will.

CAHNERS TRAVEL
a division of Cahners Publishing
205 E. 42 St., N.Y., N.Y. 10017 (212) 679-2100

An engineer's guide to configuration management

Here's an approach to product development that can improve quality, lower costs and insure that schedules are met.

Thomas T. Samaras, Universal Monitor Corp.

Configuration management is a practical discipline devoted to reducing costs, maintaining schedules, and assuring that a product meets its requirements. Although configuration management is a part of the larger field of systems management, its usefulness extends well below the systems level and can be effectively applied to smaller products on a day-by-day basis by the practicing engineer or engineering manager.

Many of the principles of configuration management are well known to engineers and are practiced to some extent by most companies. The purpose of this article is to show the approach to and advantages of a complete and coordinated configuration management procedure.

What is configuration management?

Configuration management is a cross discipline that requires the participation of many diverse functions in the company. However, the working engineer is the keystone in its successful implementation and becomes involved in its activities at the inception of a product development/production project. The tools for effective configuration management are familiar to all engineers **(Table 1).** They include specifications; drawings; parts lists; numbering systems; engineering data records; and status reports on changes, hardware configuration, and documentation. What configuration management does is bring these tools together under a coordinated and integrated program of management which improves efficiency and the end product.

The rest of this article describes the elements of configuration management and shows by means of practical examples how it can help engineers avoid problems, confusion or disaster.

TABLE I – CONFIGURATION MANAGEMENT TOOLS

Specifications:	Documents that identify the major characteristics and requirements of the item to be designed and built. They also contain numerical design limits.
Engineering data:	Drawings, parts lists and wire lists that describe the configuration of the item being designed or built.
Change system:	A method for evaluating, approving, processing and controlling changes to the requirements or configuration of an item.
Numbering and nomenclature system:	A method for systematic identification of parts, components, subassemblies and end items.
Change and configuration status reporting system:	A system for informing staff and management of change status and present configuration of product.
Records:	Documents that contain all relevant data needed or used for the fabrication, inspection and test of items.

Specifications

Specifications are the initiating basis for most engineering work. Without them, one is literally shooting in the dark. On large programs, specifications are usually plentiful; but when a chief engineer asks one of his engineers to develop a circuit for an amplifier, he may omit a written specification and depend on verbal inputs. This informal method of specifying requirements often results in a circuit that doesn't do what it was intended to do or at least wasted time and labor through modified requirements and clarifying instructions that require circuit redesign. To save time and money when no written requirements are given, the engineer should develop his own list of requirements based on the verbal inputs received. He can then fill in missing requirements and clarify doubtful ones with a brief review of his document with the chief engineer.

Of course the existence of a written specification doesn't mean everything is all right. It may have important omissions, errors, or ambiguities that should be resolved before beginning design work. If a requirement seems unrealistic, it should be discussed with the originator. Perhaps the requirement can be changed to a design goal in recognition of current technological limitations.

Change management

The electronics industry is one of the most dynamic industries in the world. In fact "change" is almost synonomous with "electronics." Yet the handling of changes is often done on a random or semi-systematic basis. Change management is a formal method for making changes to a circuit, component or product. It involves these steps:

- Formal identification and description of change.
- Evaluation of change in terms of cost, schedule, requirements and its impact on other components.
- Approval or rejection of the change document or return for its revision.
- Implementation of change.
- Verification that change has been incorporated in documentation and hardware.
- Reporting status of the change and product configuration.

On complex programs, each of the above steps may require documentation, while for simpler projects they can be performed partially in documented form and partially in verbal form. The key documents in this approach are the change request and the engineering order, which describes the exact nature of the change.

Although most engineers balk at justifying design changes on forms, such as the one shown in **Fig. 1,** these documents have definite advantages:

- They force the engineer to consider all aspects of the change. Thus the benefits can be weighed against the disadvantages before submitting the proposed change for approval. In doing this, the engineer may find that the change isn't worth its cost of implementation, thereby avoiding wasting the time of others.
- They provide a record of the cost of changes during a project, thus yielding historical data for making better engineering estimates in the future.
- They allow management, with its better perspective of overall requirements, to evaluate the proposed change before too much engineering time has been wasted.

Of course, many changes considered during the design and development stage don't require management approval. For instance, design corrections, drafting errors, or design improvements that don't affect the basic specifications generally need not be submitted for approval. However, the engineer may find that some specifications

CHANGE REQUEST CR No. ______ Date ______

Job No. ______ Priority: Urgent ______ Routine ______
Part Number ______ Part Name ______

End Item Affected

Change Description

Reasons for Change

Cost of Change		**Schedule**
Labor	$ ______	Go-ahead Date ______
Material	$ ______	Completion Date ______
Fixtures	$ ______	Overall Schedule Delay ______
Equipment	$ ______	
Other	$ ______	

Other Items Affected (Hardware, Documents, Interfaces)

Originator: ______ Date ______ **Approved By:** ______ Date ______

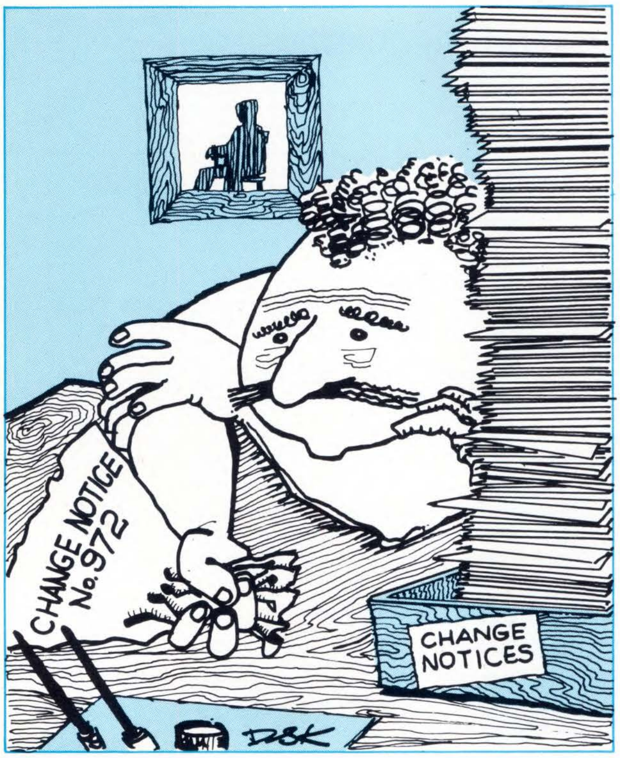
Fig. 1 — A formalized change-request procedure forces both engineering and management to consider all aspects of a proposed design change.

are unrealistic or can be improved upon considerably by using special or new techniques, but at higher development or production costs. In these cases, management approval should be obtained before proceeding.

Once the official engineering design has been released for production, almost any type change affecting the function, form or fit of the end item should be recorded on a change request. When this form is approved, an engineering order is prepared describing the exact changes to be made to drawings, parts lists, etc. This document is then distributed to all responsible persons on the project.

Do you need a formal change request system? It depends on your present requirements and problems. If changes are not extensive and no major problems exist, its use may be avoided. However, if an engineer if frequently criticized for making unnecessary and expensive changes, a change request form may help reduce this problem by giving management a chance to participate in decisions that can affect company profits and performance. It also provides the engineer with records in case he is criticized for making unauthorized changes in the product.

As mentioned before, not all changes need be recorded on a change request form. However, the following types should always be submitted in writing to management:



Configuration management is necessary in an industry where change is frequently the order-of-the-day.

- Changes affecting schedule
- Changes increasing costs by more than a certain amount defined by management
- Changes resulting in significant improvement of performance characteristics
- Changes affecting safety or reliability
- Changes affecting the specification or configuration
- Changes which will reduce life-cycle costs

Promoting integrated operations

Because configuration management has a cross-disciplinary nature, it promotes integrated operations. For instance, understanding the principles of configuration management increases sensitivity to the needs and problems of other operations or departments. Thus, the engineer becomes more aware of the impact of certain product changes on other functions, such as planning, drafting, manufacturing, procurement, testing and publications.

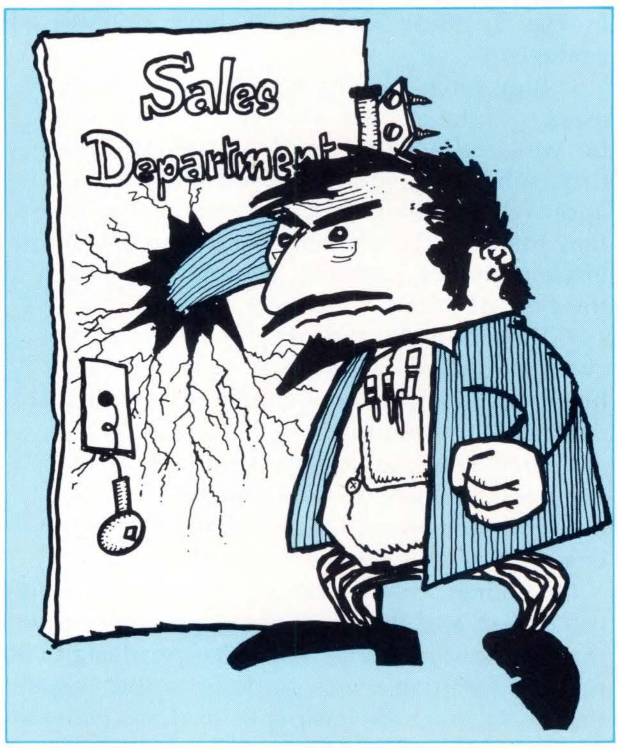
A key area which has considerable value to the success of a company is the increased interaction and integration between engineering and marketing/sales. If the company's management philosophy includes early involvement of sales people in the product life cycle, they are vitally interested in the product's configuration, specification, schedule and cost.

A sales engineer who is doing his job has already begun working on the promotion of the product and may have begun contacting potential customers. Therefore, he must be informed of changes to product specifications, configurations, etc., on a timely basis to minimize misleading customers on the cost, characteristics or delivery of the product. The distribution of specification changes, revised top assembly drawing, schedules, etc. to him can help avoid embarrassing situations. In addition, he may provide valuable information to engineering about the impact of a reduced performance characteristic on the marketability of the product. If potential customers consider this a key feature, engineering may have to reconsider the decision to relax the specification, even though the technical problems that must be overcome are difficult and expensive ones.

Handling change suggestions

Whether a product is being designed for someone within the company or for a customer, changes cost money and time. An engineer can be subject to numerous change requests, ranging from adding a few extra test points to the chassis to increasing the performance capabilities of the product. Once the product's configuration and specifications have been officially defined, change requests should be written and processed by the requester through management before they reach the engineer.

Of course, this is often not the case and the engineer is contacted directly. As a result,



Increased sensitivity to the needs of other departments is promoted by configuration management.

changes are made on informal requests to maintain friendly relations and to avoid red tape and delays. If these change requests are minor and rare during the entire project their effect will be insignificant. However, if changes are being funneled to the engineer on a regular basis, the project schedule and cost will suffer and the engineer will be blamed for a poor job.

Since most engineers will find it easier to comply with an informal change than to tell the requester that he should get written instructions to authorize increased funds, a formal, explicit and closely supervised policy of no informal change requests is needed. Thus, if perturbations to the product are to be minimized, management must take the responsibility for shielding engineers and even the project manager from informal requests for changes.

If management is not convinced of the cost involved in even simple changes, the engineer can point out that the replacement of even one resistor in a drawing which has been released to production can increase labor significantly. For example, the following operations could be required for such a "simple" change:

1. Engineer must verify that size, wattage and tolerance are compatible with circuit.
2. Engineer must obtain a few samples from local supply house if resistor is not in stock.
3. Engineer must add new resistor in breadboard and verify that the circuit works as expected.
4. Engineer must prepare engineering orders to change drawings and parts list. Approval must also be obtained.
5. Engineer must bring the engineering order to data control for release to purchasing and production.
6. Data control must update status record and prints and distribute copies of engineering order.
7. Everyone who received a copy of engineering order must review it to determine whether it affects him.
8. Manufacturing engineer must change assembly instructions and make sure engineering order is attached to affected drawing.
9. If unit has already been built, it must be recalled from stock and reworked, retested and re-inspected.
10. Purchasing has to prepare a purchase order and process it if the resistors are not stocked.
11. Shipping and receiving must inspect incoming resistors, identify them and deliver them to stock room.
12. Material control must update kits of parts for assemblies by removing old resistors and adding the new ones.
13. Material control must update inventory records.

While the time required for each operation may not be more than one half hour, the total time required to implement this change is going to be more than the simple sum of steps 1 through 13. The perturbations and shock waves that result because of the many diverse people and operations involved can result in a time cost considerably greater than expected. Therefore, it is likely that the above simple case could result in a burdened cost of more than $200.

Besides the time and cost factors, the impact of even a simple change on other circuit elements can be greater than appears at first look. For example, a minor change in the timing of an outside pulse in one circuit can at first appear to involve nothing else. However, once it is installed in the breadboard, it may be found that several other circuits have to be modified to regain the original performance desired.

Because of the complexity of electronic hardware and the current state-of-the-art, the best maxim for an engineer concerning changes is: any design perturbation to a satisfactory product or circuit will cost more in time and money then expected. (Modification of Murphy's Law.)

Early changes save money and time

The earlier an engineering change can be made, the better. As a product proceeds from the conceptual stage to development and produc-

The effects of design changes on interfaced items must be evaluated.

tion, the more expensive it becomes to implement a change. And the increase in cost and time proceeds more in a geometric fashion than a linear one. For example, a circuit change early in the project may only affect one schematic drawing. But during production it can affect several drawings and parts lists as well as procurement, material control, inspection, manufacturing and testing functions. Many operations may thus be required to implement a simple change. Therefore, trying to save time and money by skipping careful review of drawings and thorough evaluation of the breadboard can be extremely expensive.

Interface considerations

Every circuit, component and product/end item must interface with other circuits, components and end items. Therefore, explicit consideration of interface factors is required. To avoid catastrophic or embarrassing results, a helpful device is to identify all the items (including human) that the end item will have to mesh with. Then each of these interfaces can be examined from the point of view of input and output requirements. If information on the items that will be interfaced with is not available, then a list of interface requirements should be obtained from the person who gave the assignment.

If firm interface specifications can't be obtained, then the boss should be notified that certain assumptions about interfaces will be made and that if these turn out to be wrong, the project's budget will be overrun. Mechanical as well as electrical interface requirements are needed, since the shape, weight, mounting and material of the assembly housing may be critical design areas.

Uncontrolled access to drawings can result in unauthorized design changes.

When assessing the impact of a design change, its effects on interfaces must be explicitly evaluated, especially if the engineer is responsible for only a small part of a larger system. Minor increases in power consumption, weight, size and electromagnetic interference can cause serious repercussions that can undermine the entire system. Of course, changes in input/output signal levels, impedances and noise levels can also cause serious problems.

Test equipment shouldn't be forgotten. Changes in product design may require changes in special or conventional test equipment. The product engineer should get together with the test equipment engineer to discuss what changes are needed and when.

Engineering changes may also affect subcontracted items. Therefore, be sure to formally notify each subcontractor of changes that could affect his work. If its affect on his work is not certain, he should be contacted to evaluate it. This step may help avoid having an apparently insignificant change cause serious problems on a subcontracted item. For example, what appears to be a minor mechanical design change to accommodate some additional circuit boards may require scrapping completed housings.

Controlling access to vellums

What about the integrity of released drawings? When drawings have been signed off for release to manufacturing, can the engineer be sure that a designer or draftsman can't make changes to them without his knowing about them? Uncontrolled access to drawings is officially taboo in most companies; but is the system for vellum control strictly followed? If an engineer can walk into data control and have the vellum released to him without documented authorization, then others can probably do the same.

The consequences of unauthorized changes can range from none to a critical malfunction of the end item and injury to personnel. In addition, the responsible engineer will be blamed for approving such a design. Even when someone else tampered with the vellum, if the change is undocumented, it's up to the engineer to prove that an unauthorized change was made.

While the responsibility for the document control operation lies with someone else, the engineer is in an excellent position to observe the effectiveness of the system and whether it is being followed by the staff. When it is not, a conference with the chief engineer and data control manager can help correct the situation and avoid future difficulties. If a formal procedure defining the method for obtaining the original for changes after release doesn't exist, a meeting with interested staff members may be necessary to obtain one.

In essence, an undocumented design change can result in (1) having the wrong parts or missing parts when the item is ready for manufacture or (2) incorrect manufacturing instructions. When this occurs, a well planned production effort can become bogged down.

Advance releases

The user of advance releases of critical documents is a technique for officially issuing incomplete drawings and parts lists so that receipt of long leadtime items or quotes on subcontract items can be obtained as soon as possible. Planning, drafting and manufacturing can also obtain valuable information from advance document releases to begin their work before the documents are released for production.

The things that the engineer should watch out for in using advance releases are that they are stamped in large red letters, ADVANCE RELEASE, and that the production release is made as soon as feasible and copies distributed to all those working with the document. When possible, advance copies should be collected and destroyed after formal release.

Part number reidentification

Although the electronic engineer is not responsible for the actual reidentification of a product or component, he is the one who determines whether a design change will make items built to the latest drawings functionally or physically noninterchangeable with previously built items. Proper identification of items, such as printed circuit boards, is extremely important in the repair and replacement of defective boards in the field and in the stocking of replacement boards. If interchangeable boards are identified with different numbers, excess replacement parts will be stocked in the home plant and at repair centers.

Identification of noninterchangeable boards with the same number can cause even more serious problems, such as equipment damage or excess troubleshooting to determine that the replacement board is not identical to the previously used one.

To minimize problems in this area, the engineer should familiarize himself with the part number identification system being used and the method for indicating noninterchangeability, and should always notify the designer and draftsman that a new part number is necessary.

Documenting retrofits

Changes to delivered products are often necessary, especially for an advanced design product. Failure to document and report these changes to the correct people can have several expensive consequences:

- Other field engineers may have to repeat the design modification.
- The original engineer or project manager will not update the released engineering documentation, such as drawings and parts lists.
- In-process products will not have the change made to them during production.
- Support groups will not update their documents, such as operation and maintenance manuals and test procedures.

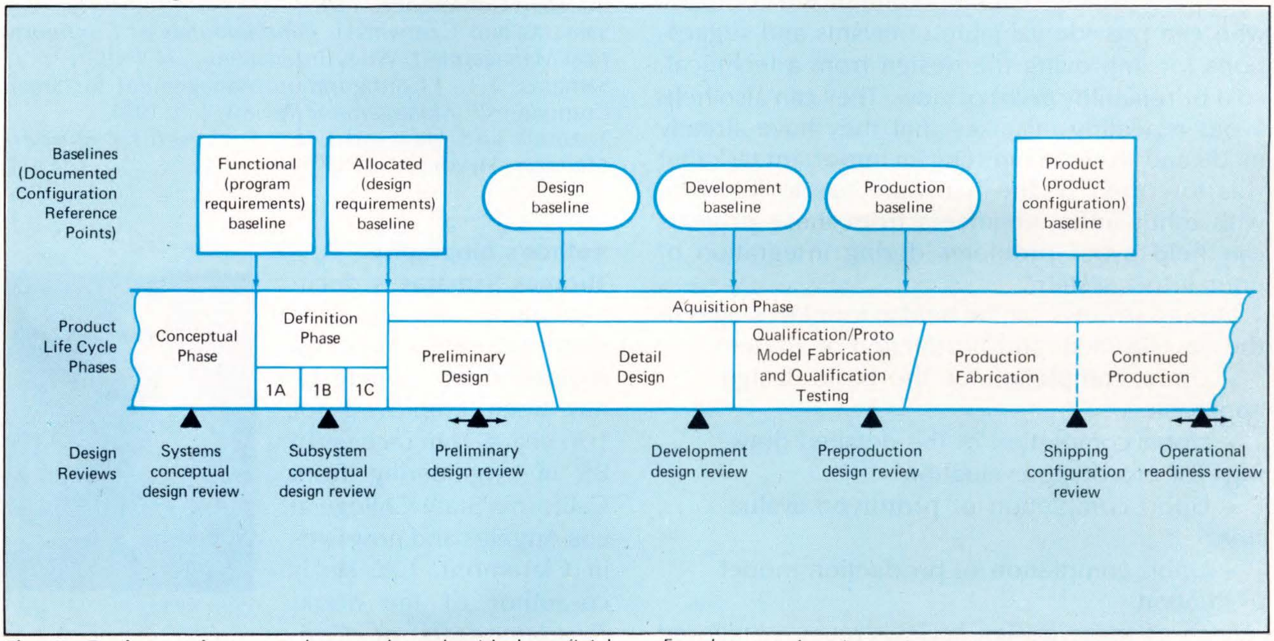


Fig. 2—Design reviews can be conducted with beneficial results throughout the life cycle of a product. *(Adapted from Fundamentals of Configuration Management—see bibliography).*

Do you need configuration management?

Knowing the elements of configuration management is one thing, but how do you know when more attention, or even drastic action, such as a network of formal procedures, is needed in your company? The following can serve as a checklist of problems that require immediate attention:

- Final product doesn't match original requirements or engineering data/documentation.
- Information on changed designs is not reaching the people who need it soon enough to minimize delays and expenses.
- Design changes are not being incorporated into production hardware.
- Conflicts and mutual recriminations are increasing due to poor inter-departmental communication and notification of design changes.
- Long leadtime items are not being ordered or received on time.
- Engineers are spending too much time detecting and correcting design errors or omissions that should have been caught earlier.
- Subcontracted items are not satisfactory in terms of configuration, performance and interface factors either because of failure to provide positive change requirements notification or because of poor configuration management techniques on subcontractor's part.
- Drafting and production costs are increasing due to many design changes after drawings have been released to production.
- Numbering, release, approval, etc., procedures are being constantly changed; no fixed or stable system being followed. Also notification of change procedures is not reaching the people with a need to know.

- Increased malfunctions will result in customer dissatisfaction and may affect future sales.

To avoid these problems a retrofit report should be completed whenever a field change is made, and sent to the home plant for updating production drawings.

Design reviews

Because design reviews are not officially required for a project doesn't mean that they can't do some good. The purpose of a design review is to obtain the benefits of pooled experience. There are usually several people in the company who can provide valuable criticisms and suggestions for improving the design from a technical, cost or reliability point of view. They can also help avoid repeating mistakes that they have already made and to avoid omitting an important task that was forgotten. If the hardware has to interface with other units, engineers from these projects can help avoid problems during integration of units into a system.

Design reviews can be held at four key stages in the development and production of an item:

- Upon completion of the basic design approach
- Upon completion of the detailed drawings for prototype evaluation
- Upon completion of prototype evaluation
- Upon completion of production model evaluation

Each of these design reviews must be tailored to the stage of development of the product. A series of design reviews for a product's life cycle is shown in **Fig. 2.**

The key output of a design review should be a list of action items that must be accomplished. The responsible person and completion date must be recorded. Once the list has been released, follow-up is necessary to ensure that all action items are being implemented or have been completed. □

Bibliography

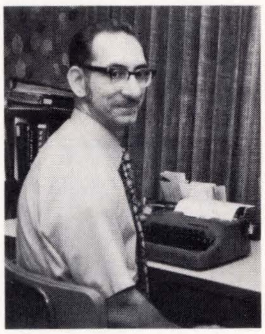
Kempter, R.H., "The New Approach to VE Changes Through Configuration Management," Proceedings of the Save Conference, 1970.

Samaras and Czerwinski, *Fundamentals of Configuration Management,* Wiley-Interscience, N Y, 1971.

Samaras, T.T., "Configuration Management for Small Companies," *Management Review,* July 1970.

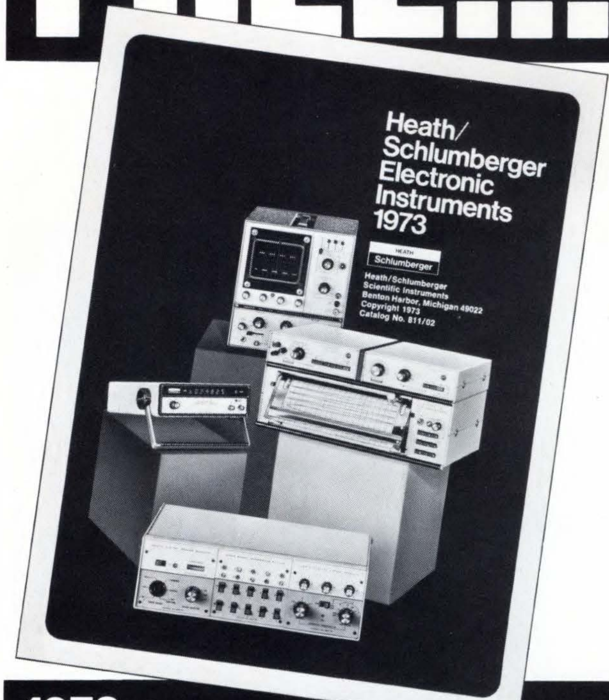
Turmail and Haavind, *The Successful Engineer-Manager,* Hayden, N Y, 1971.

