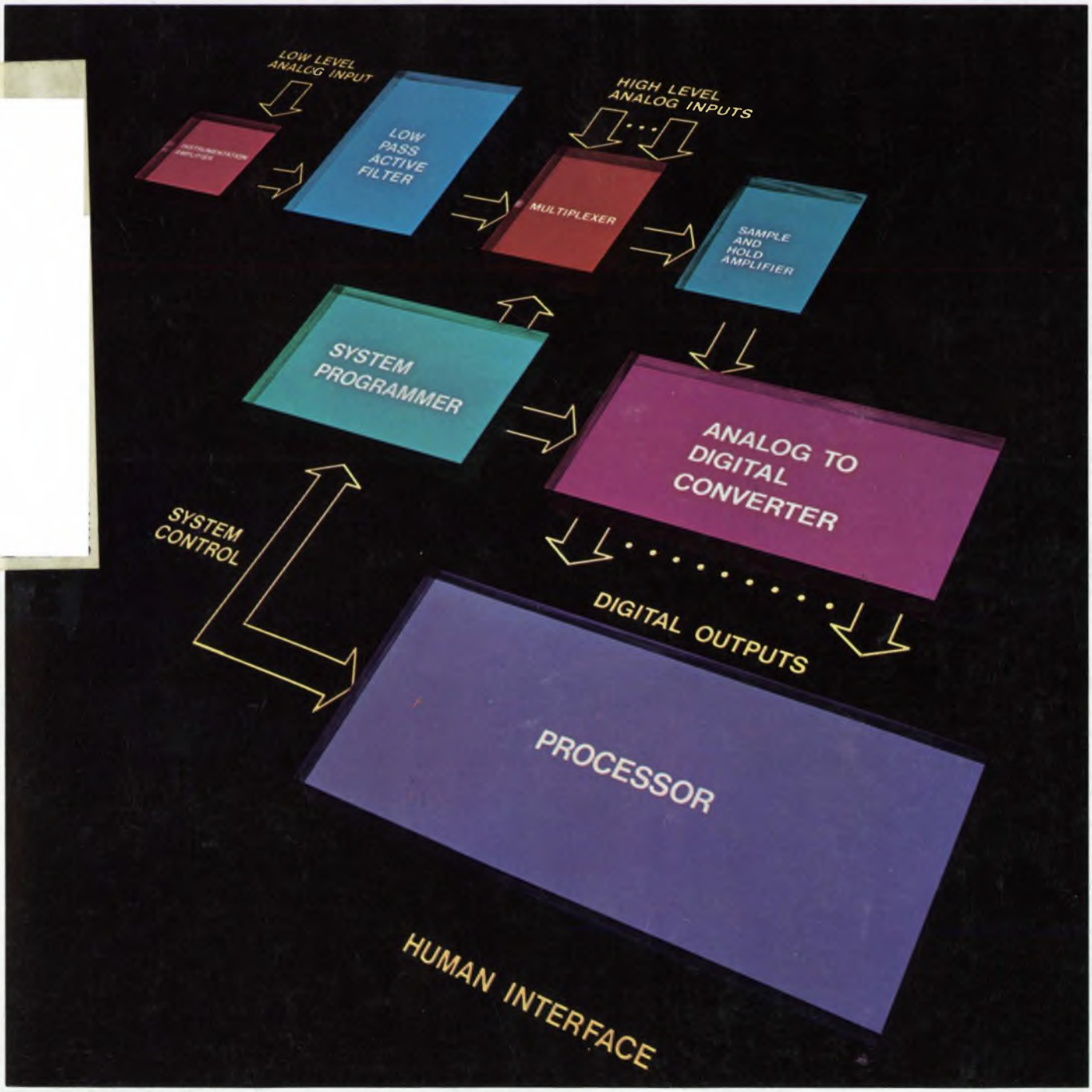
VOL. 22 NO. 12

Electronic Design

FOR ENGINEERS AND ENGINEERING MANAGERS

JUNE 7, 1974

The data-acquisition maze: With a complex array of analog and digital circuits, systems are hard to specify. Each functional block has problems, and each must be compatible with all its neighbors. Specs and performance can vary from company to company. For a look at what's available and what to look out for, see pg. 70.



...and they're off the shelf!

PICO Electronics' patented construction combines mass production with the utmost in reliability to produce the smallest possible transformer.

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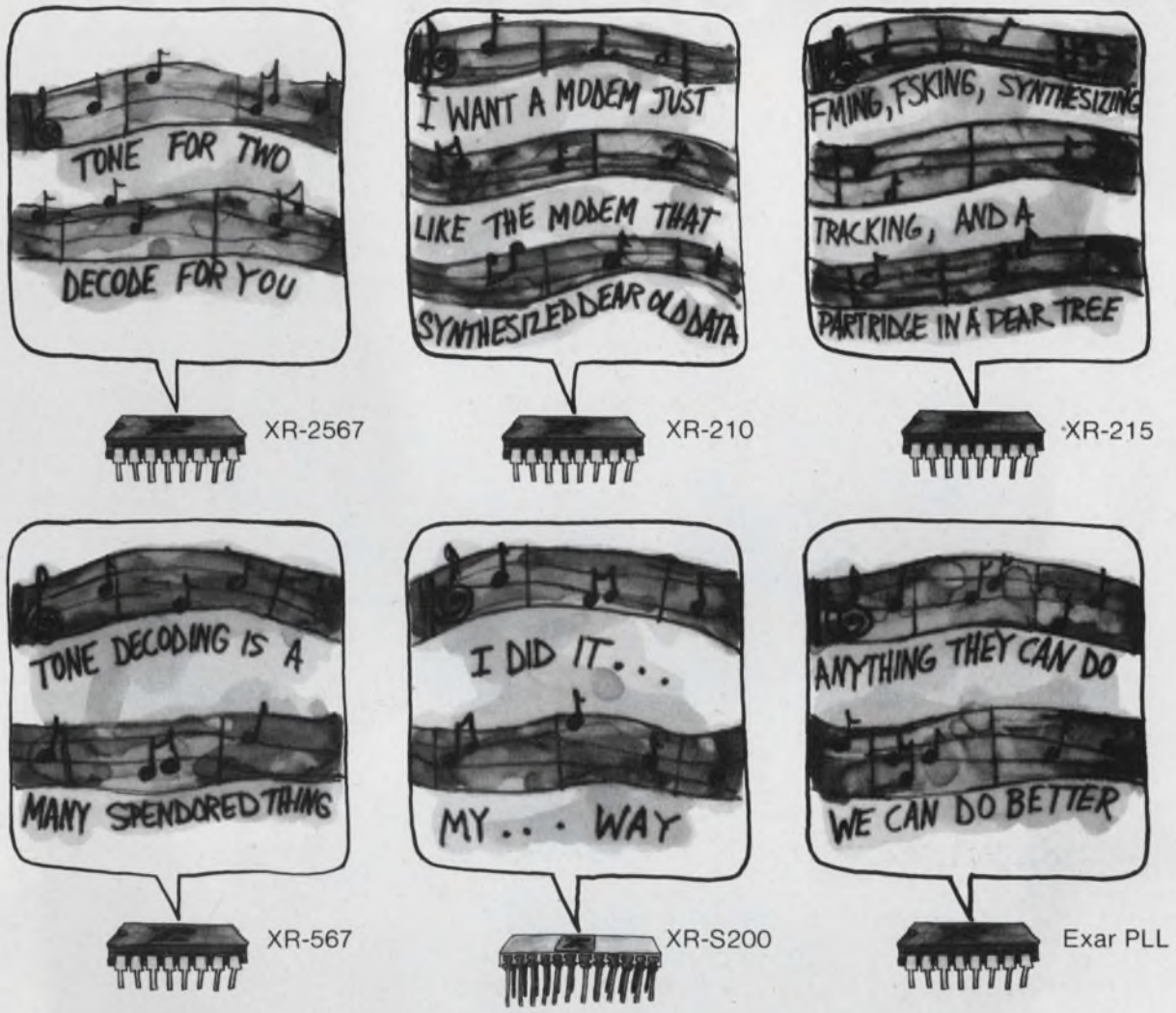
YOU HUM THE TUNE, EXAR PLL WILL SING IT



We have the broadest chorus line of Phase Lock Loop circuits available today. Take a brief look at our ever-expanding PLL line:

The *XR-210* is designed for FSK Modulation and Demodulation and features a self-contained output logic driver, compatible with RS-232C requirements.

Use the *XR-215* for FM or FSK demodulation, frequency synthesis and filter tracking. It has a 5V to 26V supply range and 0.5 Hz to 35 MHz frequency bandwidth. Whatsmore, it's bipolar logic compatible.

The XR-S200 is a do-it-yourself building block. With this you design your own PLL circuits by selecting external connections and components. You get instant prototypes with minimum fuss and costs.

Moving right along . . . the *XR-567* PLL is designed for tone and frequency decoding. It has a bandwidth adjustable from 0 to 14%, sinks up to 100 mA of load current and has a logic compatible output. Our dual version, the *XR-2567*, is a real hummer with even better temperature tracking and matching characteristics. Power supply rejection is improved by an order of magnitude over the single version. The dual outputs can switch up to 100 mA at 26 volts.

All together now. We would like to send you the complete musical score on our PLL products. Our data sheets are good and they're filled with applications data. Write now, write.

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INFORMATION RETRIEVAL NUMBER 2

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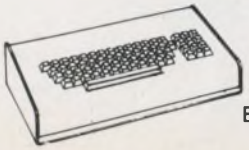
You see, we can control the quality of our switches because we fabricate most of our own parts (moldings, stampings, springs, printed circuits, etc.) And we can keep the price down because we're loaded with automatic equipment to handle high volume.

But the real difference is in the *people* you work with at Cherry...from your first contact with a technically trained sales representative...through careful analysis and recommendations by engineers who are really concerned about *your* problem... to production scheduling and customer service men who follow-up and expedite to make sure we keep our delivery promise to you.

Of course we're proud of our modern facilities and equipment...but what we're proudest of is our reputation for customer service. Try some.

Test a free sample "tiger" from the pussycats at Cherry. Ask for our latest catalog which contains complete information on all our switches and keyboards, and we'll include a free sample switch. Just TWX 910-235-1572...or PHONE 312-689-7700... or circle the reader service number below.



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INFORMATION RETRIEVAL NUMBER 3

VOL. 22 NO.

Electronic Design 12

FOR ENGINEERS AND ENGINEERING MANAGERS

JUNE 7, 1974

NEWS

TECHNOLOGY

PRODUCTS

Departments

Cover: Photo by Chadman Studios, Boston, courtesy of Datel Systems Inc.

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From CPU 8080 Microcom

Intel's new 8080 n-channel microcomputer is here—incredibly easy to interface, simple to program and with up to 100 times the performance of p-channel MOS microcomputers.

Best of all, the 8080 is real—in production at Intel and available in volume quantities, today. It's also available through distributors along with a growing line of peripheral circuits and a new version of the Intellec 8, a program and hardware development system for the 8080, all supported with software packages, design documentation and manuals, and backed by more than 100 man years of microcomputer expertise.

The 8080 is the inevitable successor to complex custom MOS and many large discrete logic subsystems. It is the industry's first general purpose n-channel microcomputer and the first high performance single-chip CPU, with extremely simple interface requirements and straightforward programming. It runs a full instruction cycle in 2 microseconds.

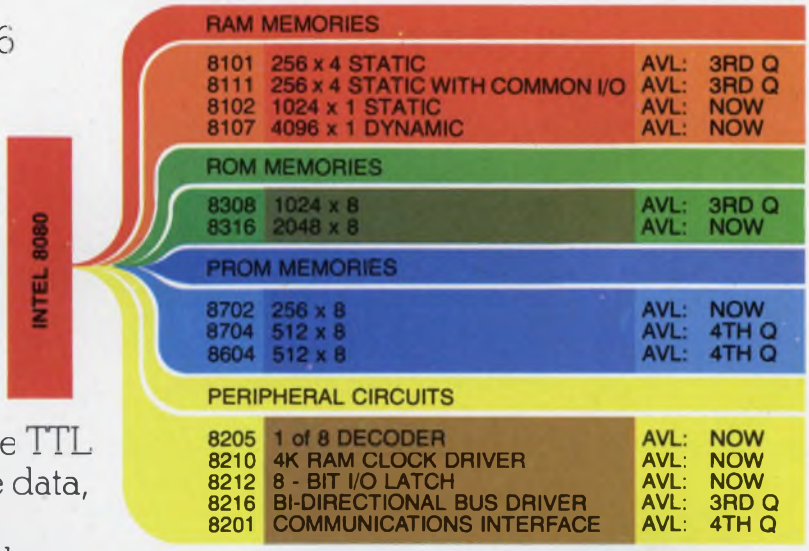
As such, the 8080 extends the economic benefits of Intel's p-channel microcomputers to a new universe of systems that need fast, multi-port controllers and processors. These systems include intelligent terminals, point of sale systems, process and numeric controllers, advanced

to software, the puter is here.

calculators, word processors, self-calibrating instruments, data loggers, communications controllers, and many more.

You can use 256 input and 256 output channels, handle almost unlimited interrupt levels, directly access 64 kilobytes of memory, and put many satellite 8080 processors around a single memory.

Interfacing is minimal and design is easy with the 8080 because all controls are fully decoded on the CPU chip itself and inputs and outputs are TTL compatible. There are separate data, address and control buses.



INTEL 8080 PRODUCT FAMILY

The 8080 microcomputer has 78 basic instructions, including the 8008 set plus new ones that make possible such features as vectored multi-level interrupt, unlimited subroutine nesting and very fast decimal and binary arithmetic.

Program development for the 8080 can be done either on a large computer using the Intel software cross products (PL/M systems language compiler, macro-assembler and simulator), or on an Intellec 8 development system with a resident monitor, text editor and macro-assembler.

The new 8080 product family includes performance matched peripheral and memory circuits configured to minimize design effort and maximize system performance. Large, low cost RAMs, ROMs, PROMs and I/O devices are available now and we will soon announce other 8080 LSI support circuits.

The 8080 is easier to use and more economical than any high performance microcomputer in sight. It's here now, in volume, from the inventors of the microcomputer and the people who lead the industry in production and design support.

Intel Corporation, 3065 Bowers Avenue, Santa Clara, California 95051. (408) 246-7501.

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INFORMATION RETRIEVAL NUMBER 4

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Peter Coley

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across the desk

Nuclear transients can be complicated

The article "Protect Against Nuclear Transients" (ED No. 4, Feb. 15, 1974, p. 64F) is misleading. The technique, as presented, considers only the upset aspect of hardening and completely ignores neutron degradation and the latch-up phenomenon of junction-isolated integrated circuits. The latter effect is more detrimental and can occcur for radiation doses similar to upset. The article presents the radiation from nuclear blasts as a single entity, whereas there are different particles and rays, each with its distinctive effects.

The author does not mention that the discharge of capacitors by ionization radiation is a limitation of the data-storage technique. The increase in the size and weight of systems in which this technique is used, and the reduction in speed make shielding a definite tradeoff in many cases.

Henry Kay
Staff Engineer
Intelcom Rad Tech
P.O. Box 80817
San Diego, Calif. 92138

The author replies

I do not believe the article was misleading. It was very clearly stated that my technique applied only to the transient-upset phenomenon.

As for neutron degradation, this is a long-term effect that should be clearly treated as such and included in other long-term aging effects. However, neutron degradation can be serious. Depending upon who supplies the data, this can result in a ±40% degradation in long-term component design tolerance. In addition, while semiconductor manufacturers may brag about their hardened devices, it's hard to pin them down to actual figures, such as of merit, design and neutron-dosage levels. Some companies are actively engaged in large-scale testing programs to establish reliability figures and exposure rates. But these data are not easily available to outsiders.

As for the latchup phenomenon in junction-isolated integrated circuits, I thought it was common knowledge that this device is very susceptible to scrambling at low-dosage levels when used in registers, latches and counters. This deficiency was known at least two years ago, so the junction-isolated technique was replaced by other hardening techniques.

With regard to the discharge of capacitors caused by ionizing radiation, a better choice of dielectrics—use of glass or ceramic capacitors rather than organic dielectrics—is needed.

Let me turn to the matter of tradeoffs between size, weight and speed of circuits hardened by the RC storage network vs the use of shielding. First, Mr. Kay does not appear to have been exposed to contract requirements that forbid the use of shielding unless there is no other way to protect circuits; then it may be permitted by special contractor approval. Second, almost all communications systems for very-long-range and satellite applications do not make use of very high-speed toggle or through-

(continued on pg 8)

Electronic Design welcomes the opinions of its readers on the issues raised in the magazine's editorial columns. Address letters to Managing Editor, Electronic Design, 50 Essex St. Rochelle Park, N.J. 07662. Try to keep letters under 200 words. Letters must be signed. Names will be withheld on request.

(continued from page 7)

put rates. The limitation here is not on internal-circuit performance but rf carrier bandwidth restrictions. Third, the RC storage hardening technique has been incorporated directly in the basic chip for a number of integrated circuits. Hence the increase in weight is negligible for these special IC devices.

Finally, let me assure Mr. Kay that I am neither a salesman for semiconductor devices nor am I interested in pushing the use of shielding. To each his own.

Antonie N. Paolantonio, P.E.
17806 Elkwood St.
Reseda, Calif. 91335

The company's name is Process Computer

Discerning readers of our computer issue (ED No. 9, April 26, 1974) may have noticed that Process Computer Systems—the company whose ad appears on pages 277 and 279—was somehow given a new name in the microprocessor story on page 90.

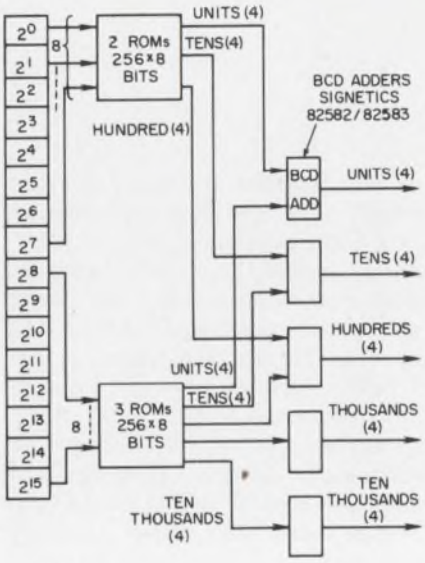
The caption on that page, and the references to the company in the text, referred to the company as Process Control Systems, instead of Process Computer Systems. Our apologies.

Binary/BCD converter corrected by reader

Fig. 5 in "Fast BCD/Binary Conversions" (ED No. 22, Oct. 25, 1973, pp. 84-89) raises a question. The ROM that takes care of the first seven bits (numbers up to 127) provides numbers up to only 99. How do you generate the numbers between 100 and 127?

A possible implementation (see figure) uses two ROMs (256 × 8 bits) for the first 8 bits and three for the next 8, instead of 3(512 × 8) ROMs.

Lucien I. Facchin
Dept. of Computer Science
University of Illinois
Urbana, Ill. 61801.



The author replies

Mr. Facchin's comment is correct.

The only thing I could suggest other than use of an additional ROM to obtain the one-bit output would be to use a hardware decoder. This could be less expensive and more efficient.

H. A. Raphael
Manager, Processor Electronics
The Singer Co.
Business Machines Div.
San Leandro, Calif. 94577.

A word of caution on CMOS and power

The article "Focus on CMOS" (ED No. 6, March 15, 1974, p. 86) mentions that a CMOS digital IC has increased power-supply drain as its input or output frequency increases. It also notes that CMOS devices have a large noise immunity, so you can, in many cases, drive them from a TTL gate. The article does not mention, however, that if you do not drive the CMOS all the way to its V_{cc} level, it will draw more power on a dc or quiescent basis.

For example, if a low-power TTL output at 3 V dc drives a CMOS input gate, the CMOS gate may draw perhaps 0.05 to 0.5 mA of drain. This won't usually squander your power budget or melt your CMOS, but it is a price you will pay when you try to avoid the use of pull-up resistors for the TTL.

Robert A. Pease
Staff Engineer
Teledyne Philbrick
Allied Drive at Route 128
Dedham, Mass. 02026

Those 'distracting' ads improve his thinking

With all due respect to the "future woman engineer" (see "Women in Ads leave Future Engineer Cold," ED No. 5, March 1, 1974, p. 16), I must differ with her sentiments on the use of women in professional advertising.

As one who conscientiously reads the dozen or so technical magazines, journals and newspapers that cross my desk fortnightly, I find a definite need for the variety of color, style, size and approach exhibited by the advertisements that appear in ELECTRONIC DESIGN. What is more desensitizing, more boring than an advertising message devoid of impact, appeal and emotion?

What Joyce Wetenkamp apparently does not yet realize is that good engineering, like any other logical thinking process, thrives not on a lack of noise-like irrelevancies but rather on an abundance of them. A thinking process with no noisy distractions soon grinds to an unproductive conclusion. We need those jogs, those distractions to keep us "loose" and out of the ruts.

So here's a toast to the Guardian Angel, the Tektronix model, the Wavetek jitter-buggers and pretty Heather David. May they continue to smile at us, catch our attention, distract us from our complacencies and remind us what it is all about. Here's to more, not less, pretty people in your ads.

George V. Colby Jr.

7 Hawthorne Road
Lexington, Mass. 02173

MEASUREMENT COMPUTATION NEWS
innovations from Hewlett-Packard

JUNE, 1974

in this issue

New wave analyzer for precision and portability in the field

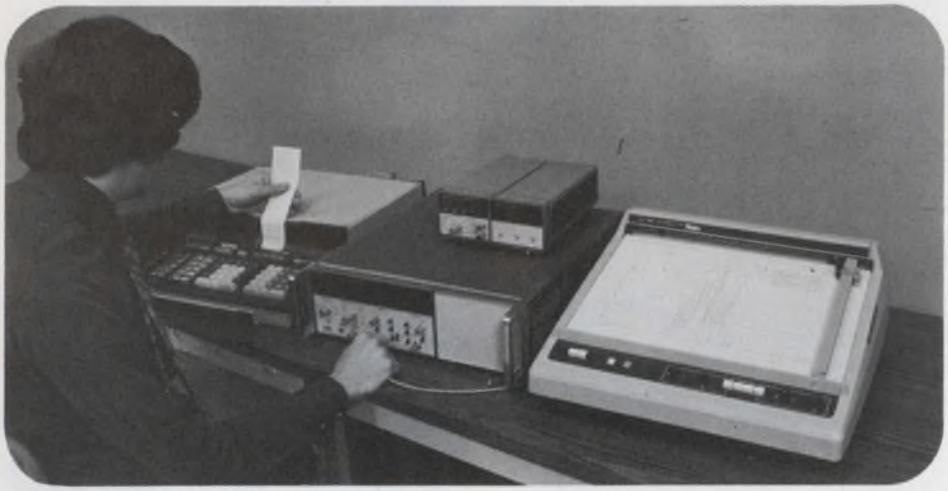
Here, the 3581A wave analyzer checks field equipment performance for the Omega navigation system, a global system that should become fully operational in 1975.

HP's new low-frequency analyzer has a built-in counter for frequency accuracy and a battery option for convenience and portability. Take the 18 lb. (8.1 kg) wave analyzer where you need it the most—out in the field—to check power or telephone lines.

Accurate single-frequency measurements are fast and easy, from 15 Hz to 50 kHz with 1 Hz resolution and 3 Hz bandwidth. The built-in counter displays tuned frequency on a 5-digit LED readout. Signal amplitude appears on a four-scale analog meter. Two scales are for log displays of 90 dB and 10 dB (expanded), and the other two are linear with 1 or 3 full scale.

(continued on page 3)

Super-counter for superb time interval measuring and easy system interface



The HP 5345A counter's unmatched capabilities in time interval measurements and automatic systems operation pay off in applications such as the time interval jitter measuring system shown above.

Precision time interval measurements are central to measuring rise time, propagation delay, slew rate, and phase. These are just a few applications that can be served better than ever by the time interval capability of HP's new 5345A electronic counter.

Compatibility with the HP interface bus makes the counter a natural for systems applications. For example, the system shown above is easily assembled using an HP 9820A calculator, 9862A plotter, and the 5345A counter to analyze time interval jitter.

The 5345A offers 2 ns single-shot time interval resolution. With an improved averaging technique, resolutions to 2 ps are achieved for repetitive signals. High sensitivity of the 500 MHz input amplifiers (better than 10 mV rms) ensures accurate trigger level settings. And for very fast pulses in 50Ω systems, you can switch to 50Ω impedance to prevent error-causing reflections.

The 5345A also makes frequency, frequency average, period, period average, ratio, totalize, and gated measurements over the dc to 500 MHz bandwidth. Plug-ins extend the counter's capability for communications and microwave measurements.

There's more. Just check the HP Reply Card.

Calculator control and HP's new ASCII programmable modules that extend the 5345A's measurement capabilities are explained in a new series of application notes. The series includes: the characterization of voltage controlled oscillators, determining probability density distribution of a series of measurements, frequency stability measurements, and the measurement of fractional frequency deviation and FM deviation. VCO characteristics covered are: the transfer function measurement, differential and integral non-linearity and dual VCO tracking error.

Each application note describes how to connect the necessary equipment, how to operate the resulting calculator-controlled system, and certain key measurement considerations that should be noted. The notes also include a complete listing of the HP 9820/21 calculator program and a flow diagram of the software.

To learn more, check the HP Reply Card.

New quality counters at surprisingly low prices

These new counters have 25 mV sensitivity, LED displays, measure ratio as well as frequency, and weigh just 4.75 lbs. (2.2 kg).

Two new electronic counters carry extremely low price tags, yet offer high-stability crystal time bases crucial to counter accuracy and usually found only in costlier models. Either new counter is ideal for production line testing, frequency monitoring, service and calibration, training classes or—at this price—even for hobbyists and radio hams.

The 80-MHz model 5381A has a 7-digit display. Model 5382A counts to 225 MHz and displays 8 digits. Resolution is 10 Hz at 0.1 sec gate time, 1 Hz at 1 sec, and 0.1 Hz in 10 sec.

Aging (drift) rate is <3 parts in 10^7 per month, reducing recalibration. Temperature-resistant and rugged, the two counters also protect against overload. Even in their wide-open settings, they'll take 200 Vdc without harm.

A three-position input attenuator lets you measure noisy or high voltage inputs. Unlike other low-priced counters, these will also operate on an external precision time base through a built-in rear connector.

For more information, check the HP Reply Card

Get 4-channel lab quality recording with portable tape recorder

The 3960A instrumentation tape recorder gives you portability along with performance and features found only in the most expensive laboratory machines. Portability is the ruggedness of the solid aluminum casting, the capability of operating from either ac or dc power sources, and a built-in dc calibrator.

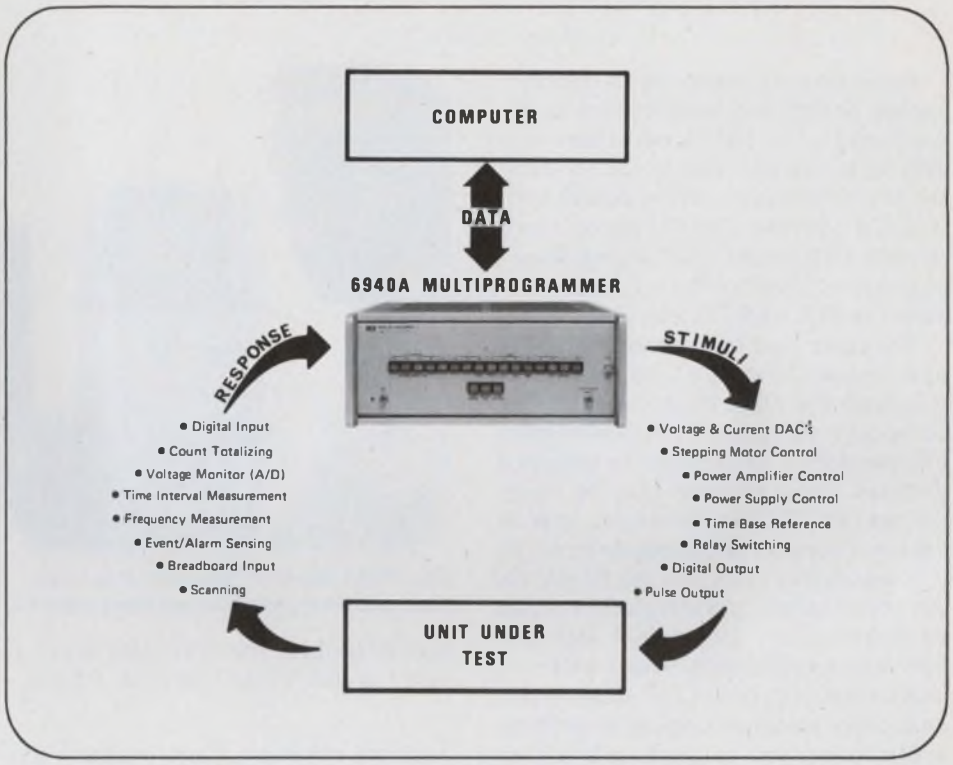
Use the 3960A in data acquisition and data reproduction applications. Tape speeds range from 15/16 ips for long-term FM recording of slowly changing phenomena to 3¾ ips for acoustic evaluation and up to 15 ips for vibration studies. The low-speed performance is outstanding, an important asset to medical researchers and others who record slowly changing variables.