Author's biography



Thomas Samaras is documentation and controls manager at Universal Monitor Corp., where he has been employed for 1-1/2 years. Tom received a BS in engineering from California State College at Los Angeles and now lives in Claremont, CA. He is co-author of the book, *Fundamentals of Configuration Management.*

FREE...



1973 Heath/Schlumberger electronic instrumentation catalog.

The new '73 Heath/Schlumberger instrumentation catalog is here...52 pages of high performance electronic equipment ...all at budget-stretching prices. Whatever it is that you need in electronic equipment for test and design work, R&D applications or for teaching, Heath/Schlumberger has it... at less than you planned to spend. 600 MHz frequency counter with 7-digit LED readout and complete programmability for only $795* (left)...dual trace 15 MHz scope only $595*...multi-range, multi-speed strip chart recorder system just $675* ...a patchable mini-computer interface system, just $1250* ...the famous Malmstadt-Enke Lab Stations...dozens of plug-in circuit cards...power supplies...generators...digital multimeters...and hundreds of other instruments. To get your FREE copy of this catalog now, visit your local Heathkit Electronic Center or use the coupon below.

HEATH
Schlumberger

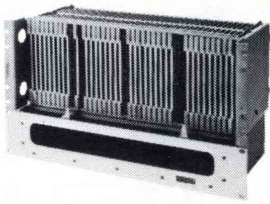
Heath/Schlumberger Scientific Instruments
Dept. 581-232
Benton Harbor, Michigan 49022

☐ Please send 1973 Electronic Instrumentation catalog.

Name ______________________
Title ______________________
Company/Institution ______________________
Address ______________________
City __________ State __________ Zip __________

Prices & specifications subject to change without notice.
*Mail order prices; F.O.B. factory. •EK-355

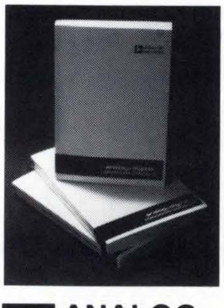
CHECK NO. 36



Everything-in-one-cage basic RAM system made up of everything-on-one-card memory modules. Up to 32K Bytes. Very fast: from 150 ns access time, 180 ns cycle time. Priced lower than any other memory system in this speed range. Consumes less than half the power of any system of equivalent speed. Highly reliable. TTL design comes with either driver-receiver or Tri-State outputs. Cooling kit and power supply offered as option. Two series are available: BSM 4000 holds up to 16K Bytes, BSM 8000 holds up to 32K Bytes. Cages fit standard 19" racks. **Ideal for industrial test equipment and incremental add-on memory for special purpose computers.** Write for complete information. Better yet, call for fast delivery. From the people who really know memories: **Electronic Memories & Magnetics,** Phoenix Semiconductor Facility, 3883 North 28th Avenue, Phoenix, Arizona 85017. Phone: (602) 263-0202.

CHECK NO. 30

Analog Devices' A-D Conversion Handbook.



Everything you need to know to know everything about converters.
$3.95.

It's all here in one big book. Over 400 pages of practical information that'll help you understand, specify, and apply A/D and D/A converter products. A complete explanation of how to use converters and other analog components to acquire and distribute data in a wide variety of instrumentation and control systems, automatic testing, communications and signal analysis, CRT displays, lots of other applications.

From the people who make more kinds of A/D and D/A converters than anyone else. Us.

Just send us this coupon and a check for $3.95, and we'll send you the handbook.

ANALOG DEVICES

Please send me a copy of the *Analog-Digital Conversion Handbook.*
☐ Enclosed is my check for $3.95. ☐ Please bill me later.

Name ______________________
Company __________ Dept./MS __________
Street ______________________
City __________ State __________ Zip __________

Mail to: Analog Devices, Inc., Box 796, Norwood, Mass. 02062

CHECK NO. 32

EDN DESIGN AWARDS

Poor man's LED driver is TTL compatible

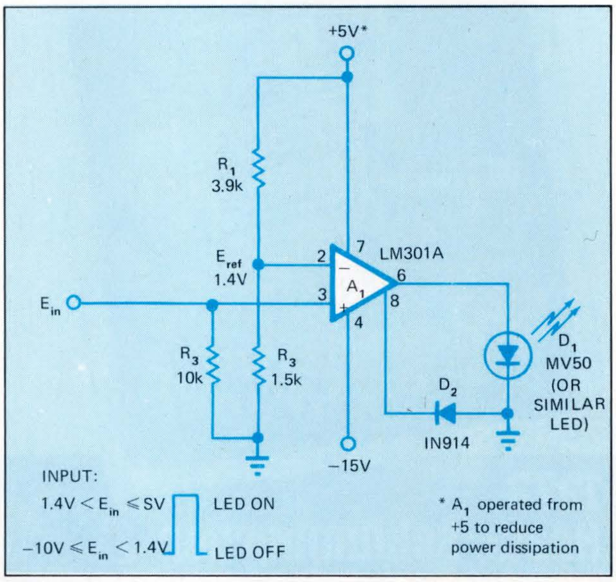
Walter G. Jung
Forest Hill, MD

A simplified, unique and quite economical LED driver can be built by taking advantage of the internal current limiting and ability to voltage clamp an op amp of the 101 family.

The circuit uses an LM301A as an open-loop voltage comparator, A_1, with LED D_1 connected to receive the total source current from A_1. For positive outputs of A_1, the low forward impedance of D_1 will cause A_1's internal current-limit stage to conduct and deliver the full I_{sc} + to D_1. For negative output swings of A_1, D_2 clamps the output to $-0.5V$, preventing reverse breakdown of D_1.

The circuit realizes the full available open-loop speed of A_1, since the amplifier is uncompensated and the internal voltage amplification stages are kept out of saturation by the clamping of D_2 and the current-limiting action. Therefore, D_1 may be toggled with response times in the μsec range.

The approximately 20 mA of current available for D_1 is compatible not only with the MV50 but also with a number of other LED types, including the popular LED-phototransistor isolators. The circuit, as shown, uses a TTL-compatible input, with the R_1-R_2 reference divider biasing A_1 in the center of the TTL output transition region. Other input configurations are possible, of course, as long as the input common-mode limits of A_1 are observed.



Microsecond toggling of LEDs is possible with this LED driver. The circuit is TTL compatible, and the output is current limited.

The circuit offers two-to-three orders of magnitude, better voltage and current sensitivity at the switching threshold compared with a simple transistor saturated switch. It also has the bonus of a temperature-stable threshold level for voltage monitoring applications. ▭

To Vote For This Circuit
Check 150

Make exceptionally stable and linear light measurements

C. D. Royce
Intel, Inc., Santa Clara, CA

Phototransistor collector current is expressed as:

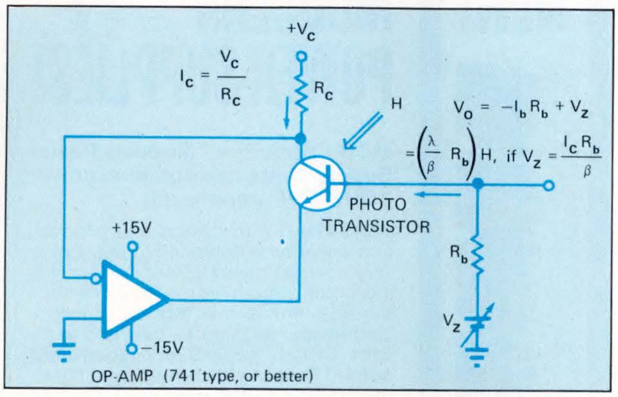
$$I_c = \beta I_b + \lambda H,$$

where λ is the light sensitivity factor in $\mu A/mV/cm^2$. The normal light measurement technique is to measure I_c once λ is known for the particular device being used. However, λ varies significantly with temperature, collector current and light intensity (H), thus making it almost useless for precision measurements. By regulating I_c to a fixed value, as accomplished by R_c and $+V_c$ in the diagram, base current may be expressed as:

$$I_b = \frac{I_c}{\beta} - \frac{\lambda}{\beta}H$$

Note that base current becomes negative when H exceeds a critical value, thus giving a positive voltage V_o.

A low-impedance voltage, V_z, on the order of millivolts "zeroes out," the $-\frac{I_c}{\beta}R_b$ contribution to V_o with reasonable time stability to make 0.1% measure-



With this arrangement, V_o/H is constant until $-I_b$ exceeds approximately 1.2 I_c.

ments. Or, a mechanical method of "chopping" the light from O to H mV/cm² can be used to produce a square wave on V_o that is easily measurable with a precision ac voltmeter to totally eliminate the $\frac{I_c}{\beta}R_b$ error.

Measurements show that $\frac{V_o}{H}$ is constant until $-I_b$ exceeds approximately 1.2 I_c, depending on the device, and that the $\frac{\lambda}{\beta}$ ratio is independent of collector current and temperature. Also, the $\frac{\lambda}{\beta}$ ratio has a much narrower range of variation than λ (about ± 30% from unit to unit as opposed to a 20:1 range for the same transistor type) and is even reasonably close between various transistor types, including photodarlingtons. □

To Vote For This Circuit
Check 151

Ac-to-dc converter uses integrated circuits

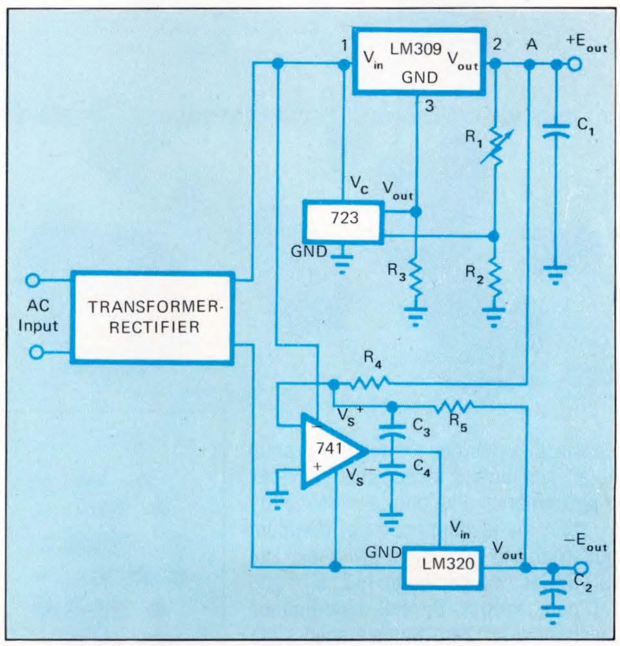
Eugene R. Hnatek
Signetics Corp., Sunnyvale, CA

This unique approach to ac/dc converter design uses integrated circuits as the semiconductor components. Discrete transistors and diodes are not used because of their inherent lack of fail-safe features as well as due to the present availability of power regulator ICs at reasonable costs.

The converter is completely foolproof. Both the LM309 and LM320 voltage regulators have internal current limiting to limit peak output currents to a safe value. Also, thermal shutdown is provided to keep each IC safe from overheating. Each regulator is thus "blow-out" proof.

The 741 op amp is also a foolproof device. It has internal overload protection on the inputs and output; it doesn't latch up when the common-mode range is exceeded; and it is also free from oscillation.

The circuit operates in the classical manner: an ac voltage is applied to a transformer and rectifier to obtain raw, but useable, positive and negative dc voltages. These voltages are fed, respectively, to the LM309 and LM320 series regulators to obtain the desired output voltages. In this circuit, both the LM309 and LM320 are used as positive and negative regulator pass transistors due to their high current capabilities and foolproof protection features. The 723 regulator is used only as a precision voltage reference which regulates the ground terminal of the LM309.



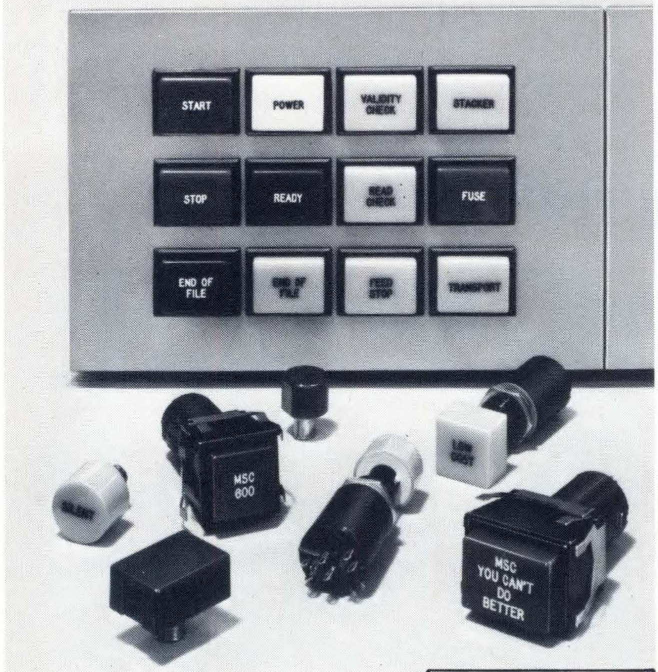
ICs replace the conventional discrete transistors and diodes in this ac-to-dc converter.

Resistors R_1 and R_2 are used to set up the positive output voltage and as a supply to the 723 reference. The 741 is used to invert the positive voltage to a negative voltage for the 320. The connection point A on the positive output is fed back through R_4 to the inverting input of the 741 to enable the negative output to track the positive output. Capacitors C_1 and C_2 are used to smooth

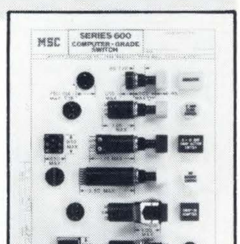
"computer-grade" lighted pushbutton switches from MSC

quality & reliability

for under **$3.00** in production quantities



Here is a low-priced "computer-grade" lighted pushbutton switch that provides top performance and long-term reliability from the leading maker of premium industrial and aerospace switches. The MSC Series 600 comes in 1, 2, 3, 4 and 6 pole, form A, B, or C, Low-Bounce mechanical or Zero-Bounce solid-state logic p.c. board versions. It is available with alternate action or momentary action in silent or tactile-feel operation that is fast enough to handle switching of most any high-speed electronic logic systems. Mechanically rated to last over one million actuations. You'll get more for your money at MSC!



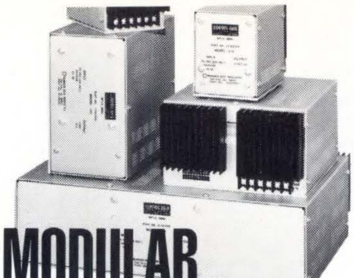
Write today for new catalog and product selector guide

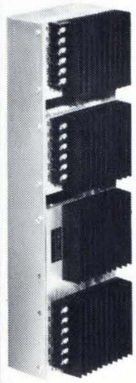
MSC *. . . you can't do better!*

MASTER SPECIALTIES COMPANY

1640 Monrovia, Costa Mesa, Calif. 92627 • (714) 642-2427 • Telex 678-433

CHECK NO. 31





NEW! MODULAR POWER SUPPLIES!

MCD "Stak/Pak" Modular Power Supply Units can optimum-power YOUR EDP peripheral!

VERSATILITY in design and production are almost unlimited to meet your very specific needs! Stak/Pak "building-block" modules—consist of four models, three mechanically interchangeable packages—deliver 5 to 24 volts DC/2.0 to 35.0 amp ***controlled*** output! They put the power-punch into lowest-cost-to-the-user over the life of the product.

CAPITALIZE on MCD's 15 years' know-how in meeting **Control Data® 's**"inside needs." Send for the MCD Stak/Pak Modular Power Supply fact brochure.

MAGNETIC COMPONENTS DIVISION

CONTROL DATA CORPORATION

7801 Computer Ave. So., Minneapolis, Minn. 55435
(612) 920-8600 TWX 910-576-2978

CHECK NO. 29

Introducing the expensive dual-trace scope that doesn't cost a lot.

The B&K Precision Model 1470.

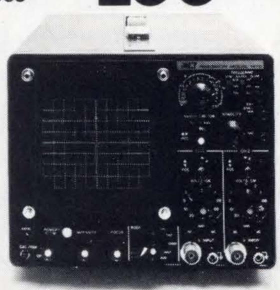
The compact 5-inch solid-state 1470 is specially designed to meet 80% of all your scope applications.

It has DC to 10 MHz bandwidth with 10 mV/cm sensitivity. Sixteen triggered-sweep speeds range from 1 μsec/cm to 0.2 sec/cm. Triggers on input signals as low as 5mV.

$499.95

Sound good? Our prices become even more remarkable once you see our specs.

Call your B&K distributor. Or write Dynascan Corporation.



Very good equipment at a very good price.

B&K

Product of
Dynascan Corporation
1801 West Belle Plaine Avenue, Chicago, Illinois 60613

CHECK NO. 33

the output voltage.

With the following component values the circuit provides a +15V, 1A output and a −15V, 1A output with a total circuit efficiency of 80%.

R_1 = 5.6k, R_2 = 5.6k, R_3 = 300Ω, R_4 = 20k, R_5 = 20k

$C_1 = C_2 = 47\mu F$, $C_3 = 0.05\mu F$, $C_4 = 0.03\mu F$

The positive output can be adjusted to any value (within the LM309's operating specifications) by means of R_1 and R_2 or by replacing the 309 with an LM340 (μA7800) fixed voltage regulator of the desired output voltage rating. The negative output can also be changed by selection of a different output voltage rating LM320 regulator. □

To Vote For This Circuit Check 152

Circuit protects power supply regulator from overcurrent

S.J. Pirkle
Hewlett-Packard, Waltham, MA

Although many regulated power supplies have current foldback, short-circuit regulator dissipation may exceed that for rated output current. This circuit provides protection by turning the power supply off upon overload and returning power after the normal load has been restored. Operation is such that the regulator and the load are both protected. If a zener-SCR crowbar is to be used, as in this illustration, an additional advantage is that shutdown extinguishes the SCR, permitting automatic restoration of power following a transient.

Referring to the illustration, a 5V regulator with an overvoltage crowbar paralleling the load is shown in an example application. Within the dotted lines are the components required for overcurrent protection. Resistors R_1 and R_2 act as a voltage divider. At maximum current, resistor R_3 and the load provide voltage division equal to that of R_1 and R_2. Together, these dividers form a bridge. When the voltage at the noninverting input to U_2 falls below that of the inverting input (overhead), Q_1 switches off, immediately removing voltage to the load.

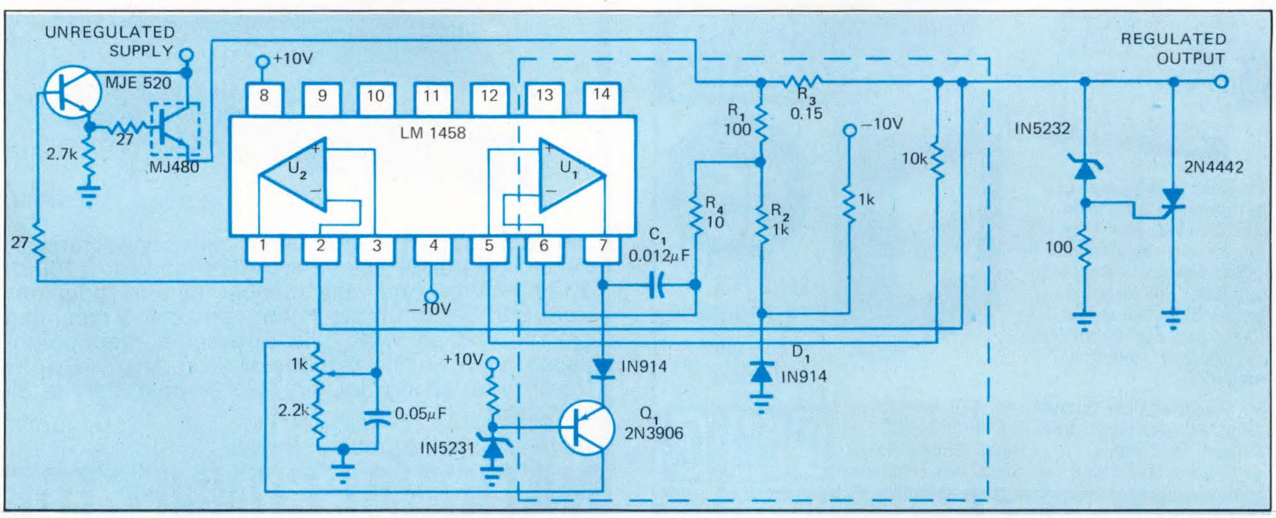
Since bridge balance is unaffected by voltage, the regulator input remains off as the output falls to ground. U_1, sourced with current from R_4 and voltage divider R_1 and R_2, then rises from ground at a rate controlled by C_1. When the output of U_1 reaches the reference voltage, Q_1 turns on, restoring power to the load.

If the fault has been removed (extinguishment of the SCR if crowbarred), the noninverting input to U_1 rises at an equal or somewhat faster rate than the inverting input, maintaining the application of power. If the overload condition persists, shutdown cycling continues, limiting average load current to a few milliamperes.

Shutdown time for this circuit may be computed by:

$$t = \frac{V_o(R_1 + R_2)\, R_4 C_1}{V_d\, R_1}$$

and is approximately one second. □



Components within dashed lines protect the regulator from overcurrent condition frequently encountered when the overvoltage crowbar is activated.

To Vote For This Circuit Check 153

Lamp test becomes circuit test

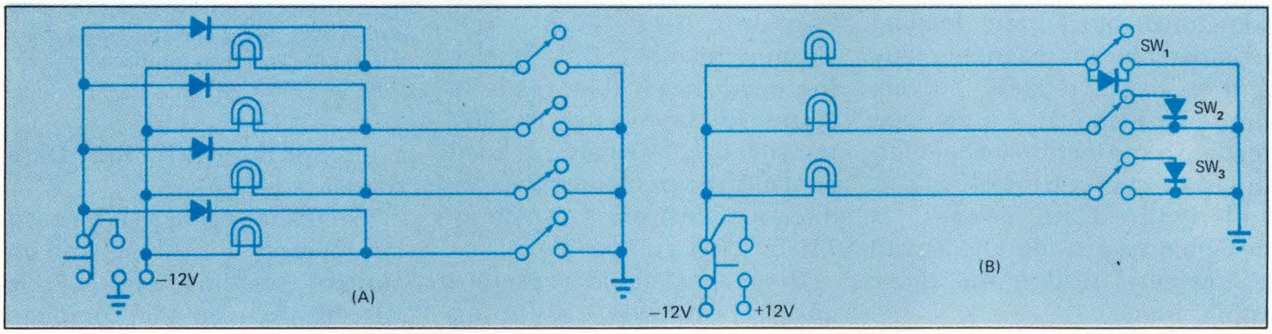
Edwin R. DeLoach
Astro-Dynamics Electronics, New Orleans, LA

Lamp test circuits commonly use diodes connected as illustrated in **(a)**. This arrangement provides a testing means to locate faulty lamps or other indicators. However, it does not check the circuit for faulty or loose connections, broken wiring or faulty sensor switches.

This can be accomplished with no additional components merely by placing the test diodes in the circuit, as shown in **(b)**.

The circuit functions as a monitor status indicator when the test switch is in the nontest position. Then when a switch completes the circuit, the lamp is energized, indicating status.

Circuit testing is provided when the polarity on the system is reversed. Thus, every switch is "shorted" by the action of the diodes. This provides lamp testing and continuity check of the entire circuit. Note that switches 2 and 3 are connected differently than switch 1. This configuration necessitates current flow through the switch contacts, and provides indications of dirty switch contacts or open wipers as well. □



Circuit continuity can be tested, as well as the lamps, by connecting the diodes of the conventional lamp testing circuit (A) as shown in (B).

To Vote For This Circuit Check 154

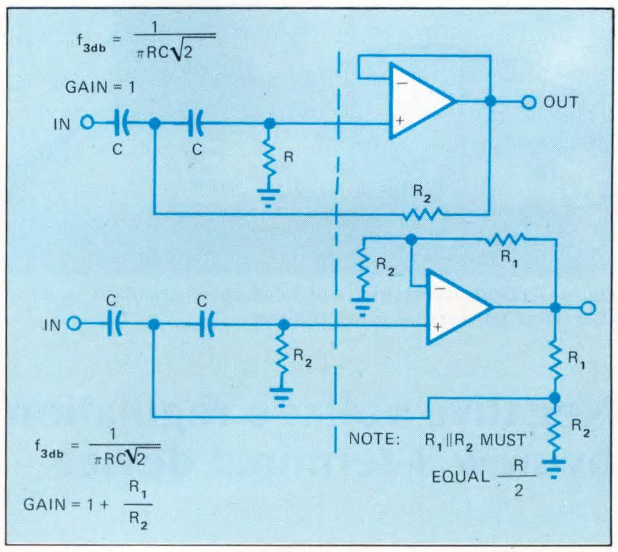
Op amp in active filter can also provide gain

Arthur D. Delagrange
Sykesville, MD

A common single pole-pair Butterworth filter (top circuit) has unity gain in the passband. Frequently a designer requires some additional gain when part of the signal is filtered out, since the amplitude of the remaining signal is normally smaller. The op amp can also provide the gain in most instances.

A modification of the circuit for this purpose is shown (bottom circuit). The filter characteristic is the same except for the gain factor shown. This can be easily shown by taking the Thevenin equivalent of the part of each circuit to the right of the dotted line. It will be the same for both cases, so the voltage at the op amp noninverting input will be the same for both circuits.

This method also works for the low-pass version of the filter, but the lower voltage divider will consist of two capacitors. The method also applies to other filter characteristics, such as Chebyshev. □



A unity gain Butterworth filter (top) can be modified (bottom) to provide gain to compensate for input-signal attenuation during the process of filtering.

To Vote For This Circuit Check 155

Punched-tape reader uses ac drive to cut data entry cost by 50%

PROGRESS IN TAPE READERS

Most punched-tape readers use dc stepping drive to advance the tape, and therefore require stepping logic to control operating modes and tape direction. For applications requiring only sequential block data loading (comparable to magnetic tape entry), these readers provide unused capability. A new tape reader from Electronic Engineering Company of California, called the Data Loader, is designed to provide OEMs with a low-cost reader for those applications.

Designed for synchronous operation only, the Model DL-9150 uses an ac drive motor to advance the tape, thus eliminating dc drives and stepping logic. By eliminating circuitry required for asynchronous operation, the cost compared to conventional readers has been significantly reduced. In addition, the unit should provide better reliability.

One input command controls the sprocket-driven Data Loader which reads at fixed rates up to 150 characters per second, moving unidirectionally right. The unit uses EECO's self-cleaning pivotal LED/photoelectric read head that reads all standard tapes up to 50% transmissive. A single pc board contains the photoamplifier and interface electronics, which are TTL/DTL/RTL compatible.

The reader should be useful in applications where stepping-mode operation and priority interrupt are not required, such as testing, program loading, inventory control and timekeeping or security systems. In these cases, data collected over a period of time can be stored on punched tape and later read into a computer with the Data Loader.

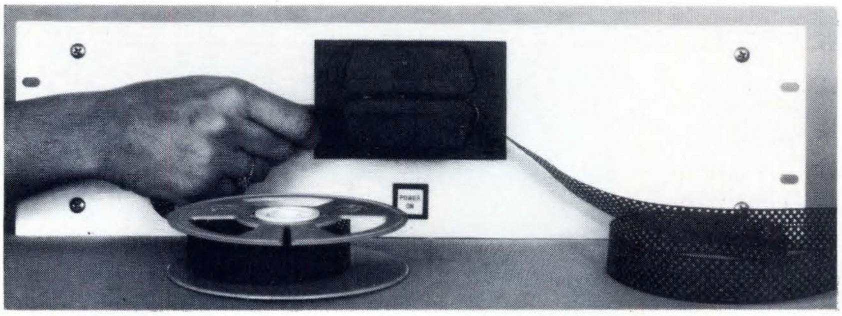


Fig. 1—LED/photoelectric read head reads standard tapes at fixed rates up to 150 characters per second using ac drive.

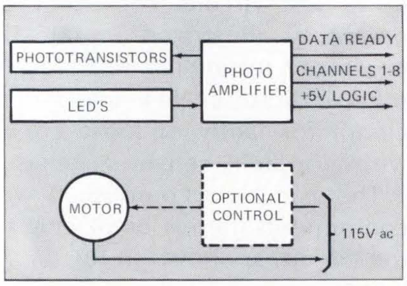


Fig. 2—Use of an ac drive motor and elimination of dc drives and stepping logic is the key to low-cost approach for synchronous data loading.

The reader could also be used for memory refreshing and in control systems where it is possible to read the complete tape into the mainframe memory at one time for storage.

Size of the reader (rack mounted) is 19 in. wide, 5¼ in. high and 6 in. deep (max.). Weight is less than 15 pounds. Quoted delivery is 30 days.

Available options include choice of direction, bidirectional operation, run/stop and remote-control relay assembly, inverted logic and optional packaging.

Price of the DL-9150 is $285 in unit quantity.

Electronic Engineering Company of California, 1441 E. Chestnut Ave., Santa Ana, CA 92701. Phone(714)547-5651.

Negative voltage regulation made easy by new 3-terminal device

PROGRESS IN LINEAR ICs

National Semiconductor Corp. has introduced the first negative 3-pin fixed voltage regulators, designed to simplify voltage regulation and power distribution.

Following in the footsteps of the familiar LM140 series, the LM120 series is composed of four regulators, requiring only external compensation capacitance.

The existing preset output voltages are now available in −5V, −5.2V, −12V and −15V.

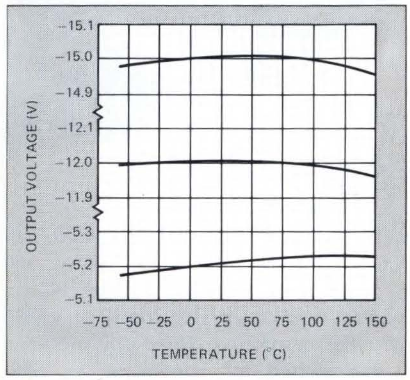
The output current goes as high as 1.5A with a preset output voltage error less than ±3%.

The current limiting and temperature limiting, both blowout protection techniques on the same chip work independently of each other. The current limiting device works to protect against momentary faults. The thermal shutdown device prevents junction temperature from exceeding safe limits during prolonged overloads.

The LM120 series may be programmed to handle higher output voltages with the aid of a resistive divider. The obvious low quiescent drain current (4 mA max.) allows this technique to work effectively with good regulation.

The LM120 series is available in TO-5 and TO-3 packages. The TO-5 is rated at 200 mA and 2W; the TO-3 is rated at 1A and 20W. The price of the TO-3 unit, which has an operating temperature range of −25°C to +100°C, runs $8.95 for 1-24 and $5.95 for 100-999. National Semiconductor offers this device in three quality grades: the LM120, LM220 and LM320, with the LM320 being the least expensive; and the LM120, the most expensive. The differences are in temperature range, output voltage tolerance and line regulation.

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



The temperature-vs-voltage characteristic is shown for three versions of the 3-terminal regulators.

Solid-state relays switch 10A and feature zero-crossing turn-on and turn-off

PROGRESS IN SOLID—STATE SWITCHING

A line of solid-state power relays just announced by Monsanto brings designers a new and important technique for line-voltage handling. The products are an outgrowth of Monsanto's standard opto-isolator line.

The MSR100 handles a 4V, 8-mW input with a normally-open, 120V ac contact rating. The MSR101 is identical to the MSR100 except that the output is a normally-closed contact. The MSR102 accepts an ac input voltage of 90 to 280V, with a normally-open, 120V ac contact. The MSR103 is similar to the MSR102, but with a normally-closed contact. All units are capable of switching 10A.

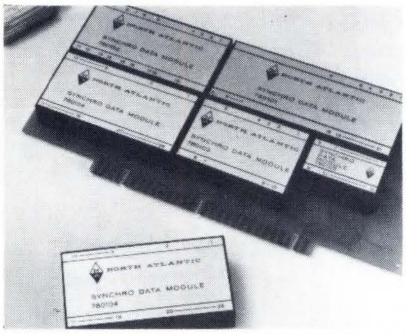
Two major features of the new series are a zero voltage turn-on and a zero current turn-off capability. The inputs are compatible with TTL and MOS logic. The units are self-enclosed in a small package and employ a light-emitting-diode emitter with a solid-state detector and other circuitry. The output stage is a Triac with very high dv/dt capability. The output stage has a surge current rating of 100A peak with a 10A continuous rating.

Lifetime of the Triac is extended through the use of an SCR in the trigger circuit to hard-fire the Triac gate.

Monsanto Commercial Products Co., Electronic Special Products, 10131 Bubb Rd., Cupertino, CA 95014. Phone (408)257-2140.

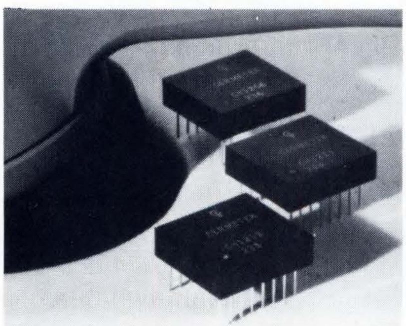
For more information, check **151**

The MSR series solid-state relays can operate from TTL- or MOS-level inputs to switch 120V ac. Turn-on is accomplished at the zero-crossing point of the ac waveform and turn-off occurs at the zero-current point.



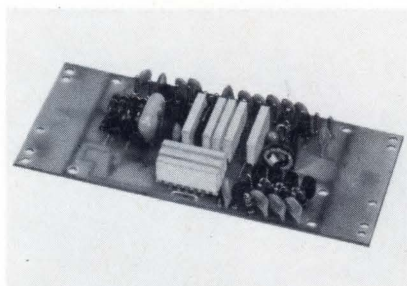
LOW-COST PC BOARD S/D AND D/S CONVERSION MODULES. Series 780 synchro data modules provide typical per-channel conversion cost of only \$650 at 14-bit resolution. The 14-bit modules are designed for conversion in both direction and for resolvers and synchros. Accuracy is 3 minutes ±0.9 LSB for the S/D and R/D modes, and 4 minutes for the D/S and R/S modes of operation; operating temperature is 0 to 70°C and input angles range from 0 through 360°. Tracking rates are 4000°/sec. North Atlantic Industries, Inc., Terminal Dr., Plainview, NY 11803. Phone(516)681-8600. **170**

INSTRUMENTATION AMPLIFIER HAS ±0.5 μV/°C DRIFT. Model 3625 instrumentation amplifier comes in three versions: Models 3625A, 3625B and 3625C with input voltage drifts of 3, 1 and 0.5 μV/°C, respectively, at a gain of 1000. Bias current is only 100 nA and dc gain linearity is ±0.02%. Gains of 10 to 1000 can be selected by the use of an external resistor, in the presence of ±10V common-mode voltages. Input impedance is 1000 MΩ and CMR is 100 dB. Output is ±10V at ±5 mA and input noise is 5 μV rms from 10 Hz to 10kHZ. \$29, \$45 and \$59, respectively. Burr-Brown Research Corp., International Airport Industrial Park, Tucson, AZ 85706. Phone (602)294-1431. **171**

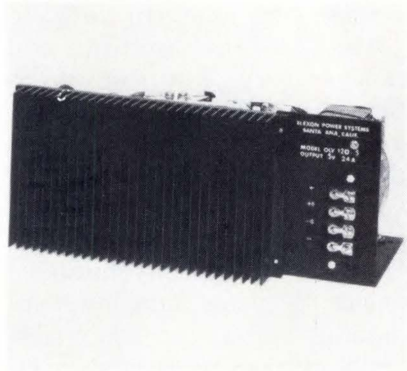


NEW MODULES MAKE \$45 MODEM PRACTICAL. A line of low-cost hybrid modules for FSK modem applications has been introduced. The manufacturer estimates that originate-only and answer-only modems could be produced at a parts cost of \$45 each, of which \$33.55 represents the 100-quantity cost of the modules. The thick-film double-DIP spaced 16-pin modules use switched active resonator circuitry to eliminate many of the problems associated with phase-lock loop circuits. Individual 100-quantity pricing is \$14.50 for the CH1211 demodulator; \$10.65 for the CH1212 modulator; and \$8.40 for the CH1256 bandpass filter. Cermetek, Inc., 660 National Ave., Mountain View, CA 94040. Phone (415)969-6433. **172**

LOW-COST 5A HYBRID VOLTAGE REGULATORS. A 5A hybrid dc voltage regulator series has three circuits each, for both positive (CJCA001, CJCA003 and CJCA005) and negative (CJCA002, CJCA004 and CJCA006) circuits. The series is available with FET internal current source (CJCA 005 and 006) as well as current limiter (CJCA 003, 004, 005 and 006). Regulation is 0.5% max, for no load to 1A load. Output voltage range is 8 to 50V with max. output current of 5A. Packaged in a hermetically sealed TO-3 case, each regulator is priced from \$13.49 (quantities of 100). Solitron Devices, Inc., 1177 Blue Heron Blvd., Riviera Beach, FL 33404. Phone (305)848-4311. **173**



TONE ENCODER/DECODER. The SS-80J/192 sub audible-tone encoder/decoder has been especially designed for use in the Motorola Motrac series of two-way radios. It utilizes thick-film modules that fit into a gold plated edge connector on a pc board allowing direct plug-in, plug-out operation. Completely compatible with all Motorola, General Electric and RCA sub-audible tone systems, it is available in standard or special frequencies from 20.0 to 250.0 Hz and can accommodate up to six tone frequencies which may be electronically switched if required. Alpha Electronic Services, Inc., 8431 Monroe Ave., Stanton, CA 90680. Phone (714)821-4400. **174**



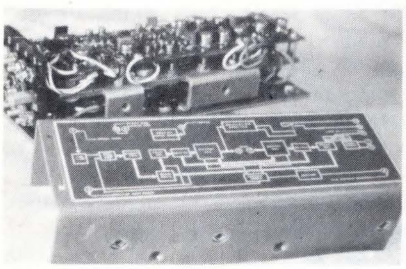
\$1.08/W OEM REGULATED POWER SUPPLIES. The newest series of low-cost (\$1.08/W) OEM regulated power supplies by Elexon provides 15 different output voltages from 4 to 28V dc with current ratings of 24 to 6.8A. Built-in features of the OLV-120 Series include 0.1% line and load regulation, 0.1% ripple and noise, remote sensing, adjustable high-ratio foldback current limiting, and electrostatically shielded transformers. The new open-frame units are convection cooled and will operate continuously from 0°C to +55°C at full rated output. From \$129 each in 1 to 9 quantities. Elexon Power Systems, 3131 S. Standard St., Santa Ana, CA 92705. Phone (714)979-4450. **177**

50-mW C-BAND AND 100-mW S-BAND OSCILLATORS. The WJ-2812 and WJ-2804-100 Series of voltage controlled oscillators offer full 50 mW of power output across 4 to 8 GHz and 100 mW from 2 to 4 GHz, respectively. Individual units are designed to meet the environmental specifications of MIL-E-5400, Class 2. Tuning-voltage-vs-frequency curves are approximately exponential and monotonic, allowing ease of linearization. WJ-2804-100 units are upgraded oscillators whose tuning-voltage requirements remain at +60V dc max. Watkins-Johnson Co., 3333 Hillview Ave., Palo Alto, CA 94304. Phone (415)493-4141. **175**

HIGH-SPEED SAMPLE-AND-HOLD MODULE. The Model ISH-5105 sample-and-hold module features a 200-psec aperture time. It contains an analog switch, holding capacitors, and input and output buffer amplifiers. Available in either commercial or nuclear instrumentation module (NIM) packaging, the ISH-5105's operation is initiated upon external command. Inter-Computer Electronics, Inc., Box 507, Lansdale, PA 19446. Phone (215)822-2929. **178**

BINARY-ANGLE-TO-SINE AND COSINE CONTROLLER. The DD109 (up to 15 binary-angle bits) expands the Model DD108-A and DD108-B binary-angle-to-sine translators to full 4-quadrant 17-bit-output sine and cosine operation with the following features: 0.95 and 1.5 μsec translation and 0.088° LSB and 0.011° LSB resolution for Models A and B, respectively. Accuracy is ± 0.005° $\tan^{-1}$ for both. Packaging is in a fully encapsulated 2×4×0.4-in module. Interface Engineering, Inc., 386 Lindelof Ave., Stoughton, MA 02072. Phone (617)344-7383. **179**

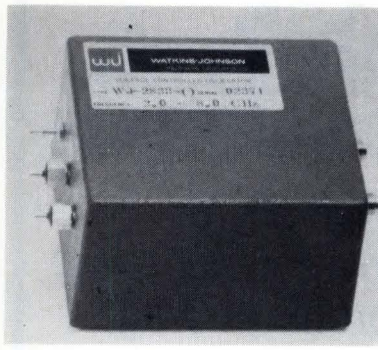
HIGH-PERFORMANCE MIL-SPEC DC-TO-DC CONVERTERS. A new line of high-performance, MIL-spec dc-to-dc converters termed the J-20 Series operates from 28V aircraft-type batteries and provides outputs from 2 to 20V dc at 20W. Features include efficiencies up to 50%, small size of 3×2×3-1/2 in., regulation of 0.02% +3 mV for line and 0.05% +10 mV for load and ripple of 0.01% +2 mV rms. Operating temperature is −55°C to +100°C. Aaron-Davis Co., 1720 22nd St., Santa Monica, CA 90404. Phone (213)829-1834. **180**



NEW CONTROL CONCEPT FEATURES HIGH EFFICIENCY AND SMALL SIZE. A new type of control concept is said to reduce the size and weight of high-power controllers by as much as 50%. Called Two-State Modulation, it provides precise amplification of high-power signals commonly found in military applications for high-current power supplies and motor control. The concept achieves a lower over-all cost through its ability to operate directly from standard dc power, thereby eliminating costly dc-to-ac inverters. The technology and patent right are available to the control industry through a licensing program. Control Systems Research, Inc., 1811 Main St., Pittsburgh, PA 15215. Phone (412)782-4460. **182**

10W, 1.5-GHz HYBRID POWER SPLITTER. Model SMC-1500-3SP power splitter is new strip-line 3-dB hybrid unit that can also be used as a power combiner. It is furnished complete with a load termination for 10W of cw power. The SMC-1500-3SP is sealed for all-weather outdoor service and features a center frequency of 1.5 GHz, bandwidth of 100 MHz min., coupling of 3 dB ±0.5 dB and VSWR of 1.25:1 max. Insertion loss is 0.2 dB max. and isolation is 18 dB min. $275. Spectrum Microwave Corp., 328 Maple Ave, Horsham, PA 19044. Phone (215)672-9191. **181**

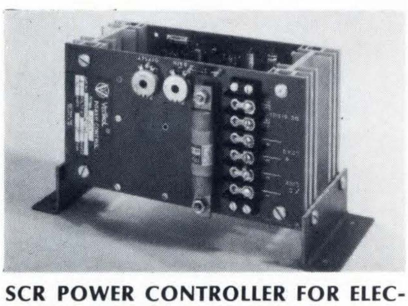
100-TO-400-MHz 100-mW LINEAR-POWER AMPLIFIER. Model SMA-100-400P low-cost solid-state amplifier operates over the passband of 100 to 400 MHz with 20-dB minimum gain and a linear power output in excess of +20 dBm. Features include small size of 2-1/4×1-3/8×1-3/8 in., and a dc input of +20V at 130 mA. The amplifier uses SMA female rf connectors and costs $195. Spectrum Microwave Corp., 328 Maple Ave., Horsham, PA 19044. Phone (215)672-9191. **185**



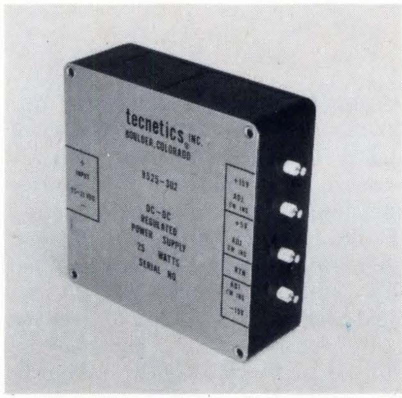
DUAL-OUTPUT VOLTAGE CONTROLLED OSCILLATOR. A voltage controlled oscillator produces useable rf output power at two harmonically related frequencies. The WJ-2833 delivers 20 mW across the 4-to-8-GHz range and 2 mW over the 2-to-4-GHz range. All outputs are phase coherent for easier operator control. The solid-state oscillator offers such options as isolators, heaters, filters and linearizers in any combination. Tuning voltage versus frequency curves are approximately exponential and monotonic, allowing ease in linearization. Watkins-Johnson Co., 3333 Hillview Ave., Palo Alto, CA 94304. Phone (415)493-4141. **186**

PHASE-SEQUENCE DETECTORS. The Series 200 phase-sequence detectors for use on 3-phase electrical power are designed to be permanently installed in equipment and machinery that are sensitive to phase rotation. Occupying about two cubic in. of space, each unit gives a lighted indication when the desired phase sequence is connected. Available in a full range of voltages and frequencies, each detector can be purchased with either a molded-in lamp assembly or external lamp terminals. Time Mark Corp., 4566 E. 29 St., Tulsa, OK 74114. Phone (918)939-5811. **184**

INSTRUMENTATION AMPLIFIER FEATURES HIGH ACCURACY AND SELECTABLE BANDWIDTH. An instrumentation amplifier designated the Model "B" of the 8300 XWB Series features gain accuracy and linearity of 0.01% on any of ten switch-selectable gain settings that cover the range of unity-gain to a gain of 1000. A vernier gain control further extends this range to a maximum of 2500. Bandwidths (-3d B) are from dc to 10 Hz, 100Hz, 1kHz, 10 kHz and 100 kHz. At the 100-kHz bandwidth, the input noise is less than 6 μV and the settling time is only 30 μsec to within 0.01% of full value. $585. Preston Scientific, Inc., 805 E. Cerritos Ave., Anaheim, CA 92085. Phone (714)776-6400. **183**

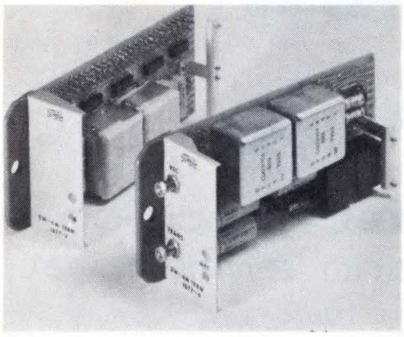


SCR POWER CONTROLLER FOR ELECTRICAL HEATING. Additions to the Vectrol line of "Cube Pac" design SCR power controllers are the VTC 500 and 700 Series. They are low-cost, zero-voltage switching, proportional power controllers for single and three-phase applications. The series is designed to provide linear control of power from zero to 100% of the output voltage into resistive loads only. Standard units are available in 120, 208, 240, 277, 380 and 480V models with ratings up to 80A for single-phase and up to 50A for three-phase loads. Under $80 in lots of 100. Vectrol Inc., 1010 Westmore Ave., Rockville, MD 20850. Phone (301)424-6900. **187**

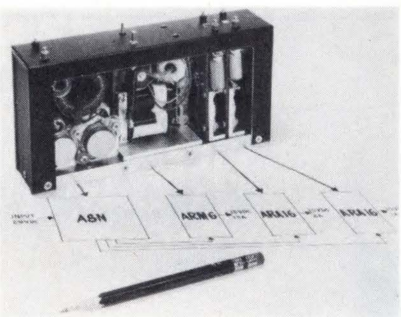


Dc-TO-dc CONVERTER HAS HIGH reliability, multiple output at 25W. Model 9525 Series has an operating case temperature up to +100°C. MTBF calculations per MIL Handbook 217 made at +85°C case temperature result in 40,000 hours for dual and 20,000 hours for triple-output units. Units are designed to meet vibration, shock and altitude requirements of MIL-E-5400K. Output impedance is 0.02Ω from 0 to 10 kHz, regulation with line input from 25 to 31V dc is 0.1% and no-load-to-full-load regulation is 0.2%. $240 for single, $270 for dual and $330 for triple-output units. Tecnetics, Inc., Box 910, Boulder, CO 80302. Phone(303)442-3837. **189**