The FM signal-to-noise ratio at 15/16 ips is 44 dB. At higher speeds, the FM signal-to-noise ratio is 48 dB. Data electronics for direct recording has a frequency response up to 60 kHz and up to 5 kHz for FM.

For more information, check the HP Reply Card.

The 3960A recorder uses ¼ in. (0.6 cm) tape or standard 7 in. (17.8 cm) reels.

HP multiprogrammer system expands your I/O capability to 240 channels



Multiprogrammer mainframes and plug-in cards let you design and build low-cost automatic test systems more efficiently.

You'll never run out of computer I/O slots when you design your automatic test system around the 6940A multiprogrammer. You need just one 16-bit duplex computer I/O channel to interface with the multiprogrammer. The 6940A holds up to 15 plug-in analog and digital I/O cards, mixed in any combination. Some plug-ins convert programmed data into analog and digital output signals to stimulate units under test; others convert analog and digital responses into digital data for input to the computer.

If you need more than 15 programmable I/O channels, simply add 6941A extender mainframes. Each extender holds 15 plug-ins, and you can add up to 15 extenders—giving you a total of 240 plug-in cards controlled from one computer I/O slot.

Just one software driver controls any variety of multiprogrammer plug-ins. This lets you make changes and additions in the type and number of I/O cards without worrying about reconfiguring the software driver or operating system.

There's more. Just check the HP Reply Card.

(continued from page 1)

It's ideal for harmonic analysis, fm and phase noise measurements of high-frequency signals, evaluating sonar devices, and analyzing low-frequency radio transmission systems. Portability lets you check power line interference simply, accurately, on-site.

A communications version, model 3581C, analyzes telephone voice channels, both single and up to 12 multiplexed. You can also pinpoint interference on data channels, look for spurious tones, and analyze levels of transmitted tones. We even provide a loudspeaker, headphone jack, and transformer so you can patch the 3581C directly onto telephone lines. Optional rechargeable batteries run the analyzer for 12 hours.

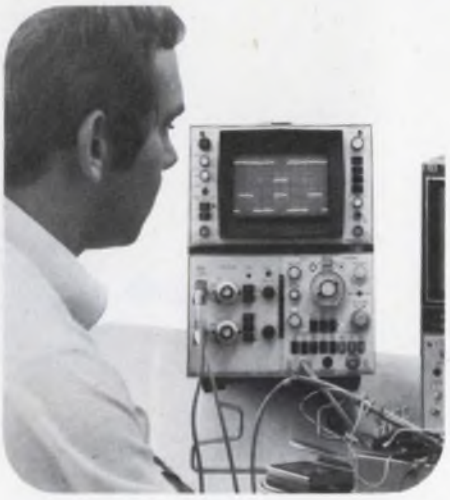
To learn more, check the HP Reply Card.

Scope plug-in aids design and troubleshooting

Accurate measurements in digital/analog design and troubleshooting are supplied by the 1835A two-channel 200 MHz vertical plug-in for HP 183 series oscilloscopes. Wide bandwidth, coupled with the 1 ns/div sweep speed of HP's 1840A and 1841A time base plug-ins, is ideal for timing measurements in ECL and TTL circuits.

You can trigger from either channel A or B, maintaining true time relationship with the other channel. With the composite mode, each channel triggers independently in alternate or chopped displays. Either channel may be inverted, and an ADD mode lets you look at the two channels differentially (±A±B).

Integrated circuits provide 10 mV/div deflection factor, and a thick-film planar attenuator offers selectable 1 MΩ or 50Ω input impedance. The 1 MΩ (ac/dc) input has only 12 pF shunt capacitance for minimal loading. In probing applications, you can reduce this low capacitance even further by using 10:1 divider probes. The 50Ω input termination has low VSWR for pulse fidelity.



The 1835A 200-MHz bandwidth plug-in displays glitches that could cause timing problems.

Send the HP Reply Card for details and specifications.

Universal card reader inputs 300 cards per minute

HP's 300 cards-per-minute optical mark reader is flexible as well as fast: the 7260A accepts all types of punched or marked card, even specially designed forms. With appropriate clock marks, single cards may be both punched and marked, in any number of columns from 1 to 80.

The 7260A can be used with terminals, computers or remote data systems via a modem or direct connection. Data rates are switchable from 110 baud to 2400 baud. Data is stored in bunfers so that you can optimize the card feed rate for high transmission efficiency. The 7260A transmits 7-level ASCII code, but other decoding options are available.

Quantity and OEM discounts are also available.

For more information, check the HP Reply Card.

This desktop serial card reader is quiet enough for the office, fast enough to keep up with your computer.

New line printer handles calculator output

Usually line printers are considered computer system peripherals; but now HP offers a reliable line printer for your 9830 calculator system.

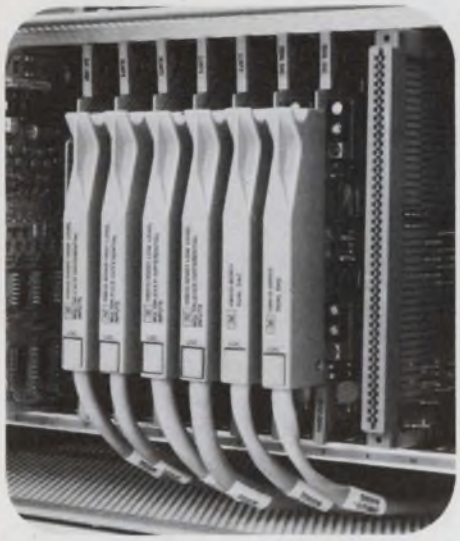
The new HP 2607A line printer prints 200 lines per minute, has a full 132 column line width, and 8-level tape control for vertical formatting. The 64 character set is standard USASCII code; characters are styled from a 5 × 7 dot matrix. The line printer is so compact, you can use it on a movable stand or keep it on a desktop or tabletop next to your calculator.

Installation is quick and easy. Simply plug an 11287A interface card into the 9830 calculator, connect the interface cable, and configure the system to your requirements. With the powerful programming capability of the 9830, it's difficult to tell where the calculator system ends and the computer system begins.

To learn more, check the HP Reply Card.

This new line printer substantially increases the through-put of the 9800 series calculators.

New multiplexer options for HP 9600 systems



Each multiplexer input circuit provides high common mode rejection from transients and noise. Drift is eliminated by an offset sampling amplifier which further improves accuracy.

Two new multiplexer options for HP 9600 series computerized measurement and control systems let you input analog signals as low as 10 mV.

The 12760 is a relay low-level multiplexer while the 12761A is a solid-state model. Either one switches low-level analog inputs to an HP 2313B A/D interface subsystem. To install the multiplexer, simply slip a printed circuit card into the subsystem.

Both multiplexers accept 16 differential analog inputs and have programmable gains. The solid-state model provides 8 low-level ranges from ±10V to ±800V full scale. Sampling rate is up to 50 Hz. The relay multiplexer provides 7 low-level ranges from ±10mV to ±400V full scale and offers protection against high common mode voltage and rejection. Sampling rate is up to 20 Hz.

Send the HP Reply Card for details and specifications.

New low-cost microwave step-attenuators

Automated manufacturing and testing procedures enable HP to offer precision coaxial step-attenuators with outstanding performance at attractive prices. There are two attenuation ranges, 0-70 dB and 0-110 dB in 10 dB steps. The units can be specified for either dc—18 GHz or dc—4 GHz frequency coverage. The HP 8495/8496 attenuators contain thin-film (tantalum or sapphire substrate) attenuation elements that are switched in or out with extremely high repeatability (typically within 0.02 dB), even after thousands of switching cycles.

Both units have high accuracy (typically 1.6% to 4 GHz, 4% to 18 GHz) and low VSWR (1.35 at 4 GHz, 1.7 at 18 GHz). Bench models have three connector types available: type N, SMA and APC-7. Step-attenuator versions for installation within equipment are also offered.

There's more. Just check the HP Reply Card.

Compact size makes these precision attenuators ideal for beach use or installed in equipment.

Expedited entry keyboard speeds calculations

The new expedited entry keyboard for the HP-81 business calculator makes problem-solving even faster.

Thanks to a new optional expedited entry keyboard, the HP-81 business desktop calculator solves problems as fast as you can use it. The calculator stores up to 64 keystrokes while simultaneously performing your previous calculations. You can start a new problem while the calculation is solving another.

This preprogrammed business machine solves problems of investment analysis, loans, bonds, annuities, depreciation and statistics. Simply key in your figures, and the calculator prints the answer. There's no programming involved—if you can use an adding machine, you can operate the HP-81.

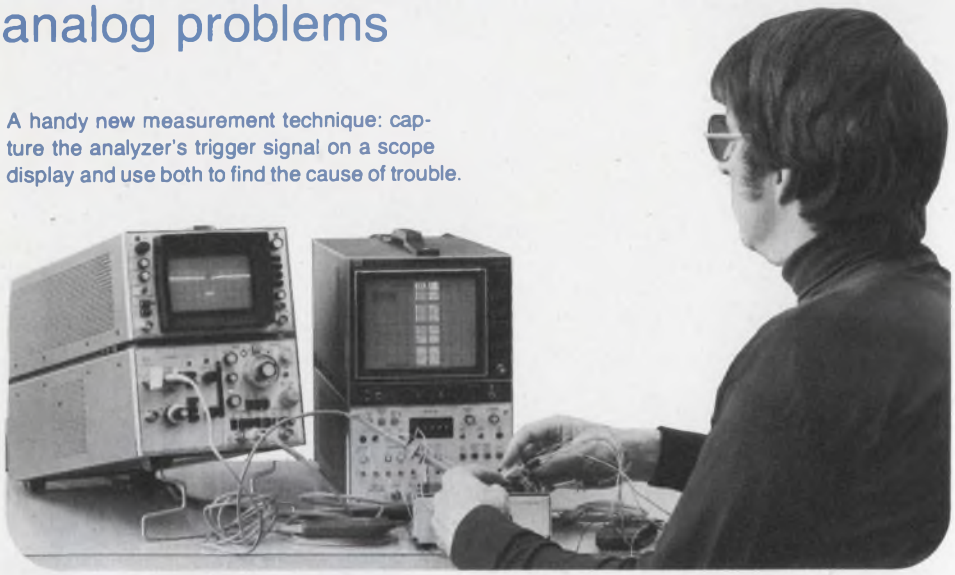
Besides the built-in financial functions, the HP-81 can compute mean and standard deviation, correlation coefficient, and a two-variable trend line. If you make an error, such as dividing by zero, an error message tells you why the operation cannot be performed.

All this computational power comes in a small 13.5 lb (6.12 kg) machine that fits easily on a corner of your desk.

For more information, check the HP Reply Card.

Digital triggering pinpoints analog problems

A handy new measurement technique: capture the analyzer's trigger signal on a scope display and use both to find the cause of trouble.



Twelve-bit parallel pattern recognition capability enables the 1601L logic state analyzer to trigger on a particular logic pattern. The unique trigger signal, available as a front panel output, is an extremely powerful tool in digital circuit analysis. By applying this trigger signal to an oscilloscope, the scope's display is positioned in the same "time window" as the digital event.

Let's look at a practical application of digital triggering. Functional checks of a two-decade BCD counter reveal that it is resetting to zero at state 89 rather than 99. A problem on the reset line is the probable cause. However, when the oscilloscope is connected to the master reset line, several pulses that could cause the problem are displayed. The one that's causing the premature reset is not readily apparent. By connecting the analyzer trigger output to the scope's external input and setting the analyzer trigger switches to state 89, the glitch is readily apparent.

Send the HP Reply Card for details and specifications.

HP solid-state sweepers deliver high power output

High power output across all bands—a value feature of HP's 8620 solid-state plug-in sweeper.

The 8620 series solid-state sweepers cover 3 MHz to 18 GHz with high power output that makes these solid-state sweep oscillators comparable to BWO-type sweepers. Standard units deliver at least 40 mW to 4.2 GHz and ≥10 mW all the way to 18 GHz.

Modular design gives you unparalleled flexibility. Start with either of two mainframes, then choose from 9 single-band plug-ins or RF module combinations to get multi-band coverage conveniently and compactly. Standard features include 1% sweep linearity, low spurious signals, high stability, fully-calibrated Start/Stop, and ΔF sweeps.

In 6 weeks or less, your 8620 sweeper will be delivered and operating.

Send the HP Reply Card for details and specifications.

New low prices for HP-45, HP-35 pocket calculators

In these days of rising inflation, powerful computation capability in the palm of your hand now costs less. Prices for the HP-45 and HP-35 have been reduced.

The HP-45 has a 4-register stack, 9 addressable memory registers, and more than 44 sophisticated functions. You can perform register arithmetic, polar/rectangular coordinate conversions, metric/U.S. conversions, logarithms, and trigonometric functions in 3 different input modes—degrees, radians and grads.

The HP-35—with 4-register stack and an addressable memory register—handles logarithms, exponents and trigonometric functions within seconds.

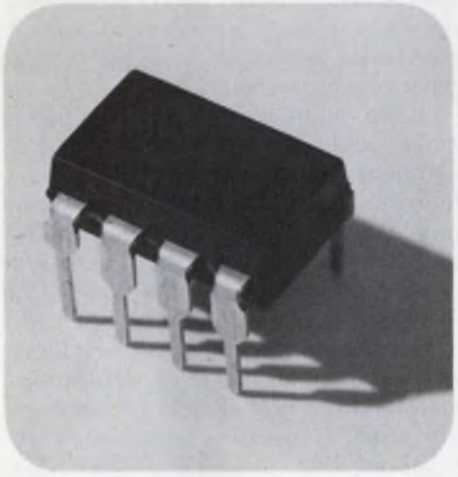
Each calculator comes with a carrying case, an ac adapter/recharger, and an owner's handbook.

For more information, check the HP Reply Card.

New lower prices for the HP-45 and HP-35 are really something to smile about.

HEWLETT-PACKARD COMPONENT NEWS

Introducing three new isolators



For maximum dc/ac isolation between each input and output, use HP's new 5082-4364 dual isolator.

HP now offers the 5082-4370 series isolators containing a high gain, high speed photodetector that provides a minimum current transfer ratio (CTR) of 300% at input currents of 1.6 mA for the 5082-4370 and 400% at 0.5 mA for the 5082-4371. The excellent low input current CTR lets you use these devices in applications that require low power consumption. Separate pin connections for the photodiode and output transistor permit high speed operation and TTL-compatible output.

Also available is a dual version of our popular high-speed optically-coupled isolator. The new 5082-4364 consists of a pair of optically-coupled gates in an 8-pin dual-in-line package. It's completely TTL compatible and has propagation delays of 50 ns. The high speed of this device makes it ideal for use as a line receiver in high noise environments.

There's more. Just check the HP Reply Card.

Optoelectronics at a glance

HP's new short-form *Optoelectronics Catalog* describes our complete line of lamps, displays, and isolators—in just 6 pages. This concise guide contains the three latest additions to the HP optoelectronics line: the 5082-7740 common cathode LED display, the 5082-4487 low-cost LED lamp, and the 5082-7430 low-power numeric display.

For your free copy, check the HP Reply Card.

New diode and transistor catalog now available

Which diode or transistor meets your design specs? Simply refer to HP's new *Diode and Transistor Catalog*, a comprehensive reference containing complete specifications on:

- Microwave transistors
- Schottky diodes
- PIN diodes
- Impatt diodes
- Step recovery diodes
- High reliability devices

The catalog includes packaging specifications and drawings to aid the circuit designer.

For your free copy, check the HP Reply Card.

New large-digit LED display

LEDs are growing—in size as well as popularity. Now, HP offers a seven-segment display with large .43 in. (1.1 cm) high numbers. The 5082-7750 series devices are common anode LED displays with a choice of right or left hand decimal point.

You can read these bright displays from up to 20 feet away. Distance viewing is also enhanced by the high contrast ratio and wide viewing angle. IC compatibility makes the 5082-7750 series ideal for electronic instrumentation, point of sale terminals, TVs, radios, and digital clocks.

Send the HP Reply Card for details and specifications.

Standard 0.3 in. (0.66 cm) dual-in-line package permits easy mounting on PC boards or in standard IC sockets.

New scientific minicomputer system performs maxi-computer information management tasks

Compact, streamlined, and capable: HP's new S/250 scientific information management system.

If you are in charge of an engineering laboratory or research project, your data management procedures may be inadequate for the rapid accumulation of information. You need to store growing data files yet access them quickly. Not only do your variables change, but the data sets interact dynamically. Timely reporting gets difficult. Outside services may be unreliable and costly.

Then there's the security problem—preventing unauthorized personnel from accessing sensitive data. Until now, you could find the capability that you need only in large, expensive computers.

The new HP S/250 scientific data management system solves all these problems. This compact system combines a proven minicomputer with a versatile disc operating system and powerful data base management software. You can use it in a dedicated environment or in multiple modes. You can write application programs in FORTRAN, ALGOL and assembly language. The built-in data manipulation software (IMAGE/2000) reads, updates, deletes and modifies data. Format the output for reports according to your preference, without knowledge of computer programming.

In the multiple user mode, 32 people can concurrently enter data, retrieve it and generate reports. In the data communications mode, a special telecommunications software package enables the S/250 to communicate directly with an IBM 360 or 370. And of course, the S/250 interfaces with other HP systems.

Standard hardware features include floating point arithmetic, micro-programmed fast FORTRAN processor, 48K bytes of memory, removable cartridge disc that stores 4.8 million bytes (alternately expandable to 93 million bytes), keyboard display console, 200 lpm line printer, 1600 bpi magnetic tape drive, and microprogramming capability. Like all HP computer systems, the S/250 is supported worldwide.

To learn more, check the HP Reply Card.

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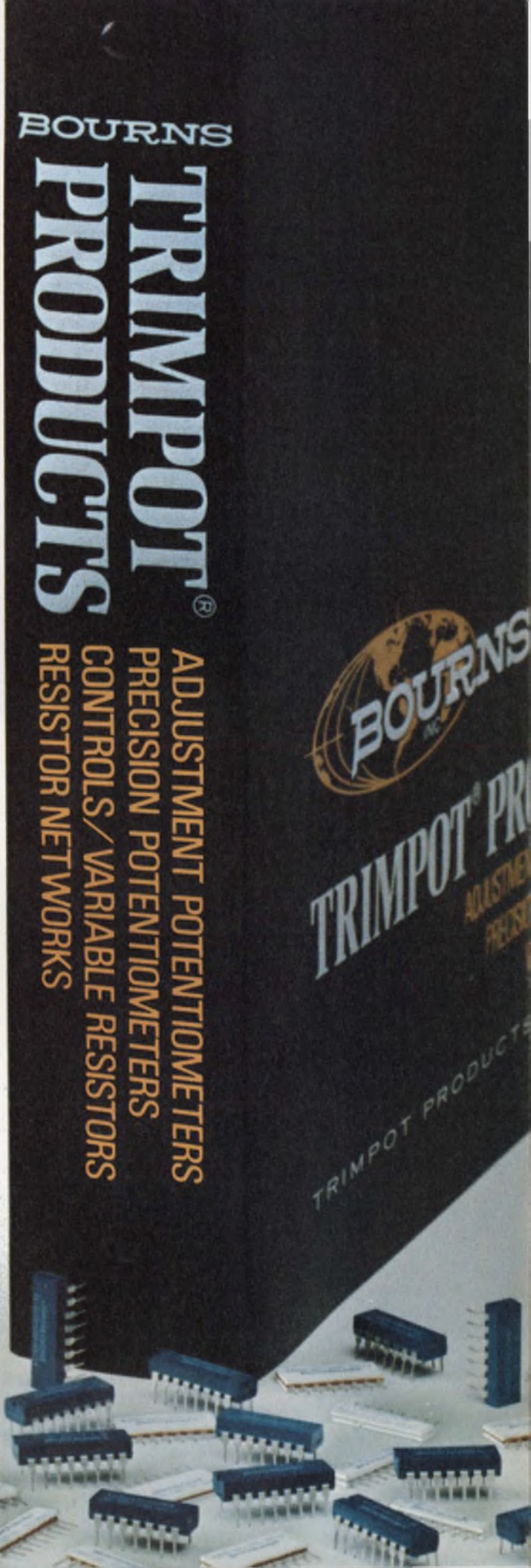

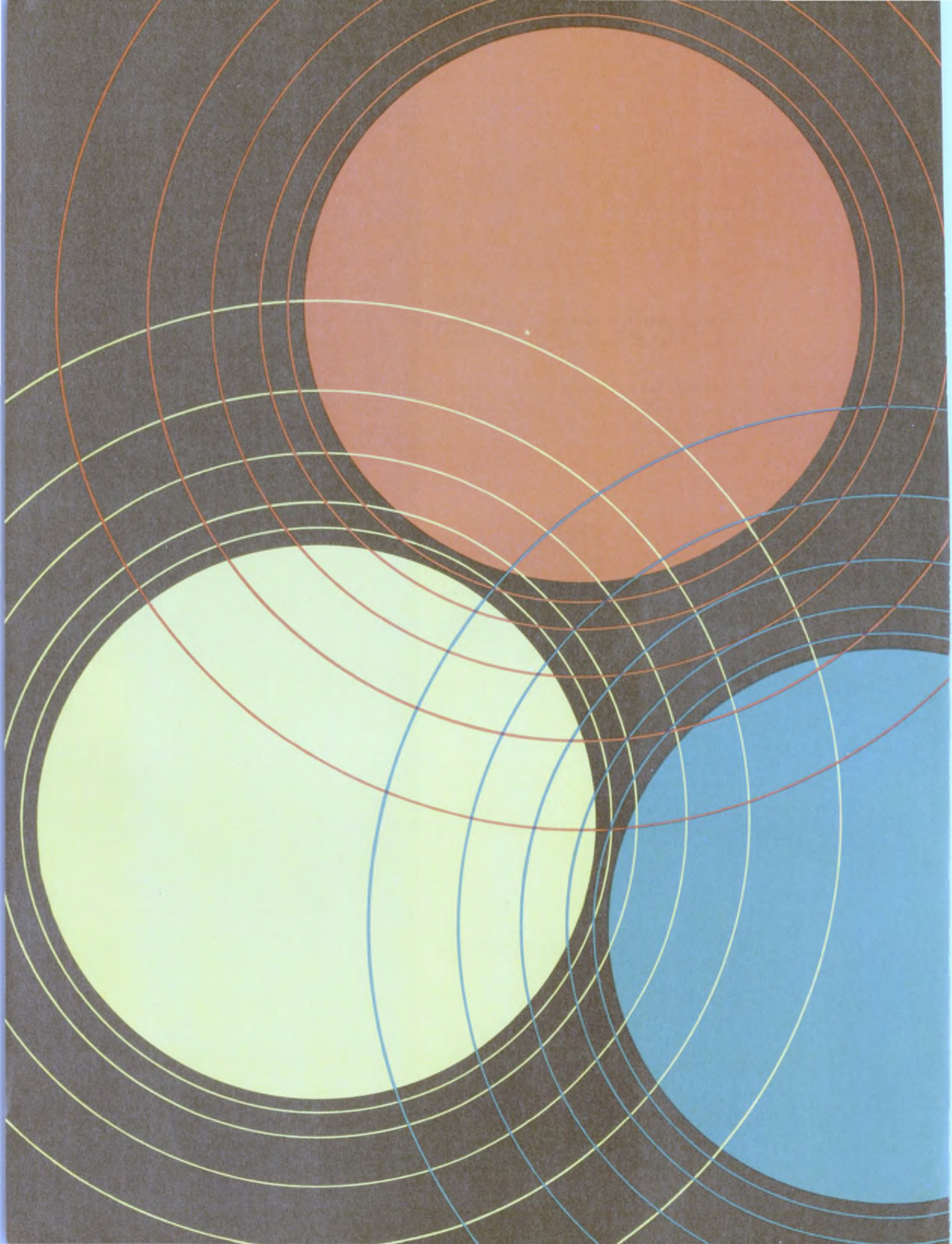

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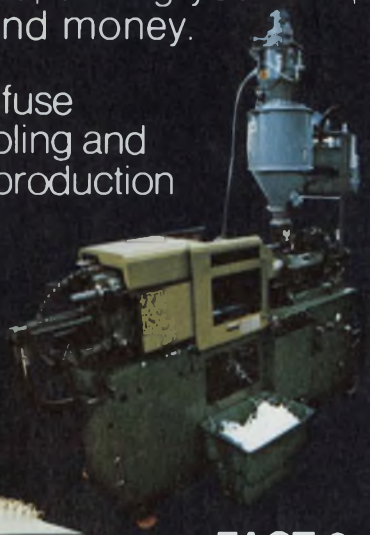

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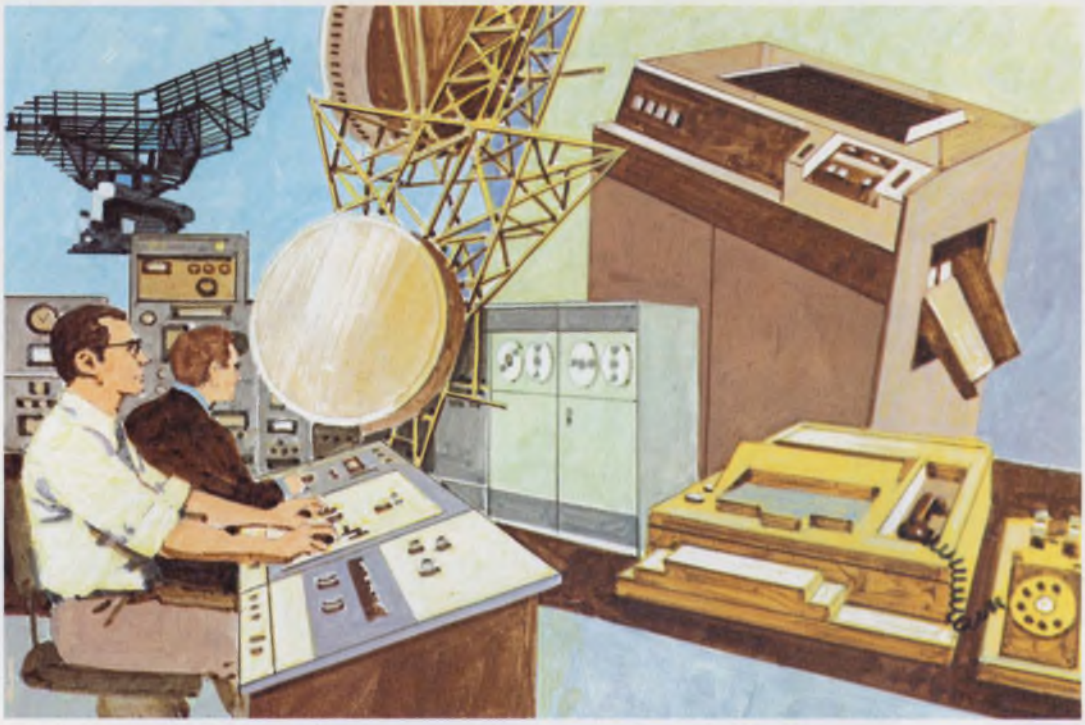

Copiers, computer peripherals, communication equipment, business machines, precision instruments—you'll find our R10 in a multitude of applications requiring a compact, reliable, multi-pole relay. That's because it probably gives you more design options than any other single relay.

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R10 relays have U/L Component Recognition. Models to 6PDT have C.S.A. Component Recognition. Life expectancy is to 100 million operations, depending on contacts and load. The R10 is available with a voltage- or current-sensitive coil. Pick-up ranges from 2.25 to 86 VDC, 5 to 86 VAC, or 0.85 to 45 milliamp, with proper power supply. Depending on the number of contacts, the R10 weighs from 22 to 40 grams.

R10 relays are in stock at your leading electronic parts distributor; or call your P&B representative. For your copy of the 226-page catalog showing the complete P&B line write Potter & Brumfield Division of AMF Incorporated, Princeton, Indiana 47670; or phone 812 385 5251.

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INFORMATION RETRIEVAL NUMBER 13

EC54

Bubble memories advance from chip to module stage

Progress in magnetic bubble memories has advanced from the chip-fabrication stage to the development of bubble-memory modules.

At the International Magnetics Conference in Toronto, several researchers described their work. Among the developments discussed were these:

- A bubble memory from Hewlett-Packard, designed for use in calculators, computers and instruments.
- A simplified packaging method that uses flat-faced coils to produce the magnetic driving field.
- An experimental 460,544-bit mass memory that could replace fixed-head discs.

According to Richard B. Clover, an engineer at Hewlett-Packard Laboratories in Palo Alto, Calif., the HP memory module contains conventional garnet bubble chips, wire-wound coils that produce the magnetic driving field and a permanent magnet structure to produce the bias field. The unit is housed in high permeability, magnetic shielding material.

A novel feature of the HP bubble memory is the double differential detection scheme used. This technique, Clover explained, uses two pairs of chevron stretcher detectors for each serial data stream. By use of this approach, a nearly optimum signal-to-noise ratio is obtained, even in the presence of permalloy domain switching noise, flux pickup from the drive field and turn-on transients.

The differential detector, said Clover, produces a signal that is twice as large as it normally would be, and it yields a device that is independent of the bias field and temperature.

While he would not give the size of the module that was tested, Clover did indicate that the ultimate aim was to produce a memory of several million bits that could be used with desk-top electronic calculators, instruments and minicomputers.

At the same session, Harumi Maekawa, senior engineer at Fujitsu's Solid-State Laboratory in Japan, described a new method of packaging bubbles with flat-faced drive coils. The chief advantage of the coils, he said, is that they simplify the construction of bubble-memory modules.

The basic structure, Maekawa explained, consists of two sets of flat, elliptically shaped, spiral coils. Each set of coils is composed of two orthogonal coils. Up to 16 bubble chips can be mounted on a substrate, which is then sandwiched between the two sets of coils. The rotating drive field is generated when sine and cosine currents are applied to each set of coils.

In explaining why he chose this approach, Maekawa noted that the structure simplified module fabrication and made it possible to remove chips easily if needed. With the more convetnional solenoid coils now used, this is very difficult.

What is probably the largest working bubble-memory module to date was described by Paul Michaelis, a researcher at Bell Laboratories, Murray Hill, N.J. According to Michaelis, the experimental module contains 32,896 14-bit words, for a memory size of nearly half a million bits. This capacity is provided by 28 chips, each of 16,448 bits, assembled on two substrates.

The memory is driven by a 102-kHz rotating field, has an average access time of 2.7 ms and a read/write time of 5 ms.

CCDs proving worth in digital memories

When charge-coupled devices were introduced four years ago, many designers said that they were good for imaging and linear applications but that they could never compete with standard technology in the digital memory area. Last month the advantages of CCDs in digital memories were underscored at the International Magnetics Conference in Toronto.

CCDs have distinct advantages for memory applications, particularly in the area of high density, papers at the conference indicated. In a presentation on mass-memory applications, Douglas Colton, a researcher from Bell-Northern Research, Ottawa, noted that the technology had advanced to the point where 16-kilobit chips could be fabricated on wafers about the same size as current 4-k RAMs—and at between one-quarter and one-half the price.

Elaborating, Colton pointed out that a serial device could be fabricated on a chip that is 20% smaller than current 4-k devices, while a decoded 16-k memory would require a chip about 10% larger.

In discussing costs, he noted that the serial 16-k unit would cost only one-fourth as much as 4-k RAMs, while a decoded version would be one-half the price.

As for operating characteristics, Colton said that such a 16-k chip could operate at data rates of between 5 and 10 MHz and have an access time of between 25 and 50 μs.

Colton predicted that chips of this type would be announced by late this year or early 1975. Information from other sources indicates that the earlier date is more likely.

Peering further into the future, Colton said that with CCD technology, 32-k and 64-k memory chips would be possible. He noted, however, that electron-beam fabrication would be necessary to achieve this density.

Joe E. Brewer, an engineer from Westinghouse's Defense and Electronic Systems Center in Baltimore, another speaker at the memory session, disagreed with Colton. He said that if CCD technology was combined with MNOS, cell areas of 0.5 square mils per bit would be possible. This he continued, would allow the fabrication of 64-bit devices on a chip 245 by 245 square mils.

Westinghouse is currently working on NOVCAM (nonvolatile charge-addressed memory) devices, Brewer reported. He stressed, however, that the company had not fabricated such large devices.

In explaining why such high density is possible with a NOVCAM device, Brewer said that much of the overhead circuitry required by CCDs is eliminated. This, he continued, is because the information is stored in a nonvolatile mode in the MNOS portion of the device.

Electron beam produces ICs of 0.2-μ line width

With the introduction of the first commercial electron-beam micropattern generator, ICs with line widths down to 0.2 μ on 0.4-centers can be produced from stored digital patterns.

Shown at the Semicon-West '74 show in San Mateo, Calif., the generator—the EBMG 600—is built by Radiant Energy Systems in Newbury Park, Calif. It gives the semiconductor industry a capability that existed before only in the research laboratories of companies like Hughes Aircraft, IBM and Texas Instruments.

Without such equipment, line widths of less than 2 μ are impractical to produce. The width on the new ssytem is held to $\pm 10\%$.

The EBMG 600 can be used for the production of masks or for direct pattern writing on a silicon wafer.

In the direct-writing mode, a 2-1/2-in. wafer can be written in about one hour. According to William B. Livesay, vice president of engineering at Radiant Energy Systems, the process would take about four hours if conventional photolithigraphic techniques, including an optical pattern generator, were used.

The system includes a computer-aided-design capability by which an operator can develop and design the device structure on an interactive graphic display. Then with the push of a button, he can write the pattern directly into a silicon wafer.

The electron beam is produced by a tungsten field-emission cathode of about 0.5-μ dia. The electrons pass through an aperture, then through an electrostatic lens. After passing through the lens, the electrons are focused, through a set of deflection coils, past the secondary electron detector and then onto the substrate target. The substrate is mounted on an x-y movable table.

A Nova 800 minicomputer with 32 k of core, from Data General, Southboro, Mass., controls the system with the aid of a magnetic tape deck, a 1.2-megaword disc and an interactive graphic display.

The company expects to introduce the EPS-1200 and the EPS-1500 electron-projection and alignment systems to do this job. (see p. 36 of this issue.)

The 1978 automobile: Processing systems

"By 1978 automobiles will be testing on-board processing systems to handle such functions as electronic fuel control, ignition control with automatic spark advance, generator control and cruise control."

The prediction is made by Robert B. Hood, manager of advanced automotive products at Fairchild Camera and Instrument, Mountain View, Calif. Hood, who will speak at the Automotive Electronics Conference and Exposition in Detroit, June 11 to 13, says the auto industry will probably have a system in which all vehicle communications are handled via digital multiplexing.

The same box for on-board processing systems, he says, could also be part of a closed-loop servo control for the throttle position, for the distribution of cylinder-to-cylinder fueling and ignition selection, for signal processing for the dashboard tachometer, for diagnostic functions and for some emissions control—perhaps direct exhaust gas feedback.

With digital multiplexing, Hood says, vehicle wiring harness will be reduced to perhaps four wires: positive power (battery), data bus, control bus and negative power (ground).

The problem, he explains, is not in the complex areas like LSI, as formerly believed, but in the sensing function and the development of actuate functions. The actuate functions are particularly difficult, Hood says, because the load used by the automobile manufacturers for electric window motors and for electric seat controls are subject to large transients in current and voltage.

Electonics will dramatically improve safety, emissions and economy, Hood says, and "in the long run, electronics will decrease the cost of cars."

New switch cuts cost of liquid-crystal panel

Using liquid-crystal light valves and a new type of switch, Rockwell International has developed a portable control panel that it says is 10 times cheaper to produce than the mosaic of switches and lights now used.

According to Larry Tannas, head of the Display Technology Group in the Anaheim, Calif., company's Electronic Research Div., the panel —called a keyboard entry device— is a one-piece sandwich of plastics, glass and organic films. It is completely transparent.

The panel measures 4 by 8 in. and contains 64 separate switch/display elements. Switches are composed of a layer of flexible plastic, on which are deposited indium-tin oxide contact, a liquid film of a transparent petroleum dielectric and another indium-tin oxide electrode on a glass substrate. When pressure is applied to the switch, the liquid dielectric is forced out, and the two switch contacts come together.

The glass substrate of the switch is the top half of another sandwich, this one comprising the liquid-crystal light valve.

To use the keyboard entry device, the engineer places a sheet of paper that contains the data for display under the transparent panel. By appropriate circuit design, the panel can display information in a normally visible mode or a normally blocked mode. In the blocked mode, the liquid-crystal light valves prevent the information from being viewed, notes Tannas.

The unit was originally developed for the Navy Electronics Laboratory Center in San Diego.

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The 643's are DC versions capable of switching up to 60v/400Ma or 250v/100Ma. They actually exceed current and voltage switching capabilities of opto-isolators. In communications, use them for keyer switching — or as telegraph relays.

Finally, the 644 is a low offset voltage unit that solves switching problems in instrumentation applications. Use it for low level transducer signal switching, series choppers, scanners, sample-and-hold, multiplexing, etc.

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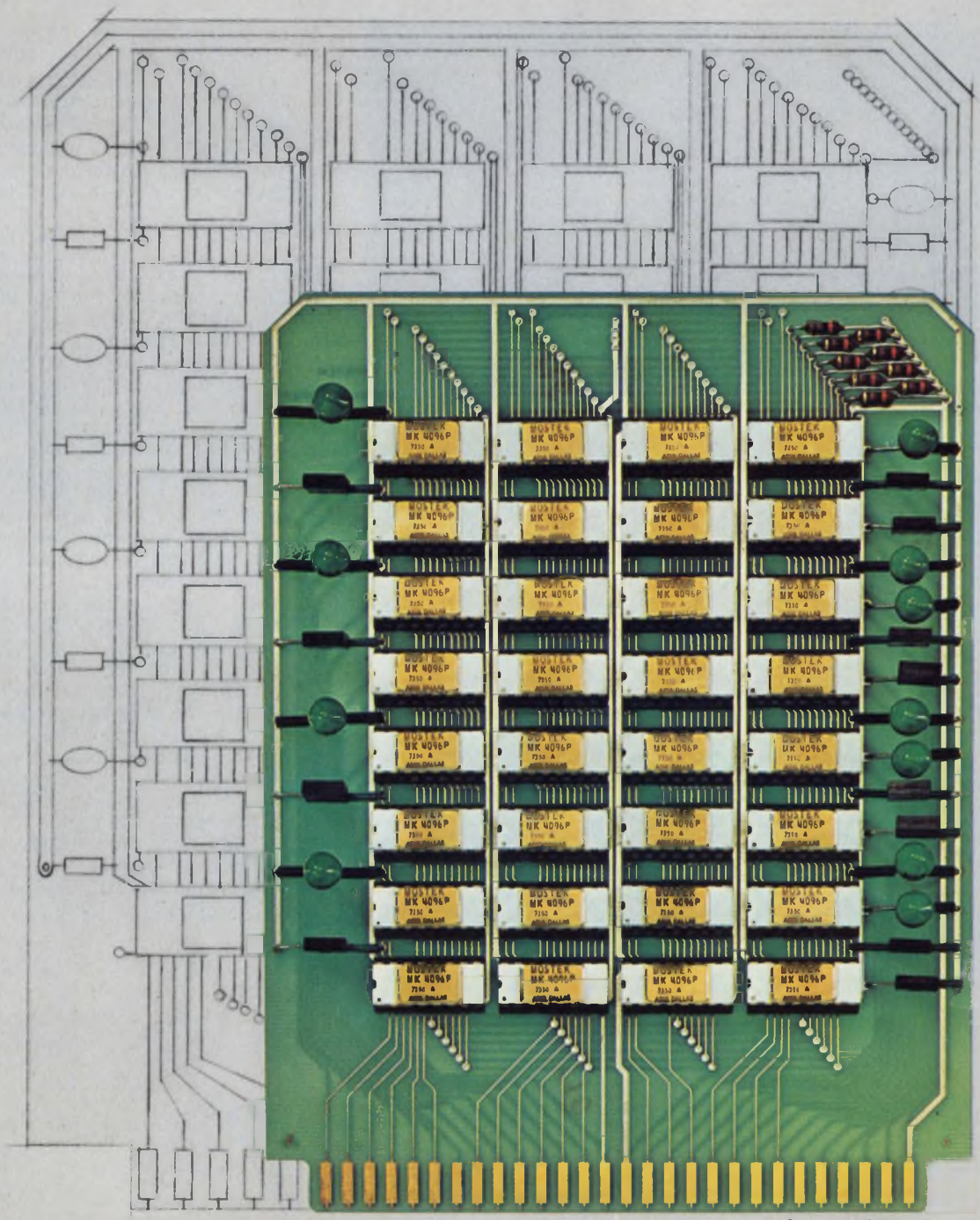
INFORMATION RETRIEVAL NUMBER 15

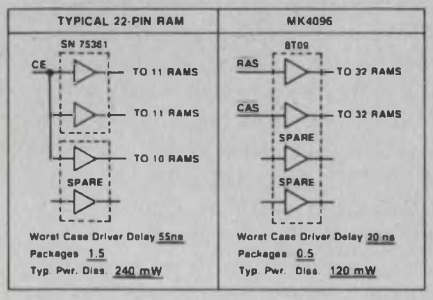
MOSTEK's 16-pin 4K RAM makes memory design easy.



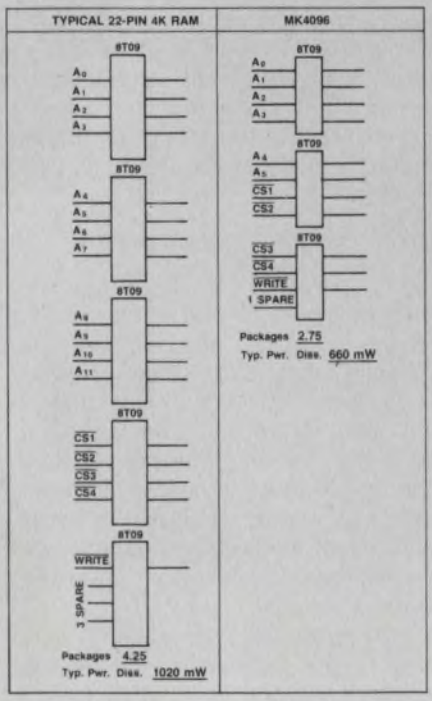
MOSTEK's MK 4096P enables you to reduce memory board size by 50%.

With MOSTEK's MK4096P you can reduce memory board size by 50% and power dissipation by 45% over 22-pin RAMs with no increase in package count. Add up the advantages for yourself.

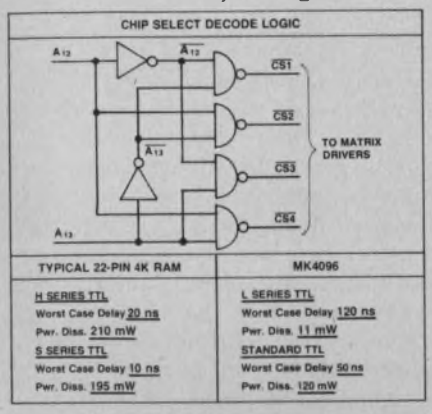
The MK4096 incorporates TTL-compatible clocks, eliminating the need for special high-voltage clock drivers required by 22-pin competitive devices. Low clock line capacitance with the MK4096 means fewer drivers and less delay.



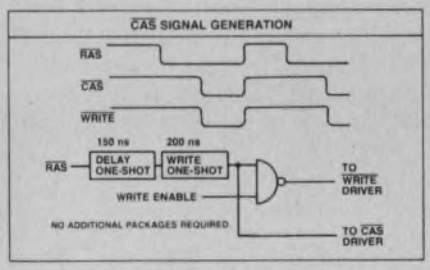
Fewer signal lines and signal drivers required. Compared with 22-pin packages, the MK4096 requires six less address lines to be driven throughout the memory matrix. In addition to making PC layout easier, this means fewer address drivers are required.



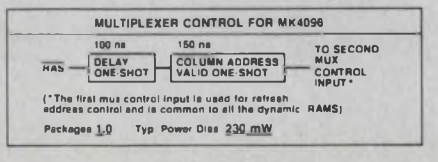
Only standard TTL required for chip select decode logic. Using MOSTEK's MK4096, two-level decode logic for a 16K by 8 memory matrix can be implemented with standard or "L" series TTL, whereas "H" or "S" series is required by competitive 22-pin 4K RAMs. This is because the MK4096 requires decoded chip select information to be valid at the Column Address Strobe ($\overline{CAS}$) leading edge which is 150 nsecs into the cycle. The 22-pin alternates require valid chip select information no later than 70 nsecs after the cycle begins.

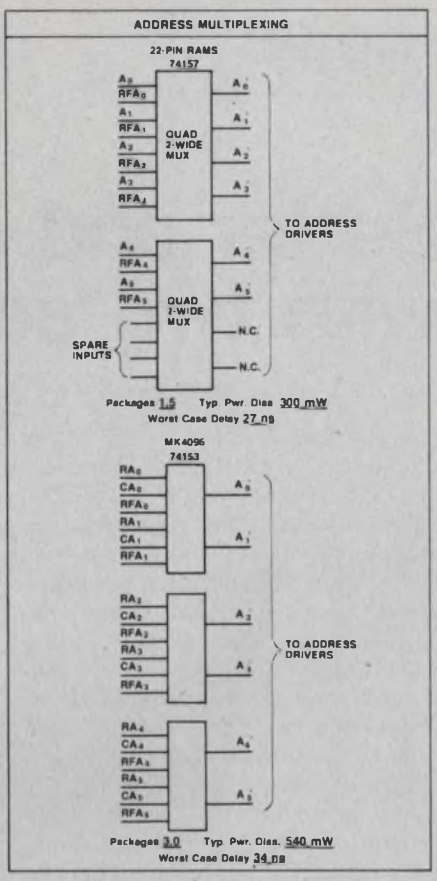


No additional packages required for second strobe or clock signal. Timing specifications for the MK4096 allow use of the existing $\overline{WRITE}$ signal timing logic as the Column Address Strobe generator so no additional timing channel needs to be added to the memory controller. Thus there is no requirement for additional packages.



Address multiplexing is accomplished easily. Multiplexing of addresses is common to all memory systems using dynamic RAMs due to the refreshing requirement. 22-pin 4K RAMs require a 6-bit refresh address as does the MK4096. The only additional requirement with the MK4096 is that the address be multiplexed in two 6-bit bytes, accomplished with a multiplexer that is 3-wide instead of 2-wide and a multiplexer control that is 2-bits wide instead of 1-bit wide.





Result? The MK4096 scores highest in density, lowest in power dissipation and requires no additional packages in the memory controller.

	TYPICAL 22 PIN 4K RAM	MK4096
Total Packages	7.25	7.25
Total Typical Power Dissipation	1770 mW	1561 mW
Total Power Dissipation Including Rams	23.53 W	14.36 W

Add up the advantages of MOSTEK's 4K RAM and you'll understand why it's already becoming the industry leader in design ease, performance and volume availability. Call your nearest MOSTEK distributor or representative for more details or contact MOSTEK, 1215 West Crosby Road, Carrollton, Texas 75006, (214) 242-0444.

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news

Better and cheaper ICs on the way with two advances in processing

The first machines for fully automated processing of IC wafers are now commercially available, and the benefits for designers are expected to be substantial.

Dr. Sam Harrell, vice president of engineering for the Cobilt Div. of Computervision Corp., Sunnyvale, Calif., developer of the machines, sees a breakthrough in IC production speed, accuracy, uniformity and lower costs.

[In a related development, the first commercial electron-beam-projection system is expected shortly, with promise of faster, denser, more reliable ICs. p. 36.]

"There are a number of important variables in photoresist processing which are pinned down by automating the system," Harrell explains. "The automated processor assures the condition of the wafer surface—protecting it from scratches and contamination from handling. Other parameters more closely controlled by the machine than by operators are: the uniformity of the resist coating, the time-temperature cycle in baking, and mask alignment, contact and exposure. Finally the small size of the machines permits a smaller, more controlled clean room."

Called the Autofab I and II, the two fabrication systems differ in layout but not in performance. Autofab I delivers the completed wafers at the opposite end from where they are loaded, and Autofab II uses a U-shaped process, delivering them at the same end of the system.

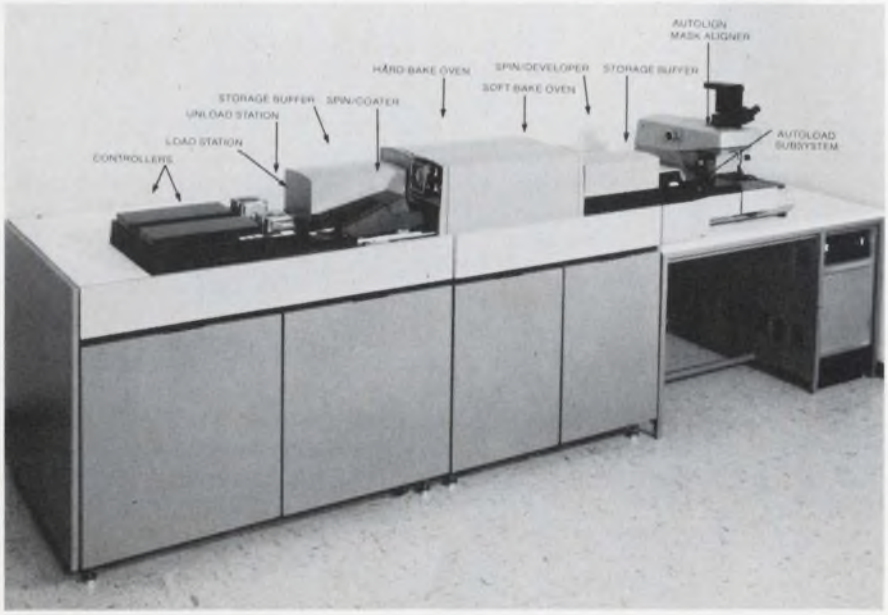
The systems are reported to process up to 180 1.5-to-4-in. silicon wafers an hour from raw material to the ready-to-diffuse state. The process is totally automatic, limiting the function of the operator to loading and unloading wafer cassettes and watching fluid supplies.

In conventional IC production, a silicon wafer, containing a large number of potential chips, must go through the wafer fabrication step several times. Each time a layer is added or etched away—during oxide growth, epitaxial growth, diffusion or metallization—the wafer-fabrication process defines the limits of the area to be processed. A thin layer of photosensitive emulsion or resist is applied to the wafer. The wafer is coated with an emulsion while it spins, to produce a uniform thin layer.

Next, the coated wafer is soft-baked to drive off the solvents from the resist, put in contact with a photo mask and exposed. After exposure, the wafer is developed and unexposed areas are removed by a solvent.

Finally the wafer is hard-baked to render it ready for processing. Errors produced by faulty coating, poor mask alignment or improper development are cumulative—making wafer fabrication a major factor in determining IC yield and quality.

Northe K. Osbrink
Western Editor



Automated wafer-fabrication system, the Cobilt Autofab II, measures 6 by 12 ft. It can process up to 180 IC wafers an hour.

Up to 25 steps automatically

In operation, a standard cassette holding 15 wafers is placed on an unloading station—and the system takes over. The cassette is lowered, and a wafer is picked out by a drive belt and delivered to a photoresist spinning station. The spinning cycle has a controlled acceleration rate, and as the resist is applied, the wafer undergoes a programmed cycle of spinning at various speeds.

After spinning, the wafer is carried to the bake oven. Inside the oven, the wafer is handled by an Archimedes screw system, designed to allow the maximum number

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of wafers to fit in a limited area. Because of the better control of heat flow in the closed oven, the equipment is said to consume about half the electrical energy of a conventional open-ended tunnel oven.

At the oven output is a "buffer storage," which can hold up to 50 wafers.

Once coated and soft-baked, the wafers are delivered to the Autolign machine by a series of rubber drive belts. The mask aligner uses a closed-loop position-sensing and control system to bring the wafer into alignment with the mask. The mask and wafer are brought into contact only during exposure, and a low-pressure nitrogen pillow behind the wafer allows uniform contact with a minimum of pressure.

After exposure, the wafer is delivered to a spinner for solvent development, and finally to a hard-bake oven and the output station.

Autofab I is about 3 ft wide and 22 ft long, and Autofab II is the same width and 11 ft long. Both units are in the $100,000 price range, with deliveries scheduled to start in the third quarter of this year. ■■

Electron-beam-projection system gives 3-way improvement in ICs

Faster, denser and more reliable ICs are promised with the imminent availability of the first commercial electron-beam-projection system.

The new machine, called the EPS-1200, is being developed by Radiant Energy Systems, Inc., Newbury Park, Calif., and the company says it will be available before the end of the year. In addition to improving ICs, the machine is said to be capable of improving production by eliminating defects caused when masks wear out.

According to Evan Friedmann, the company's manager of electronic engineering, the EPS-1200 can handle 3.5-in. wafers. The throughput rate is currently 60 wafers an hour, but that should be increased soon to 180 wafers an hour, he says.

The electron-projection system, the result of four years of developmental work, uses a PDP 8/E minicomputer to provide totally automatic operation. Several companies, including IBM and Thompson CSF, have tried to produce a commercial electron-beam-projection system, Friedmann reports, but have not yet been successful.

For a commercially acceptable system, he explains, two requirements must be met: A means of making high-speed, accurate alignments must be developed, and a way of making low-distortion image projections must be found.

Friedmann says that Radiant Energy Systems achieved accurate, high-speed alignment by projecting an electron beam, detecting any error signal that results from misalignment and then feeding the error signal into the PDP 8/E mini. The mini takes the signal, calculates where the electron beam should be and produces a signal that controls the magnetic field that steers the beam. Thus the computer closes the feedback loop to correct the beam position.

Why low distortion is important

Explaining why a low-distortion image is important, Friedmann points out that multiple alignments are necessary in the manufacture of a device. If there is localized distortion in the magnetic field, positioning of the wafer in the magnetic field becomes extremely difficult. To overcome the highly restrictive mechanical requirements of such a system, it is necessary to eliminate magnetic distortion in both the focusing and steering fields of the electron beam. Radiant Energy Systems does this by maintaining, as nearly as possible, a perfect axial electric field and by choosing the proper materials and geometrical configuration.

The electron-beam-projection system can produce ICs between 0.2 and 0.5 μ wide. This is an order of magnitude better than results with conventional photolithographic techniques. The smaller line widths mean that it is possible to produce higher-density devices that are faster and more reliable.

A one-order-of-magnitude decrease in line size means that theoretically it is possible to increase the density of ICs by two orders of magnitude. But, as Friedmann points out, that is not exactly so. The more devices that are fabricated on a chip, the more interconnects required. This increase in space-eating interconnects limits density increases to less than two orders of magnitude. Still, the space saving is great.

The increased density of electron-beam-fabricated circuits can result in simpler circuits. For example, with MOS devices, it often is necessary to "go off chip." This frequently means that additional driver circuits are required. But if the functions of several chips can be performed by a single device, it is possible to minimize the interface circuitry.

Another big plus for the electron-beam system, Friedmann says, is that infinite mask life is possible; there is no mechanical contact between the mask and the substrate.

The highest resolution for an optical system is obtained when the mask comes in contact with the substrate. As soon as the mask moves away from the substrate, diffraction effects result in loss of resolution. This is because it is difficult to focus and control photons.

Electrons, however, do not suffer from these problems. They can be controlled both magnetically and electrically. As a result, it is possible to focus an image with extremely high resolution. ■■

Jules H. Gilder
Associate Editor

Ludwig Lectures.

Getting a fix on fast settling.

In numerous linear-circuit applications where the nature of the signal is pulse-like or step-like it is essential to reach a new level quickly and accurately after a large signal transition. However, we find that we cannot predict this performance from the classical specifications of frequency response and slew rate. Therefore, a direct specification —settling time— was established which defines the maximum total time required from the occurrence of an abrupt input transition until change is *satisfactorily complete.*

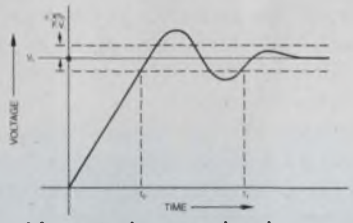
A slight misunderstanding...