ACTIVE TOUCH-TONE FILTER QUADS. The new Touch-Tone bandpass active filters feature four audio frequency filters in one unit. They are designed to accommodate the 8 Touch-Tone frequencies in two groups of four frequencies each. One assembly responds to the lower tone group of 697, 770, 852 and 941 Hz. By choosing the appropriate two-tone pair, one from the low group and one from the high group, any one of 16 possible output combinations may be activated. Each filter has a 5% 3-dB bandwidth and a 20 dB gain. $80 each. Polyphase Instrument Co., Bridgeport, PA. Phone(215)279-4660. **191**



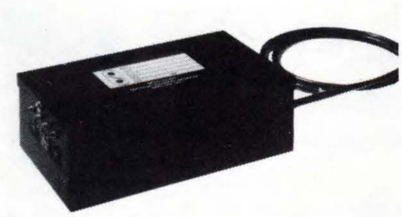
FOUR-WIRE TERM SETS. Models 1677-3 passive four-wire term sets and 1677-4 active four-wire term sets meet all transmission requirements for both toll and private-line applications. A full line of precision balancing networks are available for piggy-back installation, requiring no further mounting space. Passive units provide loss on four-wire sides from 0 to 16 dB in 0.25-dB steps; active units provide gain or loss (-16 to +16 from two-wire to four-wire and vice-versa). Units are interchangeable with each other. Pulse Communications, Inc., 5714 Columbia Pike, Falls Church, VA 22041. Phone (703)820-0652. **188**



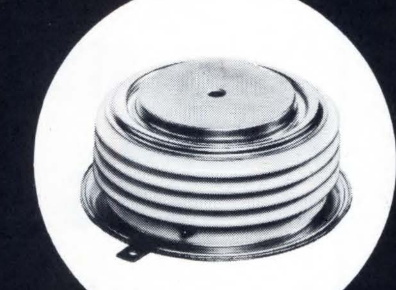
9.3W/IN.[3] MAGNETIC-AMPLIFIER REGULATORS. The ARM Series units are available with outputs from 5V dc at 20A to 100V dc at 1.3A with power densities of 9.3W/in.[3] They also feature regulation of 1%, 85% efficiency and can operate from ac or dc inputs through the choice of the input driving modules. This choice of input driving module allows the designer to design his own custom power supply by choosing from a selection of standard modules without additional engineering charges. Arnold Magnetics Corp., 11520 W. Jefferson Blvd., Culver City, CA 90230. Phone (213)870-7014. **190**

OP AMP DELIVERS ±30V AT 1A. The Model 150 is designed to deliver ±30V at 1A for driving synchros and reactive loads. It features a 20-kHz full power bandwidth, a 1-MHz unity gain bandwidth and a common-mode voltage range of ±25V. Packaged in an8-pin TO-3 case, the hybrid amplifier is output protected for short circuits and has rectifiers for inductive-load kickbacks. Operating temperature range is -55°C to +125°C. $69. M.S.Kennedy Corp., Pickard Dr., Syracuse, NY 13211. Phone(315)455-7077. **193**

MINIATURE CRYSTAL OSCILLATOR. A complete crystal controlled oscillator comes in a 1.33×1.33×0.35-in. package. Believed to be the smallest self contained 920-to-1200-MHz crystal controlled oscillator on the market today, the 5044-1006 has a center frequency accuracy of ±0.0005% and a stability of ±0.002% from -40°C to +70°C. Power output is +7 dBm into a 50Ω load and non-harmonically related spurious signals are 45 dB down. Harmonics are down by 30 dB. $350. Scientific Research Corp., 4722 Eisenhower Blvd., Tampa, FL 33614. Phone(813)884-1411. **192**



MINIATURE HV POWER SUPPLIES OFFER IMPROVED PERFORMANCE. The RM line of regulated, solid-state, high-voltage dc power supplies to 30 kV offers improved regulation of 0.1%/W of load regulation for full-load variations and improved ripple of 0.1% pk-pk for all load conditions. The supplies are available in 1.5, 3 and 6W models and feature fully enclosed shielded metal cases and are encapsulated for environmental protection. From $145. Spellman High Voltage Electronics, Corp., 1930 Adee Ave., Bronx, NY 10469. Phone(212)671-0300. **195**



TWO *New* SCRs
from NATIONAL ELECTRONICS
featuring

- Patented Regenerative Gate
- High di/dt with low power gate drive

F-390 850 A RMS, 500-1300 V. DC motor control and power supplies.

F-395 700 A RMS, 100-600V. Fast switching, high frequency for inverter use.

NATIONAL ELECTRONICS
a varian division
geneva, illinois 60134 (312) 232-4300

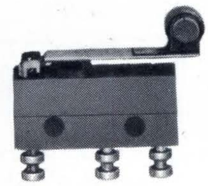
CHECK NO. 28

NEW

smallest precision snap action switch yet!

Case dimensions of our new 4900 Series switches are less than .250″ by .300″ by .100″. Ratings are 2 amp. 125-250V AC; 2 amp. (Res.) and 1 amp. (Ind.), 30V DC. Meet MIL-S-8805 specs. Available with 4 types of terminals, pin plunger and various lever type actuators.

new sub-miniature switches



Our new 4800 Series sub-miniature switches are rated 5 amp. 125-250V AC with 5 amp. resistive and 2½ amp. inductive ratings at 30V DC. Case dimensions are approximately .400″ by .800″ by .250″. Available with 6 terminal types, a variety of lever actuators and optional bifurcated or dual gold contacts. Meet MIL-S-8805 specs. McGill Manufacturing Co., Inc., Electrical Division, Valparaiso, Indiana 46383

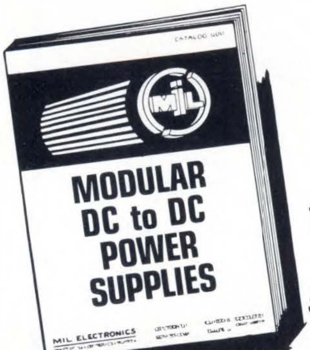
Available from Authorized McGill Electrical and Electronic Distributors

McGILL®
ENGINEERED SWITCHES

CHECK NO. 34

OVER 1000 DIFFERENT STANDARD MODELS

HIGH VOLTAGE for PHOTOMULTIPLIERS



TRIPLE OUTPUTS for AD-DA CONVERTERS

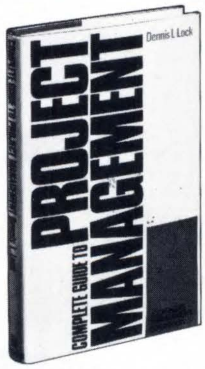
5 VOLTS for DIGITAL IC's

MILITARY INDUSTRIAL

FREE
28 page catalog containing power supply selector index.

MIL ELECTRONICS, INC.
LOWELL, MASS. 01854 617-453-4142

CHECK NO. 35



COMPLETE GUIDE TO PROJECT MANAGEMENT
by Dennis L. Lock

Here is the perfect introduction to project management, the technique that was created to deal with the complex activities of modern industry—planning, costing, controlling and evaluating projects so they are completed on time and to specs and budget.

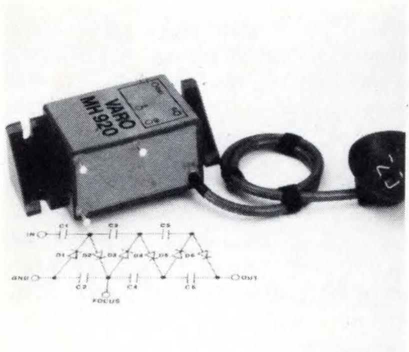
With over 60 how-to-do-it illustrations and many practical examples, this book covers all the basics including defining the task, estimating costs, pricing, planning the time scale, scheduling, materials control, maintaining the program, modifications, build schedules, concessions and relating achievement to expenditures. CPM and PERT are also explained.

Complete Guide to Project Management is essential reading for anyone, on either the technical or managerial side of industry, with any responsibility for projects. **224 pp. $10.95**

Order Today—15-Day Free Trial—Satisfaction Guaranteed or Money Back—Send check and we pay shipping

Cahners BOOK DIVISION
89 Franklin St., Boston, Ma. 02110

S58/M0809



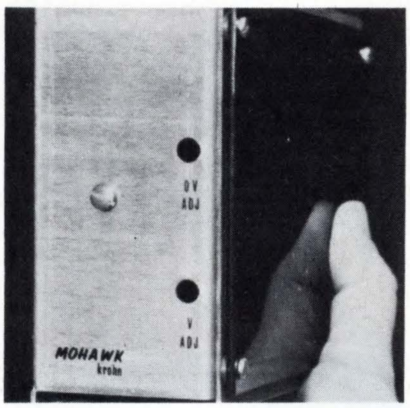
HV 25-kV TRIPLERS WITH FOCUS TAP. A new series of high-voltage triplers for solid-state and vacuum-tube TVs feature a nominal 25 kV dc output with 8 kV pk-pk maintained and are available in two versions, each with a focus tap. The MH919 Series contains 5 diodes and 5 capacitors with a focus tap and is designed for pulse-input solid-state TVs. The MH920 Series contains 6 diodes and 6 capacitors with a focus tap and is designed for sine-wave-input vacuum-tubes as well as solid-state TVs. Varo Semiconductor, Inc., 1000 N. Shiloh, Garland, TX 75040. Phone(214)272-4551.
194

HIGH-RELIABILITY FEEDBACK CIRCUIT. A new, high-reliability, low-cost feedback circuit for step-up output transformers employs a separate winding to control the gain of the op amp normally driving the transformer and offers several distinct advantages. It eliminates the need to trim out the normal dc offset of op amps and it compensates for secondary-load changes by automatically adjusting the closed-loop gain of the op amp resulting in a smaller and lighter transformer. The new circuit will add about $5 to the cost of a transformer. Perkin-Elmer Corp., Industrial Products Div., Main Ave., Norwalk, CT 06856. Phone(203)762-1000. **200**

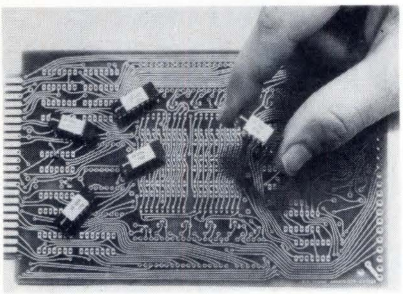
30-TO-300-MHz AMPLIFIER. Model PAM-350 amplifier provides state-of-the-art performance in ultra-high dynamic-range broadband linear amplifiers for the 30-to-300-MHz frequency range. This new amplifier features a solid-state design, a push-pull amplifier configuration and is said to provide outstanding intermodulation performance. A low noise figure and excellent VSWR are additionally claimed features. American Electronic Laboratories, Inc., Box 552, Lansdale, PA 19446. Phone(215)822-2929.
198

INDUSTRIAL ac/dc-TO-dc CONVERTERS. A new line of low-cost industrial ac/dc-to-dc power supplies termed the Q6-20 Series operates from 103 to 127V ac, 45 to 880 Hz and 140 to 180V dc. Outputs are available in 5, 6, 12, 15, 24 and 28V dc at 20W. Regulation is 0.01% for line and 0.2% for load and ripple is 0.005% +1 mV rms. Operating temperature is -20°C to +71°C. Case size is 4-in. long×4-in. wide×2-in. high. Aaron-Davis Co., 1720 22nd St., Santa Monica, CA 90404. Phone(213)829-1834.
197

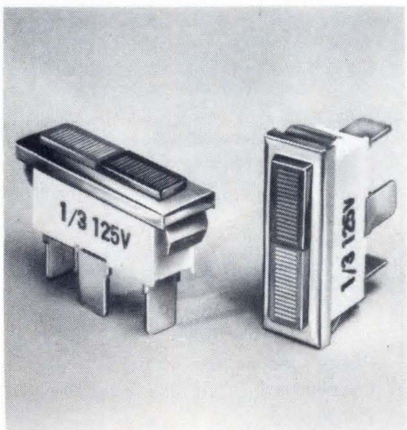
LOW-NOISE 6.1-GHz VCO. The new SSC-12010 is a varactor tuned, Gunn-effect oscillator with a center frequency of 6.1 GHz. Mechanical frequency selection covers 500 MHz. The SSC-12010 provides a minimum output power of 20 mW with 25-MHz electronic tuning and 10 mW with 40-MHz electronic tuning. FM noise (100-Hz bandwidth) is less than 5 Hz, at 1 kHz from carrier; AM noise is less than -120 dB in any 100-Hz bandwidth, 1 kHz from the carrier. Sperry Electronic Tube Div., Waldo Rd., Gainesville, FL 32601. Phone(404)372-0411. **199**



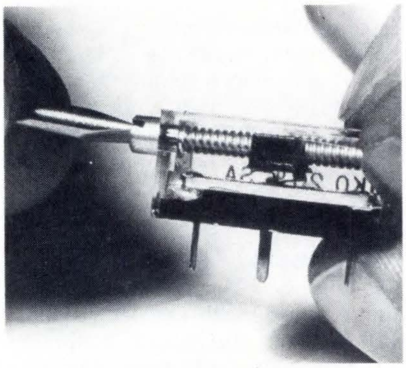
Ac-TO-dc SILICON CARD-CAGE REGULATED POWER SUPPLIES. A new series of card-cage power supplies is designed to give max. flexibility in determining power requirements in prototype work. Designated as Series 3127, the supplies slip into a card-cage alongside the circuit boards thus eliminating problems associated with cable routing, installation and noise. Eleven models include overvoltage protection, a card-rack adjustment slide and mounting case. Adjustable outputs range from 4.4 to 28.6V dc. $86. Mohawk Industries, Inc., 73 N. 2nd St., Easton, PA 18042. Phone(215)252-0968. **196**



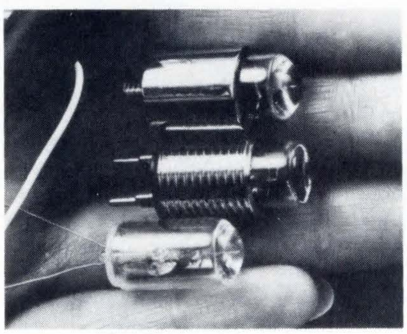
RAM EVALUATION CARD CUTS DESIGN TIME. A 2048 bit, 4-bit/word RAM evaluation pc card is being offered by Electronic Arrays to assist the potential user of EA's new N-channel Si-Gate RAM s to evaluate the performance of the memory devices. The B-1500 pc card is designed to accept up to eight EA 1500, EA 1501, or EA 1502 Random Access Memory IC's, along with the timing, control and interface circuit components necessary to construct an 8k-bit memory. The completed board provides the evaluator with a complete 2048 × 4-bit memory system. All the necessary level shifting is performed on the card, so the user interfaces only with TTL signal levels. Components cost for a completely loaded card for full evaluation, exclusive of the memory devices, is approximately $70. Electronic Arrays, 501 Ellis St., Mt. View, CA 94040. Phone(415)964-4321. **255**



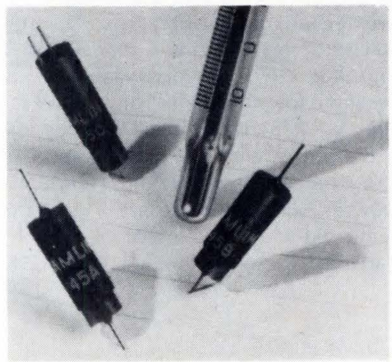
TWO INDICATOR LIGHTS COMBINED IN SINGLE MOUNTING. 31-ML-2 Series rectangular indicator lights feature two 31 Series indicator lights mounted in a common bezel. These units not only greatly improve panel appearance by keeping to a single-bezel mounting, but save time and labor during assembly as well. The series is available in units combining up to four lights; a lighted switch can be substituted for a light in any of the configurations. Recommended panel thickness for series use is up to 0.090 in. Leecraft Mfg. Co., Inc., 21-10 44th Rd., Long Island City, NY 11101. Phone(212)392-8800. **256**



SEE THROUGH PC TRIMMER POTENTIOMETERS ARE SEALED. The trimmers are available with either wirewound- or cermet-resistance elements having 0.5% linearity. All are 18-turn, 0.75 in. long × 0.33 in. high × 0.25 in. wide, with standard pc terminals. The cermet-element units have 4-contact wipers for added reliability and low noise. The wirewound-element Type 121S sealed trimmer is supplied in standard resistance values from 10Ω to 10 kΩ ±10%. Rating is 1/3 W at +40°C, derated to zero at +100C. Temperature coefficient is 20 ppm/°C. The cermet-element Type 131S sealed trimmer has standard resistance values from 100Ω to 1 MΩ ±10%. Its 1/2 W rating derates to zero at +110°C. T.C. is ±150 ppm/°C. Price of both Type 121S and 131S Dip10HMatic Trimming Potentiometers in quantities of 100 is $1.32 each. Dip10HMatic Div., Harry Levinson Co., 1211 E. Denny Way, Seattle, WA 98122. Phone(206)323-5100. **257**

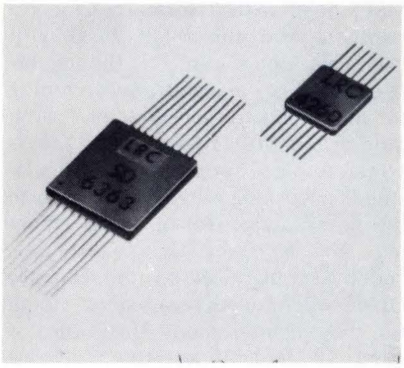


PRECISION LAMPS HAVE VARIABLE BEAM PATTERNS. Different lamp intensities and beam patterns are determined by the selection of lens, filament types and ratings. The T-4/TL-4 Series bulbs are available in clear, thin, or heavy lens. Filament types are bar or C-2R. Six filament ratings are produced. The series is offered in unbased, epoxy based, brass based and aluminum based versions. This wide variety of ordering specifications for the T-4 and TL-4 lamps permits the electronic designer or engineer to use the series in a number of applications: computers and peripheral equipment, fiberoptic devices, high intensity indicators, photo detection drivers and medical instrumentation. LAMPS, INC., 19220 S. Normandie Ave., Torrance, CA 90502. Phone(213)323-7578. **258**

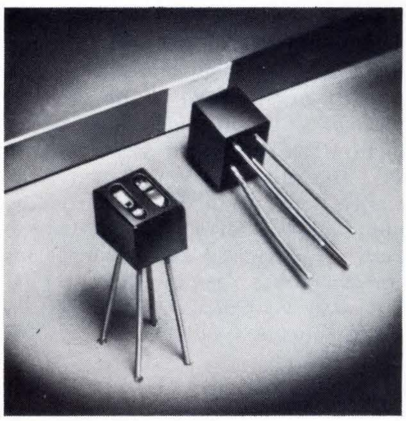


TEMP SENSING REED RELAY LINE EXPANDED. Originally these sensors were available only as Form B (normally closed) and standard operating temperatures were limited to two; TS 50 and TS 70 operating at 50°C and 70°C respectively. The switch line is now expanded to include Form A (normally open) and Form C (single pole, double throw) units. The operating temperatures for all switches now range from −20° C (−4°F) to 100° C (212°F) in 5° increments. "Specials" can be made to function up to 300°C (572°F). Prices in 1000 lots are: Form A, $1.50; Form B, $1.25 and Form C, $3.40. Samples for evaluation can be supplied only on telephone or letterhead inquiries. Hamlin Electronics, Lake & Grove Sts., Lake Mills, WI. Phone(416)648-2361. **259**

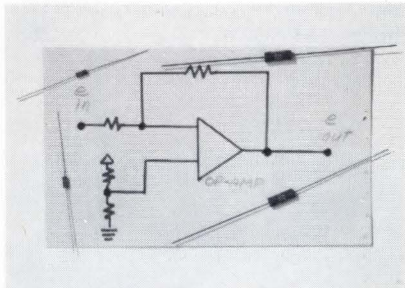
PUSHBUTTON INDICATOR AND SWITCH/INDICATOR combines attractive panel appearance and large rectangular lens with a wide variety of highly reliable TEC-LITE indicators and switch/indicators. Included in this series are the PBL, PTL, RBL, RDL and transistor controlled TIL models, available in nine lens colors. Quickly installed snap-in mounting fits panels up to 1/8 in. thick. TEC, Inc., 9800 N. Oracle Rd., Tucson, AZ 85704. Phone(602) 297-1111. **260**



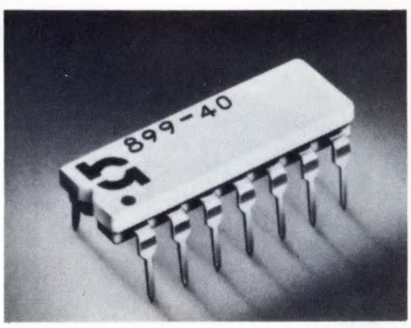
SWITCH DRIVERS ARE DESIGNED FOR USE WITH 4- AND 6-BIT PHASE SHIFTERS and multi-throw switches. Two inverting solid-state switch drivers designed for use with phase shifters as well as with SP4T and SP6T switches are used with both series and shunt switches. Total switching time is less than 500 nsec for the SP4T driver and less than 1 μsec for the SP6T driver. Models 4260 (for SP4T) and 6383 (SP6T) are compatible with both TTL and DTL logic. A pull-up circuit built into each input provides a convenient means of dc testing microwave switches of phase shifters. The switch driver is at logic "0" when the input is tied to dc ground. Prices in quantities of 1 to 9 are $140 (Model 4260) and $210 (Model 6363). LCR, INC., 11 Hazelwood Rd., Hudson, NH 03051. Phone(603)883-8001. **261**



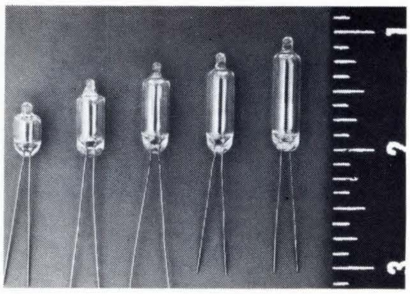
HIGH-SENSITIVITY OPTO-PAIR YIELDS FAST, STABLE RESPONSE. The units combine a high-output gallium-arsenide infrared emitting diode (LED) and a sensitive silicon NPN phototransistor chip, with the emitter and detector elements both positioned on the same perpendicular plane. This ensures response to radiation only when a reflective surface comes into the field of view of the phototransistor. Fast response is indicated by the typical rise and fall times of 60 μsec. High sensitivity is exemplified by a typical high-current output of 0.5 mA when the unit is positioned at 0.2 in. from a 90% reflective-white surface. Photocurrent output of the units is a typical 125 μA. For Model STRA-850A, min. output is 60 μA, while Model STRA-850 has a min. output of 20 μA. SENSOR TECHNOLOGY, INC., 21012 Lassen St., Chatsworth, CA 91311. Phone(213)882-4100. **262**



PRECISION THIN-FILM RESISTORS FEATURE LOW REACTANCES. Excellent electrical characteristics coupled with small size allow the new MAR resistor to be used for precision applications. The parts are also available in matched sets and module assemblies. MAR resistors maintain the low-reactance characteristics of thin-film devices, and have temperature coefficients, long-term stability and tolerances comparable to precision wirewounds. Yet MAR resistors are smaller in size and more economical than precision wirewounds. The resistors are laser spiralled, offering a clean, fracture-free cut for stability, outstanding performance and long life. The final encapsulation is solid epoxy. Availability in production quantities is from four to six weeks ARO. IRC Fixed Resistors, An Operation of TRW Electronic Components, P.O. Box 887, Burlington, IA 52601. Phone(319)754-8491. **263**

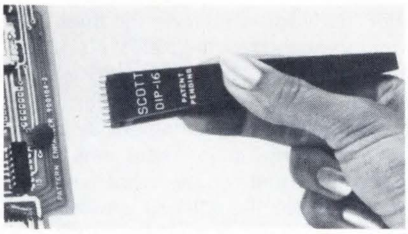


8-RESISTOR DIP NETWORK INTERFACES 1103 WITH 3208A. The Series 899-40 RESNET™ DIP Network, designed specifically for interfacing the Intel 1103 Memory with the Intel 3208A TTL Sense Amplifier, has been introduced by Helipot. Series 899-40, offering total compatibility with automatic-insertion equipment and major reductions in pc board space and "on the board" costs, is optimized for the 1103. It provides six 600Ω resistors for terminating six interconnecting bit lines. The network also provides a voltage divider to supply the 150 mV threshold level required for the 3208A. The unit uses standard 5V TTL power for the threshold setting network. Price is $2.50 (1-99 quantity). Beckman Instruments, Inc., 2500 Harbor Blvd., Fullerton, CA 92634. Phone(714)871-4848. **264**



FORMED-TIP NEON LAMPS OFFERED IN FAMILY OF SIZES. A complete family of Formed Tip neon lamps is now available in a variety of lengths: 0.500 in. max.; 0.625 in. max.; 0.750 in. max.; 0.850 in. max. and 0.940 in. max. Viewed end-on, these T-2 formed-tip lamps give 20% greater brightness than conventional neon lamps. Ideal for end-on indicator light and visual display applications. All formed-tip lamps are available with attached resistors for customer design. Glowlite Corp., Pauls Valley, OK 73075. Phone(405)238-5541. **265**

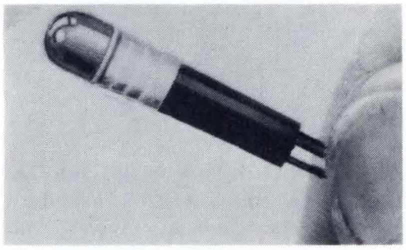
GALLIUM-ARSENIDE PHOSPHIDE LAMPS ARE LOW COST. Miniature light-emitting-diode lamps with axial lead, Model 521-9189, are intended for panel lighting, film annotation, circuit-status indication, numeric and alphanumeric displays and in visual indicators. Maximum ratings for the lamp include: forward dc current of 40 mA; reverse voltage of 3V; storage temperature range of −40°C to 80°C. Units are priced at $0.35 in quantities of 1000. Dialight Corp., 60 Stewart Ave., Brooklyn, NY 11237. Phone(212)497-7600. **266**



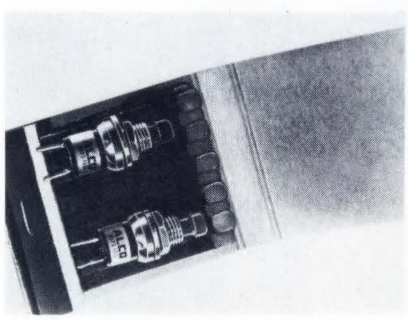
"DIP-SERT" SIMPLIFIES DUAL-IN-LINE PACKAGE INSERTION. Called the "Dip-Sert/16", the device is said to reduce DIP insertion times by a factor of 20 or more. Operators mounting 16-pin packages on pc cards have been found to average less than 4 sec per package. Price is $2.94 each. Scott Industries, Paramount Bldg., N. Chelmsford, MA 01863. Phone (617)251-8595. **267**

SOLID-STATE KEYBOARD INTRODUCED. Called a Solid-State Super Switch(TM) Keyboard, its internal LSI allows programming of any number of functions. Offered as standard rollover functions are: N-key rollover; N-key rollover/two-key lockout; N-key lockout/two-key rollover; two-key rollover and mechanical simulation. The keyboard's ferrite-core switches are contactless and have 100-million cycle reliability. The keyboard is splash-proof, with thermoplastic housing and umbrella-type buttons that repel hazards such as spilled drinks, hairpins and paperclips. Typical power consumption of the Super Switch Keyboard is 300 mA from a 5V dc line. Current drain is essentially constant regardless of the number of keys depressed. Licon, Div. Illinois Tool Works Inc., 6615 W. Irving Park Rd., Chicago, IL 60634. Phone(312)282-4040. **268**

DIP SOCKETS COMBINE VERSATILITY WITH LOW PROFILE. These socket pins directly accommodate IC and semiconductor device leads to give max. circuit density by eliminating large socket castings. Easily inserted in 1/16 in. circuit boards, the gold plated sockets allow DIP devices with any number of terminals, to be mounted end-to-end or side-by-side. The posts are interconnected using either wire-wrap(TM) or solder techniques. Internal four fingered nickel gold plated berrylium-copper spring clips give optimum electrical connection and lead retention. Solid-nickel and gold plated brass shells insure excellent solderability or wrapability. Free samples and full specifications are available from Vector Electronic Co., 12460 Gladstone Ave., Sylmar, CA 91342. Phone(213)365-9661. **269**



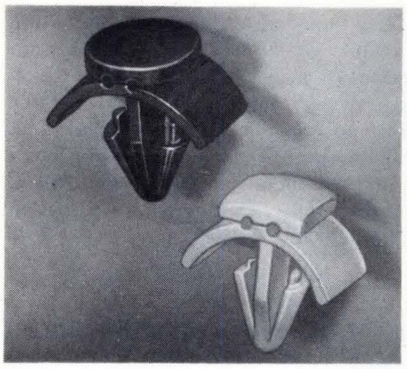
INDICATOR LIGHTS SPECIALLY DESIGNED FOR INDUSTRIAL APPLICATIONS. Designated the SIND Series, the lights are available at a unit price of 76¢ in quantities of 5000 or more. Described as the smallest of front relampable indicator lights, the SIND Series features patented "Easy Lamp" bases for quicker, easier lamp replacement and are available in red, green, yellow and white translucent caps. The series is designed especially for use in high-density packaging applications, with mounting characteristics, on 0.225 in. centers that ensure excellent visual signals for operating functions. Major specifications of the SIND series of indicators include: 5V, 60 mA, M.S.C.P. of 0.05 ±35%, with a 50,000 hour life. Shelly/Datatron, 1562 Reynolds Ave., Santa Ana, CA 92707. Phone(213)451-8491. **270**



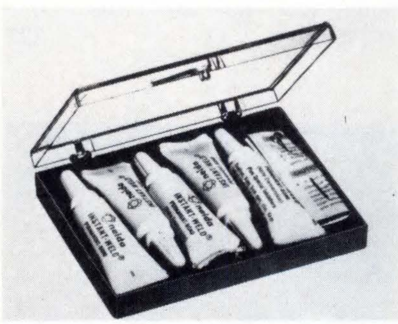
MINIATURE PUSHBUTTON SWITCHES FOR THE ECONOMY MINDED DESIGNER. They are available in two models, the MSPS-103B with "Normally Closed" contacts and the MSPS-103C with "Normally Open" contacts. Though low in cost, they are manufactured according to high-standard specifications. Both models feature silver plated brass contacts and terminals. A special shoulder bushing is provided to reduce the possibility of tear-off when mounted. The Normally Closed switch is coded with black button; the Normally Open switch is coded with a red button for easy identification. This series is rated 3A at 125V ac. The MSPS-103 switches are available in 500 lots at 42¢ each. Alco Electronic Products, Inc., 1551 Osgood St., N. Andover, MA 01845. Phone(617)686-3887. **271**

HIGH-VOLTAGE PUTTY EASILY MOLDS AROUND UNEVEN OBJECTS. It eliminates arcing in high-voltage television transformers, anodes, tube sockets, filament wire; any application where high-voltage arcing is a problem (to 40 kV). The putty is designed to replace corona dope. According to Oneida, the putty will last for years. High-Voltage Putty is packaged in 6 in. lengths for convenient use. Oneida Electronic Mfg. Inc., 848 N. Cottage, Meadville, PA 16335. Phone(814)336-2125. **272**

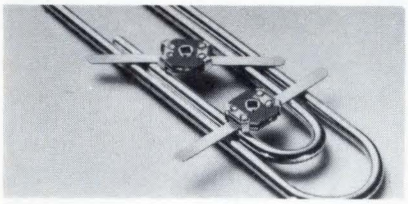
DISPLAYS DESIGNED FOR DIRECT MOS INTERFACE. The SP-330 Series (1/3 in.) and SP-350 Series (1/2 in.) offer improved electrical characteristics not previously available in displays of this type. These improvements include reduction of the anode voltage, the cathode current and the blanking requirements. Units in both of the new series are available in one and one-half digit, three-digit and two and one-half digit models. Sperry Information Displays, P.O. Box 3579, Scottsdale, AZ 85257. Phone(602)947-8371. **273**



NYLON MOUNTING STUDS INTRODUCED. Primarily designed for mounting cable clamps, these "Snap-Grip" Studs will also find other countless fastening and holding applications in electronic, aerospace, appliance and automotive assembly jobs. Assembly is fast, the "wing tip" of the stud compresses slightly as it is pressed into the hole and then snaps back as it clears the mounting hole, locking it in position. Snap-Grips are made of 6/6 nylon, black or natural color, in two standard stock sizes: the MS-4 fits a 0.166 in. dia. mounting hole in panel or chassis and the MS-6 is for a 0.187 in. dia. mounting hole. Weckesser Co., Inc., 4444 W. Irving Park Rd., Chicago, IL 60641. Phone(312)282-8626. **274**

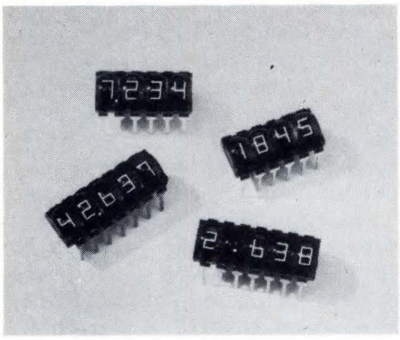


5 CYANOACRYLATE ADHESIVES AVAILABLE IN EVALUATION KIT. The powerful, single-component adhesive is said to have a tensile strength up to 5000 lbs/in.^{2} in each drop. Four different formulas are available to provide users with the one best suited for the types of materials they want to bond. The 5-pack Evaluation Kit contains all of the types, conveniently packed in 2-gram tubes totalling up to 760 one-drop applications. Red Label-101, for use when bonding any combination of plastic, rubber, ceramic or glass. Sets in 10-20 sec. Blue Label-102, for use when bonding any combination of plastic, rubber, ceramic or glass. Sets in 45-60 sec. Yellow Label-747, for use when metal is one or both of the bonded components. Sets in 30-45 sec. Green Label-240, holds porous materials. Sets in 60-120 sec. The Kit has been made up to help users find the most effective type for their specific bonding applications. It's available for $7.95 postpaid. Oneida Electronic Mfg. Inc., 848 N. Cottage, Meadville, PA 16335. Phone(814)336-2125. **275**



MINIATURE "BEAM LEAD" VARIABLE CAPACITORS ARE HIGH "Q". The Series 9401 "beam lead" trimmers feature Q's of > 10,000 each at 100 MHz and lead configurations perfect for stripline, hybrid circuit and pc mounting. They are uniquely suited as replacements for many chip capacitors and provide a means of easily and reliably trimming without cut-and-try adjustment techniques using abrasives. Applications include impedance matching and trimming solid-state circuits, balancing semiconductors and microwave components, VHF-UHF coupling, as well as equalizing fixed capacitors. The series includes five models having capacitance ranges from 0.2 pF to 4.0 pF with additional models available up to 50.0 pF. All models have test voltages of 500V dc and are easily adjusted by rotating a special tuning socket. Johanson Mfg. Corp., 400 Rockaway Valley Rd., Boonton, NJ 07005. Phone(201)334-2676. **276**

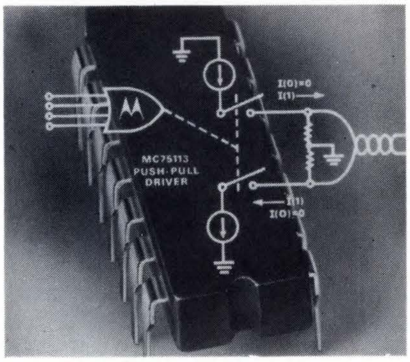
LED IS DIRECT REPLACEMENT FOR T-1 INCANDESCENTS. Two low-cost, miniature LED solid-state lamps, the RL-209 and RL-T1, are intended for high-volume usage in arrays and indicator-light applications. Both come in a red diffused molded package and are designed with the leads coming out the bottom of the package for ease in panel mounting. Both the RL-209 and RL-T1 are priced at $0.42 in 1000 quantities. Litronix, 19000 Homestead Rd., Cupertino, CA 95014. Phone(408)257-7910. **277**



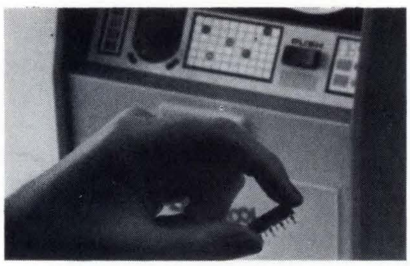
COMPACT LED DISPLAY LINE EXTENDED. These Model 5082-7400 series are 7-segment monolithic displays 0.11 in. high. Built-in magnification increases apparent luminous intensity, thus reducing power requirements. Options include either the standard right-hand decimal point, or a centered decimal point where good legibility in a multicluster display is desired. Packages are standard 12 (3- and 4-digits) or 14 (5-digits) pin DIP consisting of a plastic encapsulated lead frame with integral molded lenses. The shoulders of the lead frame pins are intentionally raised above the bottom of the package so that the display can be tilt mounted up to 20° from the pc board. For improved contrast, a red dye is incorporated in the plastic to filter out all visible light except the 655 nM wavelength emitted by the display. Hewlett-Packard, 1501 Page Mill Rd., Palo Alto, CA 94304. Phone (415) 493-1501. **223**

OP AMP HAS GUARANTEED SETTLING TIME OF 1μSEC TO 0.01%. Other features of the 1324 include excellent bandwidth and slew rate (10 MHz and 35 V/μsec, respectively), freedom from latch-up, TO-100 packaging with 715-compatible pin-out, simple compensation and excellent stability. The damping of the 1324 ensures a smooth controlled roll-off by using a Miller integrator around what is basically a single-stage amplifier. To obtain high-speed operation, the amplifier has a novel high-current, high-gain front-end which is balanced for good CMRR characteristics. Teledyne Philbrick, Allied Dr. at Rt. 128, Dedham, MA 02026. Phone (617) 329-1600. **278**

TWO DUAL-SENSE AMPLIFIERS FEATURE OPEN-COLLECTOR OUTPUTS. The SN75232 has a threshold sensitivity of ±4 mV, while the SN75233 has ±7 mV. Performance features include internal-reference amplifier compensation, adjustable input threshold voltage, time and amplitude signal discrimination and two independent signal channels. The SN75232 and SN75233 use standard logic supply voltages and are TTL and DTL compatible. Texas Instruments Inc., 13500 N. Central Expressway, Dallas, TX 75222. Phone (214) 238-2011. **222**

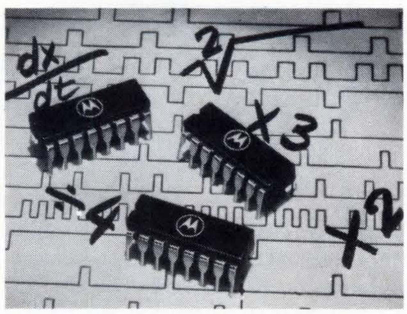


TWISTED PAIR-LINE DRIVERS MAINTAIN CURRENT BALANCE. This high-speed twisted pair-line driver uses a matched current source and current sink to maintain equal, but opposite currents in the two lines. The currents are controlled by the condition of the input logic gates. This driver is particularly useful in party-line systems where several drivers and receivers share a common transmission line. Motorola Semiconductor Products Inc., P.O. Box 20912, Phoenix, AZ 85036. Phone (602) 273-6900. **224**

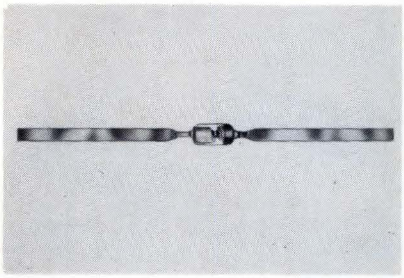


8-INPUT DATA SELECTORS ROUTE DATA IN 4.5 NSEC. The S54S151, S54S251, N74S151 and N74S251 Schottky clamped, high-performance, 8-input data-selector multiplexers are available for use in very-high-speed data routing applications. These multiplexers select one of eight data sources when so directed by the binary address inputs. Both true and complementary data are presented when the strobe input goes low. The S54S151 and N74S151 are functionally and mechanically interchangeable with the S54151 and N74151 respectively, and in most TTL systems can be utilized to upgrade the performance of existing designs, as delay times are typically half that of the S54151 or N74151. The S54S151 and N74S151 have 3-state outputs which permit the outputs to be connected to a common bus. Prices are expected to be slightly more than $5 per device when purchased in lots of 100. Signetics, 811 E. Arques Ave., Sunnyvale, CA 94086. Phone (408) 739-7700. **225**

FM GAIN BLOCK SIMPLIFIES COMMERCIAL RECEIVER DESIGN. The Type ULN-2131M FM Gain Block linear-monolithic integrated circuit is designed for use in communications and high-fidelity FM receivers. This device consists of a three-stage limiting amplifier section, a regulated power supply, an AM detector and 330Ω input and output terminations with 7 pF shunting capacitance required for 10.7 MHz ceramic filters. Gain can be adjusted without effect on input and output conditions by addition of a fixed resistor between pins 3 and 7. When used with Sprague Type ULN-2111 or ULN-2113 FM Detector/Limiter circuits, sensitivity in the 10 to 15μV range can be obtained. Absolute max. ratings are: supply current, I_{cc}, 22 mA; supply voltage, V_{cc}, 16V; input voltage (pins 1 and 3), ±3.0V; power consumption (internal), P_D, 750 mW; operating temperature, T_A, −40° C to +85° C. Sprague Electric Co., 115 Northeast Cutoff, Worcester, MA 01606. Phone (617) 853-5000. **227**



CMOS RATE MULTIPLIER PERFORMS ARITHMETIC FUNCTIONS. The MC14527 BCD rate multiplier can be used to perform arithmetic, algebraic and differential equation functions. It has two inputs: one a pulse frequency and the other a BCD number. The output of the device is the product of the frequency and BCD number. MC14527 multipliers are internally synchronous for high speed operation up to 5.0 MHz, typical. Motorola Semiconductor Products Inc., P.O. Box 20912, Phoenix, AZ 85036. Phone(602)273-6900. **232**

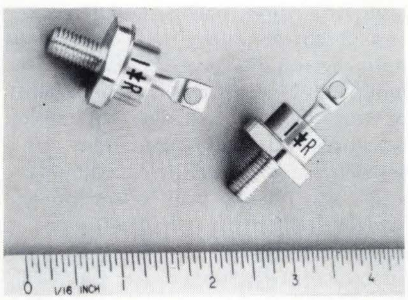


UHF/VHF VARACTOR DIODES PROVIDED WITH RIBBON LEADS. This 803GT Series varactor tuning diodes are intended for use on one sided pc boards incorporating UHF/VHF stipline circuitry. At frequencies up to 1000 MHz, the glass package is virtually lossless which, with its low 1.4 nH inductance, provides an almost ideal variable capacitance circuit element. The capacitance at − 4V ranges from 3 to 44 pF with Q values over 800 for the 3 pF devices at 50 MHz. The ribbon leads of approximately 0.005 in. thick by 0.050 in. wide make one sided pc board soldering a cinch. The glass body of the diode is 0.165 in. long and 0.080 in. dia. These diodes are available with voltage breakdown values of 25V with capacitance tuning ratios of 2:1 from 2V to 25V bias. The diodes are useful in UHF/VHF pre-selectors, synthesizers, TCXO's and VCXO's. With a temperature coefficient of capacitance of 200 ppm/°C typically, the 803GT Series insures long-term stability and reliability up into low-microwave-frequency ranges. MSI Electronics Inc., 34-32 57th St., Woodside, NY 11377. Phone (212)672-6500. **233**

3-STATE LINE DRIVERS INCREASE DRIVER FAMILY. A tri-state line driver has been added to the computer interface family of Advanced Micro Devices. The Am78/8831 can be operated either as a quad single ended or dual differential driver. Because it offers a tri-state output it is particularly suitable for party-line operation where several drivers are connected to the same bus. Introduction of this device brings to ten the number of drivers and receivers available. Available in both the military and commercial ranges, it offers high drive capability as well as common bus operation. These drivers undergo 100% temperature cycling, stabilization bake and hermeticity testing to the requirements of Military Standard 883. Additionally, all units are tested to the standard's requirements for fine and gross leak hermeticity and centrifuge stressing. Advanced Micro Devices Inc., 901 Thompson Pl., Sunnyvale, CA 94086. Phone(408)732-2400. **234**

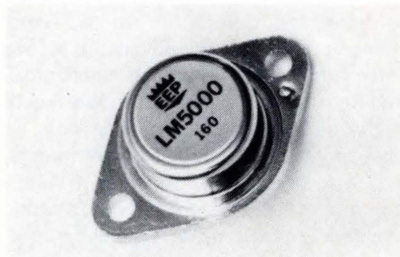
FM DETECTOR REQUIRES SINGLE TIMING COIL. The TYPE ULX-2213 FM Detector and Limiter combines a three-stage limiting amplifier and a balanced quadrature discriminator. Although primarily designed for use in FM receivers at 10.7 MHz, the device is equally suited for any FM application in the 5 kHz to 50 MHz frequency range or in portable or mobile designs where a lower nominal voltage supply is required. Sprague Electric Co., 115 Northeast Cutoff, Worcester, MA 01606. Phone(617)853-5000. **235**

HIGH-GAIN POWER AMPLIFIER IS RATED AT 5W. TYPE ULX-2205 High-Gain Power Amplifier performs the complete audio amplifier function from volume control to speaker. Built-in thermal overload protection and output current capability make this amplifier ideally suited to automotive entertainment applications or where the low-impedance speaker could accidentally be shorted. Where higher speaker impedances of 8 and 16Ω are required, the TYPE ULX-2205 has a high-voltage capability. Sprague Electric Co., 115 Northeast Cutoff, Worcester, MA 01606. Phone(617)853-5000. **236**



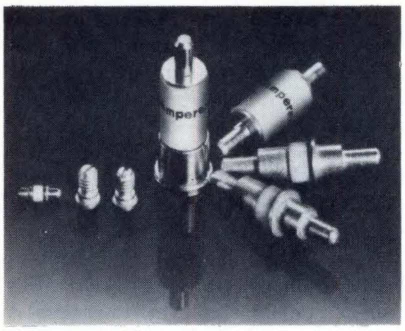
50A, 15V HOT CARRIER DIODES FEATURE LOW FORWARD DROP. Type 5OHQ015 Schottky's max. peak forward voltage drop of 0.87V at 157A and 25° C (0.65V at 100A) makes it possible to design higher efficiency rectifiers, which result in savings in power costs, heat sinking, package size and cooling system requirements. It is especially suitable for high-frequency (over 20 kHz) rectifier circuits. The device features epitaxial construction and oxide-nitride passivation. Prices in 100-999 quantities are $9. International Rectifier Corp., Semiconductor Div., 233 Kansas St., El Segundo, CA 90245. Phone(213)678-6281. **238**

PNP-NPN COMPLEMENTARY PAIRS ARE RATED AT 10A. These transistors are characterized by identical gain characteristics over a wide collector current range. Current gain matching is uniform from less than 100 mA to 10A, collector current. Input voltage for the complementary pair are also identical over the same collector current range. The transistors have low-saturation voltages, the 5A VCE (sat) is less than 0.5V and the VBE (sat) is less than 1.2V at 5A. The devices are specified with collector to emitter voltage ratings to 140V. This complementary family of transistors is also characterized by fast switching capability. The transistors typically have a f_t of 80 MHz and are capable of less than 1 msec turn-off time at 5A. Kertron Inc., 7516 Central Industrial Dr., Riviera Beach, FL 33404. Phone(305)848-9606. **239**

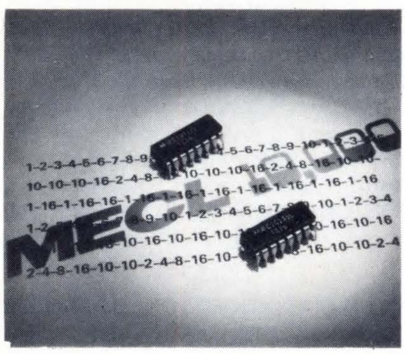


HYBRID-VOLTAGE REGULATOR SUPPLIES 3A AT 5V. This high-power hybrid-voltage regulator consists of monolithic circuitry and a power-transistor chip. It was designed as a power supply for TTL and DTL ICs in control and measuring equipment and other industrial uses. Very few external components and no further adjustment are required. In addition, built-in circuit protection against continuous overload and short circuit damage is provided. The devices are hermetically sealed in TO-3 package, 2-pin configuration. Price is $5 each in orders of more than 100. European Electronic Products Corp., 10180 W. Jefferson Blvd., Culver City, CA 90230. Phone(213)838-1912. **240**