The major areas of concern are in defining the input conditions, and what it means for the output change to be satisfactorily complete.

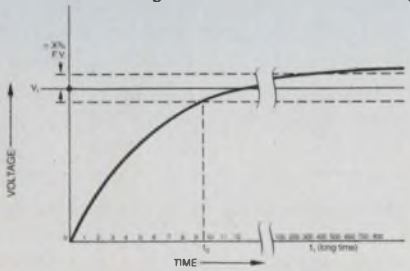
The real settling spec ought to cover these by defining a settling time to within X% (for example .01%) of final value for a large signal change (usually 10V) on the input. But both must be stated.

Close, but no cigar.

Some vendors base "Settling Time" specs on a small step change at the input and you still don't know what will happen in the large signal case. But the issue of "satisfactorily complete" on the output is full of cute pitfalls— let me show you.



Notice in the curve that the output first occurs with ±X% of full-scale-error-to-final-value at t_0 but doesn't stay within this error band. It thereafter bangs around due to the underdamped nature of the system. The real settling time should be stated as t_1.



Now look at graph B. The response is critically damped and settling seems to occur at t_0. But watch out. If we look far down scale we note that the apparent final level V_1 wasn't the final level at all. Question, how long do you wait to define what V_1 (final level) really is? You have to figure that out.

This long settling "tail" often occurs with time constants long compared to any computable electrical time constants in the system and is usually the result of less than ideal thermal management or slight pole/zero mismatch. If you're trusting your vendor's settling time measurements, make sure that you (and your vendor) understand his definition and their use of it, otherwise you're in trouble.

Who needs it?

Anyone handling signals having discontinuities needs fast settling. For example, following a multiplexer, on a PAM Bus, at the output of a DAC, in building a precision square wave, at the input to an oscilloscope, etc.

How good can you have it?

At Philbrick we give you *guaranteed* settling time because we figure your system has to always meet its spec— not just typically and that's more than just important. We offer a host of op amps, discrete modules, hybrid IC's and monolithic IC's with state of the art settling including our T0-99 units, 1322 (300 ns to .1%), 1324 (1 μsec. to .01%) guaranteed. The star of the show is our new DIP unit with FET inputs, the 1430, which offers 100 ns to .1% and 200 ns max to .01%. And you don't give up dc performance to get it. The 200 ns to .01% is just what you need for a fast 12 bit system. The open loop gain of 200K, input currents of 150pA, and an offset voltage of 1mV give you the dc accuracy to go with it. The 50 mA output capability will let you drive almost anything, but you don't pay for it with high quiescent current and its attendant power consumption.

Don't settle for less.

You could have the fastest settling op amp in the world and get lousy system settling unless you're very careful. Some of the common pitfalls that catch people are things like too much load capacity, too much summing point capacity, too high a circuit impedance for the stray and input capacities, use of inductive wire-wound resistors, and not figuring on the effect of current source output capacities in current-to-voltage converter applications. You've got to handle your power supplies very carefully too, by bypassing up close to the unit with the right kind of capacitor.

In any event, to make sure you get the right story on settling time and use the information properly, telephone, (617) 329-1600. Or write us, Dedham, Mass. 02026. In Europe, Tel. 73.99.88, Telex: 25881. Or write, 1170 Brussels, Belgium.

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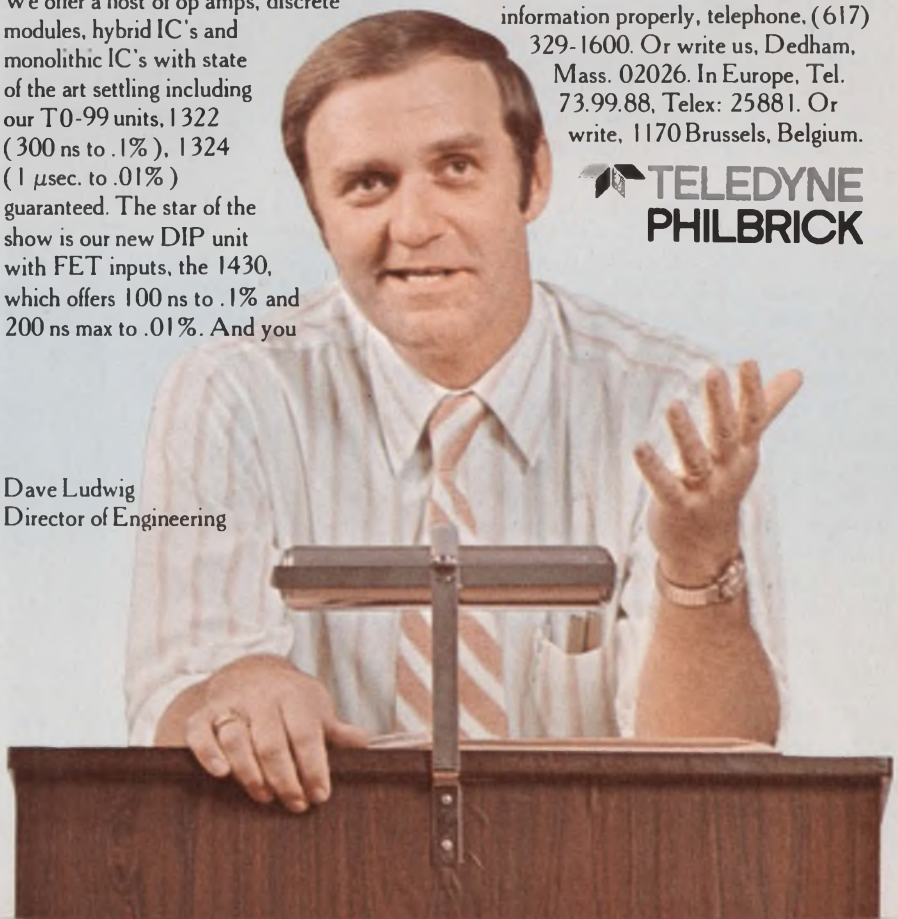

Dave Ludwig
Director of Engineering

Comes the satellite revolution in American communications

At first glance, domestic satellites are only a small part of the nation's communications network. Just one such American satellite is up—Westar—and only one other satellite—another Westar—is scheduled for launching this year.

But that's just the tip of the iceberg.

Within three years at least five other domestic communications satellites will be launched. And by then, the state of communications in the United States will have been changed unalterably. A new era of faster, cheaper, more versatile communications is opening.

Four corporate organizations are now either providing communication services via satellite or are preparing to. Some are leasing channels from Canada's Telesat Anik II satellite. One plans to lease channels from Western Union's Westar. Three are building satellites of their own. And they all have their own earth stations and will build more in response to demand.

Western Union's system, which is holding a third Westar in reserve, uses five earth stations.

American Satellite Corp. and RCA both lease channels from Canada's Telesat Anik II satellite.

American Satellite, a subsidiary of Fairchild Industries, plans to cancel its channels with Anik II and lease channels from Westar.

RCA Globcom has four earth stations working with its Anik II channels and will soon build two more to serve Alaska. By early 1976, RCA expects to have three satellites of its own in orbit, with plans to build more earth stations as business demands.

CML, a joint venture composed of Comsat General, MCI and Lockheed, is an approved participant in the competitive satellite arena but has not formally asked for approval of a technical design. "We will do this sometime this year," a spokesman for the joint venture says. "We hope to have a system up in early 1977."

A fifth satellite system, not in competition for private business with these four—at least for the first three years of operation—will be put up by Comsat General for American Telephone & Telegraph and General Telephone and Electronics. This system will consist of three satellites in orbit, with a fourth held in reserve for immediate launching, if needed. AT&T and GTE will build a minimum of nine earth stations for their satellites, which they will operate themselves.

Roaring into orbit in April, Westar is the first of four planned domestic communication satellite systems. Westar, owned by Western Union, has 12 channels.

AT&T and GTE's satellite channels will provide, by satellite, more of the same data-transmission service now available with their land lines—telephone, television and telecopier. They will simply accommodate the normal, expected growth in domestic communications, and they may even bring down the prices a little.

The competing systems, on the other hand, promise new services. Voice, video and digital data transmission, which now costs industry billions of dollars a year via noncompetitively operated land lines, will be much cheaper and therefore will be used to a much greater extent. Western Union says its satellite services will cut costs to industry by 50%.

Instead of buying these services from AT&T, a company will be able to lease channels from competitive carriers and set up its own internal network. A big corporation, for example, will be able to bring together its far-flung division managers for conferences via satellite and closed-circuit television.

Reports, designs and schematics can be facsimiled from one plant to another over a company's own leased network, instead of being

John F. Mason
Associate Editor

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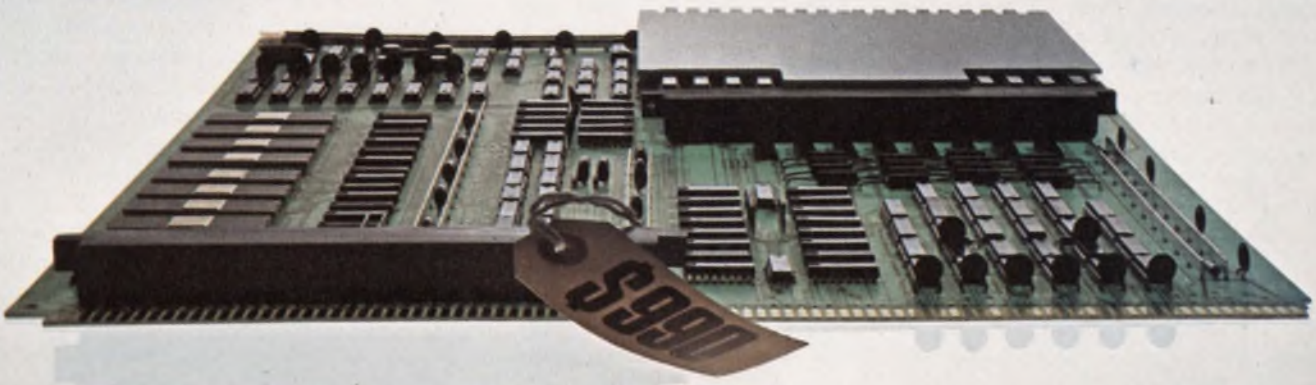

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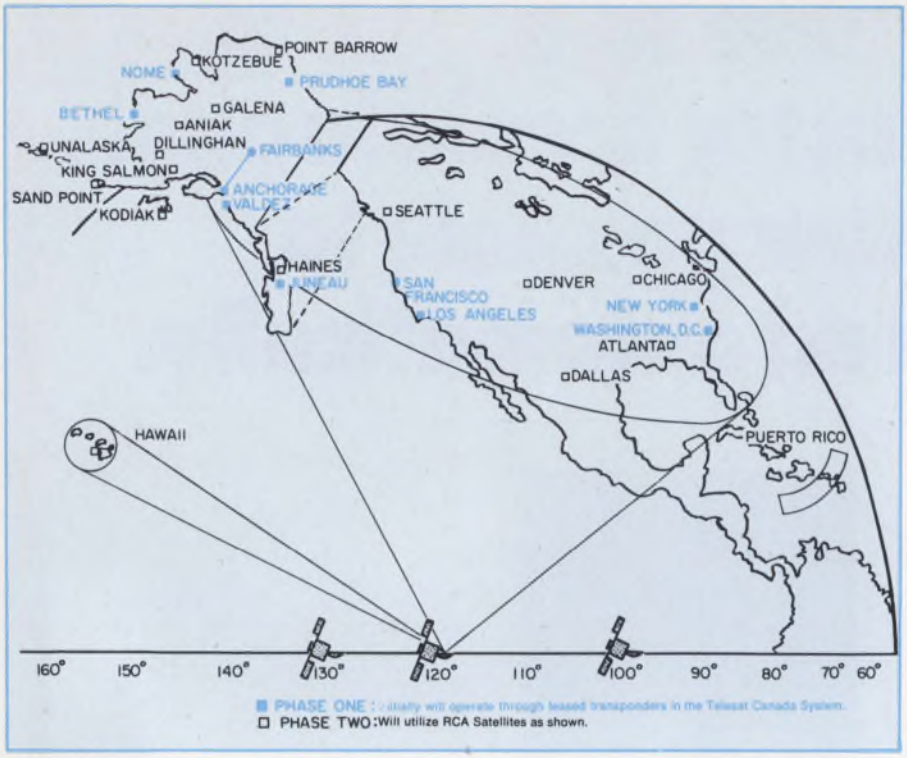

RCA Globcom now leases channels from Telesat Canada's Anik II satellite. With Phase II, Globcom will use its own 24-channel stations with a number of new earth stations, as shown.

sent by mail. And the Federal Government will get data around the country faster and cheaper than it now does.

Cable television will get a boost from these commercially owned networks, especially with the aid of single-channel-per-carrier devices—equipment that enables a ground station to receive a channel addressed specifically to it.

All this has been slow in coming because the Federal Communications Commission has moved with caution, big companies have jockied around with first one joint-venture partner and then another, the potential market has been hard to pin down, and powerful pressure groups have been at work. One big potential customer the carriers had counted on for a long time slipped right through their fingers—the television networks.

"TV was interested until AT&T cut the land-line rates so drastically they cooled off," one carrier representative says.

Meanwhile designers didn't know what to do. Some companies thought a 124-channel satellite would be about right.

What finally went up was Western Union's 12-channel Westar, built by Hughes Aircraft and almost identical to the Canadian Anik II, which also has 12 channels and also was built by Hughes.

CML's design is not final yet, but it will probably operate at 12 and 14 GHz, instead of the 4 and 6 being used by the other stations. And it will use "between four and 12 wide transponders—transponders 105 MHz wide rather than the 36 MHz width being used by the others," a spokesman says.

RCA's Globcom is going a step beyond its competitors. Its satellites, now being built by the RCA Astro-Electronics Div., Princeton, N.J., will each have 24 channels. It will weigh 2000 pounds, light enough to be lifted into orbit by the relatively inexpensive Thor-Delta 3914 rocket.

Comsat General's satellite being built for AT&T and GTE will also provide 24 channels but will weigh 3700 pounds and will be boosted into orbit by the more expensive Centaur rocket.

What today's network is like

Westar, like all domestic communications satellites in orbit or planned for orbit, is synchronous, hanging over a fixed position on the earth. Each transponder is capable of relaying to any of its five earth stations data at 50 megabits per second, one color television signal with program audio or 1200 one-way voice channels.

The spacecraft is spin-stabilized. Electrical power is supplied by approximately 20,500 solar cells, which cover the drum-shaped spinning body. Approximately 200 W of prime power are needed for proper operation of all its communications systems, and this should still be available after seven years of operation.

The heart of the system is a communications repeater, which consists of 12 independent, fixed-gain amplifiers, each with a bandwidth of 36 MHz. Common to all transponders is a wideband receiver that establishes the system noise temperature, translates 6-GHz receiver carriers to 4 GHz for down transmission and amplifies the 4-GHz carriers to an intermediate power level prior to channeling the transmission.

Two multiplexers, each incorporating six waveguide filters, allot received signals to odd and even transponders. High-efficiency TWT amplifiers boost the signals.

The Westar satellite antenna is a lightweight, five-foot-diameter parabolic reflector skeleton with supporting ribs fabricated of an aluminum honeycomb graphite-fiber composite. A gold-plated, metallic-knit material covers the parabolic skeleton.

The antenna feed consists of four horns, common to both transmit and receive, and of separate feed-drive networks for incoming and outgoing signals. Transmit signals are polarized parallel to the satellite spin axis and receive signals perpendicular to it.

Each of the five earth stations has a single 50-foot-diameter antenna pointed at the prime traffic-carrying satellite. A second 50-foot antenna will be installed at all earth stations during the first quarter of 1975 to provide access to the second satellite.

The earth stations will be equipped with either analog or digital multiplex, as required. They initially will access five transponders, through appropriate transmitters and receivers to provide a network for voice and data traffic.

RCA's 24-transponder system,

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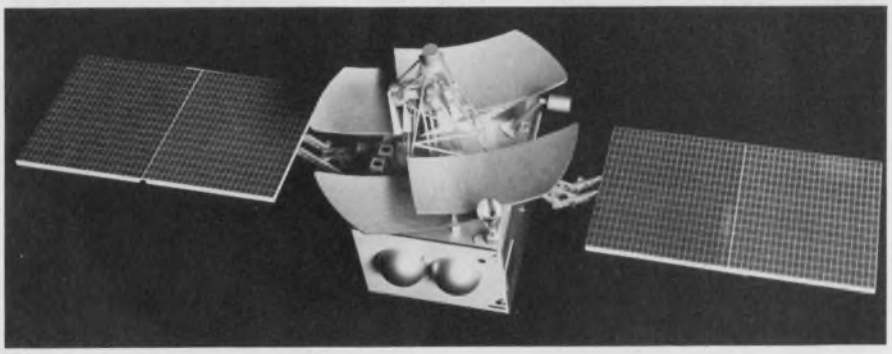


A new generation of domestic communications satellites will emerge with RCA Globcom's 24-channel satellite, scheduled to go up in early 1976.

still under development, will incorporate three features not found in the 12-channel domestic communication satellites:

1. Three-axis attitude control, which allows extra weight in the communications payload and power margins over current dual-spin satellites.

2. Cross-polarized signals to enable frequency reuse.

3. Graphite-fiber, epoxy-composite material for each of 24 input and output filters. These are considerably lighter than the invar filters normally used.

"Three-axis stability was not formally requested in Globcom's performance requirements," says C. R. Hume, manager of the RCA Satcom satellite program in Princeton. "It just turned out to be the best solution. It provides more power and enables us to operate all 24 transponders at once. You don't get the power out of a spinner that you do out of a three-axis craft, whose panels are pointed toward the sun all the time."

Cross-polarization has allowed RCA to get twice the amount of channels from the same frequency band, Hume says. "What we've done," he explains, "is arrange the antenna reflector so that one paraboloid overlaps the other."

The 500-MHz band is divided into 12 channels, spaced 40 MHz apart and polarized. A second group of 12 interstitial channels is cross-polarized with respect to the first group.

"If you feed one reflector from a horn with rf that is polarized in one direction, the wires will reflect those waves," Hume notes. "If, however, you also illuminate it with a signal that is polarized in the other direction, the wires will not reflect that polarization; the signal passes through because the material is rf transparent. But you're getting reflection from both antennas, one from the back and one from the front."

Significant weight reduction was achieved by switching from invar to graphite-fiber, epoxy-composite filters as the basic material for waveguides. The material consists of layers of graphite fibers bonded with interleaved layers of cured epoxy resin. This factor, coupled with constraints associated with the mechanics of fiber application to the waveguide cross-section, results in a waveguide laminate design that provides a coefficient of thermal expansion similar to that of invar along the length of the waveguide and across the waveguide width. The thickness of the material used in the waveguide, however, has a significantly different expansion characteristic.

RCA considered going even further in reducing the weight of the filters, by examining an elliptical design. "But there are still electrical design problems not solved in such a configuration," Hume says. "There are more couplings between the sections than there are using the Chebyshev approach."

RCA's satellites are also designed for operation in the 4 and 6 GHz bands—4 GHz down and 6 GHz up.

Looking to the future

RCA considered going to the relatively unused 14-GHz frequency rather than the much-used 4 and 6-GHz band, which is the standard frequency for common-carrier microwave links. Using 4 and 6 GHz means building earth stations far enough outside of a city to avoid interference with the normal microwave communications. And this, in turn, means building costly communications from the earth station to the city.

"The 14-GHz band wouldn't have interfered with anything in a city and could have been brought right into town," Hume says. "But the cost of putting 14-GHz equipment in the satellite outweighed all these advantages and 4/6 GHz equipment was used.

"Eventually we'll probably go to 40 GHz, using a completely digital mode. But technologically, 40 GHz isn't quite here yet."

AT&T is going to experiment with 32 GHz in the satellite that Comsat General is building for it.

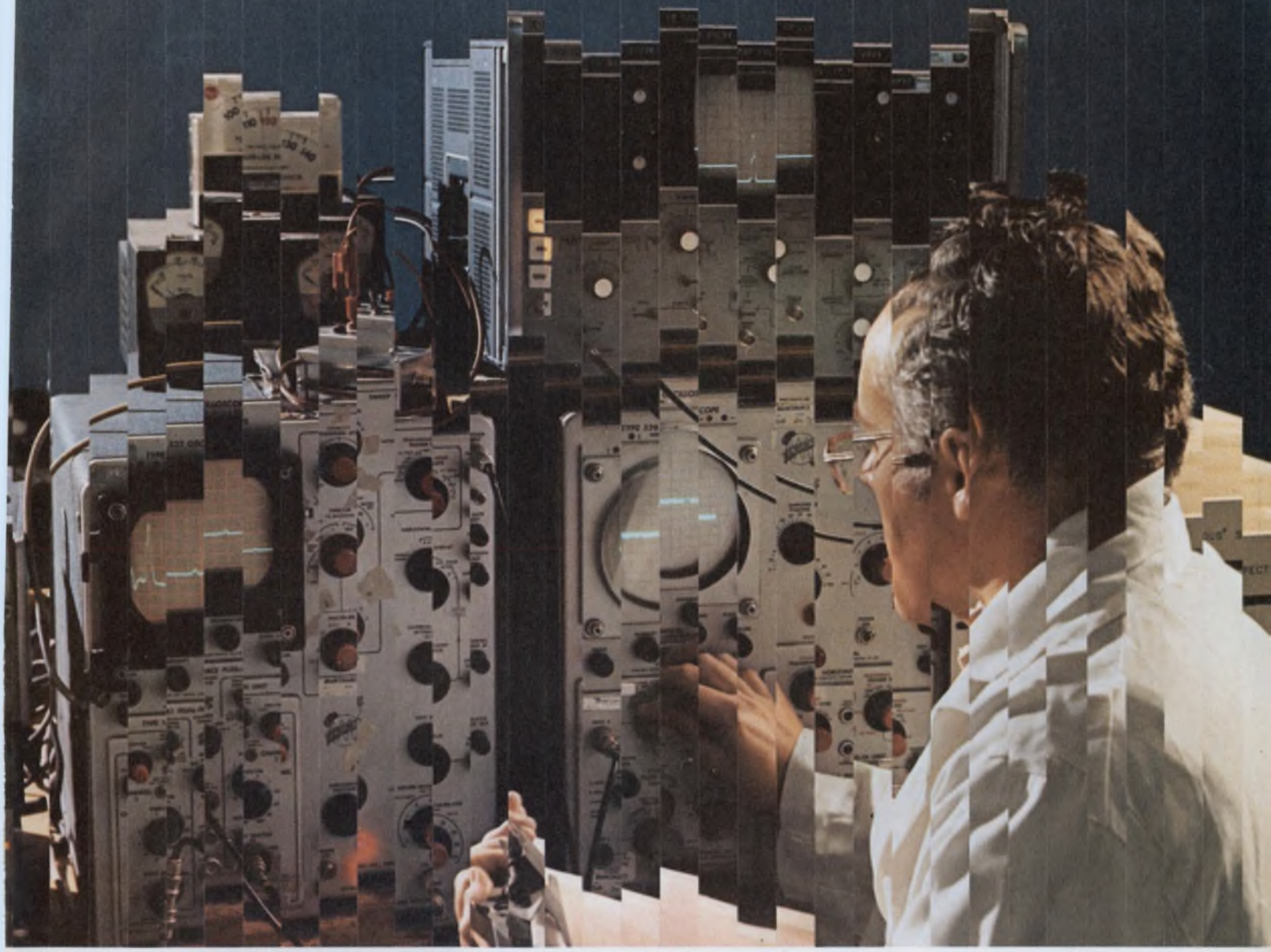
"Advanced technology is used throughout the design where it pays to do so," Hume says. "ICs and CMOS are common. There may be some LSI, but no significant amount. LSI doesn't really pay off in a package this small."

"We're using a 98-foot antenna now because we happen to have one," Hume says. "But generally speaking, for four or five circuits, you need a 15-foot antenna. When you have 50 or more circuits, a 33-foot antenna is useful. And for thousands of circuits, you need a 98-footer."

Hume adds: "With FCC approval we propose to use 10-foot antennas in places like Alaska, where they have to be taken in by helicopter."

The big innovation in ground networks is the single-channel-per-carrier technique, which is incorporated in earth stations being built by the General Electric Space Div. in Valley Forge, Pa. The stations are equipped with a Demand Assigned Multiple-Access capability, a GE spokesman explains, which permits any incoming trunk at any location to be connected to any other trunk. The transmission link consists of a pair of simplex satellite circuits allocated from the pool of circuits. The selection and allocation of these circuits is managed by a system routing center, where the satellite transponders are divided into multiple simplex channels. Thus the system is capable of communicating with multiple satellites as well as multiple transponders within a satellite. ■■

Still fighting snap, crackle and pop?



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INFORMATION RETRIEVAL NUMBER 20

Electrochromic display offers challenge to liquid crystals

The strong lead held by liquid crystals in low-power display applications may soon be challenged by a new device known as the electrochromic display.

In a presentation at the recent Electronic Components Conference in Washington, D.C., Satyen K. Deb, director of research for the Optel Corp., Princeton, N.J., noted that like the liquid crystal, the electrochromic display is passive—doesn't emit light—and can be used either in a transmissive or reflective mode. Although still in the laboratory, the device has several advantages that make it more attractive than liquid crystals. These include data-storage capability, wide viewing angle and a wider temperature range of operation.

In explaining what an electrochromic display is, Deb says that it is made from a material whose light-absorption properties are changed by an externally applied electric field. Ordinarily, he continues, electrochromic materials do not absorb light in the visible range of the spectrum; so they are completely transparent. But when a moderate electric field is applied, the material develops an absorption band in the visible spectrum and takes on a color, Deb reports.

This color change remains even after the electric field is removed and lasts from minutes to months; hence the memory capability of the display. The color change can be reversed and the display returned to its original state when the polarity of the applied electric field is simply reversed.

Fabrication is simple

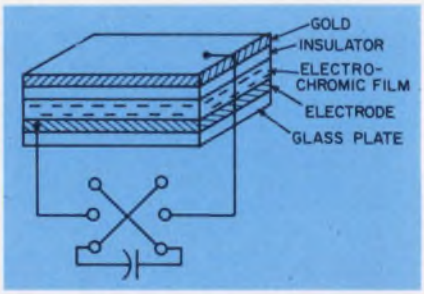
As with liquid-crystal displays, the fabrication of electrochromic devices is relatively simple. A thin film of electrochromic material—such as tungsten trioxide—is evaporated onto a transparent, conducting glass substrate. The film, which ranges in thickness from 0.3 to 1 μ, can be deposited either by sputtering or thermal evaporation, Deb says. A second layer of insulating material is then deposited over the oxide layer. The sandwich like structure is completed by the third layer—a transparent gold electrode.

When a dc voltage is applied to this structure so the electrode adjacent to the electrochromic layer is made negative, electron injection occurs, and the material turns deep blue. When the polarity of the voltage is reversed, no electron injection is possible. This happens because an electron-blocking layer is present near the second electrode, and the injected electrons are extracted back to the newly formed anode.

Since this display is absorptive, it does not have the disadvantage of a narrow viewing angle, like liquid crystals.

The electrochromic display also has a clearly defined threshold voltage that determines the point at which coloration will occur. The existence of this threshold makes it easy to matrix—address the display. The threshold voltage is a function of the electrochromic ma-

(continued on page 47)



The electrochromic display is a solid-state passive display. When the lower electrode is negative, the electrochromic film turns deep blue. Reversing the polarity makes it clear again.