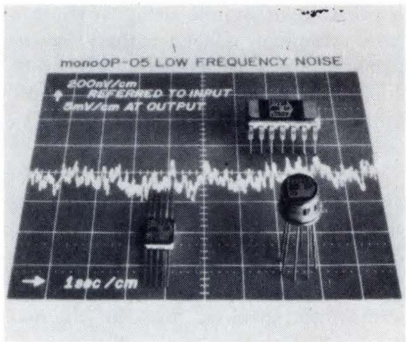
12 CIRCUITS ADDED TO SCHOTTKY TTL PRODUCT LINES. The new units include five gates, four JK flip-flops and three MSI functions. The MSI devices currently being introduced include the 93S05 variable-modulo counter, 93S41 arithmetic logic unit (ALU) and the 93S42 carry-lookahead device for use with the ALU. These circuits allow 16-bit addition in 19 nsec. Pinning is interchangeable with Fairchild's standard 9N, 9H SSI and 9300 MSI TTL families. Fairchild Semiconductor Components Group, 464 Ellis St., Mountain View, CA 94040. Phone(415)962-3816. **241**



4 LINES OF MICROWAVE DIODES FOR COMMUNICATIONS OFFERED. The four lines include 11 Schottky barrier devices, four tuning varactor diodes, 23 Gunn effect devices, and five IMPATT devices; a total of 42 devices available for applications in C, X and Ku band systems. The 11 Schottky barrier diodes are intended for low-noise mixer and detector applications up to 18 GHz. These devices have the advantage of low noise combined with greater mechanical stability than point contact diodes such as the IN23 that they generally replace. Type BAV46 is optimized for applications requiring minimal 1/F noise at X band. 1/F noise at 1 KHz is typically 10 dB while sensitivity is 1.0 μA/μW. Typical applications for the BAV46 with its extremely high-tangential sensitivity, are in doppler radar systems and in intruder alarms. All eleven types in this group are available in matched pairs. Amperex Electronic Corp., Hicksville Div., Hicksville, NY 11802. Phone(516)931-6200. **242**

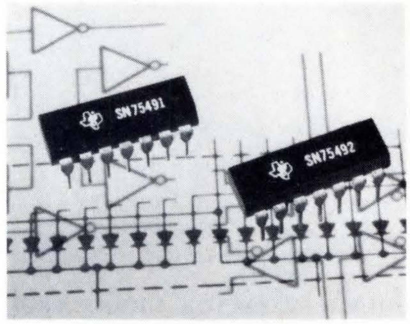


FIRST TWO COUNTER CIRCUITS JOIN 10k LOGIC SERIES. The MC10136, is a universal hexadecimal up/down (0 to 15) counter; the other, MC10137, is a universal BCD decade up/down counter. Either can count at rates over 100 MHz (typically 150 MHz). Both units are high-speed synchronous counters of MSI complexity. These counters are intended for applications in high-speed central processors, peripheral controllers, minicomputers, high-speed digital communication equipment and instruments. Motorola Inc., Semiconductor Products Div., Box 20924, Phoenix, AZ 85036. Phone(602)273-3466. **243**



FULLY PROTECTED OP AMP PROVIDES LOWEST NOISE AND DRIFT. Similar to the SSS725 in its noise and drift performance, the mono OP-05 offers in addition a vastly improved slew rate of 0.25V/μsec (vs 0.008) and greatly decreased input bias currents of 1.0 nA (vs 30 nA) thus enabling operation in high-source impedance circuits formerly requiring super-"β" op amps. No additional external components are required for frequency compensation or input protection, saving 4 compensating and 2 to 4 protection components normally required by 725 designs. The mono OP-05 inputs are protected against ±30V differential voltages by series resistors and clamping diodes. The resistive loads are split to accommodate a 20 kΩ nulling pot; offset nulling actually optimizes the offset voltage drift. Precision Monolithics Inc., 1500 Space Park Dr., Santa Clara, CA 95050. Phone(408)246-9225. **244**

SERIES PROVIDES SWITCHING POWER FOR LASER DIODES. The switching time of the KS Series devices also provide drive power for the replacement of mechanical or solid-state circuitry for dc to dc converter (chopper) circuits. The KS Series has also been successful in driving "LED displays" as well as switching power supplies and switching regulators. A typical 5A device ranges from $5 to $10 and the complete family ranges in price from $2 to $22 and is rated from 0.25A to 20A with voltage capabilities to 120V. Kertron Inc., 7516 Central Industrial Dr., Riviera Beach, FL 33404. Phone(305)848-9606. **245**



TWO ICs DESIGNED FOR MOS-TO-LED DISPLAY INTERFACE. Designated the SN75491 and the SN75492, these MOS-to-LED drivers are believed to be the only monolithic ICs currently on the market to perform this interfacing function. These two ICs are used together with MOS ICs and with common-cathode LEDs in serially addressed multi-digit displays. This time-multiplexed system, which uses a segment-address-and-digit-scan method of LED drive, minimizes the number of drivers required. The SN75491 replaces eight transistors and 12 resistors while the SN75492 replaces 12 transistors and 18 resistors. The 491 is a quad segment driver with 50 mA of source capability for driving the individual segments of a LED display. The 492 is a hex-digit driver and features 250 mA sink capability. They are also well suited for several other applications. These include quad or hex high-current PNP transistor drivers, and base/emitter select NPN transistor drivers. Texas Instruments Inc., P.O. Box 5012, Dallas, TX 75222. Phone(214)238-3741. **246**

DUAL FLIP-FLOP IS RATED AT 1W. The SW-20, intended for use in frequency divider or countdown applications, operates with a broad range of supply voltages. Internal regulation minimizes both power drain and changes in characteristics with supply voltage and temperature variations. The circuits have output buffers to isolate the flip-flops from noise associated with output wiring, and the input circuitry contains a Schmitt trigger to provide noise immunity. Inputs are provided with clamp diodes to minimize undershoot. The circuits are relatively insensitive to narrow noise spikes and other disturbances on the input signal that may be related to system wiring reactances. Maximum rating for total power applied to the package is 1W at +25°C and 0.5W at 75° C. Min. and max. voltages are −0.5 to +19V dc. Stewart-Warner Microcircuits, 730 E. Evelyn Ave., Sunnyvale, CA 94076. Phone(408)245-9200. **247**

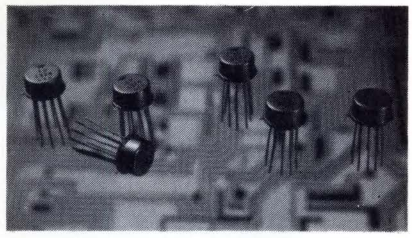
SERIAL MOS DELAY LINE WITH MORE THAN 20,000 BITS in a 4-1/2 × 6 in. package is priced at less than 1/2 cent per bit. Model 2261 is the first in a series of a complete line of solid-state digital memories. Application for these new units include CRT refresh memories, delay line and line printer memory replacements, line storage, and other applications requiring digital delays. Data input and output is compatible with DTL/TTL. Unit requires only a single clock and NRZ data. Clock and data rates range from 5 KHz to 4 MHz. Melcor Electronics Corp., 1750 New Highway, Farmingdale, NY 11735. Phone(516)694-5570. **248**

TWO HIGH-POWER OP AMPS DELIVER LARGE OUTPUT CURRENTS. The LH0021 will provide output currents in excess of 1A at voltage levels of ±12V; the LH0041 delivers currents of 200 mA. The LH0021 is supplied in 8-pin TO-3 package rated at 20W with suitable heatsink. The LH0041 is supplied in both 12-pin TO-8 (2.5W with clip on heatsink) and a power 8-pin ceramic DIP (2W with suitable heatsink). Letterhead inquiries only. National Semiconductor Corp., 2900 Semiconductor Dr., Santa Clara, CA 95051. Phone(408)732-5000. **249**

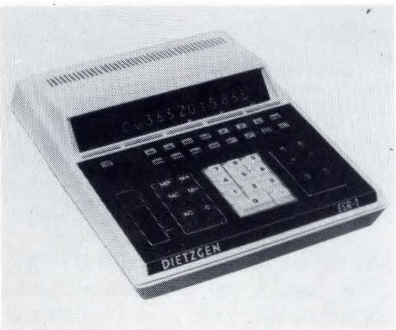
TTL-COMPATIBLE WAVEFORM GENERATOR/VCO FEATURES HIGH STABILITY. A new monolithic IC waveform generator and voltage controlled oscillator, the 8038, produces simultaneous sine-wave, square-wave and triangular-wave outputs with minimum amplitudes up to 6V, 28V and 10V p-p, respectively. The 8038 is available in three versions, each with a different temperature drift specification: 8038A has 50 ppm/°C max.; 8038B, 100 ppm/°C max.; and 8038C, 50 ppm/°Ctyp. Output frequency is tunable from 0.001 Hz to 1.0 MHz. Intersil, 10900 N. Tantau Ave., Cupertino, CA 95014. Phone(408)257-5450. **251**

SCHOTTKY BARRIER DIODES, BOTH SILICON AND GALLIUM ARSENIDE, were specifically designed for mixer, detector and switching applications in the UHF to Ku Band. Series A2G170 and A2G130 Mixer diodes are optimized to provide 5.5 dB noise figure for X Band. Series A2S100 silicon diodes are designed for applications from C to Ku Band. Prices from $3 in small quantities. Aertech Industries, 825 Stewart Dr., Sunnyvale, CA 94086. Phone(408)732-0880. **254**

4K-BIT RAM IS ELECTRICALLY ALTERABLE. SMC N-4412 is a 4096-bit electrically alterable random access memory with decoding and sensing contained on a single monolithic silicon structure. The 4412 makes use of a proprietary process, Coplamos, which provides the higher speed inherent in an N-channel structure and improved density. Access time is less than 180 nsec. Standard Microsystems Corp., 35 Marcus Blvd., Hauppauge, NY 11787. Phone(516)231-5151. **252**



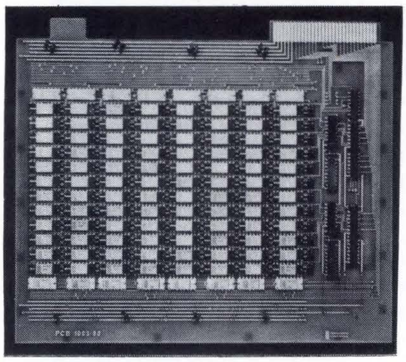
FAST SETTLING MONOLITHIC OP AMP is low cost. A fast, guaranteed, 100% tested settling time of 1 msec to 0.01% at a low price of $7.50 in 100s are the key features of the Model 1324, a new monolithic op amp from Teledyne Philbrick. The superior performance of the new op amp is entirely the result of innovative circuit design. Other features of the 1324 include excellent bandwidth and slew rate (10 MHz and 35 V/μsec, respectively) freedom from latch up, TO-100 packaging with 715 compatible pin-out, simple compensation, and excellent stability. For critical applications, the 1324/01, a selected version of the 1324, is available with improved bias current and offset drift specifications, for $11.50 in 100s. Teledyne Philbrick, Allied Drive at Route 128, Dedham, MA 02026. Phone(617)329-1600. **253**



SLIDE-RULE MAKER GOES ELECTRONIC. Several exclusive features are offered in the Model ESR-1 electronic slide rule including a full 12-digit display, automatic cube root and hyperbolic functions in addition to all transcendental and trigonometric functions. The 16-funciton slide rule also features the direct conversion of radians to degrees and degrees to radians, as well as degrees, minutes and seconds to decimal equivalents. Dietzgen Corp., 2425 N. Sheffield Ave., Chicago, IL 60614. Phone (312) 549-3300. **201**

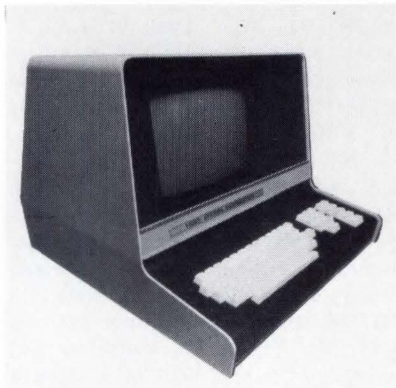
CASSETTE DATA TERMINAL INCLUDES A NONIMPACT PRINTER. The NCR 260-6 ASR (Automatic Send-Receive) uses heat patterns to form letters and numbers on heat-sensitive paper and operates at 300 wpm. With its ability to store data on magnetic tape cassettes, the terminal need not be continually attended. Messages can be keyed in the left for later dial-up retrieval by the computer. Similarly, messages from the computer can be received and stored on the tape for later printing. Information is stored in tape cassettes in 200 separate 80-character blocks. Rental price is $150/mo. NCR, Dayton, OH 45409. Phone (513)449-2150. **202**

MODEM WORKS OVER BOTH CONDITIONED OR UNCONDITIONED LINES. The digital adaptively equalized ADS 440/48 is a full-duplex 4800 bps data modem designed to operate over voice-grade telephone lines. A switching option permits operation at 2400 bps in situations where line conditions are intolerable, or the unit may be used to multiplex 2 independent 2400 bps data channels. Standard test features include local data and line loopback plus remote data loopback for 1-point system testing. $3000. American Data Systems, 8851 Mason Ave., Canoga Park, CA 91306. Phone(213)882-0020. **203**



8k × 12 EXPANDABLE RAM SYSTEM. The RAM 1A features low standby power dissipation of 4.0W, access time 350 nsec, cycle time 450 nsec, and it is TTL compatible. The RAM 1A is developed around the fully proven MF 1103 silicon gate, p-channel 1k × 1 MOS RAM. The RAM 1A memory system is comprised of an interface and control module providing TTL interface, address register, data input register and timing logic and one or more identical memory modules. The memory module is organized as 8k words × 12 bits. Up to 4 memory modules may be used with each I&C module to provide a total memory system of 384 kilobytes organized as 32k × 12. Price is less than $0.01/bit. Microsystems International Ltd., Box 3259, Station C, Ottawa, Canada K1Y4J1. **204**

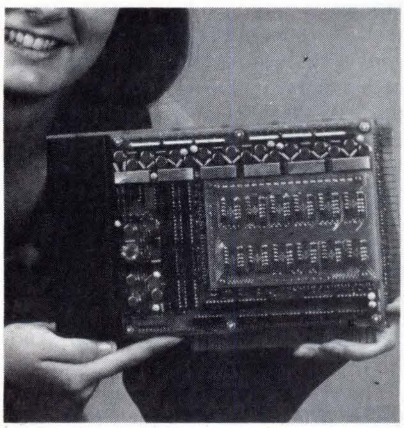
FLOPPY DISC SPORTS HIGH CAPACITY AND FAST ACCESS. In addition, the 651 has a write protect feature and the highest data transfer rate of any competitively priced flexible disc file. It features track-to-track access time of 10 msec with 10 msec settle time. This fast positioning time, along with the 80 msec average latency time, provides improved data throughput. Data can be formatted in either sector or index mode starting with 132-byte records with 32 records/track (64 tracks) up to 1 record of 4880 bytes/track, making a maximum capacity of 312,500 bytes (2,500,000 bits). $750. Memorex Corp., San Tomas at Central Expwy., Santa Clara, CA 95052. Phone(408)987-2200. **206**



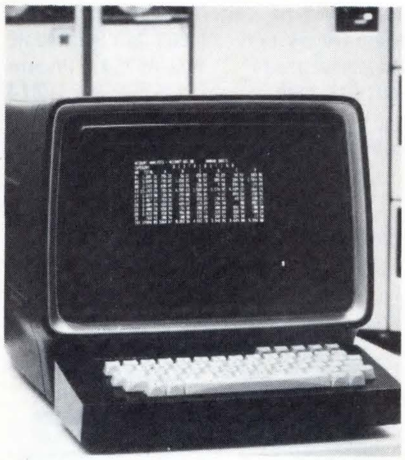
CRT DATA TERMINAL HAS SOLID-STATE MEMORY. Model VST-1440 data terminal features an MOS memory capable of storing and displaying 1440 characters, a display of 80 char./line in 18 lines on a 12-in. CRT and a TTY-style keyboard plus a 10-key numeric pad. The terminal generates all 128 ASCII characters and displays 64 different ASCII characters. The equipment decodes a number of control functions for computer or remote control operation. All controls are located on the front panel, including a selector switch for baud rates of 110, 150, 300, 600 and 1200. $1995. Video Systems Corp., 7300 N. Crescent Blvd., Pennsauken, NJ 08110. Phone(609)665-6688. **205**

12 PRODUCTS ADDED TO SPC-16 FAMILY. New products are: in peripherals—a low speed line printer, a head-per-track disc storage drive, a combination paper tape reader/punch and a combination line printer/card reader controller; in process I/O hardware —a high-speed floating point processor, a series of heavy-duty I/O boards including ac switching interfaces, a new line of A/D and D/A converters and a new series of digital I/O; in data communications equipment—a new asynchronous communications multiplexer; and in software programs—new RTOS-16 and multi-user BASIC software. General Automation, Inc., 1055 S. East St., Anaheim, CA 92805. Phone(714)778-4800.

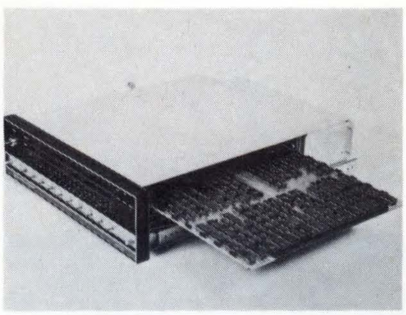
PORTABLE DATA TERMINAL HAS OWN ACOUSTIC COUPLER AND PRINTER. The 150T terminal is capable of operating at 10 or 15 cps (110 or 150 Baud) and can be operated anywhere there's a 115V outlet and a telephone. The 150T keyboard generates all 128 ASCII codes with preselected odd, even or no parity. The printer will produce the full 64 ASCII dense subset. Lower-case recognition circuitry will cause printing of upper-case graphics, allowing communications with a processor that sends upper and lower case. Single or multi-copy printing is standard. Half- or full-duplex operation is switch selectable, operating at 100 or 150 wpm. $2100. MITE Corp., 446 Blake St., New Haven, CT 06515. Phone(213)387-2572. **207**



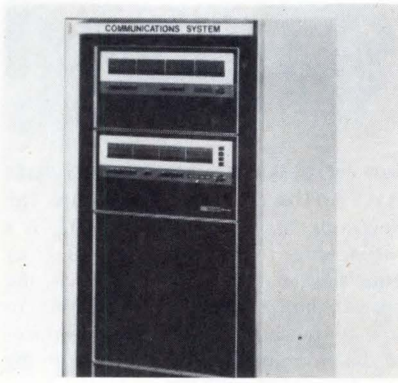
COMPACT CORE MEMORY FOR SMALL STORED PROGRAMS. The Model 9100 is designed for use by OEMs and is the first memory to use the new 18-mil Ampex Temperature Independent (TIN) cores, which eliminate the need for temperature compensation and forced air cooling equipment. The 3-D, 3-wire memory operates reliably with access times faster than 400 nsec and is priced at less than $.015/bit in quantities. Capacities are 1k, 2k and 4k words of up to 9 bits each, and in 1k and 2k words of up to 18 bits each. Ampex Corp., 13031 W. Jefferson Blvd., Marina del Rey, CA 90291. Phone(213)821-8933. **208**



INPUT DATA TERMINAL SPORTS LARGE-CAPACITY CRT. The TD 800 input and display system provides on-line communication and display of data at low cost and can operate on the same communication line with a mixture of terminals. A group of TD 800's can share the same data set and be polled as a single address by a central computer system. The system displays white alphanumeric characters on a black background. Users can select a TD 800 with a display capacity of either 960 characters or 1920 characters. Data is displayed in 12 or 24 lines of 80 characters each. $4750 for the 96-character TD 800. Burroughs Corp., Burroughs Pl. Detroit, MI 48232. Phone(313)972-7083. **209**

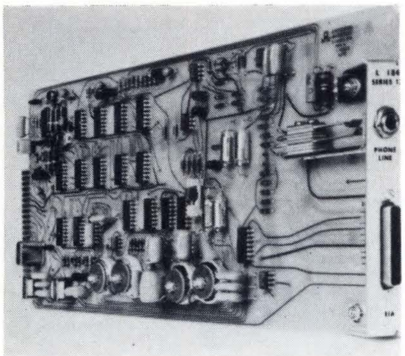


APGEN 1 SPEEDS ARRAY PROCESSING IN NOVA MINIS. APGEN 1 is a hardwired array processing arithmetic and logic unit which speeds up the array processing capabilities of any Data General computer by a factor of 6 to 70. It performs addition, subtraction, multiplication and division of two arrays composed of 16-bit words. It is also capable of taking the square root, integrating, accumulating and performing logical operations on the element of arrays. APGEN 1 plugs into the mainframe of any Nova computer without modification to it. Interfaces to other minis are available. Elsytec, 212 Michael Dr., Syosset, NY 11791. Phone(516)364-0560. **210**

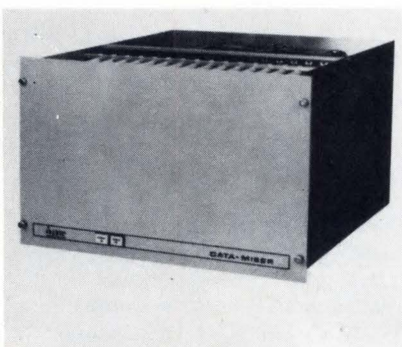


COMMUNICATIONS PROCESSOR INCLUDES 2 CPUs. Each of the 1600/16's independent CPUs contains separate I/O systems and microprogram control memories. A common main core memory and CPU-to-CPU interrupt system permits separation of line discipline and character handling with the message processing tasks. One CPU, a GP computer, is dedicated to system control, control of peripheral devices and message processing. The second CPU, called the communications operating module (COM-60), services up to 256 synchronous and/or asychronous communications channels operating full or half duplex with throughput up to 40,000 cps. $29,000. Microdata Corp., 17481 Red Hill Ave., Irvine, CA 92705. Phone (714)540-6730. **211**

CONTROLLER FOR LARGE-SCALE DATA COMMUNICATIONS SYSTEMS. The system, which can handle up to 1024 asynchronous lines, is the largest offered by any minicomputer manufacturer. The controller can be used with any Nova computer. The Multiline Asynchronous Controller features the ability to handle a large number of lines and to be expanded and maintained while still on-line, making it suitable for message switching systems. The system can handle line speeds up to 9600 baud. The controller lets communications systems designers set up large-scale systems economically. For instance, a 192-line system, made up of 128 lines with modem control and 64 lines without modem control costs under $60,000, or about $300 per line. Data General Corp., Southboro, MA 01772. Phone(617)485-9100. **212**

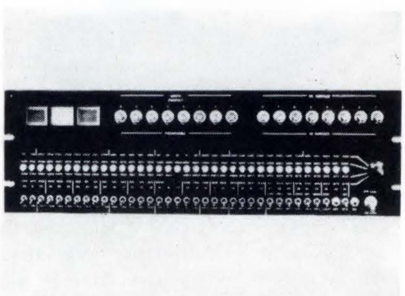


103F MODEM REPLACEMENT PROVIDES HALF & FULL DUPLEX OPERATION. The new modem, designated L 184/12, is a replacement for the Bell 103F or equivalent data set. It operates in the answer mode over 2-wire leased or private transmission lines and interfaces to data terminal equipment through the standard EIA RS-232-B/C interface. The L 184/12 offers built-in circuitry for fast isolation of troubles anywhere in the system. Two pushbutton switches located on the front panel of the Series 12 chassis allow testing of the modem-to-computer interface and the modem-to-remote equipment interface including the transmission lines. Anderson Jacobson, Inc., 1065 Morse Ave., Sunnyvale, CA 94086. Phone(408)734-4030. **213**

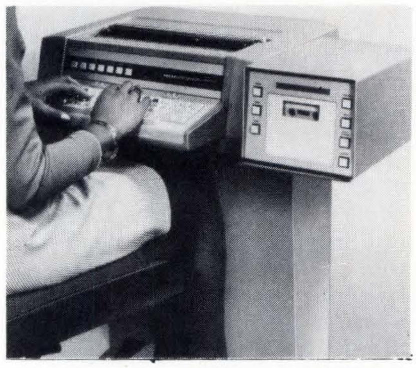


DISC MEMORY SYSTEM PLUGS INTO PDP-11. The DATA MISER provides a plug-compatible moving head disc memory system with 1.25M words of storage that includes the software, controller, disc, power supplies and cabling required to plug into the PDP-11 Unibus. It can be field expanded by adding up to seven additional discs to the initial controller to increase the data storage capacity to 10M words. The system is fully DEC DOS compatible or an IMS DOS monitor already recorded on the disc is available. Data transfer rate is 10 msec/word with an average random access time of 75 msec. Price is $4950 for 1.25M word capacity. International Memory Systems, 14609 N. Scottsdale Rd., Scottsdale, AZ 85254. Phone (602)948-2120. **214**

DISC-CARTRIDGE SYSTEM FOR D-116 MINIS. The disc drive is available with recording densities of 1100 bpi or 2200 bpi. The moving head drive features a high-density transfer rate of 1.56 MHz. Data is recorded on an IBM 2315 equivalent cartridge. Single-density recording provides on-line storage of 1.2M bits for the D-116 minicomputer. Double-density recording at 1.56 MHz permits storage of 2.4M and 3.2M bits, respectively. The cartridge-disc system operates under Digital Computer's disc-operating-system (DOS). Prices begin at $5000. Digital Computer Controls Inc., 12 Industrial Rd., Fairfield, NJ 07006. Phone(201)227-4861. **215**

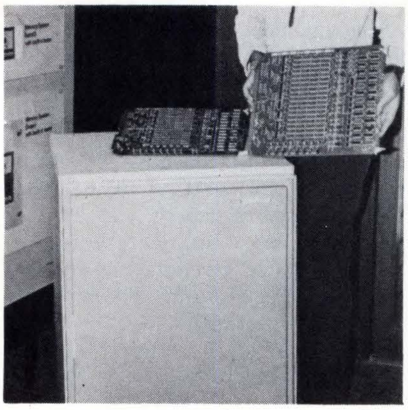


DISC CONTROLLER INTERFACES DISC DRIVES TO PDP-15 COMPUTERS. The DC-18 connects the PDP-15 single-cycle I/O channel and controls up to eight IBM 2311, 2314 compatible disc drives. Operating features of the DC-18 include: simultaneous seek operations, ease of programming since it requires only 8 commands, verification of track location by hardware, error checking of all data transfers by hardware, ease of maintenance, hardware monitoring of many subsystem status conditions, low core requirements for software, read or write multiple records with a single command and direct transfer to or from memory for data, thus eliminating blocking I/O channels. $15,000. Telefile Computer Products, Inc., 17785 Sky Park Circle, Irvine, Ca 92664. Phone(714)557-6660. **216**

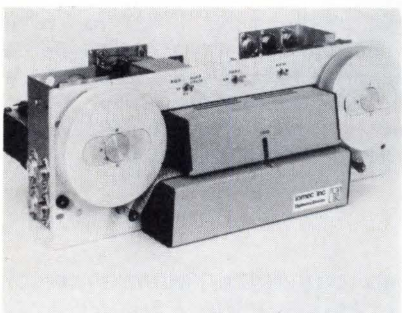


TERMINAL INCLUDES INTEGRATED MAG TAPE BUFFER. Called the EDT 300 MSR (Magnetic Send-Receive), the 30 cps data communications is an integrated package of Data Services' EDT 300 KSR with a magnetic tape cassette buffer. Storage is approximately 50,000 characters. The MSR buffer transmits at 10, 15, and 30 cps, with a full rewind capability of less than 90 sec. The impact printer of the EDT 300 MSR operates in half or full duplex modes at selectable speeds of 10, 15, and 30 cps in serial form and prints 118 columns in upper and lower case ASCII characters. Data Services Co., 16 McKee Dr., Mahwah, NJ 07430. Phone(201)529-1170. **217**

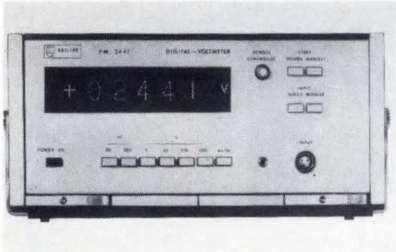
DATA TABLET FEATURES HIGH ACCURACY AND LOW COST. The tablet features an accuracy of ±0.005 in., absolute coordinates in both single-shot and free-run modes, excellent stability and linearity, insensitivity to ambient conditions, no practical limit to size, silent operation, freedom from protrusions above the tablet surface, unencumbered cursor and stylus and no mechanical parts to wear. The system comprises a tablet, cursor or stylus and electronic controls. It is easily interfaced with a computer for real-time operation, either directly or via voice-grade phone line. Scriptographics Corp., 398 Kings Hgwy., Fairfield, CT 06430. **218**



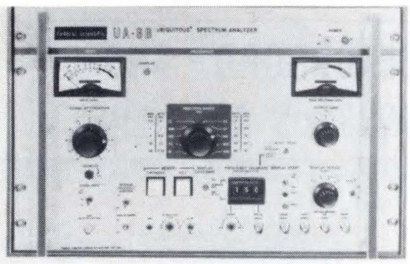
ADD-ON MEMORY FOR SIGMA 5/7 SAVES 50%. The self powered memory unit is contained in its own enclosure and is fully hardware and software compatible. The SG-57 cables directly to the Sigma memory bus and operates with a cycle time of 650 to 750 nsec. The memory has all interface lines fully protected in both current and voltage modes and includes an off-line computer simulator test system. Field expansion is quick and easy with plug-in memory cards in 4k increments up to 16k. Each memory bank may be expanded with up to 16 ports. The basic 4k system costs $16,000. Signal Galaxies Inc., 6955 Hayvenhurst Ave., Van Nuys, CA 91406. Phone(213)988-1570. **219**



PAPER TAPE HANDLER FEATURES QUIET OPERATION. The 4040 consists of a new tape handler panel integrated and specifically designed to compliment the Model 2540 tape reader. The 4040 combination operates synchronously up to 300 cps right to left, with 400-character rewind. Up to 320 ft. of 4.5 mil. tape or 580 ft. of 2.5 mil. tape in widths from 11/16 to 1 in. (5 to 8 level) can be handled interchangeably on 5-in. reels. The newly designed tape handler eliminates large transient currents and switching noise. $1170. Iomec Inc., Digitronics Div., Route 9, Southboro, MA 01772. Phone(617)481-2500. **221**

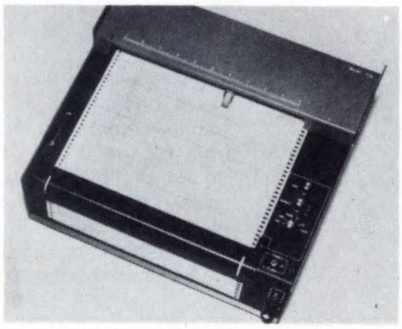


AUTO RANGING PRECISION DVM OFFERS 10 GΩ IMPEDANCE. The Philips auto-ranging DVM with $10^{10}\Omega$ input impedance, designated PM2441, can be used for precision bench measurements with either manual or automatic ranging, or in a fully automated or remote controlled system. It measures 1 μV to 1 kV in 6 ranges and has an input circuit that is floated and guarded. CMR is 150 dB dc and 120 dB ac, maximum scale reading is 19999 and accuracy on all scales is ±1 digit (0.005% of reading ±0.005% of full scale). $1890. Test & Measuring Instruments, Inc., 224 Duffy Ave., Hicksville, NY 11802. Phone (516)433-8800. **108**

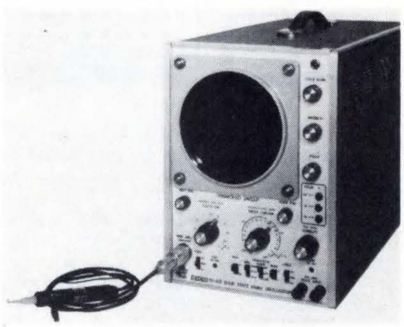


500-LINE REAL-TIME ANALYZER HAS EFFECTIVE RESOLUTION OF 650 LINES. Ubiquitous spectrum analyzer Model UA-6B is claimed to be the only 500-line real-time low-frequency analyzer which performs as if it had 650 resolution elements. This improved resolution is achieved through the incorporation of a proprietary computer designed analysis filter which provides 30% better resolution for the closely spaced frequencies—the true measure of performance of a spectrum analyzer. Model UA-6B also features automatic peak-tracking capability. Federal Scientific Corp., 615 W. 131st St., New York, NY 10027. Phone(212)286-4400. **109**

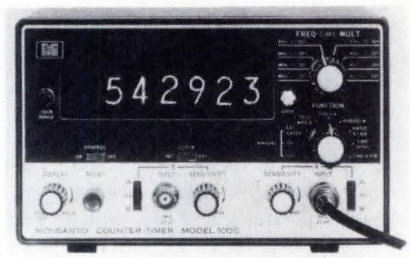
HIGH-SPEED CORRELATION AND PROBABILITY ANALYZER. A 100-point, real-time digital correlation and probability analyzer features a 2-MHz sampling rate and 1500 points of precomputation delay selectable in blocks of 50. Model SAI-42A operates in 3 modes—auto and cross correlation, probability density and distribution and signal enhancement. Features also include a 50-μsec real-time processing rate, portability, outputs that can be displayed or read out on analog or digital devices and size of $17 \times 8-{}^{3}/_{4} \times 22$ in. $6500. Signal Analysis Operation, Honeywell, Inc., 595 Old Willets Path, Hauppauge, NY 11787. Phone(516)234-5700. **110**



$595 10-IN. FLAT-BED STRIP-CHART RECORDER. A 10-in. flat-bed strip-chart recorder for only $595 is lightweight (11 lbs.) and easily transportable, spans from 1 mV to 100V full scale with a constant 10-MΩ input resistance, features 12 chart speeds, has a 30in./sec pen response and an accuracy of ±0.25% of full scale. Finger-tip controls, chart reroll capability and disposable felt pens are standard on the Model 736. Options include an event marker, remote pen lifter, alarm control switches, battery operation and an integrator. The unit is guaranteed for 1 year. Precision Standards Corp., 1701 Reynolds, Santa Ana, CA 92705. Phone(714)546-0431. **111**

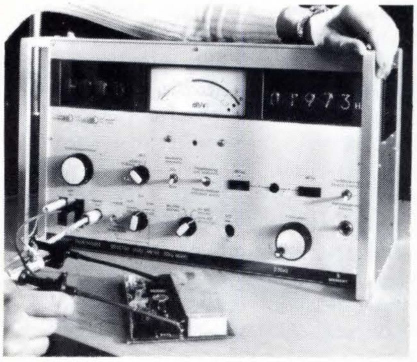


SOLID-STATE TRIGGERED-SWEEP 10-MHz SCOPE FOR ONLY $379.95. At $379.95, including an exclusive dual probe, the Eico Model TR-410 claims to be the industry's lowest priced lab-quality 10-MHz triggered-sweep scope. A single dual probe allows direct or 10:1 low-capacitance operation. Features include 3-way operation (120V ac, 100V ac and 220/230V ac, all at 50 and 60 Hz), BNC connectors, 3 calibration voltages (2, 5 and 10V) and screwdriver-adjustable horizontal and vertical dc balance. Vertical and horizontal selection of ac or dc modes of amplification is also standard. Eico Electronic Instrument Co., Inc., 283 Malta St., Brooklyn, NY 11207. Phone(212)949-1100. **112**

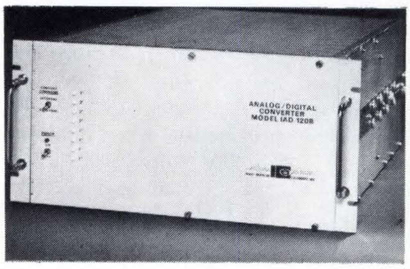


FULL-FUNCTION 50-MHz COUNTER/TIMER. A full-function counter/timer features operation to a frequency of 50 MHz. The Model 100C is equipped with a 6-digit display and features an adjustable display time with storage. The counter is said to be controlled by a highly accurate crystal clock. Other features include 2 input amplifiers with individual trigger controls and a sensitivity of 50 mV rms. FCC Approval No. 3-172 has been granted the Model 100C, and it is priced at $565. A 7-digit display unit is available for $605. United Systems Corp., a Subs. of Monsanto, 918 Woodley Rd., Dayton, OH 45403. Phone(513)254-6251. **113**

A/D CONVERTER PROVIDES BINARY OR BCD OUTPUTS. A high-speed A/D converter provides either binary or BCD coded outputs. Designed for use in medium- and high-speed data-conversion systems, Model GMAD-3 can be supplied with a variety of resolutions and conversion speeds. Four levels of resolution are available with binary output—from 11 bits plus sign with 7-μsec conversion time up to 14 bits plus sign with 10-μsec conversion time. With BCD output, either 3-digits-plus-sign resolution in 32 μsec or 4-digits-plus-sign resolution in 40 μsec can be provided. The unit price of the GMAD-3 is $1750. Preston Scientific, Inc., 805 E. Cerritos Ave., Anaheim, CA 92805. Phone(714)776-6400. **114**

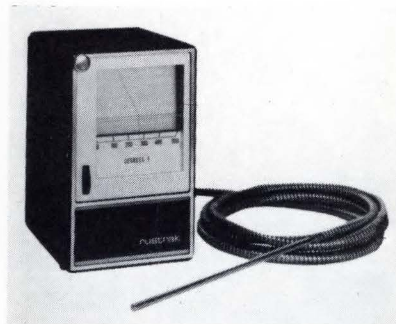


SELECTIVE LEVEL AND VOLTAGE METER FOR 10 Hz TO 60 kHz. A selective level and voltage meter operates from a low 10 Hz to 60 kHz. With the new D2040 analyzer it is possible to investigate acoustic and mechanical oscillations below the threshold of audibility. The analyzer is tunable over its full frequency range without band switching, and all its functions can be remote controlled. It operates as a superheterodyne receiver with the resolution throughout the full frequency range being 1 Hz. Siemens Corp., 186 Wood Ave., S., Iselin, NJ 08830. Phone(201)494-1000. **115**



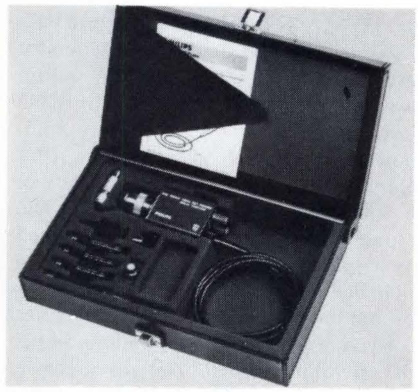
HIGH-SPEED A/D CONVERTERS. Two high-speed A/D converters are available. Model IAD-1208 8-bit unit offers speeds up to 10 MHz and includes a narrow aperture sample-and-hold, a sub-ranging A/D encoder, system timing logic, power supplies and display. Model IAD-2104N is an A/D encoder that offers 4-bit resolution and 56-MHz conversion rates. It has a 200-psec aperture time. Both units are packaged in NIMs (nuclear instrumentation module). Inter-Computer Electronics, Inc., Box 507, Lansdale, PA 19446. Phone(215)822-2929. **116**

DIGITAL THERMOCOUPLE INDICATOR FOR $450 This line of digital thermocouple indicators is priced at $450. The H610 Series of indicators is designed for panel mounting. They display temperature directly in degrees Fahrenheit and operate from type J, K or T thermocouples. Accuracy of the H610 is within 2°F, and repeatability is 1°F. The maximum zero drift is ±1°F per year. Additional features include a 0.65 in. high display and an out-of-range and thermocouple burn-out indication. The H610 can be delivered within 4 weeks. Howell Instruments, Inc., 3479 S. Vickery Blvd., Fort Worth, TX 76107. Phone(817)336-7411. **117**



MINIATURE ELECTRONIC THERMOCOUPLE RECORDER HAS 2% ACCURACY. The 2155A miniature thermocouple recorder offers 2%-of-span accuracy, automatic cold-junction compensation, spans from as little as 250°F up to 2000°F and zero or 2-to-1 offset. Thermocouple calibrations of type J or K are available. A 2-rpm, 115V ac, 60-Hz chart drive motor is standard, and interchangeable gear trains can be selected which provide chart speeds from 1/8 to 60 in./hr. Dimensions are 5-5/8×3-5/8×4-1/8 in. Gulton Industries, Inc., Gulton Industrial Park, E. Greenwich, RI 02818. Phone(401)884-6800. **118**

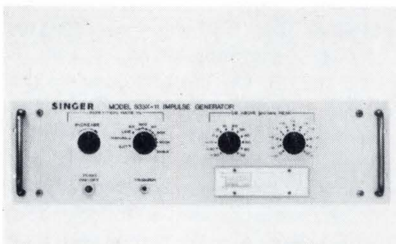
DIGITAL IC TESTER. A compact $500 IC functional tester for digital ICs of the TTL, DTL and CMOS families in DIP, TO-5 and flat configurations is the Model 1248. The instrument tests ICs before they are mounted in a circuit, determining in from 1 to 5 sec whether or not the device inputs and outputs operate according to the required logic relationships. It does not require a reference IC for comparison and is a true functional tester, yielding an absolute result. Electro Scientific Industries, 13900 N.W. Science Park Dr., Portland, OR 97229. Phone(503)646-4141. **119**



ACTIVE SAMPLING SCOPE FET PROBE HAS 1-GHz BANDWIDTH. An active FET probe is designed for use with GHz - bandwidth sampling scopes. Designated PM9345, it was developed by Philips for use with its RM3400 1.7 - GHz sampling scope and is priced at $375. The PM9354 converts the intrinsic 50Ω input impedance of the sampling scope to 1 MΩ in parallel with 4 pF. Probe bandwidth is dc to 1 GHz, and rise time is 350 psec. Dynamic range is ±1V. The probe also has an independent dc offset range of ±1V. A slide switch on the probe housing allows conversion from ac to dc. Test & Measuring Instruments Inc., 224 Duffy Ave., Hicksville, NY 11802. Phone(516)433-8800. **120**

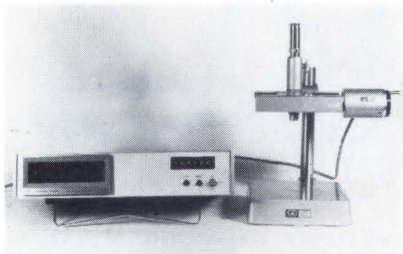
LOW-COST PHASE-SENSITIVE VOLTMETERS. The new Series 311 solid-state portable phase-sensitive voltmeters measure total, fundamental, quadrature and in-phase voltage as well as phase angle from 380 to 420 Hz. In addition, these instruments measure total ac voltage from 20 Hz to 20 kHz. Priced at only $700, they measure phase with 0.1° resolution to ±1.5° accuracy. Band-pass filtering in conjunction with phase-sensitive detection assures noise and harmonic levels below 50 μV rms. Dranetz Engineering Laboratories, Inc., 2385 S. Clinton Ave., Plainfield, NJ 07080. Phone(201)755-7080. **121**

rf GENERATOR PROVIDES 10W OUTPUT IN S-BAND. This rf generator provides a minimum of 10W CW output power over the 3.0- to 3.5-GHz frequency range. Model 1216H combines both the rf source and a TWT amplifier in a single compact unit. Use of a solid-state source, tunable over the entire range with a single control, as well as a solid-state power converter and a metal/ceramic TWT in the amplifier permit the compact size. The unit carries a 1-year warranty with no limit on hours of operation. $4550. Hughes Electron Dynamics Div., 3100 W. Lomita Blvd., Torrance, CA 90509. Phone(213)534-2121. **122**



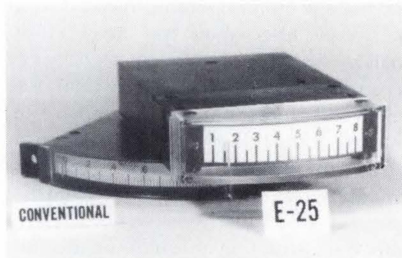
IMPULSE GENERATOR IS DESIGNED FOR RFI TESTING. A variable repetition rate impulse generator intended primarily for use as a calibrator for substitution-type interferance measurements features 4 triggering modes: internal, power-line frequency, external or manual—a versatility not found in other generators. Pulse rate can be varied continuously from 50 Hz to 5 MHz or from 0 to 5 MHz by manual or external triggering. Spectral output is flat to 100 MHz and is less than 5 dB down at 1 GHz. Model 533X-11 is an all solid-state unit. Singer Instrumentation, Los Angeles Operation, 3211 S. LaCienega Blvd., Los Angeles, CA 90016. Phone(213)870-2761. **123**

WWVB TIME SYNCHRONIZER. Model SP-465 WWVB time synchronizer provides an economical and direct method for dissiminating time and frequency information in synchronization with NBS Radio Station WWVB broadcasts anywhere within the boundaries of the continental United States. Time synchronization accuracy is 1 msec, and frequency synchronization to 1 part in 1011 is obtainable. The Model SP-465 is a valuable aid for engineers requiring time correlation of data gathered from different remote locations. It is also a primary standard for the Public Utilities and Metrology Standard Labs for time and frequency calibration. Datametrics, 127 Coolidge Hill Rd., Watertown, MA 02172. Phone(617)924-8505. **124**



DIGITAL READOUTS. Introduced is a line of electronic digital counters featuring English or Metric adaptability as well as English-to-Metric or Metric-to-English conversions. It can be adapted to micrometer slides, precision stages and related items of Gaertner Scientific Corp. manufacture. These precise and convenient systems with optical incremental encoders have readouts that are obtained on bidirectional 5- or 6-digit displays reading to 0.00005 in. In the metric unit, readings are 5 digits to 00.001 mm. The design permits installation of the metric system on English screws for English-to-Metric conversion. Gaertner Scientific Corp., 1201 Wrightwood Ave., Chicago, IL 60614. Phone(312)281-5335. **125**

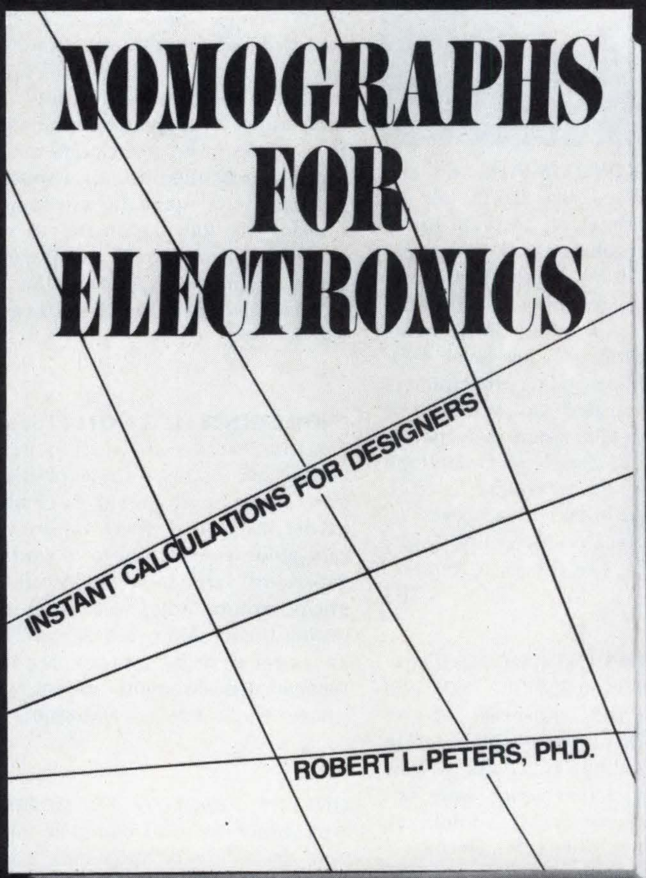
LINE OF MEGOHMMETERS. A complete line of megohmmeters for measuring insulation resistance features fixed and variable dc test voltages ranging from 5 to 5000V. The meters can be used for determining insulation and leakage measurements on meters, cables, electronic assemblies and components, dielectric materials, electrical appliances, tools, capacitors and resistors. The 2030 Series of small portable units have battery operated transistor power supplies. The 2030A has a resistance range of 10 to 2,000,000 MΩ; and the 2030B from 1 to 20,000,000 MΩ. Dc test voltage for both models is a fixed 500V. Freed Transformer Co., Inc., 1718 Weirfield St., Brooklyn, NY 11227. Phone(212)386-1300. **126**



LIGHTWEIGHT ILLUMINATED EDGE-READING PANEL METERS. The new Series E-25 and E1-25 "parkermeter" panel meters are designed for applications that require a wider scale face for reading ease. Series E-25 edge-reading meters provide a meter face $3/4 \times 2\text{-}1/2$-in. (The actual scale length is 1.80 in.) The meter case extends 4 in. behind the mounting surface. Series E1-25 has scale illumination provided by two subminiature 5, 12, 18 or 28V lamps. $80. Airpax Electronics, 6801 W. Sunrise Blvd., Ft. Lauderdale, FL 33313. Phone(305)587-1100. **127**

PHASE-ANGLE VOLTMETER SPANS BROAD FREQUENCY RANGE. A phase-angle voltmeter series which makes precision measurements over 30 Hz to 300 kHz is the PAV-4 Series which has a wide dynamic range (300 μV to 3000V), harmonic filtering and high input impedance with or without input isolation. Each of its three mainframes accepts a range of fixed and variable-frequency plug-ins. The fixed-frequency plug-ins give minimum phase accuracy of 0.5° at all frequencies. Signal and reference inputs may be direct or floating from ground. Input impedance at all frequencies is 10 MΩ from 30 Hz to 300 kHz. Singer Instrumentation, Los Angeles Operation, 3211 S. LaCienega Blvd., Los Angeles, CA 90016. Phone (213)870-2761. **128**

line up answers to electronics questions



New, reliable shortcut to solving electronics problems offering greater-than-slide-rule accuracy! Use these practical, straightforward linear graphs as your own "desk-top computer" to work out engineering problems.