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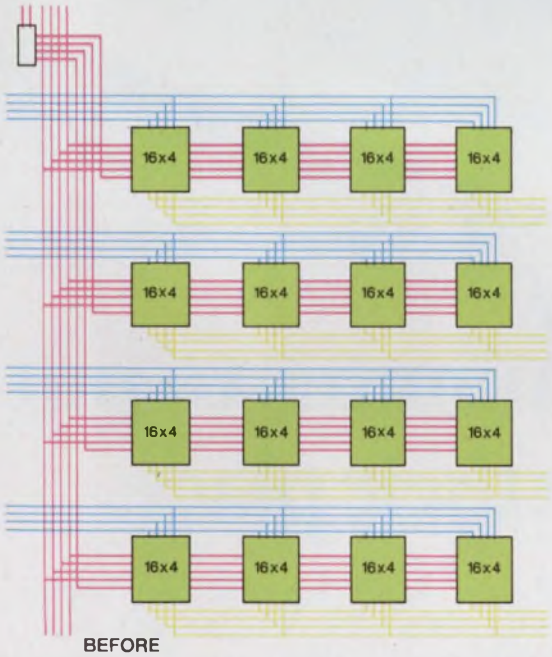

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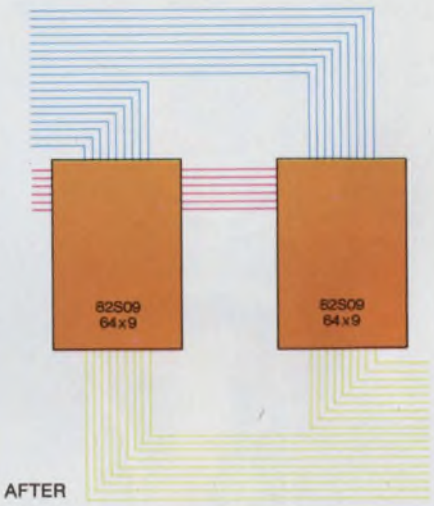

AFTER

		"Before"	"After"
Parts Cost*	Decoder 8225/7489	$ 2.80 96.00 $98.80	$ 0.00 85.20 $85.20
Board Space		1.5	1.0
Access Time (1)	Decoder 8225/7489	20ns 50ns 70ns	0 45ns 45ns
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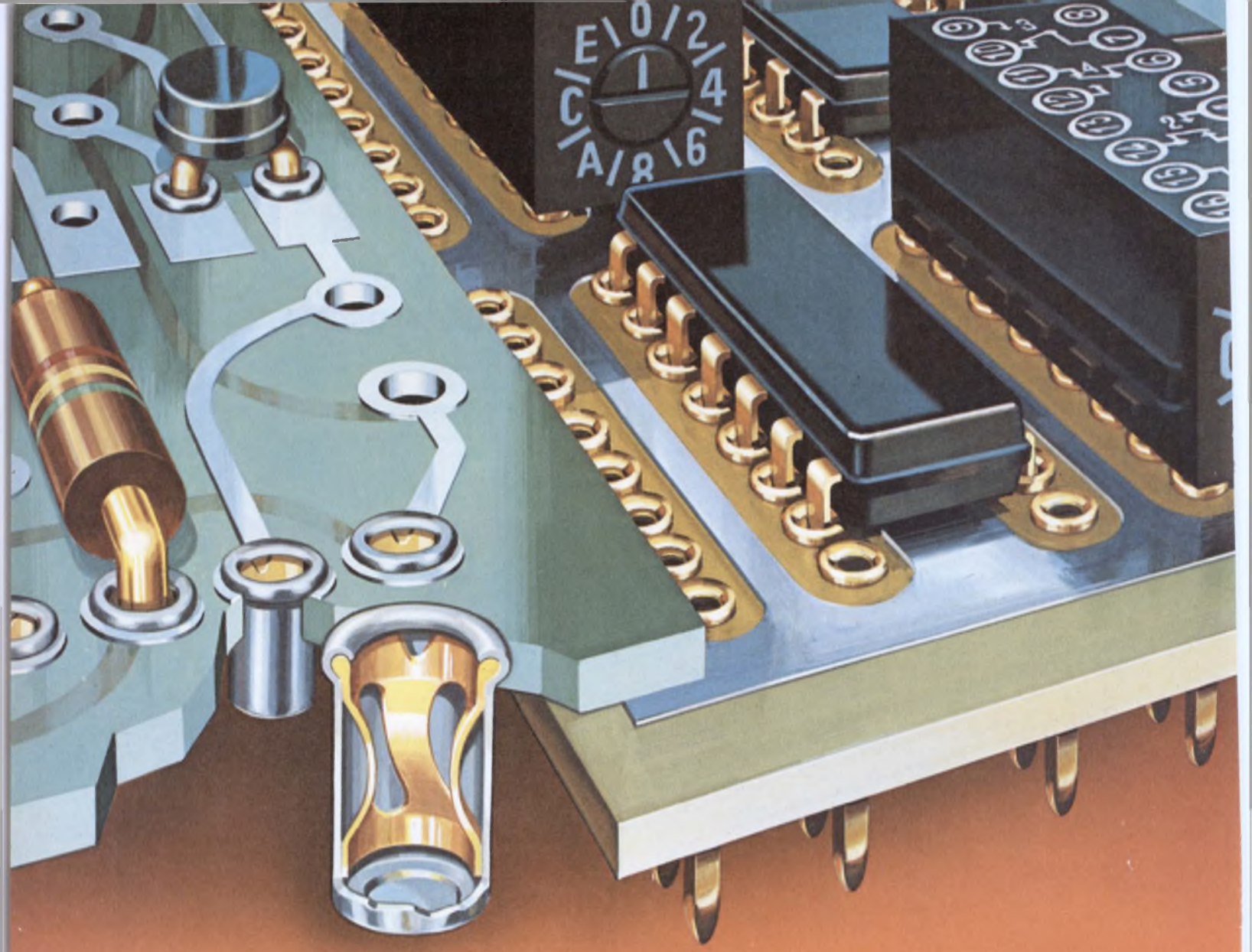

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(continued from page 44)

terial used, the thickness of the electrochromic layer, the thickness of the insulating layer and the materials from which the electrodes are constructed.

The response time of the display varies over a wide range depending on the fabrication, the materials and the mode of operation. Because of the relatively high charge density required for a high-contrast display, the writing speed is relatively low (200 ms).

They consume less power

Electrochromic displays look so good that, in an informal evening panel session, even Robert Young, a senior scientist with American Microsystems in Sunnyvale, Calif. (and a proponent of liquid-crystal technology) admitted that the new display could outshine liquid crystals in some ways. Specifically, Young noted that because of its memory capability, the electrochromic display could consume less power than a liquid crystal one. Explaining further, he noted that while higher peak power is needed to operate the device, this power is only needed to change information. No power is required to retain the information in memory. Thus the average power consumed could be lower. Another advantage, Young admits, is that the electrochromic device described by Deb is a solid-state unit, and has a broader range of operating temperatures than liquid crystals.

Electrochromic displays do have some problems, however. They are not as fast as liquid crystals, says Young. And because they require an erase signal, circuits will have to be redesigned to use them.

James H. Becker, principal scientist for Xerox Information Systems, Dallas, Texas, also sees some problems with electrochromic displays. The main one is that the displays operate in a current instead of a field mode. The current-mode operation can result in unwanted and uncontrollable space charge in the device. The space charge could move around and disrupt the operation of the display. Another possible problem, notes Becker, is that since evaporation is used to fabricate the device, its size is limited to that of a CRT.

Despite the disadvantages, the consensus of the engineers present was that electrochromic displays could become very important. Whether they do or not, however, depends on how many companies get involved. According to Becker, only a few companies have publicly acknowledged that they are working on these displays. If they are to become commercially successful, a much more concerted effort is needed, he says. ■■

COMPARISON OF SEVERAL TYPES OF DISPLAYS

	Plasma Discharge	LED	Liquid Crystals		Electrochromics	
			DS	FE	Inorganic	Organic
Display	Active	Active	Passive	Passive	Passive	Passive
State	Gas	Solid	Liquid	Liquid	Sol/Liq	Liquid
Voltage (Volts)	200-300	1.5-5	15-20	3-8	0.25-20	.2-1.5
Current/cm^2 or Charge	0.1 mA	10-100 mA	10 mA	1.5 mA	2-20 mC	~2 mC
Response Time	10 μSec	0.1 μSec.	10-100 mSec	200 mSec	200 mSec	20 mSec
Threshold	Yes	Yes	No	Yes	Yes	Yes
Storage	No	No	No	No	Yes	Yes
High Ambient Light	Poor	Poor	Good	Good	Good	Good
Directionality	None	None	Yes	Yes	None	None

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Low-cost, standard MIC units are within designer's reach

Two approaches to the solution of a pressing problem in the microwave industry—the lack of a low-cost standard microstrip integrated-circuit (MIC) package—will be discussed at this month's International Microwave Symposium at the Georgia Institute of Technology in Atlanta. Both of the new packages are reported ready for production.

Present custom versions of MIC packages are expensive, and this is limiting their use.

Bendix offers a package

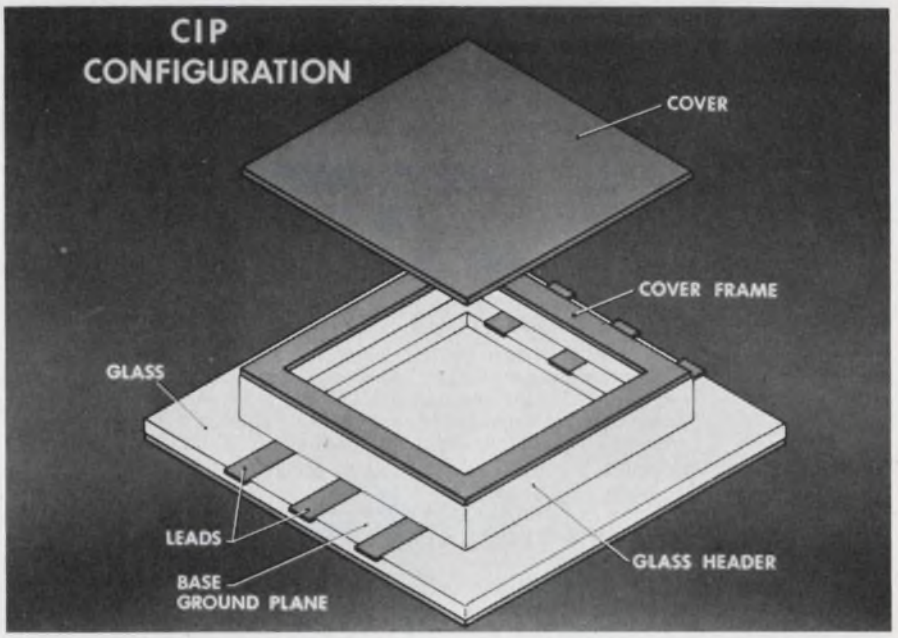
One new approach to a standard MIC package will be described by Dean Nelson, an engineer with the Bendix Electrical Components Div., Sidney, N.Y., in a paper on "Microwave Planar Packages." The principal advantage of the Bendix approach, called a Controlled Impedance Package, are reductions in space, weight and cost, according to Nelson.

The package, he points out, is square (See figure). It has a flat, glass base, with the leads fabricated on the base. The sides of the package are of glass, and a metal cover is hermetically sealed on top of the sides.

The MIC substrate carrying the microwave circuitry is set inside the glass housing, and the substrate's microstrip leads are connected to those of the package.

The Bendix package costs less, he says, than buying a custom-machined box and putting a number of coaxial connectors on it. In quantities of 1000, the package costs about $11. This includes the tooling costs, Nelson says, pointing out that for higher production runs, the cost drops considerably.

"Our package uses no coaxial connectors or coaxial feed lines, which means that the total package can be made much smaller and lighter," the Bendix engineer says. "Instead, based upon microwave stripline theory, we have developed a package in which leads coming



Circuit connections to the Bendix microwave IC packages are made by means of striplines. No coax connectors are used. The Controlled Impedance Package is mounted on a special mother board prepared for this system.

◄ INFORMATION RETRIEVAL NUMBER 24

out of the package are of very tightly controlled dimensions and spacing. And the dielectric material we use between the leads further aids in controlling the feedline impedance.

"Because of this particular design, you can couple directly from the feed line to the circuitry inside the package without the need for coaxial connectors.

Nelson points out that the excellent impedance matching provided by the package minimizes distortion of microwave pulses.

The package is supplied as a basic unit without internal circuitry. The MIC circuitry is provided by the purchaser.

"Our package is developed around MIL-Standard 883," Nelson says, "and is hermetically sealed. It meets the maximum leakage requirements of 1×10^{-8} cm^3/s."

Packages stamped out

A second approach to a standard MIC package—a hermetically sealed MIC formed by impact extrusion—is a high-production, low-cost process, according to two representatives of Microwave Associates, Burlington, Mass.

The two—John Miley, engineering group leader, and Kachas Derdiarian, manager of mechanical engineering—will tell the symposium of the company's approach in a session on "The Real World of MIC Packaging."

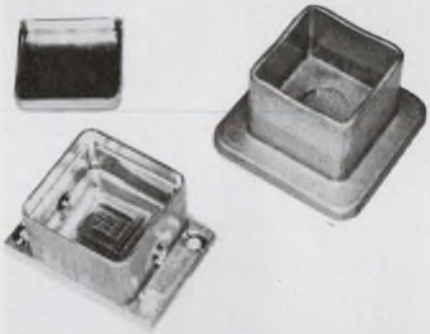
"The government is looking for some way to mass-produce a standard, low-cost MIC box that will meet environmental specs and provide a hermetic or vacuum seal—similar to MIL-Standard 883, which is the monolithic-chip military standard," Miley notes.

"Our package, developed under a production-engineering-measures contract for the Army Electronics Command in Ft. Monmouth, N.J., can be punched out in large quantities. We compared housings for a 1-by-2-in. ceramic MIC substrate, and in quantities of about 1000—which includes tooling costs. Our package runs about $11.50, while the custom-machined version is about $29.

"For production in the many thousands, we see the cost, depending on package size, going as low as $1.50 to $3.

Miley says the production process is cold-flow. A slug of aluminum with the same surface area as the final package is used. The thickness of the slug depends upon the required side-wall thickness. Under very high pressure, the aluminum cold-flows to final dimensions.

Some machining has to be done, Miley notes. The piece comes out of the press with a mounting flange on all four sides. The inside mounting area must be machined, because the MIC ceramic circuit



The impact-extruded case and lid provide a hermetically sealed microstrip integrated circuit package.

requires a very flat surface. Also, holes for mounting and for coaxial connectors must be drilled. Special 3-mm coaxial connectors were developed, the engineering leader points out, to ease repair of the MIC.

The lid of the package is coined and drawn, Miley says. After the ceramic MIC and connectors have been assembled, the cover is welded onto the package. The cover is designed with a lip, so it can be opened and resealed at least once for repair, and possibly twice.

While the MIC can be mounted directly to the base of the housing, provisions are also made for use of a carrier—a metal substrate on which the MIC is placed. The carrier can be removed easily to gain access for repairs. ■■

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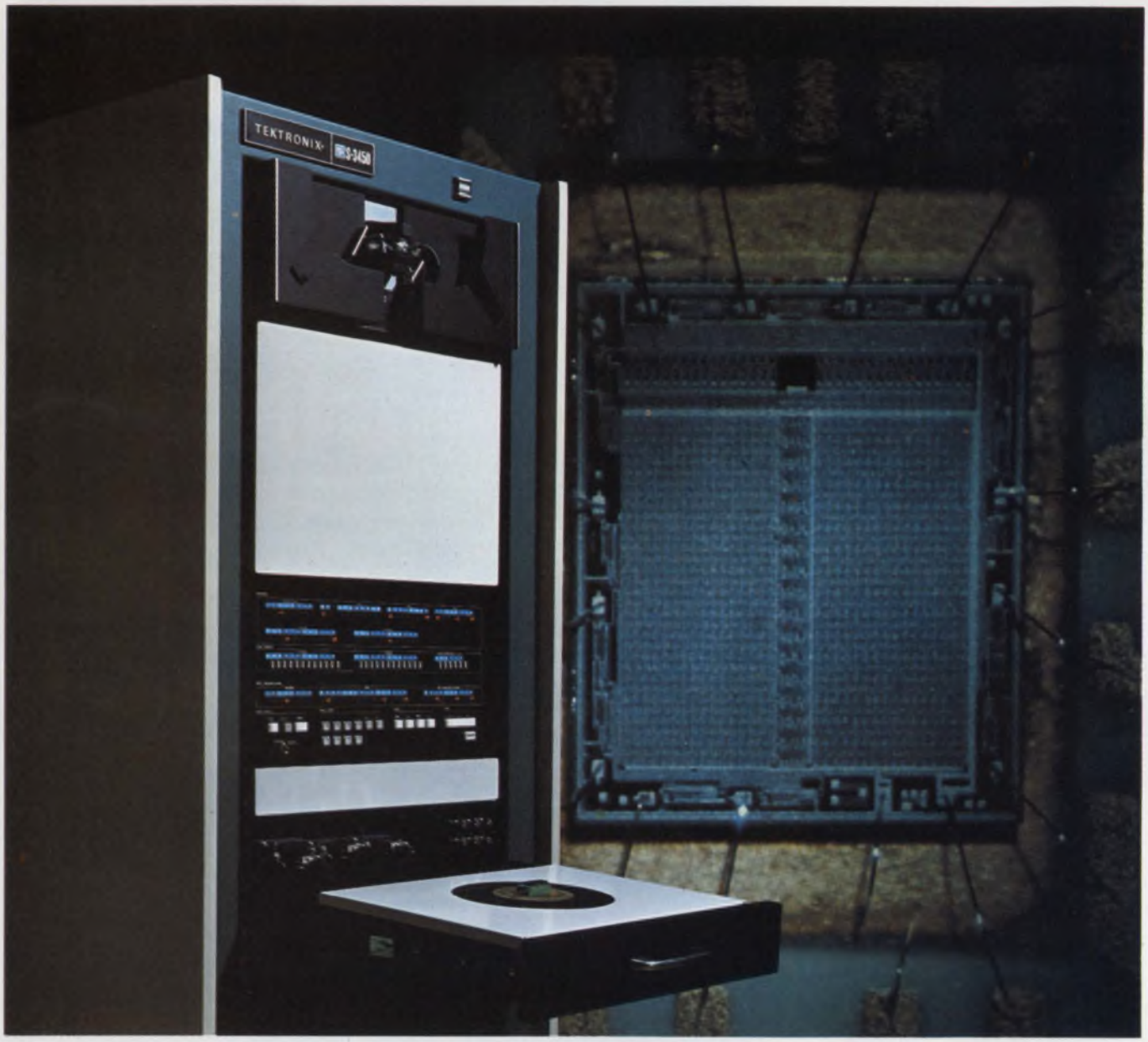

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INFORMATION RETRIEVAL NUMBER 27

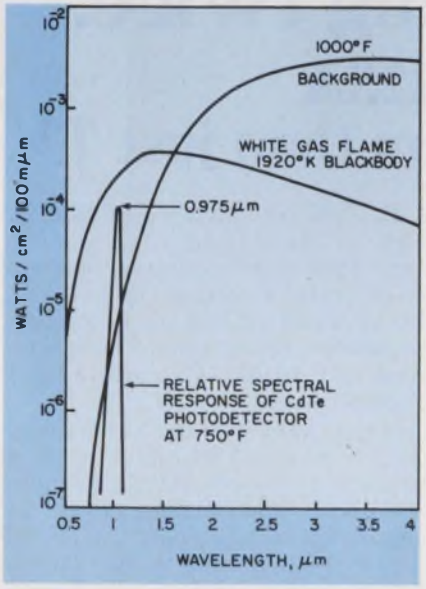
Cadmium-telluride detector has highest sensitivity yet

A cadmium-telluride photoconductive sensor has been developed that exhibits substantial sensitivity at the highest continuous operating temperature yet recorded for an IR semiconductor.

The new detector, developed by Tyco Research Laboratories, Waltham, Mass., is reported to operate continuously in a 750-F ambient and to be able to detect a six-inch-diameter flame 10 feet away against a background of 1000 F.

"Cadmium telluride is one of the few new semiconductors developed for practical uses in the last few years," says Dr. Gerald Entine, senior scientist at Tyco. He points out that the material was developed under Air Force sponsorship for a jet-engine fire detector.

"The electronic properties of cadmium telluride make it useful in devices such as infrared, nuclear-radiation and gamma-ray detectors and solar cells," Entine points out. He notes that cadmium telluride has a crystal structure similar to that of silicon and gallium arsenide, and can be produced in both P and N-type material.



The narrow spectral response of cadmium telluride at 0.975 μm makes it suitable for detecting flames against a hot, broad-band infrared background radiation.

But most important, Entine says, cadmium telluride has two characteristics needed for the high-temperature applications like the fire detector.

High temperature sensitivity

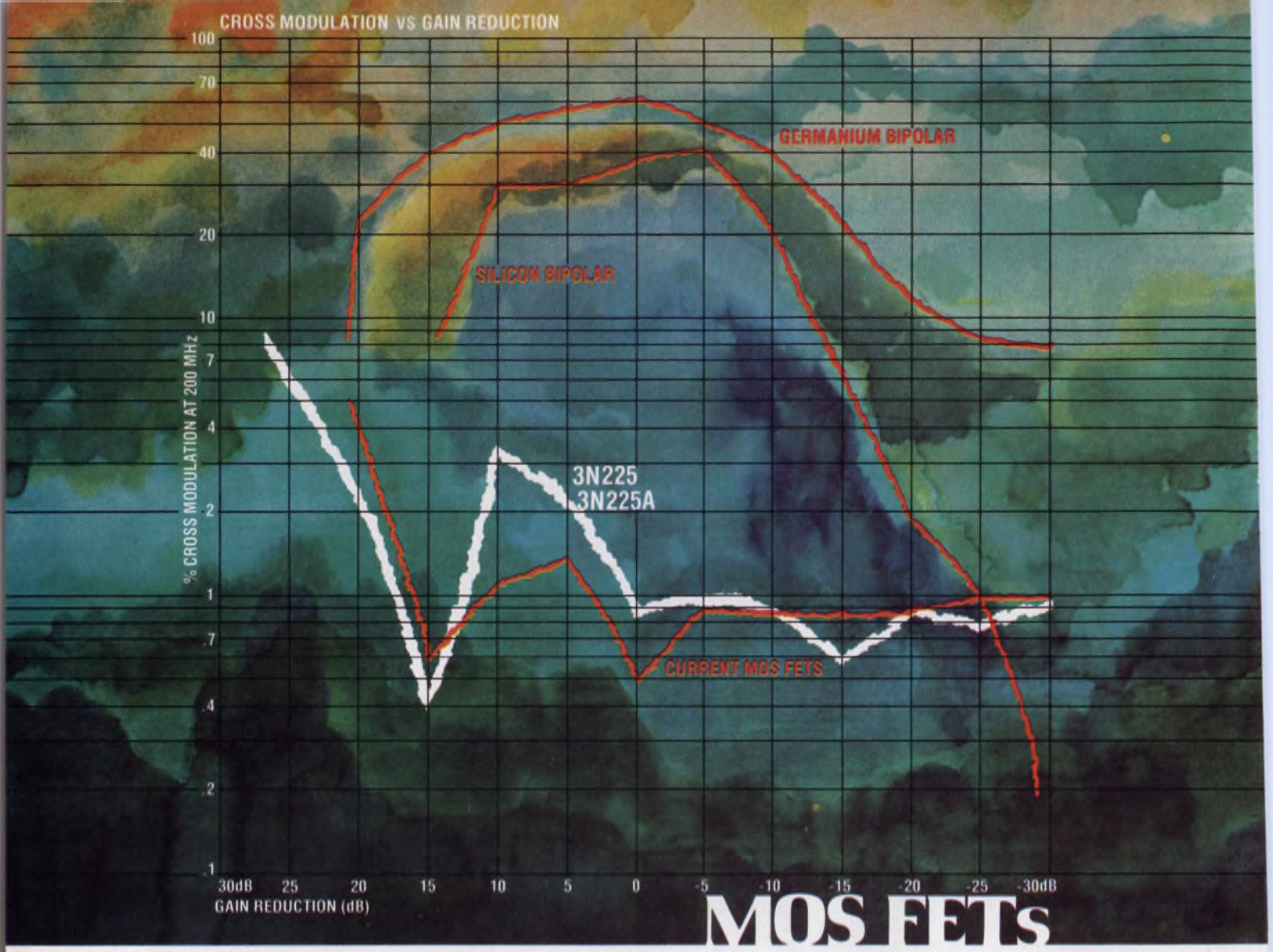
First, it has a wide energy band gap. The wider the gap, the higher the temperature at which the material retains useful sensitivity. For example, cadmium telluride has a band gap of 1.44 electron volts. A telluride sensor properly doped for this application has a room-temperature resistance of about 50 MΩ. The resistance decreases exponentially with temperature increase, typically to 500 Ω at 750 F. But the cell is still sensitive enough to detect a 50-$\mu W/cm^2$ infrared signal with a signal-to-noise ratio of better than 20 to 1.

By contrast, silicon, which has a band gap of 1.1 electron volts, has an upper useful operating temperature of about 450 F. At 750 F its sensitivity is destroyed.

Secondly, instead of having a broad response in the near-infrared, cadmium telluride has a narrow spectral peak response at 0.975 μm. This permits it to discriminate between the temperature of a burning jet-fuel flame and the broad infrared radiation of a 1000-F background.

Chlorine-doped cadmium telluride, which was developed originally for gamma-ray detectors, proved to be particularly effective for the infrared fire detector.

Each fire-detector unit contains two separate cadmium cells for redundancy. The finished assembly is comprised of two hermetically sealed sensors—in TO-5 headers with windows—secured in a hermetically sealed housing. The latter seal was included for maximum reliability. ■■



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Right now, leading TV manufacturers are designing with 3N225 and 3N225A in a big way. Especially in tuners, IF strips and UHF pre-amplifiers where linear, low noise is really an important requirement. A requirement that includes more applications than just TV, however.

Comparative Performance Data

	45-MHz		200-MHz		450-MHz		900-MHz	
	Gain	Noise Figure	Gain	Noise Figure	Gain	Noise Figure	Gain	Noise Figure
3N201 series	25	1.8	24	2.7	–	–	–	–
3N204 series	30	1.8	24	2	18	3.2	–	–
3N211 series	33	1.8	28	2.2	21	5	–	–
3N225 series	32	1.8	28	2	21	3	15	4.5

For instance 3N225 and 3N225A can be designed into CATV. Detection alarm systems. Medical electronic devices. Measuring instrumentation. Plate-wire memories. Video signal processors. And all types of mobile and fixed receivers.

Many applications that could only be realized by using vacuum tubes can now use MOS FETs like the 3N225 and 3N225A – often at significant cost savings.

For data sheet, write Texas Instruments Incorporated, P.O. Box 5012, M/S 308, Dallas, Texas 75222.

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washington report

Heather M. David
Washington Bureau

NASA seeks communications advances

The national space agency is trying to transmit more data in the same bandwidth by developing a 16-level modulation communication system that combines four levels of amplitude with four levels of phase modulation. The combination was chosen after a series of tests at Jet Propulsion Laboratory with many combinations of amplitude, frequency and phase modulation.

NASA also reports gains in antenna design. Aided by an advanced computer program, antennas have been designed to generate beam contours that can conform to prescribed, irregular boundaries of time zones or states. This will permit neighboring satellites to work well without interfering with each other.

Both efforts are part of NASA's advanced communications research program, which will continue despite the fact that the agency has retired from the business of actually producing and launching communications satellites.

A new U.S. earth-resources agency proposed

A bill to establish an Earth Resources Observation Administration has been introduced in the Senate and is being considered by the Senate Aeronautical and Space Sciences Committee. According to its principal sponsor, Sen. James Abouresk (D-S.D.), the new administration would be part of the Interior Dept. and would have primary responsibility in the Government for "turning remote sensing technology into an operational reality." The administration would be empowered to contract with NASA for the design, development and launching of future earth-resources satellites. While the present Earth Resources Satellite System (ERTS) has produced some spectacular results, Senator Abouresk says, data flows are running two months late and potential users are being discouraged from using the satellite system operationally because of the danger of termination or interruption of data.

AWACS countermeasures key to its future

The fate of the Airborne Warning and Control System (AWACS), with its huge lookdown radar designed to pick out enemy aircraft from ground clutter, will hinge on whether the Air Force can convince Congress that the radar cannot be jammed effectively. Sen. Thomas Eagleton (D-Mo.) says that a classified report by the General Accounting Office shows that the AWACS radar could be completely blacked out by inexpensive ground-based jammers. The Air Force admits that radar could be jammed, but it says this would take large numbers of jammers. The House Armed Services Committee slashed the AWACS fund request and

says it won't give full authority until the R&D program is further along and the additional electronics, recently ordered when the Pentagon decided to put AWACS in a tactical role, have been fully tested. The results of the tests, including new counter-countermeasures gear, should be available by December.

An 'agile' airborne radar to be developed

Westinghouse Electric has been selected to develop what promises to be the Defense Dept.'s most advanced airborne radar, officially named the Electronically Agile Radar. The company was one of four—which included Goodyear Aerospace, Hughes, and Raytheon—that performed advance studies to see whether a multimode, phased-array radar could be developed to combine all the various airborne radar tasks, including both air-to-air and air-to-ground functions. Westinghouse, under a $2.8-million contract, will deliver two systems by 1978 for ground and flight tests. The U.S. is not presently planning any new aircraft capable of carrying the multimode radar, although the radar could go on later models of the B-1 bomber.

U.S. to study train automation

The Office of Technology Assessment, the agency set up by Congress to provide expert advice on technical subjects, plans to examine the state of technology of automatic train controls. Its interest reportedly is being spurred by problems with the California Bay Area Rapid Transit system and other smaller systems. The office will issue a contract for a comprehensive analysis of all the basic hardware systems installed or planned for major transit systems in the U.S. But it has not yet decided who will do the study.

Capital Capsules:

The Air Force is planning advanced computer research with **an eye toward development of a radiation-hardened computer for an advanced ICBM that could one day replace the Minuteman III.** The program includes definition of an advanced computer and the development and testing of CMOS and MNOS devices. . . . The National Science Foundation is sponsoring **a study of computer science research aimed at defining what computer science is, what major research problems are under investigation and the relationship between research and application of computers to national needs.** The principal investigator, Dr. Bruce W. Arden, Chairman of Princeton University's Electrical Engineering Dept., is seeking suggestions and ideas. . . . NASA has completed **agreements with seven colleges and universities to award 20 aerospace fellowships to encourage women and members of minority groups to seek careers in engineering and certain scientific fields.** . . . The Defense Dept.'s air-to-air radar homing missile, the Hughes Brazo, **has passed its first flight test.** The missile designed to lock onto an aircraft fire-control radar, is a joint Navy-Air Force developmental effort. . . . The Environmental Protection Agency is **looking for a contractor with capability in remote-monitoring instruments and techniques** to determine how monitoring instrumentation can be used to enforce clean-air programs. . . . The Navy Regional Procurement Office, Long Beach, Calif., **plans to invite industry bids for a contract to develop an improved LED.** Use of a higher modulation bandwidth in the near-infrared spectrum allows the new diode to have increased radiance and longer life than present LEDs. . . . Aerospace Corp., acting as a prime contractor to the Law Enforcement Assistance Administration, **will subcontract for the design and fabrication of a low cost, prototype electric field-sensor system, for use with low-cost residential and small-business security systems.**

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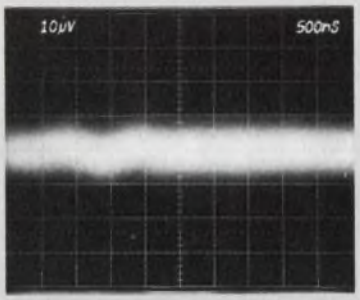
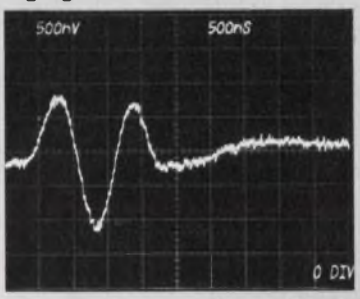


. . . is made useful by signal averaging with the DPO.



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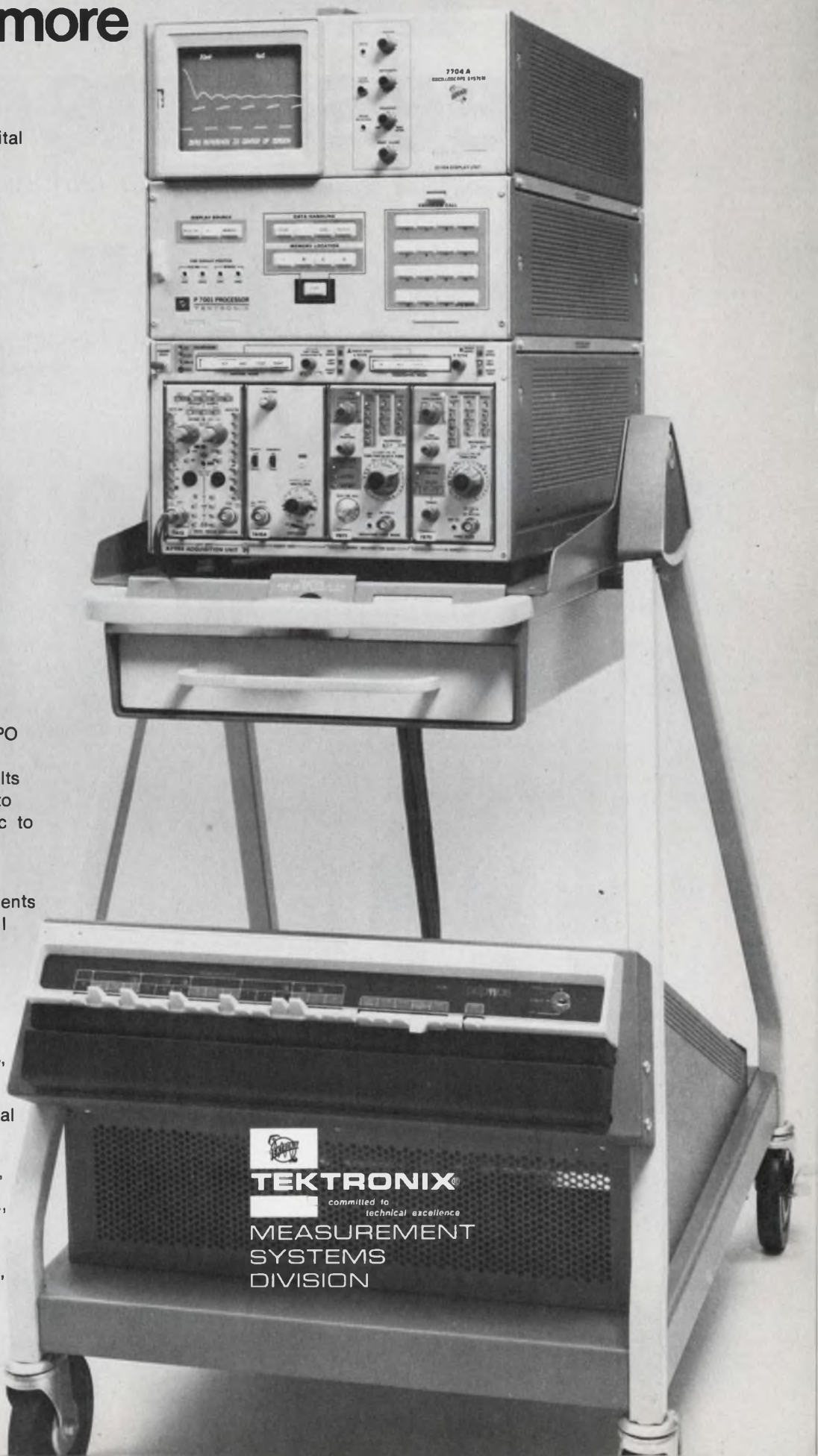
FOR DEMONSTRATION, CIRCLE 208



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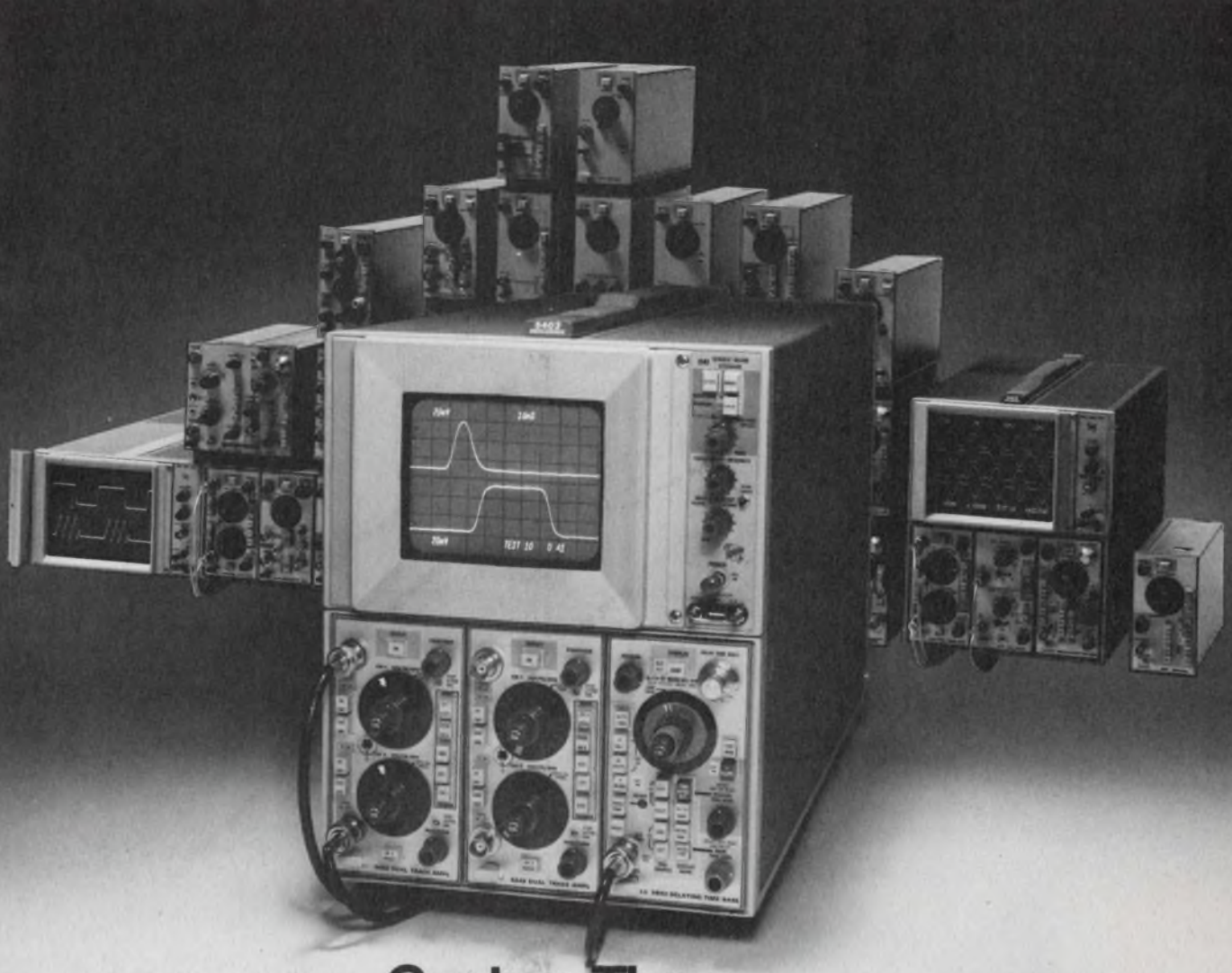

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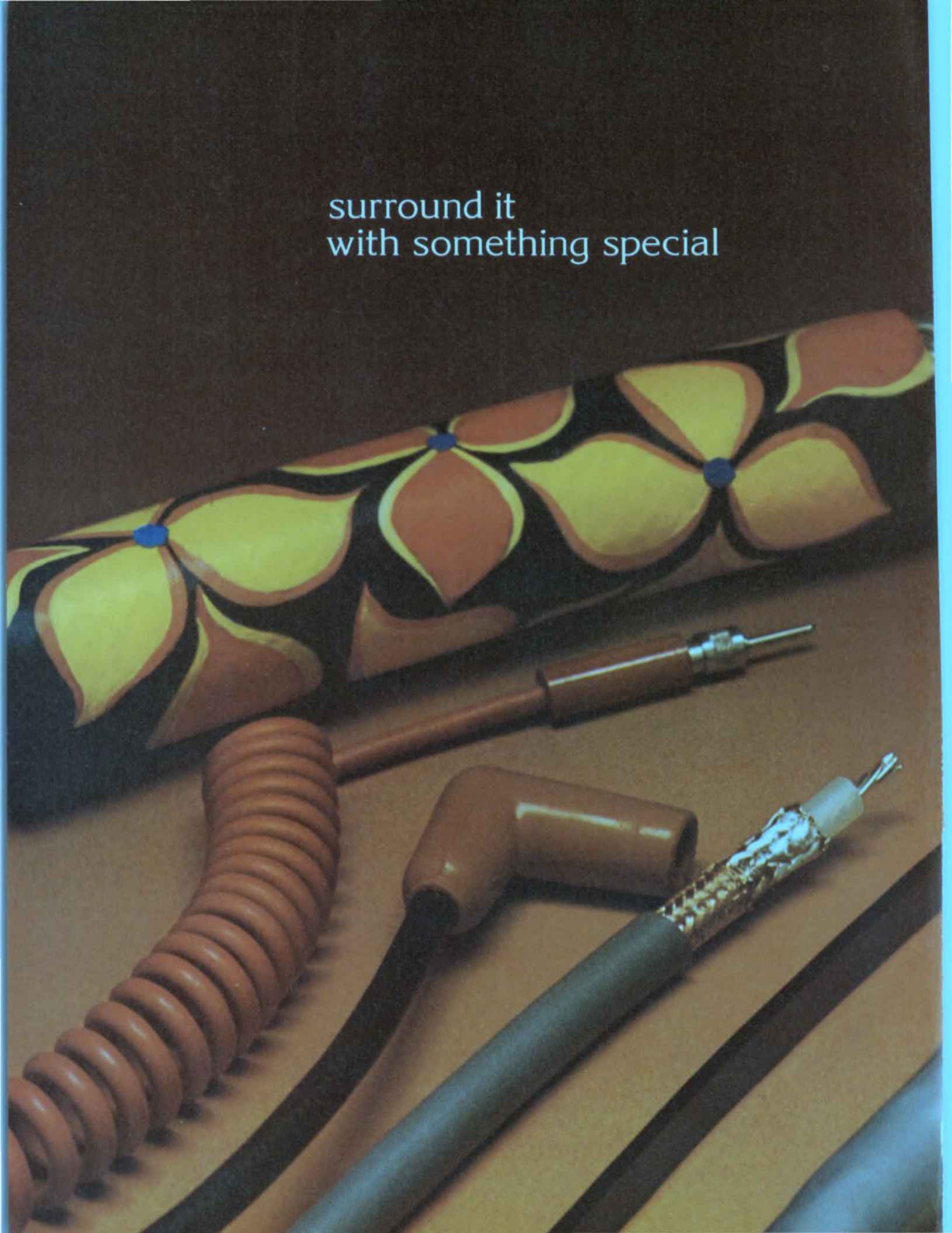
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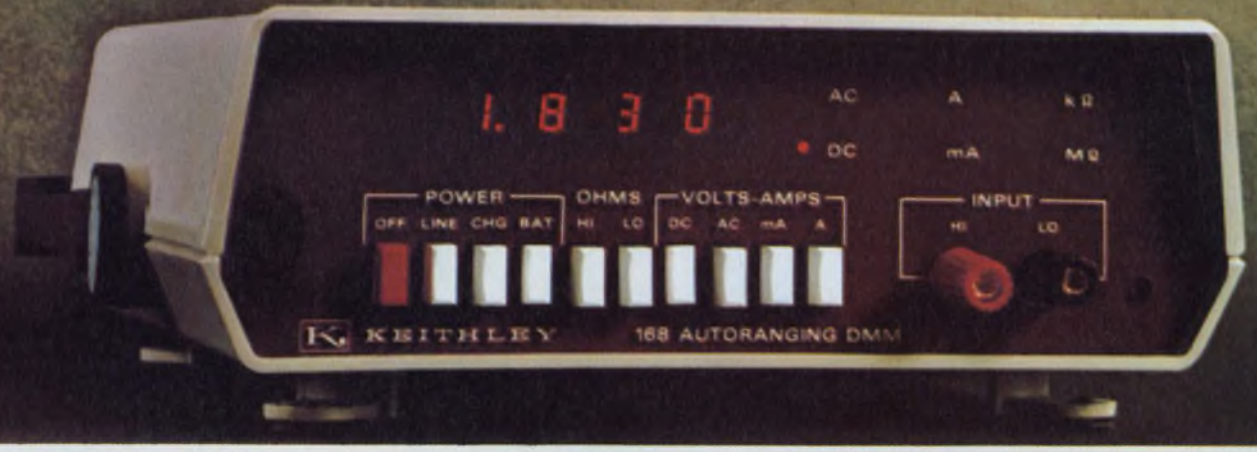

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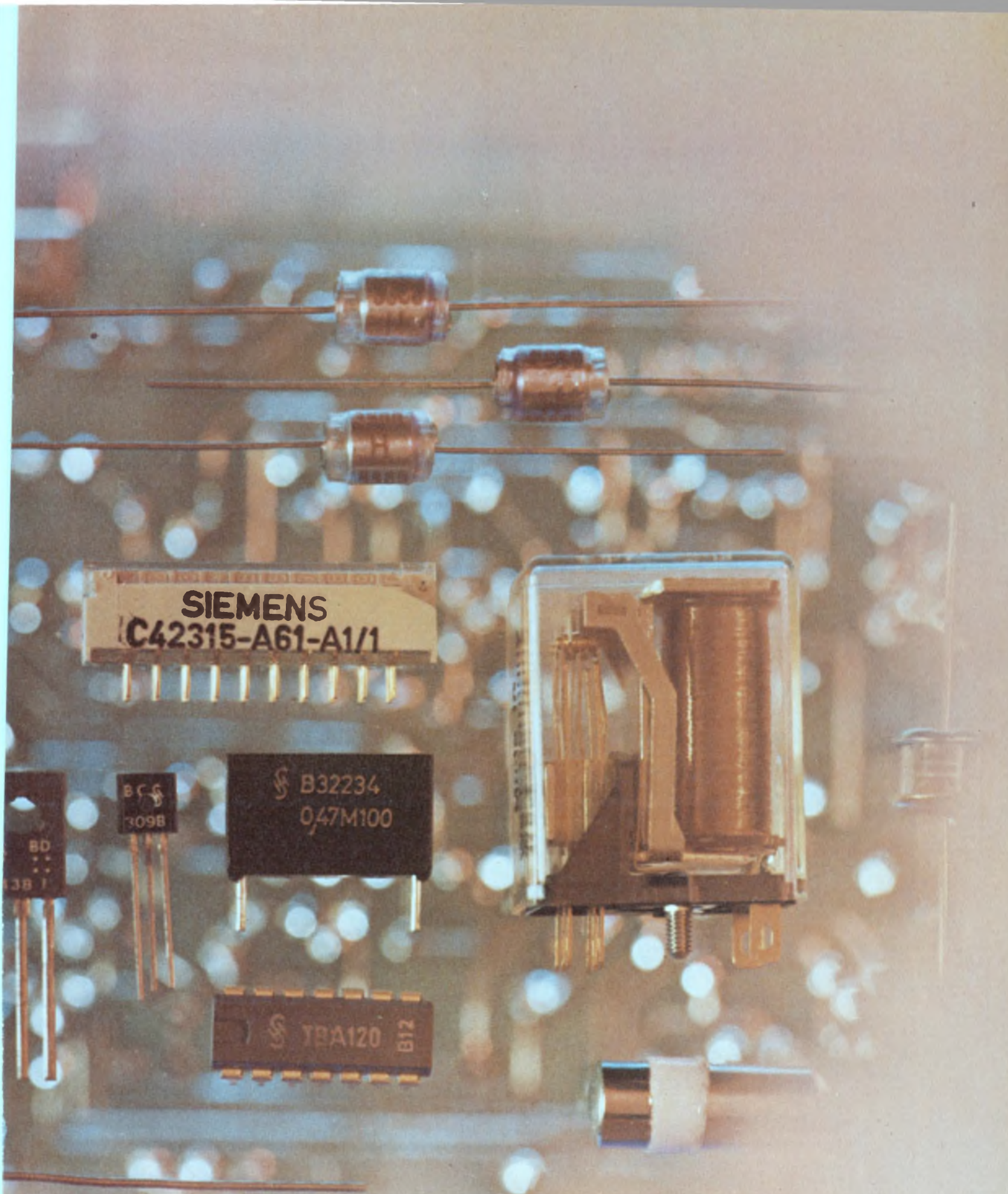

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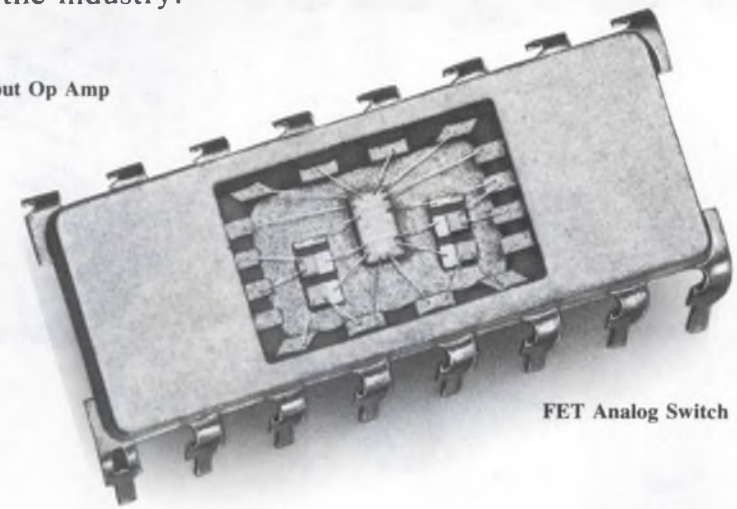

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INFORMATION RETRIEVAL NUMBER 37

editorial

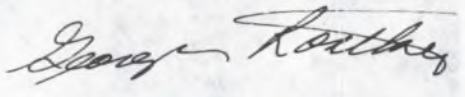
The job that couldn't be done

I don't know who wrote it, nor where. But ages ago I read a little ditty that went something like this: *The experts said it couldn't be done./ And to look at the job, who wouldn't?/ But I tried the job that couldn't be done./ And what do you know?/ It couldn't.* That seems to prove once again, that the experts are right. But they aren't always. There's a wonderful repudiation of experts in Thor Heyerdahl's *The Ra Expeditions*, published by Doubleday & Co., Garden City, N.Y., 1971. Heyerdahl wanted to prove that the ancient Egyptians could have brought their culture to South America in boats made of papyrus—yes, the stuff they made paper from. Well the experts assured him that it couldn't be done. The president of the Egyptian Papyrus Institute insisted that papyrus sinks after two weeks, even on a river. And archaeologists said that papyrus dissolves in sea water and breaks up in the waves. The experts placed papyrus reeds in a bathtub and, by golly, they sunk—proving that a papyrus boat couldn't cross the Atlantic.

But Heyerdahl wasn't smart enough to listen to the experts. With a crew of seven men in 1969 and eight men in 1970, he made two trips in papyrus boats from the Moroccan city of Safi. With the first, he almost reached, and with the second, he succeeded in reaching Barbados, off the coast of Venezuela. Each voyage covered almost 3300 miles in eight weeks.

The experts had learned than an individual papyrus reed is soft and sappy, so it will absorb water and sink. But when many reeds are roped tightly together, water won't penetrate their ends, so they'll float. Such experts, in an earlier era, might have proven that a steel ship can't float because a slab of steel sinks. As they often do, the experts performed the wrong experiment. They drew conclusions from partial evidence and incomplete experience.

Are most of us any better? How often do we reject design approaches because experts proved they can't work. How often do we assume that unexplored avenues must lead to dead ends? How many of us have the guts to say: "I know this can't work, but I'm going to try it?" The "impossible" design can be the most brilliant.



GEORGE ROSTKY
Editor-in-Chief

FOCUS on Data-acquisition equipment

Plants halted. Products ruined. Thousands of dollars lost—just because something went wrong with a data-acquisition system. It may sound incredible but it often happens. With many data-acquisition systems, a slight inaccuracy can blossom into a system shutdown.

System accuracy can never be better than the sum of its parts—and it's usually worse. Inaccuracies don't just add up. Often they are multiplied by factors like amplifier gain. Whether you build or buy a system, you need more than casual care.

Basically you have two options. And no matter which you choose, problems are certain. You can buy a complete system, where all you have to do is turn a key; or you can piece together a system from parts, and worry about matching component specs and doing the programming.

Usually a data-acquisition system will contain the following:

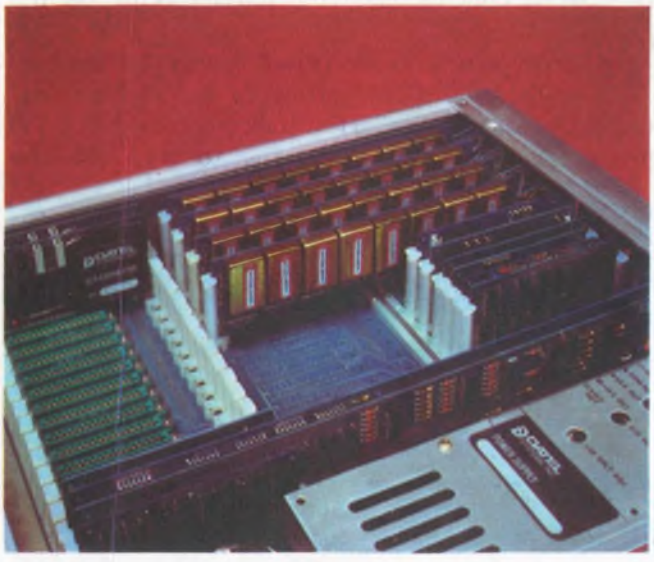
- Specialized amplifiers or other circuits to condition sensor outputs so that they can be either transmitted or converted.
- Multiplexers to combine many data signals onto one line.
- Sample-and-hold (s/h) circuits to hold analog voltages steady long enough for conversion.
- Analog-to-digital (a/d) or voltage-to-frequency (v/f) converters to convert the analog into digital form for either transmission or analysis.

Problems? Vendors have been known to exaggerate or overestimate the performance of their equipment, and this can be especially troublesome if you piece one circuit from Company A to another from Company B.

Here are some areas of potential confusion:

- System accuracy. Should individual errors be worst-case summed? Averaged? Rms'd?
- Over-all system throughput. Measurement speed depends on various settling times, conversion times and multiplexing delays.

Dave Bursky
Associate Editor



Plug-in circuit cards (left) are used in the Datel-256 data-acquisition system to perform all signal-conversion and sampling functions. This system can be expanded up to 256 channels due to its structure. Some of the front-panel options are shown above, including channel-select and manual controls.

- Noise immunity. Spikes and common-mode signals may be present on one or more of the input channels.
- Temperature stability. Voltage offsets and other errors of the individual circuits drift with temperature.
- Computer programming. Does the computer have enough memory, is it fast enough, are there enough input/output lines?
- Real system cost. This includes installation, setup, programming and maintenance.

System accuracy disappears in many ways

A data-acquisition system's accuracy depends upon many factors: signal losses during transmission, multiplexing inaccuracies, amplifier errors, s/h circuit errors, a/d converter errors and computational round-off errors. The over-all system spec should be a combination of all the possible error sources.

Errors due to transmission signal losses are easily overlooked because they occur outside the equipment. If long leads are required in a plant or lab, losses will, of course, result from line resistance, inductance, and shunt capacitance. Furthermore signals can become garbled by noise picked up from power lines, machinery or electrical equipment.

No matter what the equipment, the site at which it operates has a great deal to do with its performance. The electrical conditions of the plant or lab, power-line conditions, temperature, corrosive gases and moisture can all deteriorate system performance.

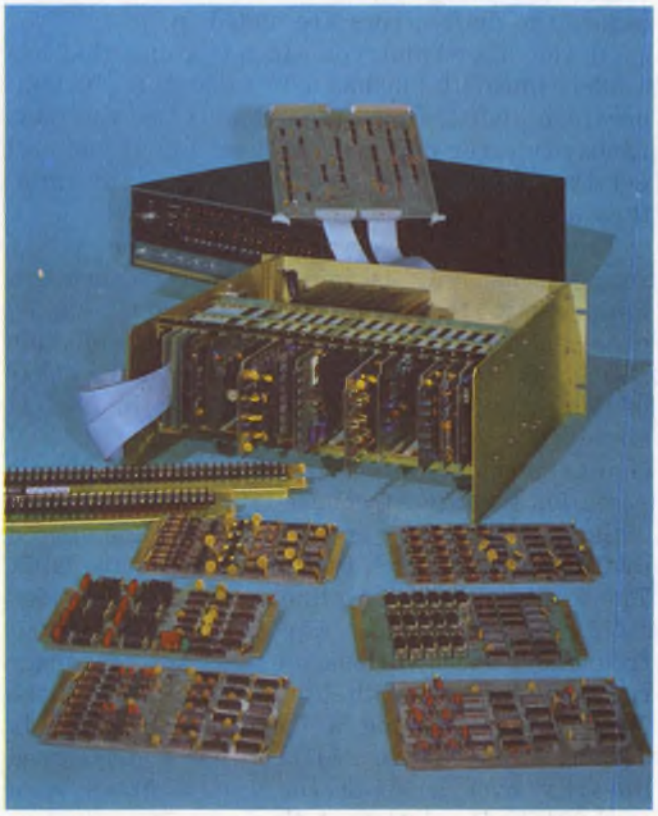
Wires scattered about in a plant or lab are apt to pick up stray noise or induced voltages if they are near power lines or heavy equipment. Even data-acquisition systems that are mounted on circuit cards in a computer mainframe have to be shielded against the heavy digital switching noise from the memory circuits and the logic.