Designed for immediate application, nomographs are the ideal tool for electronics engineers, circuit/systems designers, technicians and engineering management — or as a teaching aid for electronics students.

Available November 1972
Approx. 300 pp.
$27.50 (Tentative)

Table of Contents:

1. Ac and Dc Networks and Basic Parameters
2. Transistors and Tubes
3. Time Dependency
4. Magnetic Design
5. Control Systems and Response
6. Heat
7. Capacitors
8. Delay Lines
9. Filters
10. Inductors and Solenoids
11. Relays
12. Motors and Generators

Cahners Books
89 Franklin Street, Boston, Mass. 02110

Gentlemen:

Please send me _____ copies of NOMOGRAPHS FOR ELECTRONICS @ $27.50 ea. I understand that if I am not completely satisfied, I may return the books within 15 days for a complete refund or credit.

☐ Bill me ☐ Bill company ☐ Payment enclosed (Cahners pays postage)

Name ________________

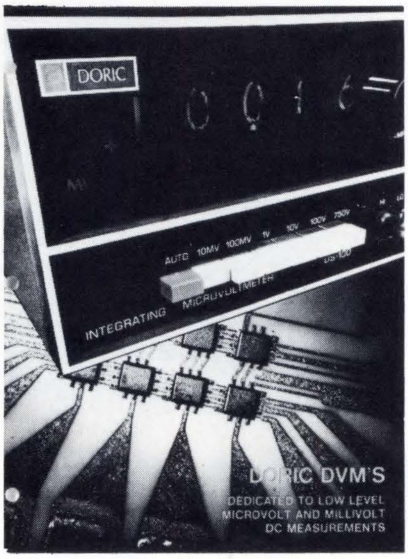
Company ________________

Address ________________

City/State/Zip ________________

(Massachusetts residents add 3% sales tax.)

S58/M0809



DIGITAL MICROVOLTMETER, Bulletin D-100G, describes the Doric line of digital microvoltmeters, accurate to ± 2 μV with 1-μV resolution and repeatability on the basic 10-mV range. The bulletin outlines the design philosophies adopted by Doric to produce instruments intended primarily for low-level measurements and how analog preamplifiers with their associated noise and drift limitations were eliminated. A section is devoted to Auto-Zero and Dual-Slope true integration, the techniques used to eliminate zero drift and "dead-band" or hystereisis errors. Doric Scientific Corp., 7601 Convoy Ct., San Diego, CA 92111. **283**

EL INSTRUMENTS CATALOG. EL Instruments announces its Winter 1972 and 1973 catalog. This expanded edition contains dozens of digital circuit design and breadboarding aids. Many new products are included which were not listed in the Summer '72 edition. EL Instruments, Inc., 61 First St., Derby, CT 06418. **279**

CUSTOM FHP MOTORS AND GEARMOTORS. A new brochure describes universal, shunt and permanent-magnet type fractional-horsepower (FHP) motors and gearmotors which can be custom designed and manufactured to meet the special requirements of the motor user. Custom motors from 1/50 to 1 hp at speeds up to 20,000 rpm can be furnished. Operating speed of these ac/dc and dc brush-type motors can be varied readily by electronic speed controls. Custom armatures and fields for assembly by the user into his product are also covered. Specialty Motors Inc., 12863 Foothill Blvd., San Fernando, CA 91342. **288**

WIRING SERVICES BROCHURE. "Wiring Services," a technical brochure, explains Cambion's computer controlled wiring service in detail and provides all the necessary customer instructions for utilizing the service. The brochure tells how to prepare a specific wiring list form and shows how Cambion uses the form to wrap IC socket boards and back planes. Cambridge Thermionic Corp., 445 Concord Ave., Cambridge, MA 02138. **280**

LOW-LIGHT LEVEL TV CAMERA. Some 10,000 times more sensitive than a standard vidicon camera, Cohu's 2856 low-light level TV camera which provides a usable picture with only 2×10^{-6} footcandles of highlight illumination on the vidicon faceplate (cloudy moonless night) is described in a data sheet. This camera, in a standard environmental housing, is fully automatic to ensure optimum pictures over a wide range of scene illuminations. Cohu, Inc., Electronics Div., Box 623, San Diego, CA 92112. **281**

"NOISE GENERATOR NOTE 1" describes Testronic's current plug-in pc card library and outlines some of the new cards under development. By combining cards in a universal cabinet and card-guide system, one-of-a-kind noise generators are built at off-the-shelf prices. Future notes will cover noise-testing theory and practical applications as suggested by reader feedback. Testronic Development Laboratory, P.O. Drawer H, Las Cruces, NM 88001. **282**

LINE OF ABSOLUTE ENCODERS. An 8-pg. brochure gives complete information on a line of solid-state absolute encoders, including single-channel, multi-channel and readout types, in conventional as well as ruggedized NEMA-12 models. The brochure contains unit descriptions, system application notes, specifications and outline drawings on the encoders, readout electronics and electromechanical transducers that make up the basic encoding systems. Astrosystems, Inc., 6 Nevada Dr., Lake Success, NY 11040. **284**

TWT-AMPLIFIER LINE. Complete specifications for its traveling-wave-tube (TWT) amplifier line are contained in a new brochure from MCL, Inc., formerly Microwave Cavity Laboratories. The amplifiers are broad-band devices that provide power needed for EMI/susceptibility testing, antenna pattern measurement, rf power instrumentation calibration and component testing. Four models—10, 20, 100 and 200W—are described in the 4-pg. brochure. MCL, Inc., 10 N. Beach Ave., La Grange, IL 60525. **285**

1973 ALLIED ELECTRONICS' CATALOG IN LARGE FORMAT. The 9- × 11-in. 420-pg. catalog is a comprehensive buying guide for everything in industrial electronic parts and supplies. Compiled to meet the needs of industry, schools, institutions and government agencies, it's also the catalog for everyone looking for one source for hard-to-get items. The catalog lists over 50,000 separate stock items from more than 400 manufacturers. Merchandise is grouped by sections and numerical cover margin tabs guide you to the products you need. Allied Electronics Catalog #730 sells for $5 (or FREE with $10 min. order) and is available from Allied Electronics, 2400 W. Washington Blvd., Chicago, IL 60612. **286**

466-PG. BOOK DESCRIBES ALL MOTOROLA MECL DEVICES. Basic performance specifications are provided for each IC device in the MECL III and MECL 10,000 logic families. In 410 pages, complete dc, ac and performance data are given for each product announced up to press time. Convenient abbreviated guides offer a quick selector for MECL logic blocks. A synoptic discussion of topics of value to the designer planning a MECL system is contained in the 36-pg. general information section. References to the extensive MECL software support available are included by way of Motorola Application note abstracts, as well as references to a sampling of MECL articles in the trade press. Motorola's MECL Data Book may be purchased for $2 per copy. Copies may be obtained by sending check or money order payable to Motorola, Inc., P.O. Box 20924, Phoenix, AZ 85036.

SOLID-STATE MICROWAVE PRODUCTS. A catalog describes solid-state amplifiers, oscillators, sources, couplers, filters and microstrip circuits available from Spectrum Microwave Corp. It describes a broad variety of products for rf through microwave application. Spectrum Microwave Corp., 328 Maple Ave., Horsham, PA 19044. **289**

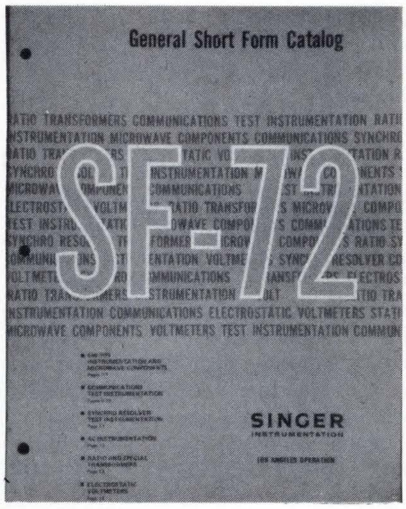
SHAFT-ANGLE ENCODERS. A 12-pg catalog covers shaft-angle encoders and their applications. The 2-color catalog describes a wide variety of encoding devices, how they can be matched to different applications and what kinds of encoders are required for a wide variety of environments. Covered are absolute, incremental, contacting, optical and magnetic types of encoders for commercial/industrial and military aerospace applications. Norden Div. of United Aircraft, Helen St., Norwalk, CT 06856. **290**

LIGHTED PUSHBUTTONS. A line of one-lamp lighted pushbuttons is described in a 4-pg illustrated brochure. The brochure provides information on the unusual lamp socket design employed, bushing mounting, panel seal options, mounting dimensions, electrical and performance specifications and ordering information. Micro Switch, a Div. of Honeywell, Inc., 11 W. Spring St., Freeport, IL 61032. **291**

ELECTRONIC INDICATING TACHOMETERS. New literature discusses a line of panel-mount, IC electronic tachometers whose accuracy, including meter error, is 1%. The Series T7000 tachometers can be provided with a display in RPM, IPM, BPH or GPM, which is linearly proportional to an input-signal rate derived from a magnetic pickup, shaft encoder or a contact closure. Specifications, operation, outline and connection details are provided in the brochure. Dynalco Corp., 4107 NE 6th Ave., Fort Lauderdale, FL 33308. **292**

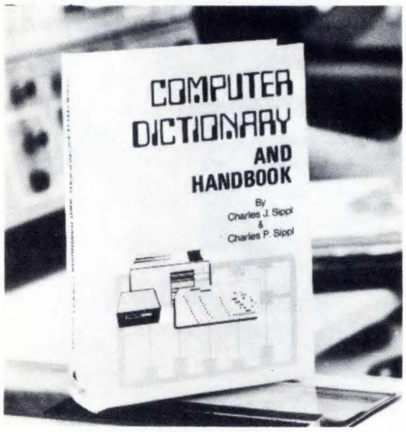
UNIVERSAL TONE-BURST GENERATOR. Singer Instrumentation's new universal tone-burst generator, Model TG-2, is described in this 4-page brochure. The instrument generates any 4 tone frequencies in all of the time formats used for tone-selective paging systems. The brochure lists all proprietary call systems with which the instrument can be used. Operating features and applications are presented together with specifications. Singer Instrumentation, Los Angeles Operation, 3211 S. La Cienega Blvd., Los Angeles, CA 90016. **293**

AM/FM/SSB SERVICE MONITOR. An 8-page brochure describes Singer Instrumentation's new communication service monitor, Model FM-10C. Features and design philosophy are described together with specifications and applications. The FM-10C is a combination frequency-meter/signal-generator with plug-in rf and scope modules. It provides a complete AM/FM/SSB servicing package in the range of 50 kHz to 512 MHz. Singer Instrumentation, Los Angeles Operation, 3211 S. La Cienega Blvd., Los Angeles, CA 90016. **294**



TEST INSTRUMENTATION is described in a 16-page brochure. Instruments covered include EMI/field intensity meters, RF current probes, antennas, microwave components, FM/AM/SSB communications test instrumentation, frequency meters, signal generators, tone generators, synchro/resolver test instrumentation, A/D converters, phase-angle voltmeters, ratio transformers and electrostatic voltmeters. The Singer Co., Los Angeles Operation, 3211 S. La Cienega Blvd., Los Angeles, CA 90016. **296**

TIME-SHARING RECORDER. A new catalog sheet includes information about a new thermistor-probe and strip-chart which extends the range of the Model LT8200 recorder to −3 to +118°F making it suitable for monitoring air conditioning and heating equipment. Amprobe Instrument, 630 Merrick Rd., Lynbrook, NY 11563. **295**



COMPUTER DICTIONARY AND HANDBOOK,
Second Edition. It's new and updated and compiled from an information base of over 22,000 separate definitions and concept explanations. Over 450 pages define computer related terms. Principles and procedures of computer systems, number systems, mathematical definitions, and computer languages are a few of the subjects covered. Catalog No. 20850, 784 pages-hardbound—$16.95. Howard W. Sams & Co., Inc., 4300 W. 62nd St., Indianapolis, IN 46268.
297

FACT SYSTEM—A 16 page brochure details characteristics of the flexible automatic circuit tester (FACT) system. It illustrates how the FACT wiring analyzer and various functional interconnection methods may be adapted to provide efficient and economical solutions to large volume, exacting test procedures for a wide variety of electronic systems and equipment. Hughes FACT Systems, P.O. Box 92904, Los Angeles, CA 90009.
298

ELECTRICAL SAFETY PUBLICATIONS.
"ISA Electrical Safety Publications" brochure describes two new reference books on electrical instruments in hazardous locations and electrical safety abstracts, a new monograph on electrical safety practices, and other publications on the topic. Three special package prices are offered. ISA, Publications Dept., 400 Stanwix St., Pittsburgh, PA 15222. **299**

SIGNAL PROCESSORS, SYNTHESIZERS are covered in a 6-page short form catalog. Products described include analog and digital filters and frequency and speech synthesizers. Specifications and prices are given. Rockland Systems Corp., 230 W. Nyack Rd., West Nyack, NY 10994. **300**

TELECOMMUNICATIONS PRODUCTS is a 32 pg. product booklet describing Lenkurt's line of video, voice and data transmission systems. Each description is accompanied by a detailed black and white photograph of the product and a reference for further information. The guide includes microwave radio transmitter-receivers, microwave radio subsystems, coaxial cable transmission systems and more. GTE Lenkurt Inc., Dept. C720, 1105 County Rd., San Carlos, CA 94070. **100**

NEW CMOS IC DATA BOOK OFFERED.
A 100-pg. CMOS Data Book includes technical introduction to CMOS; a discussion on design and operation considerations; package descriptions; a discussion on chip preparation and handling and a review of devices available in the SCL 4000A, SCL 4400A and SCL 5000A series. Solid State Scientific Inc., Montgomeryville, PA 18936. **101**

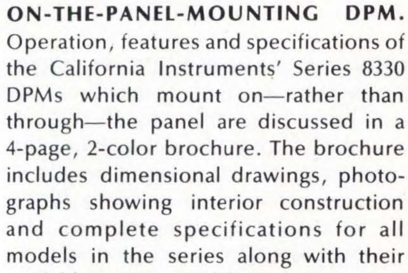
FOUR-COLOR BROCHURE ON LED DISPLAYS. The brochure provides general and technical data on a broad line of light-emitting-diode display modules. Included are module systems for 7-segment displays in a variety of configurations, which include all or part of the necessary decoding and driving circuitry for the displays. Monsanto Commercial Products Co., 10131 Bubb Rd., Cupertino, CA 95014. **102**

DISC DRIVE APPLICATION NOTE.
A 32-page application note on designing a sectored format for Pertec disc drives provides an analysis of the parameters within a disc drive which contribute to sector format considerations. Each parameter is discussed and algebraic expressions are provided. Included are formulas for calculating a sector to provide design engineers with information needed to determine sector timing requirements for specific applications. Pertec Corp., Dept. 101N, 9600 Irondale Ave., Chatsworth, CA 91311. **103**

CARD-READER SYSTEM. A 4-pg. bulletin describes a card-reader system which permits reading data from punched cards into Micro 800 and Micro 1600 computers. The system consists of a card reader, an interface controller and all necessary interconnecting cables and mounting hardware. The bulletin describes the controller, card reader and software in detail. Photographs and diagrams illustrate functional characteristics, data flow and the physical packaging of the system. Microdata Corp., 644 E. Young St., Santa Ana, CA 92705. **104**

TIME-SHARE TERMINAL PLOTTING.
An HPPLOT User's Manual shows how easily a time-share system can be commanded to plot point or line graphs, or step or bar charts. This new 22-pg. booklet is written for the user of a time share terminal equipped with an x-y plotter, but should also be interesting to anyone required to plot computer data manually. It contains listings of commands, instructions and many sample plots. HPPLOT is a software program available to users of GE and HP 2000 time-share systems. Hewlett-Packard, 1501 Page Mill Rd., Palo Alto, CA 94304.
105

PHASE LOCKED LOOPS application book is an 80-pg. guide to a new phase of monolithic circuits based on frequency feedback technology. The phase locked loop is basically an electronic servo loop consisting of a phase detector, a low pass filter and voltage controlled oscillator. The book includes phase locked loop terminology, functional applications, measurement techniques and expanding loop capability. Write on company letterhead to: Signetics, 811 E. Argues Ave., Sunnyvale, CA 94086. **106**



ON-THE-PANEL-MOUNTING DPM.
Operation, features and specifications of the California Instruments' Series 8330 DPMs which mount on—rather than through—the panel are discussed in a 4-page, 2-color brochure. The brochure includes dimensional drawings, photographs showing interior construction and complete specifications for all models in the series along with their available options. California Instruments Co., 5150 Convoy St., San Diego, CA 92111. **107**

signals and noise

Four fingered Frank— ?

Dear Mr. Egan:

Reference your October 15 issue (pg. 62) "Progress in Modules." If Acopian Corp. has discovered the perfect thermal insulator, this would be a world-shaking event indeed! On the other hand, if not, pity the poor engineer who takes the data given at face value. Elementary considerations would indicate that in a closed container there would be thermal leakage across the barrier and a constant temperature rise until all components see substantially the same thermal environment. The only thing that can be gained is an increase in the thermal time constant; i.e., a delay in the time all components reach the same temperature. From a practical point of view, the chances are that the terminal temperature of all components would be substantially higher than the conventional structure, and for the same conditions the Acopian power supply could finally disappear in a wisp of smoke!

Also, shame on you for your "touch testing." I'm sure if you had waited for the thing to reach equilibrium, you would now be known as "four-fingered Frank." I would suggest you devote your fingers to more accurate technical evaluation than on an obvious promotional hand-out!

Sincerely, but for a better EDN,
James J. Grieg
ERA Acoustics Corp.
Moonachie, NJ 07074

Manufacturer replies . . .

Dear Mr. Egan:

Mr. Grieg has made a major error in considering the power module case as a thermally closed universe. It is not. The outer surfaces of the module's circuit board end dissipate the relatively small amount of heat which leaks through a very effective (but admittedly not perfect) thermal barrier, and the temperature buildup envisioned by Mr. Grieg just doesn't happen. This is comparable to the situation of an unheated garage attached to a heated house via an (imperfectly) insulated wall. Would anyone wish to bet that, in the middle of January and with six inches of snow on the roof, the garage would have the same temperature as the house?

Acopian's claims for these new models are not based upon theoretical and unproven concepts; we have shown that they do what we say they do. The unit "touch tested" by Bob Cushman of EDN was in operation at full load for hours before his arrival, and he closely monitored it during the several hours which he spent at our plant. He left with all fingers intact.

Sincerely, to an accurate EDN
Thomas E. Skopal
Acopian Corp.
Easton, PA 18042

It makes a difference . . .

Dear Editor:

I have followed the EDN Design Course on CMOS, Parts I and II, in your November 1 and December 1 EDN magazine. The series of articles are very helpful in keeping current in the state-of-the-art developments in one area of logic design.

While reading Part II of the series, I noticed the article "Film-Resistor Specs" by Mr. Vernon Gray. This is a good and useful article too, but there is an error in the theoretical Johnson thermal noise equation on pg. 41. I discovered the error because I wanted to justify the factor 7.4 and the 10^{-12} which is under the radical. The basic Johnson noise equation is:

$$E_{n\ rms} = [4\ k\ T\ R\ \Delta f]^{1/2}$$

where k (Boltzmann's Constant) is 1.38×10^{-23} Joule per degree, T is the absolute temperature in degrees Kelvin, R is the resistance in ohms, and Δf is the bandwidth in Hz.

Thus, the constant in Mr. Gray's article should be 7.429×10^{-12}.

The thermal noise level for the 22k resistor used as an example in **Fig. 5** is correct, but the equation as printed in the figure has the same error as stated.

Roy W. Slice
Senior Engineer
EG & G
San Ramon, CA 94583

Ed note: A check with Mr. Gray confirmed the above to be correct.

Right on!

Dear Sir:

Jesse Pipkin's article, "On Engineers and Profits" is right on, right on. Design engineers are short sighted when service is considered. If they had to service what they designed, they would have second and third thoughts.

C.M. Guido
Beckman Instrument, Inc.
Anaheim, CA 92806

"ALL IT SAYS IS...IT DON'T TAKE MUCH OF A BRAIN TO FIGURE THAT OUT!"

ADVERTISERS INDEX

SALES OFFICES

Foreign

GERMANY
Mr. G. Stelmaszyk
IPC Business Press(West German Off.
Wiesenstrasse, 7,
7146 Tamm/Ludwigeburg, Germany
Telephone: Tamm 7141 3 23 78
Telex: 7 264 780

FRANCE
Mr. D. Soubeyran
Compagnie Francaise d'Editions
Division Internationale
40 Rue de Colisee
Paris 8e, France
Telephone: Paris 225 7750
Telex: France 28274 F

ITALY
Mr. F. A. Corti
ETAS-Kompass SpA
Servizio Estero
Via Mantegna 6
20154 Milano, Italy
Telephon: Milan 347 051
Telex: 33152 Kompass

HOLLAND
Mr. D. Anema
C. Misset NV
Ijsselkade 32
Doetinchem, The Netherlands
Telephone:Doetinchem 8340 25151
Telex: 45481

SWITZERLAND
Mr. H. P. Iff
Agentur Iff AG
Neustadt 57
8201 Schaffhausen, Switzerland
Telephone: Schaffhausen 53 54983
Telex: 76388

JAPAN
Mr. K. Utsumi
Asia Magazines Ltd. (IBP Division)
Akiyama Building
25 Akefune-cho
Shiba Nishikubo
Minato-ku
Tokyo, Japan
Telephone: Tokyo 03 (403) 5623
Telex: J28245 IBP JPN

UNITED KINGDOM
Mr. Douglas Jens Smith
IPC Business Press (Overseas) Ltd.
161-166 Fleet St.
London, EC4P 4AA, England
Telephone: London 01-353-5011
Telex: 267449

INTERNATIONAL COORDIN.
Mr. John Hitch, General Manager
IPC Business Press (Overseas) Ltd.
161 Fleet Street
London, EC4P 4AA, England
Telephone: London 01-353-5011
Telex: 267449

Domestic

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

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

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

BOSTON 02116
Richard Parker, District Manager
Hal Short, District Manager
221 Columbus Ave.
(617) 536-7780

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

ATLANTA 30328
Newman Ladabouche,
Regional Manager
6065 Roswell Rd.
(404) 252-7753

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

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

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

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

INDEX TO ADS, PRODUCTS AND LITERATURE Use card for free product information

Paying the lowest price for fixed resistors doesn't mean they're costing you less. Split an A-B resistor apart and discover the difference between Allen-Bradley and all the others. Our exclusive hot molding process forms the elements into an integral structure. Physically strong. With a densely packed, uniform resistance track. Note how the leads are firmly and thoroughly imbedded to reduce circuit noise. Hot molding is just one way we have engineered more quality into our resistors. Consistant A-B quality that can lower your installed costs and put more reliability into your products. If you think all resistors are the same, read "7 ways to tell the difference in fixed resistors." See your A-B electronic distributor, or write Allen-Bradley Electronics Division, 1201 South Second Street, Milwaukee, Wisconsin 53204. Export: Bloomfield, New Jersey 07003. Canada: Allen-Bradley Canada Limited, Galt, Ontario. United Kingdom: Jarrow, County Durham NE32 3EN.

CHECK NO. 2

A-B QUALITY

Allen-Bradley
Milwaukee, Wisconsin 53204