Induced voltages in the signal lines can be filtered out if their signal spectrum differs widely from the signal to be measured. You can minimize the unwanted noise with either a low-pass, bandpass, high-pass or notch type filter. Noise generated by equipment operating from the same power line can also find its way into the system if special line filters are not used or if the unit is operated in an environment for which it wasn't designed.

Noise and voltage spikes on the signal lines pose a threat to any computer system. If the spikes are large, there's a good chance they can reach all the way into the processor and burn out logic circuits. To avoid this, various isolation techniques have been developed—optical couplers are becoming increasingly popular. System operation can also be maintained by use of floating, fully differential instrumentation amplifiers, with high common-mode rejection and filtering.

The plant layout may affect operation in strange ways. With the centralization of control rooms, the sensors, in many cases, must be placed far from the mainframe equipment. Long cable runs are then required, and increased resistance and capacitance result. In some systems this increase can slow the over-all loop response or cause reading errors. Imbalances in thermocouple wire and changes in lead lengths are not always compensated for, and this can lead to calibration and accuracy problems.

Any or all of four input channels can be displayed by the Macrodyne ERDAC III data-acquisition system. The instrument digitizes and stores incoming analog signals.



The RTP series of circuit cards and card cages, from Computer Products, covers almost any data-acquisition problem you might encounter.

If you do the signal conversion at the sensor instead of at the computer, you can save on signal conditioning circuitry—by using more converters—and reap the benefit of digital data transmission. The choice is yours—you can use an a/d or a v/f converter to transmit the signal digitally.

For slowly varying signals either an a/d or v/f converter can produce accurate results. But, as signal frequencies increase, a/d converters can't follow the signal, and converter digital outputs may have substantial errors. (For more about converters see "Focus on A/D and D/A Converters," ED No. 1, Jan. 4, 1973, p. 56.)

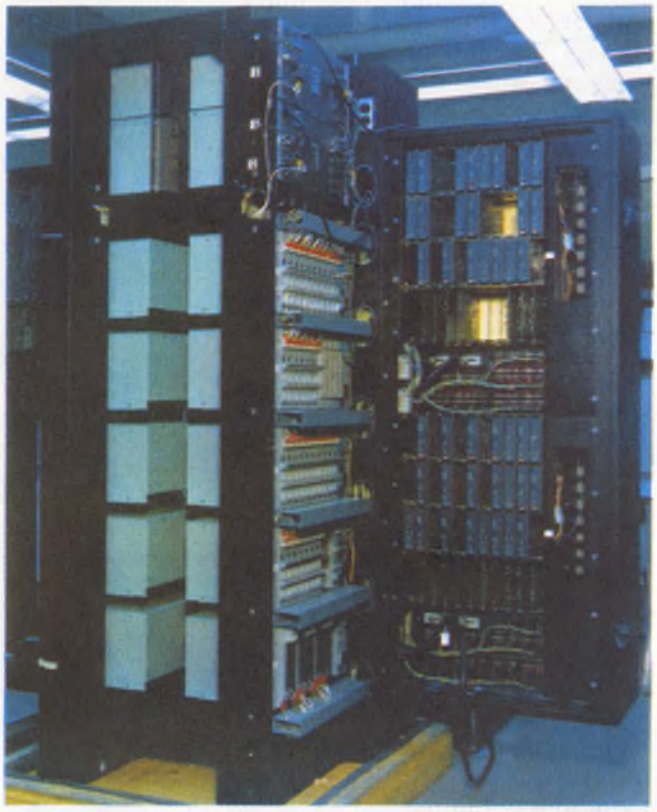
V/f converters usually respond faster than a/d's, but they introduce their own problems—linearity errors and temperature drifts. The linearity spec defines the accuracy with which the converter will change a voltage into a corresponding frequency. And the temperature coefficients tell you how much the circuit drifts with temperature.

Most manufacturers sell units that are a compromise between good linearity and temperature drift. For example, you can buy a converter that has a linearity error of 0.05% maximum, but has a temperature drift of, say, 100 to 200 parts-per-million (ppm) for every degree change in temperature. Thus, for a 10-C change the frequency might drift by as much as 2 kHz if you use a 1 MHz converter. The linearity of this converter also causes an inaccuracy of 500 Hz even before the drift errors are added in.

On the other hand, you can buy a unit that has a 0.5% linearity but has a 10 to 50 ppm/°C temperature drift. Here repeatability is the key. Linearity error may not be important if you still get the same output frequency five or ten minutes later.

Tradeoffs are everywhere—even the power supply sensitivity is important. You must examine how the units react to power-supply changes. Simple op amps have high rejection ratios, but more complex circuits can have drifts of 500 ppm/1% change in V_{cc}, or higher. If standard ±15 V supplies are used, a 0.15 V change in their output could produce a 500-Hz variation in output frequency for a v/f converter.

Several units have evolved—with a line offered by Teledyne-Philbrick typical of what's available. The Philbrick units are linear, voltage-controlled oscillators that can rapidly change output frequency over various voltage or frequency ranges. The unit with the widest range is the Model 4705, covering a frequency span of six decades from 1 Hz to 1 MHz. It has a guaranteed linearity over a six-decade input-voltage span of 0.001%. Resolution of this unit is equivalent to a 14-bit a/d converter, a stability of 44 ppm/°C and hook-up that permits unipolar or bipolar, voltage or current, inputs. Cost for the 4705 module is $125 in singles.



Large rack-mounted systems, such as these from Foxboro Corp., provide data-acquisition and control functions for large plants where safe equipment is needed.

The flow of data at either a laboratory or plant site can be controlled by the Digital Equipment PDM-70 programmable data mover. It uses simple programming.

Other modular circuits are not only making inroads, but in some cases are taking over areas such as voltage-to-frequency and frequency-to-voltage conversion. One of the newest products that can encode analog signals into digital form is the Deltaverta encoder from Hybrid Systems.

This encoder uses a form of delta-sigma modulation to produce a pulse train output that is both proportional to the input voltage and synchronous with an externally applied clock frequency. The DV-610 and DV-611 encoder and decoder modules can form a two-way data-acquisition and control system by use of time-division multiplexing. The encoding scheme is a low-cost way of acquiring analog data, with 0.01% linear-

ity and minimal signal conditioning (see "The Low-Cost Way to Send Digital Data," ED No. 2, Jan. 18, 1974, p. 68.)

At present the Deltaverta modules can accept only 0 to −10 V and deliver a TTL-compatible output. Speed is also on the low side with the optimum clock frequency for conversion about 10 kHz. If high resolution isn't necessary, these units, at $39 apiece, should prove quite useful.

Advances in a/d conversion circuitry are also taking place. Low-power circuits like CMOS are used for digital control functions within the converter. Hybrid Systems, for example, has the Model 575-12, a 12-bit, low-speed a/d converter that draws only a few milliwatts. This converter circuit has good linearity (±0.5 LSB) and is priced under $200.

Other advances are shrinking converters. Twelve-bit successive approximation converters can now fit in small, dual-inline packages. Micro Networks' MN series of DIP packaged converters are complete circuits with reference elements and amplifiers. Available in a wide variety of formats and input ranges, they are trimmed to minimize offsets and drifts.

As we've already seen, most conversion schemes work well with slowly changing inputs, but the converter outputs can't easily follow rapid voltage fluctuations.

Freeze the converter input

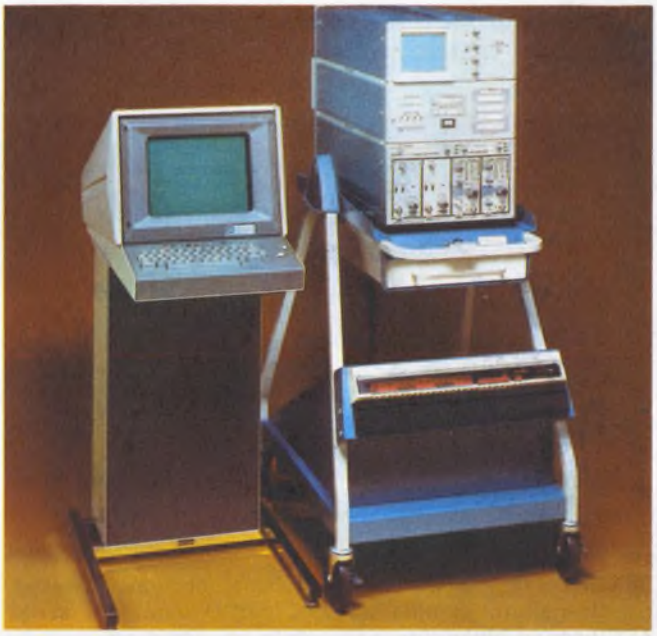
To freeze rapidly changing inputs, s/h circuits are often used in front of the a/d converter. But this doesn't completely solve the accuracy problem. The sample-and-hold circuits introduce other errors. And some of these errors aren't always mentioned on manufacturers' data sheets. A pedestal error occurs in s/h circuits each time the circuit switches from the track to the hold state. This stems from the capacitive transfer of residual charge across the turned-off switch onto the holding capacitor. The same switch signal that controls the s/h circuit causes a small voltage spike when the circuit switches to the track mode.

How long can the s/h circuit hold the captured voltage? This depends, among other things, on the dielectric absorption effects of the holding capacitor. The capacitor must be of high quality to retain a sampled voltage accurately. This is especially important in multichannel simultaneous-sampling systems, where the individual s/h circuits may not be immediately polled for data—there may be a delay of a millisecond or so. Another thing: Voltage droop, caused by input leakage currents in the sampling circuit, can also affect systems accuracy.

Does the device driven by the s/h circuit have any pump-out current? Pump-out current feeds back into the s/h circuit and produces an error voltage, or it causes errors within the signal source—ringing, noise or distortion.

As an example of how pump-out current can affect precision amplifiers, consider the following: Assume a signal source has an output resistance of 1 kΩ, a full-scale input signal amplitude of 10 mV and an operating temperature of 40 C. These conditions could produce a pump-out current of "only" 4 nA from the load device. But this would cause a 4-μV error voltage across the 1 kΩ input source impedance—a 0.04% error based on the 10-mV full-scale. To avoid results like these you must be careful when interfacing different system components to avoid accuracy losses. An amplifier that's accurate to 0.01% won't necessarily give you that system accuracy.

This Bell & Howell data-acquisition system makes possible a variety of applications. The multichannel inputs can be plotted on the X-Y recorders housed in the rack.



When connected to a 7000 series scope and a PDP-8 computer, the Tektronix digital-processing plug-in, Model 7001, does a multitude of data-acquisition tasks when hooked up to the desired scope plug-ins.

What about overload of the s/h or amplifier circuits? How fast do the circuits recover from voltage overloads? When amplifiers or s/h units are switched from channel to channel, are they going to face wide signal level variations? Look for all this information on the data sheets, but you'll rarely find any of it. Component heating can affect the accuracy of low-level signals and amplifier response: so ask the manufacturer about it if you have any doubts.

Modular s/h circuits are available from many companies. Most of the larger manufacturers of a/d converter modules, such as Teledyne-Philbrick, Analog Devices, Hybrid Systems, Burr-Brown and Intech, also have modular s/h circuits that include the holding capacitor. And some companies offer s/h modules with pinouts for an external holding capacitor.

Burr-Brown, for example, has a hybrid IC s/h circuit that requires only a holding capacitor

SERDEX data-manipulation modules from Analog Devices can transform parallel binary or BCD data into serial ASCII-coded binary for simple data transmission.

to function. The voltage droop of this amplifier is a low 0.1 mV/ms, and the capacitor determines the rest of the hold characteristics. This unit, Model SHC-23, costs $45 in singles and is housed in a TO-8 metal can.

Several companies have fabricated pairs of amplifiers with the necessary FET switches as single-chip circuits which they sell as general-purpose s/h amplifiers.

Multiplexer and scanner problems

To collect many channels of data and combine them onto a single line, you will need either a multiplexer or relay scanner. Of recent advances in multiplexers, the single-chip, 16-channel analog IC dominates; older modular circuits are slowly giving way to this new unit. Relay scanning circuits are advancing too, with better thermal design, isolation and shielding methods, but scanners may be fighting a losing battle in the long run as solid-state multiplexers move in to replace them in all systems except those that involve extremely low level signals (below, say, 10 mV).

When trying to decide which multiplexer or scanner to select, make sure you check these operating requirements:

- Can you randomly access each channel or must you sequentially scan all inputs?
- Are you mixing low-level signals?
- How much noise do the solid-state or relay switches create?
- How does voltage overload affect the unit?
- Does thermal heating from overloads affect operation?
- How much control circuitry do you need to support the multiplexer or scanner?
- Can the multiplexer be expanded? Can you daisy-chain several units for easy system expansion?

Problems faced when analyzing multiplexer specs include thermal and voltage offsets, contact resistance, switch resistance, contact bounce, switching time and level matching.

To preserve signals buried in noise—especially low-level signals—avoid solid-state switches. Noise in semiconductor materials often overrides low-level analog signals. Mercury-wetted reed relays with switched ground shields offer the best solution. Since low-level analog signals are usually of very low frequency, the slowness (100 operations/s) of mercury-wetted relays shouldn't pose any serious problems.

For low-level transducer signals, signal conditioning at the sensor location usually allows the most accurate data acquisition. If many low-level points are grouped near each other, a low-level signal scanner or multiplexer can minimize the number of amplifiers needed. You can first multiplex the signals, then feed them through a single amplifier.

In this single-amplifier approach, crosstalk within the multiplexer, bandwidth limiting of the amplifier, settling time of both the amplifier and multiplexer and other factors can destroy the signals. Other problems, like the need to run a line to the sensor to supply power for the conditioning equipment, must also be considered.

The signal conditioning boxes go by different names, but they all include amplifiers, gain controls and, sometimes, reference elements—such as thermocouple reference junctions or a voltage reference.

Most data sheets claim dazzling system throughputs. Make sure that the speed given is for the entire system and not just for the system's heart—the a/d converter. Not only should the spec include the a/d conversion time but also the acquisition time of the s/h circuit, the com-

puter delays, the processing time and the settling times.

System speed: How fast can you move data?

In a computer-based system, you can't always enter data as fast as the information arrives. Make sure the computer can handle the data while it still controls the system. If your data rate is too high, software delays can cause the system to bog down, even though you haven't exceeded the converter or front end throughput rate.

If raw input data must be processed on a real-time basis, the number of sensors to be handled should not exceed 1000. Thus if you want to sample all the points in one second and do some processing of the data, 1 ms per point would probably allow between 10 and 60 operations to be completed under computer control. Of course, the exact number of operations and points depends upon the speed of the processor.

For more than 1000 points, you'll be better off using direct memory access (DMA). This computer feature permits the raw digital data to be stored sequentially, directly into the memory. With this option, your system speed depends more upon converter and s/h circuit delays than on software limitations.

Can you talk to the system?

Putting together a system isn't the only problem. How do you control it once it's wired? Should you use a hard-wired controller with switch-selectable speeds? Or should you use program control to tell the system what, and when, to sample?

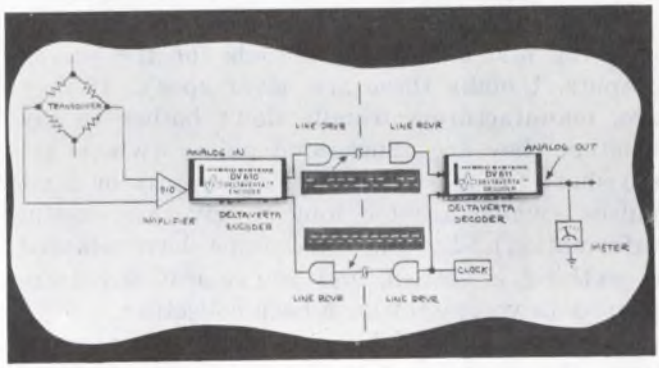
Software control is, of course, the most flexible: All you do is tell the computer which lines to switch and where to store the data. But you still have problems. In what language must the control sequence be written? How many control lines are available? Can you skip several channels or are you stuck with "dead time" (the time it takes to cycle through unused channels)? Does the system include a time clock? If it does, can the clock be computer controlled or is it under manual control? Does it have a battery back-up?

Many of the new systems use programmable read-only memories to hold control instructions. Can the memories be altered at the site? Are they inexpensive enough to be "throw away" units?

Are all your incoming data in the right form for the computer? Data may be transmitted as straight binary, binary-coded decimal, ASCII coded binary or some other form. Of course, the computer should have the processing and storage capability for the data.

The modularized construction of the Monitor Labs Model-9400 data-acquisition system can be seen in this front view. CMOS circuitry keeps the power dissipation low.

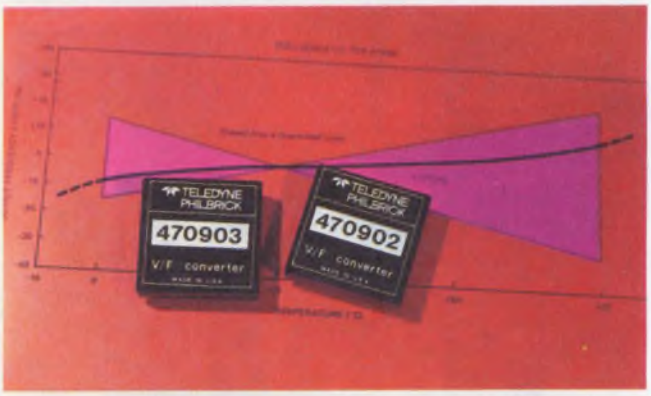
Time, channel number and parameter value are displayed on the front panel of the Digitec Model 1266 data logger. It has a built-in system clock and manual switches to control the scan rate and the scan mode.



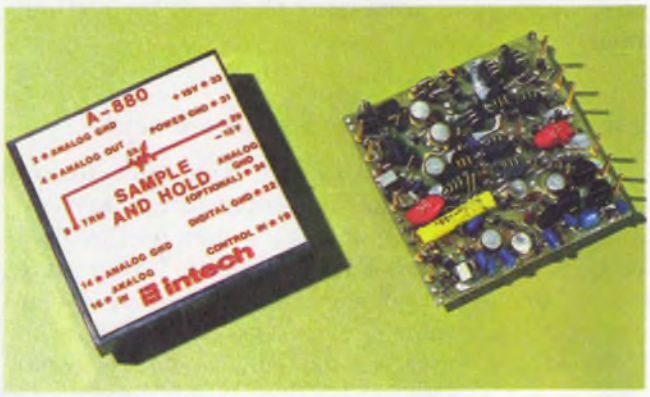
Low-cost alternatives to a/d and v/f converters for serial data transmission are available with Deltaverta encoder and decoder modules from Hybrid Systems.

Other desirable features in a data-acquisition system include some storage registers so the computer doesn't have to hold a request until the data are available. Adjustable time delays in the system can help the computer match the speed of the various subsystems. Suitable propagation delays also help guarantee that the data on the input lines have settled before they are sent to the computer for processing.

In any data acquisition setup—especially if



Frequency spans from dc to 1 MHz and voltage or current spans are handled with very low drift by Teledyne-Philbrick's line of v/f and f/v converters.



The A-880 sample-and-hold circuit, by Intech, provides a sample acquisition time of 1.4-μs and a voltage droop of only 1 mV/ms.

you assemble it yourself—many different specs must be matched.

The pieces must work together

As a start check the input circuits. There are many types of input amplifiers. You can have a flying-capacitor differential input, a true instrumentation-amplifier, or a three-wire system with or without a switched ground line. You can also have a chopper-stabilized, transformer-coupled input.

If the system has an analog output, it's wise to have a differential common-mode return for the d/a converter output—most don't. Most use a system ground that tends to be very noisy.

In the system controller, you should have blanking and unblanking signals for the analog outputs. Usually these are never spec'd. If they are, manufacturers usually don't bother to say whether they are nanosecond pulses (which are too short for most modular converters) or 5-ms pulses (which are too long to give any useful information). By the time 5-ms have elapsed everything is settled, and you've lost any transient data you might have been collecting.

Asynchronous serial lines can also present problems. What types of line drivers and receivers are used? If the data sheet lists a 20-mA current loop, this can mean any of myriad drivers and receivers—some compatible with long lines, some with short, some with coax, etc. Some lines are optically coupled and are touted for their isolation. But when manufacturers tell you they're optically coupled, they don't say you can run only 300 baud because optical coupling reduces the speed.

Signal conditioning amplifiers, whether in modular or rack-mounting form offer you many forms and quality levels to choose from. Regardless of which form you use, in data acquisition, certain specs predominate as the most critical.

For good accuracy and stability, common-mode rejection should be high and stability drift low. Rack mounted units are capable of 126 dB or better of CMRR and 0.001% gain stability. Modular units are rapidly approaching these performance levels, but still have a little way to go.

So called "instrumentation amplifiers," known for their high precision, have a major advantage over high quality op amps—ease of gain setting without deterioration of the CMRR or input impedance. All you have to change on an instrumentation amp is a single resistor—on a typical op amp you would have to tweak anywhere from two to five resistors to do the same job.

All forms of signal conditioning amplifiers are notorious for their drift, noise and other error sources (see "Focus on Analog Function Modules," ED No. 21, Oct. 11, 1973, p. 64).

High quality rack-type amplifiers usually offer the best performance—but at a price. Their voltage drifts range from one or two microvolts per degree of temperature change to less than 0.1 μV/°C. Modular devices typically have drifts that range from tens of microvolts down to about 1 μV. Some of the companies that make the precision rack signal conditioners include Ectron, Computer Products, Newport Labs, Preston Scientific, Dynamics Electronic Products, Hawkeye Instruments and Scientific Columbus.

Module houses like Analog Devices, Teledyne-Philbrick, Datel and Analogic offer modular instrumentation amplifiers that also qualify as "precision" units. Today there are even a few monolithic instrumentation amplifiers, including chopper-stabilized versions.

Watch out for high precision specs, though. An amplifier's common-mode rejection might be listed as 120 dB (a million-to-one ratio). But if we look at a 10-mV input signal and assume that a 100-V common-mode voltage exists—a likely possibility at industrial sites—a false signal of 100 μV will also appear on the input. This

additional signal actually amounts to a 1% error, thus "wasting" the 0.1% or better accuracy of the amplifier.

Not only must the common-mode rejection ratio be greater than 120 dB, it must also hold up for large line unbalance and different frequency ranges. Unfortunately the CMRR drops off rather sharply as the frequency increases above about 10 Hz.

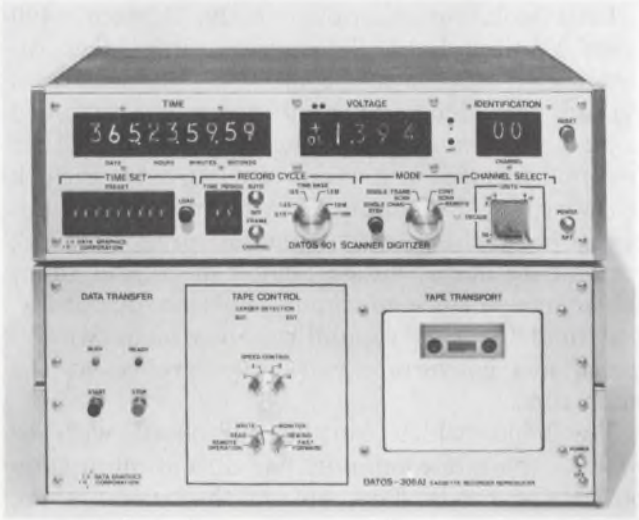
The temperature stability is also critical. Over varying temperatures, the set gain of the amplifier can change. Usually the better the amplifier, the less the change. Temperature coefficients of commercial units are now down to numbers like 0.001 or 0.003%/°C. Nevertheless, a temperature variation of, say, 40 C would change the gain by 0.12%—a large variation if we're talking about 0.001% accuracy.

Many temperature errors are referred to the input (RTI) while others look better if they are referred to the output (RTO). To compare "apples with apples," RTI errors can be multiplied by the amplifier gain to obtain the equivalent RTO errors.

To counter losses in precision due to temperature drift, the easiest solution would be to build better units. One example of what's available in rack-mounting precision amplifiers, is the 700 series of units from Ectron. These amplifiers are wideband, dc differential circuits that are available in over 500 configurations.

Basic amplifiers have common-mode voltages of 300 V, rejection ratios of 126 dB, 0.005% linearities, 0.01% gain accuracies, 0.003%/°C gain stabilities, 1 μV/°C zero stabilities and bandwidths of greater than 100 kHz.

Some options include manual or computer-controlled gain, selectable three-pole active filters, six gain ranges, a gain-range display, four or 10-line control and manual overrides. Prices for the manually controlled models start at $330, while the computer-controlled versions start at $640.



A multichannel data-acquisition system is formed when the Datos 306 cassette recorder-player and Datos 901 scanner-digitizer are combined. The equipment is from Data Graphics Corp.

Radial arrangement of components in the Computer Labs Model 7110 a/d converter keeps propagation delays constant between all the converter signal paths. This unit converts 10 bits at 10 MHz.

Another interesting unit is the triple-mode charge amplifier Model 7350 from Dynamics Electronic Products. This instrument can be used as an ac line amplifier or a strain gauge or thermocouple instrument. It has a gain of 1 to 1000, a gain charge of 0.1 to 1000 mV/pC. The 7350 has a 120-dB common-mode rejection, a 100-kHz frequency response and 5 μV of noise (referred to the input).

A differential charge amplifier permits the use of grounded transducers. This allows the transducer mass to be minimized and can also eliminate problems caused by mounting insulation. Differential action allows common-mode signals to be rejected by use of conventional guard techniques.

Other features like filters, calibrators, gain-control options are all available. The Tri-mode amplifier has a base price of $665, plus options that can range from $20 to $110. All circuits are protected against excessive input signals and output short circuits. This type of instrument is best suited for multiple applications where you cannot justify dedicated instruments for each measurement function you must perform.

Standardization does exist somewhere

About 60 companies have started to standardize their product lines to Computer Automated Measurement and Control (CAMAC) guidelines. These guidelines include standards for module sizes, card cages, specifications, ground planes, connector pinouts and methods of data communication between modules.

CAMAC equipment can mate with just about anybody's computer. This lets industry fix the design of front ends without freezing the processor design.

An automatic weighing system from Martin-Decker uses pressure transducers to acquire data through a central digitizing controller.

Several switch-selectable scan speeds are available with the Kaye Instruments Digistrip transmitter. The unit handles 15 data channels and outputs them in ASCII.

If you're not sure which CAMAC specs to call out, you can get a copy by writing to the Government Printing Office, Washington, D.C. 20402. Ask for documents TID-25875, 25876, 25877 and 26488.

Each modular instrument designed for CAMAC use is housed in a rack-mountable case that is 12 in. long × 8.75 in. high. The widths come in multiples of 0.7 in. Included within each module are control circuits that can decode the function requested, recognize the address being requested, generate interrupts and detect errors. This circuitry is included in the module in addition to the circuitry for the unit's specific function—a/d converter, d/a converter, multiplexer, shift register, etc.

Each module has a front panel with room for indicators, control switches and monitor points. Up to 32 different functions, in different modules, can be selected with a five-bit function code. Functions are defined for such actions as write, read, selective set, selective clear, clear, test status, enable, disable and execute.

Kinetic Systems, one of the many companies that offer CAMAC-compatible units, has over 50 different types. The CAMAC card cage, commonly called a "crate," can hold up to 23 unit widths (0.7 in.); costs range from about $3000 to over $10,000. The price includes cabling, power supplies and computer interface. The company's higher priced systems also include a microprogrammable branch driver, complete with its own power supplies. The individual CAMAC modules cost anywhere from $250 to $1500, depending upon the function desired.

As an example of the available modules, let's look at Kinetic Systems' 3500 series. In it are four a/d converter cards—two with 10-bit resolution and two with 12-bit. Each pair of modules offers either a single converter or a dual converter on a single card. Prices range from $850 for the single 10-bit unit to $1260 for the dual 12-bit unit. The conversion time for any of the units is less than 25 μs, and the resolution accuracy is better than ±0.5 LSB. The input impedance is greater than 100 MΩ, and input ranges of either 0 to 10 V or ±5 or ±10 V are jumper-selectable. Outputs are coded in 2's complement, when the converters are used in the bipolar mode.

Other types of CAMAC modules available include digital output registers, d/a converters, input registers, relay multiplexers, digital frequency scalers, counters, timers and controllers.

The full system: Endless varieties

When you buy a full system from one manufacturer, you eliminate the need to match many different specs. Many companies make data-acquisition systems that have tremendous flexibility through use of computer controls.

Let's look, for example, at the System 9400 from Monitor Labs. The system interfaces directly with a Nova minicomputer. Software programs are included so the unit can be controlled in assembly language, Basic or Fortran. Other features include: a low-power CMOS time clock with battery backup that lasts for days; individual channel skipping; function programming; monitoring mode; either analog or digital input acceptance; choice of input function digitizers; and multifunction capability, in which two internal a/d converters can be controlled at the same time.

The 9400, which can be purchased with or without the minicomputer, has an optimum sample rate of 1 kHz. The price of the basic system, $5650, includes software, the digital interface, a column printer, a controller board, the digital time clock and 10 input channels. Starting with this basic package, expander-controller boards

and analog input boards can be added to increase the number of channels to 1000.

Monitor offers four types of input boards that can accommodate signals from microvolts to tens of volts. These analog-signal boards are made for 10 three-wire or 10 four-wire sensor inputs. Special signal-conditioning circuits can also be connected to shape or attenuate signal levels under computer control. The digitizing circuits within the 9400 resolve analog signals to one part in 40,000, using either dual-slope or successive-approximation conversion techniques.

Expandability and flexibility are necessities for data-acquisition systems. Aside from expansion capabilities of up to 1000 points, programmable read-only memories are used for system control in Monitor's 9400 and similar systems. Thus if the control sequence has to be altered, you just plug in another set of ROMs, and your system is back on line. Skip and control-function programming are done on special cards that contain banks of switches. This means that channels can be added or taken off-line in the field—with no wiring changes.

PCM for data acquisition

Pulse-code modulation (PCM) is gaining favor for systems that involve serial-data telemetry. The Data Manager II, made by Tetrahedron, offers a PCM encoding scheme to give high signal-to-noise ratios and automatic ranging for a very wide dynamic range. It also has a parity check for error suppression and an incremental motor that offers flexible recording rates for low sampling times and long recording times. The system has 14 channels for analog inputs, a time channel, a maximum input range of ±10 V, a scanning rate that can vary from 0.01 to 20 scans/s and recording times from 800 to 4 million seconds per tape.

Options for the Data Manager system include computer interfaces for either EBCIDIC or ASCII codes; or a true digital integrator to record the difference between the digital values on any two channels and accumulate the sum of the difference.

The basic system with 14 channels sells for $9300. The maximum frequency that the equipment can handle though is quite low—only about 5 to 7 Hz.

One of the most unusual systems for data acquisition and display is the M/S 20D, made by Metra Instruments. This instrument accepts transducer signals in the 5-mV-to-5-V range and provides bar-graph CRT displays and digital readout in engineering units. It also has both BCD and serial outputs for other interfaces.

The M/S 20D can handle 20 to 80 points, and it provides a permanent record on either a tape

The Analogic 5800 data-conversion system can combine both a/d and d/a converters, sample-and-hold circuits and multiplexers to handle up to 64 channels of data.

console or a printer. The display tube is a 20-in.-diagonal CRT that provides an accuracy of 1% of full scale. Standard systems come with 50-channel capability, with automatic brightening of every fifth channel for easy identification.

Signal conditioners are also available in the M/S 20D for thermocouple inputs. The unit is pretty large—the display measures 19 × 17.5 × 13 in., and the control section is made for 19-in. rack-mounting. The cost of the basic system is $4000, and conditioning options add several hundred to thousands of dollars to the price.

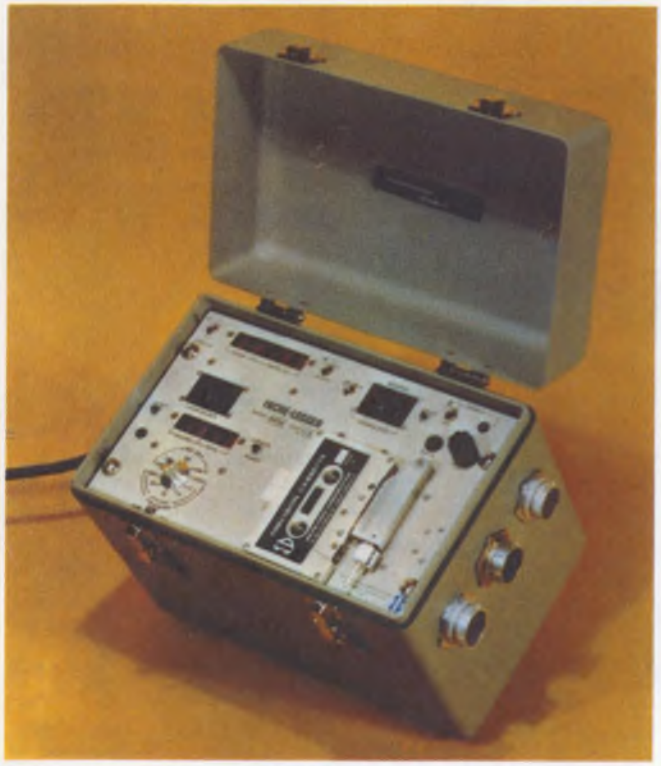
Versatility in compact units

The Gould 6000 data-acquisition system has a fully floating front end that provides 120-to-140-dB common-mode rejection. The system can be operated up to 200 V off ground, and it has up to a 200-V input protection circuit to prevent overload damage. It also has an amplifier with high input impedance and programmable gain. Input impedance is greater than 100 MΩ, and each analog input has four gain ranges.

The 6000 system accepts both analog and digital input signals—analog signals from ±10 V, full scale, down to 5 μV can be mixed with 3-digit hexadecimal, BCD or octal digital inputs. There is a choice of real-time monitoring for a single channel or all channels. You can also select a local display for a single channel of all the channels you are monitoring, or you can monitor the channels on a video or teleprinter display.

The built-in tape deck for a 3M cartridge can store 500,000 readings of 16 bits each. The System 6000 operates from 0 to 50 C, has 0.05% resolution and weighs less than 40 lb. It can handle from 8 to 128 channels.

System-6000 options include interfaces for a tape deck, a PDP-8 computer parallel input, and



For field data-logging applications, the Model 4434 data-acquisition system from Incredata has all the necessary equipment in a sturdy case.

a general-purpose serial-data input to hook up an ASCII port. You can slave extra scanners to the master unit for additional channel data acquisition. Data are recorded on the unit with a four-track, 800-bit range-encoding signal. Recording time can range from 43 minutes for a 200 point/s scan to 225 days for one scan every 10 minutes. Prices for the basic unit and some of the option cards are as follows: The 6000 mainframe costs $3400, the analog input analog cards $450, and the output interface cards for the minicomputer or general-purpose computer about $1100, respectively.

Sometimes the collection of image data is a necessity. The IDAS image data-acquisition system from Kantronics collects video data in digital form. IDAS uses a camera and a video quantizer to interface with a computer. Typical uses for the system include measurement of the contents of assembly-line products, alignment of visual video signals, enlargement of microscopic images and tracking and monitoring of laboratory-stimulated animals. The basic cost of IDAS is $3325. This includes a camera, quantizer, TV monitor, computer interface and a sync generator.

The ERDAC III system from Macrodyne is a self-contained transient recording data acquisition system. It can capture, digitize, record, display, measure and recall data. All collected data can be stored on a 3M tape cartridge.

Data that the ERDAC stores are first held in a 4-kword-by-10-bit memory and can be transferred to the tape at any time. Four analog input channels provide the display with 100-kHz maximum signals and still give a 1-MHz time resolution. To ease data transfer, ERDAC has both serial and parallel data outputs.

For data display, a built-in 4 × 5 in. CRT can be controlled to show either one or all four data channels. A moveable cursor for the display can be shifted along the X-axis (time) to set the desired triggering point. The cursor appears as a bright spot on the display. Its position is also displayed on a LED numeric readout for both time and amplitude.

But the ERDAC III doesn't come cheap—the digital scope and amplifier channels cost $12,500. The package is fairly large—10 × 16 × 22 in. and weighs about 40 lb.

Some other medium-priced systems include: Datagraphics' Models 701 and 305, Digitec's Models 1200 and 1500, Doric's Digitrend 200 and 210, Data Technology's Milliverter and DL1000, Electronic Modules' Minimux, Esterline's Model D2020 and Neff's Model 620. Most medium-priced units ($2000 to $7000) offer input ranges from 10 mV to 10 V, 3-1/2 or 4-1/2-digit resolution, 100 to 200% overranging, 0.1% or better accuracy, differential voltage between channels of from 12 to 300 V, and varying degrees of expansion capability and control options.

The more you pay, the more you get

Many computer manufacturers also offer data acquisition front ends for the units. Companies like Digital Equipment (DEC), IBM, General Automation, Data General, Texas Instruments, Modular Computer, Interdata and Hewlett-Packard sell full-sized data-acquisition systems that are used to monitor large industrial processes or to collect huge amounts of data for analysis.

Texas Instruments' TIMAP, CFS I and DFS IV are some of the largest systems. They're made for field use—on the back of a trailer-truck. These systems cost upward of $100,000 and are used mainly for geophysical data collection and analysis. IBM's System 7 also can collect, control and analyze data, but at a price of $70,000.

DEC offers many different systems based on either its PDP-8 or 11 minicomputers. For the most part, these are plant-based systems intended for collecting data from processes for subsequent control and analysis. Typical of DEC control systems is the IDACS 8/C. This PDP-8 based system offers complete control of any process by programming of input and output conditions with an industrial form of the BASIC language. A typical system consists of a PDP-8F computer, a dual tape drive, a terminal and

input/output boards.

Modular Computer's data-acquisition front end for its Modcomp minicomputers includes analog input options that allow inputs from potentiometers, amplifiers, accelerometers, flow meters, thermocouples, strain gauges, RTDs, pressure transducers, analyzers, chromatographs, spectrometers and more. Accuracy for the front-end equipment is specified at 0.05% ±0.5 LSB.

Each subsystem board for the analog inputs includes its own a/d converter and optical isolation between the controller interface and the subsystem to prevent transients from damaging the computer system or the controller. The controller can handle eight to 128 high-level analog inputs, eight to 512 wide-range medium-level signals and eight to 512 other wide-range analog inputs (mainly for low-level signals). Other optional features of these analog boards are automatic gain ranging under computer control, 15-bit resolution and ±200-V signal-handling capability.

If such large system capability isn't needed, Modular Computer also offers the MODAC subsystem. This provides 16 or 32 input channels and two, four or eight analog outputs. A serial data link allows for placement of the subsystem up to one mile from the computer.

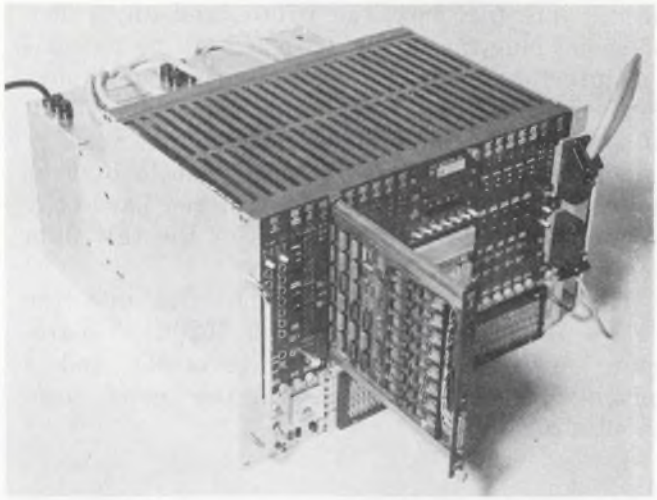
What about plant control?

Looking for large plant control and acquisition systems? Check into equipment made by companies like Foxboro Corp. Foxboro's Spec-200 system uses a building-block approach and a bus-oriented structure to facilitate assembly of a system. Rack units accept plug-in amplifiers, conditioners, converters, multiplexers, controllers, etc.—all designed to work together with almost any computer system.

Spec-200 hardware, since it is made for industrial environments, is designed to be intrinsically safe. All units comply with Underwriters Labs (U.S.), PTB (German), CSA (Canadian) and BASEEFA (English) and other safety and electrical standards around the world.

If you already own a computer system, there are peripherals that can be added to provide data acquisition and control functions. For instance, Hewlett-Packard has just introduced a front-end—the HP 30300A—for the HP-3000 minicomputer-based time-sharing system. This unit is a programmable controller with an input/output structure designed for on-line instrument connection.

The 30300A uses the HP 2100 minicomputer as its controller. The basic system comes with 8 kwords of memory, a dual-port controller, a programmable time-base generator, a self-contained power supply, a paper-tape reader and an interface kit. It also has 11 input/output channels available for data inputs. This system has a cost of about $18,000.



This CAMAC system crate, manufactured by Kinetic Systems, uses standardized plug-in modules. The modules are typically 0.7 in. wide and have uniform terminations for hook-up.

One of the options available for the 30300A is a 16-channel analog input card made for high-level signal acquisition. It contains a 12-bit a/d converter, has a 20-kHz conversion rate and costs $2000. The HP-3000 computer system, which includes a central processor with 96 kbytes of memory, a card reader, a line printer, a tape drive and 9.4 Mbytes of disc storage costs $165,000. The 3000 can be programmed in high-level COBOL, FORTRAN, BASIC and a systems program language.

Vidar Corp. offers both complete systems and individual components for data-logging or control systems. These systems range in complexity from a close-to-$1-million FM-multiplex recording system for rocket-engine measurements to a $5000 system for logging data from production lines.

One of the systems made by Vidar is the 5400 programmable data logger. It uses a minicomputer to control and supervise the monitoring of 1000 channels of low or high-level signals.

Another Vidar system, the 600/6403, designed for low-level data acquisition, can handle 20,000 channels a second and deliver 12-bit data words. It also has 10 programmable gain ranges, with autoranging capability to 12,000 samples/s.

Tektronix offers a digital-processing oscilloscope. This unit, designed for laboratory data acquisition and analysis, uses a DEC minicomputer to process digitized signals from the scope. The data are handled with any mathematical algorithm you write and are displayed on the oscilloscope.

A precision data-acquisition system can be built with an ordinary Tektronix 7000 scope, a

digital interface box, the P7001, and any range of scope plug-ins, along with a mini or calculator interface. You can add a variety of input/output devices and peripherals for system flexibility. Cassette or high-speed paper-tape reader/punch units can be used for program loading or data logging. A graphics terminal and hard-copy printer can give printed copies of the raw data or plotted results.

The basic processor box that fits into the Series 7000 scope costs about $5200. A bare-bones system, including the processor and a terminal to communicate with the scope, costs about $20,000.

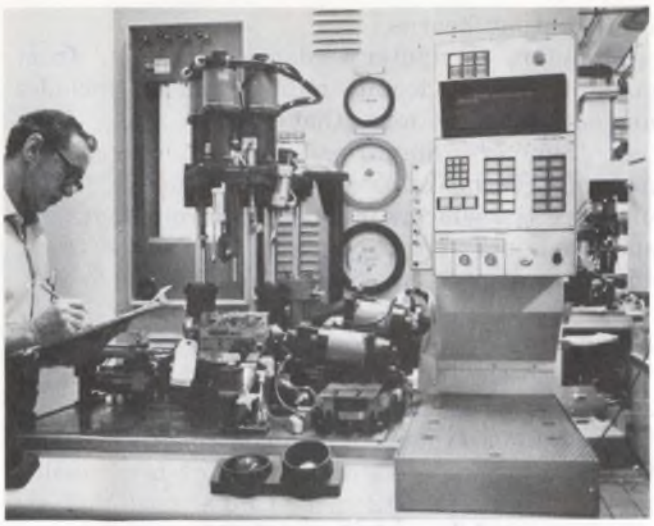
You've got to move the data

In industrial or laboratory situations it isn't enough to acquire the data; you must also send it to the processor. To do this, Analog Devices has developed the Serdex line of industrial data-acquisition and control modules. The Serdex transmitter, Model STX-1003, converts the 4-digit parallel BCD code that a/d converters can output into two-wire, compatible, serial ASCII code. This coded output is compatible with either a computer serial link or a data terminal serial link. The receiver module, Model SRX-1005, does the reverse; it converts serial ASCII to 4-digit parallel BCD for possible d/a conversion into a control signal.

The other modules in the Serdex series include a multiplexer pair, SMX-1004 and SMC-1007, which can combine up to 16 process lines onto a two-wire cable, and a clock module, SCL-1006, which can supply all the timing and control signals for all the other units. The clock module also supplies the operating voltages needed by the other units. The transmitter or receiver costs $179, the multiplexer pair $214 and the clock module $65.

Another recently developed system for serial data exchange is DEC's PDM-70—a programmable data mover with input/output slots that accept up to seven boards. The boards accept either digital or analog data. The PDM-70 takes these data and converts them into serial ASCII for two-wire transmission.

Each of the option boards contains a universal asynchronous receiver-transmitter that does the actual code conversion. The options available include a BCD or binary input board that will accept up to a 32-bit parallel word and reformat it into serial ASCII. The BCD/binary output board does just the reverse. The analog input board can handle up to four differential channels and can convert the analog signals into serial ASCII. The converter boards have programmable gains and full-scale voltage ranges of ±1.999 V, ±199.9 mV, and ±19.99 mV.



A carburetor test stand, made by General Automation, controlled by a computer-based data-acquisition system, not only tests the units but also keeps track of all the test data.

This board also has a mirror image board—the analog output option.

The control circuits within the PDM-70 let you change the control, scan sequence or routing of the signals at a moment's notice. This eliminates a lot of the down time when changes must be made in a controller. The basic main chassis, with the built-in control keyboard and alphanumeric display, costs $2050. The optional analog-signal input boards are priced at $650, and their matching analog output boards $450.

There is still another connecting link between the sensor and the computer—the card and rack system. One, manufactured by Computer Products, has real-time peripheral cards and racks that can be assembled into any type of data-acquisition or control system.

The RTP 7400 series of subsystem cards includes such functions as a/d conversion, sample/hold and low-level multiplexing control cards. Computer input/output interface cards for almost any manufacturer's computer are available from Computer Products.

In the 7400 series each functional circuit card comes completely documented, so all controls and specs can be defined. This subsystem building-block approach is a step toward standardization. At least you know which pins represent control data, power-supply and other lines. This allows rapid system changes.

The input/output expander card, which differs for each computer, controls all the cards plugged into the system chassis. Each expander board can handle up to eight peripheral subchassis, which can hold up to 16 circuit boards to perform any desired function.

One of the analog front ends is the 7480—a wide-range analog input system. This card cage

system uses either dry or mercury-wetted, three-pole reed relays, with eight relay input channels to a circuit card. Operating speed of the relay switches is 200 samples/s for the dry relays and 100 for the mercury-wetted ones.

Each sampled signal then gets amplified by a programmable gain amplifier and digitized by an integrating 13 or 15-bit a/d converter, depending upon sampling speed. The system can be expanded to handle a maximum of 512 multiplexed input channels.

The 7470 system, designed for low-level signal acquisition, uses field-effect transistor switches and transformer coupling. Common-mode rejection at 60 Hz is a comfortable 120 dB, with a 1-kΩ input unbalance. Each channel input is on a separate circuit card, but this gives a very high degree of isolation and a 300-V common-mode range.

The 7470 system includes the low-level amplifiers, multiplexer, a/d converter and computer interface/controller. This front-end system offers an over-all accuracy of ±0.05% of full scale, referred to the output; linearity of 0.03% of full scale, from best straight line; differential feedback current (pump-out) of 5 nA for any channel that is sampled 100 times a second or less, and a channel sampling rate of 8000, 4000, 2000, or 1000 channels/s. The channel sampling speed includes a/d conversion and data-transfer times.

Prices for Computer Products' RTP-series equipment start at about $900 for the input/output control boards, and $120 and up for cabling, depending upon length. The analog input subsystems, made for wide-range input signals, use expansion chassis that can hold 16 eight-channel cards and the empty chassis costs about $800.

Prices for the eight-channel input cards range from $240 a card to over $400, depending upon filtering options. The main chassis, which includes the multiplexer, a/d converter and the control circuitry, costs about $2500 and can control up to 128 channels. Prices for the low-level system mainframe are in the area of $2700 for the 64 input-channel version, with the channel cards about $100 each.

Options for the equipment line include higher-resolution converters, single or double-pole filters, automatic gain ranging, manual controllers and voltage calibrators.

Systems, but not quite systems

Many data-acquisition systems are sold without the computer, though they're designed for a direct computer interface. These usually are a "mix and match" network of specially designed circuit functions that are meant to work together to acquire data.

For instance, the Datel 256 and the Analogic 5800 are rack-mounted units that can contain a/d and d/a converters, sample-and-hold circuits, storage registers, multiplexers and the control circuitry needed to sequence all these blocks. System prices range from $1500 to $7000.

Datel's System 256 offers several options on the front panel and many internal converter arrangements. Since these rack units are arranged on a bus-oriented structure, system expandability and modifications are as simple as pulling out one card and plugging another in.

Depending upon your application, the system mainframe for the Analogic 5800 can handle up to 64 channels, while the Datel 256 system can handle up to 256. Either system can be expanded with additional chassis to handle another 256 channels for the Datel 256 system or to over 4000 channels for the Analogic 5800. Both systems also have simultaneous s/h capability.

Smaller than a rack

• There are several smaller data-acquisition units that are not quite as flexible as the systems we've just looked at but which are much lower priced. These are the single-card data-acquisition systems such as the Analogic MP6912, the Data Translation DT1610 and the Datel DAS-16-LP.

Both the Analogic and Data Translation units are basically 16-channel data-acquisition systems on 3 × 5 in. circuit cards each 0.375 in. high. These systems cost about $700 for a throughput rate of 100 kHz (12-bit words). Each unit, though, contains a 16-channel solid-state high level multiplexer, instrumentation amplifier, sample/hold circuit and 12-bit a/d converter.

The Datel DAS-16-LP is slightly different. It also is a 16-channel system, but it draws very little power and is much slower than the other units—with a 2.2 kHz throughput. It uses CMOS circuitry to keep power requirements down to the microwatt level (120 μW standby). The DAS-16-LP is also a bit larger than the other two units; it measures 4.5 × 6 × 1 in., but includes all control circuitry for the a/d converter, s/h circuit and multiplexer. The unit costs about $750.

Present systems and circuit trends for data acquisition favor greater versatility and smaller packages. Many circuits—amplifiers, a/d converters, v/f converters, multiplexers and sample-and-holds—are appearing as monolithic or hybrid ICs. System throughput speeds are on the increase, allowing more points to be sampled in less time. The use of CMOS circuits has reduced power consumption and size a hundredfold, and in the next few years further advances appear assured. ■■

(continued on next page)

Need more information?

We wish to thank the many companies that provided information used for this report. The products cited in the report were selected for their illustrative, or in some cases, unique qualities. However, manufacturers not mentioned in the report may offer similar products. Readers may wish to consult manufacturers listed here for further details. Coding: (D)—full computer based system available with or without the computer, (M)—modular PC mounting subsystems, (R)—rack type card subsystems and (S)—stand-alone, noncomputer-controlled systems.

A. D. Data Systems, Inc., 830 Linden Ave., Rochester, N.Y. 14625. (716) 381-2370. (R. Van Gelder). (M) **Circle No. 338**

Acromag, Inc., 30765 Wixom Rd., Wixom, Mich. 48096. (313) 624-1541. (R. Hennings). (M) **Circle No. 339**

Active Control Instrumentation, Box 194, East Northport, N.Y. 11731. (516) 864-2111. (M) **Circle No 340**

Acurex Corp., 485 Clyde Ave., Mountain View, Calif. 94040. (415) 964-3200. (J. Dennis). (M,R,S) **Circle No. 341**

Allis-Chalmers, Box 512, Milwaukee, Wis. 53201. (414) 475-2000. (D. Gibson). (D,R,S) **Circle No. 342**

American Astrionics, Div. of Technicolor, 291 Kalmus Dr., Costa Mesa, Calif. 92626. (714) 557-8480. (N. Vogel). (M,R) **Circle No. 343**

American Electronic Labs., Inc., Box 552, Lansdale, Pa. 19446. (215) 822-2929. (K. Farber). (R,S) **Circle No. 344**

American Instrument Co., Div. Travenol Labs., Inc., 8030 Georgia Ave., D16-2, Silver Spring, Md. 20910. (301) 589-1727. (R. Reich). (D,S) **Circle No. 345**

Analog Devices, Inc., Box 280, Route 1 Industrial Park, Norwood, Mass. 02062. (617) 329-4700. (M. Klapfish, Serdex; F. Pouliot, Modules). (M) **Circle No. 346**

Analogic, Audubon Rd., Wakefield, Mass. 01880. (617) 246-0300. (P. Pollins). (M,R,S) **Circle No. 347**

Bailey Meter Co., Sub. Babcock & Wilcox, 29801 Euclid Ave. Wickliffe, Ohio 44092. (216) 943-5500. (E. Gabrosek). (D,R,S) **Circle No. 348**

Beckman Instruments, Helipot Div., 2500 Harbor Blvd., Fullerton, Calif. 92634. (714) 871-4844. (H. Frazier). (M,S) **Circle No. 349**

Bell & Howell Co., Electronic & Instr. Group, 360 Sierra Madre Villa, Pasadena, Calif. 91109. (213) 796-9381. (R. Batiste). (D,R,S) **Circle No. 350**

Betatronics Inc., 9440 Lincolnwood, Evanston, Ill. 60230. (312) 676-1747. (H. Allen). (M) **Circle No. 351**

Biocom, Inc., 9522 W. Jefferson Blvd., Culver City, Calif. 90230. (213) 836-7263. (B. Dickey). (M) **Circle No. 352**

Biomation Corp. 10411 Bubb Rd., Cupertino, Calif. 95014. (408) 255-9500. (D. Blecki). (S) **Circle No. 353**

Burr-Brown Research Corp., International Airport Ind'l Park, Tucson, Ariz. 85706. (602) 274-1431. (R. Gadway). (M,R) **Circle No. 354**

Burroughs Corp., 1649 Wilshire Blvd., Los Angeles, Calif. 90017. (213) 488-4520. (P. Meninger). (D) **Circle No. 355**

Calex, Box 555, Alamo, Calif. 94507. (415) 932-3911. (S. Cuff). (M,R) **Circle No. 356**

Chrono-Log Corp., 2583 W. Chester Pike, Broomall, Pa. 19008. (215) 356-6771. (D. Viberman). (R) **Circle No. 357**

Columbia Research Labs., MacDade Blvd. & Bullens La., Woodlyn, Pa. 19094. (215) 532-9464. (J. Sarty). (M,R) **Circle No. 358**

Computer Automation, Inc., 18651 Von Karman, Irvine, Calif. 92664. (714) 833-8830. (R. Drew). (D) **Circle No. 359**

Computer Conversions Corp., 6 Dunton Ct., East Northport, N.Y. 11731. (516) 261-3300. (S. Renard). (M) **Circle No. 360**

Computer Labs., 1109 S. Chapman St., Greensboro, N.C. 27403. (919) 292-6427. (D. Brockman). (M,R) **Circle No. 361**

Computer Products, Box 23849, Ft. Lauderdale, Fla. 33307. (305) 974-5500. (L. Buck). (D,R) **Circle No. 362**

Computer Signal Processors, 209 Middlesex Turnpike, Burlington, Mass. 01803. (617) 272-6020. (L. Grady). (D,S) **Circle No. 363**

Conrac Corp., Sherwood Lane, Fairfield, N.J. 07006. (201) 575-8000. (P. Daro). (D,S) **Circle No. 364**

Consolidated Controls Corp., 12 Durant Ave., Bethel, Conn. 06801. (203) 743-6721. (H. Drucker). (D,S) **Circle No. 365**

Control Data Corp., P.O. Box O, Minneapolis, Minn. 55440. (612) 853-5508. (K. Nichols). (D,S) **Circle No. 366**

Control Equipment Corp., 171 Lincoln St., Lowell, Mass. 01851. (617) 459-0573. (G Stephens). (D,S) **Circle No. 367**

Control Logic Corp., 9 Tech Circle, Natick, Mass. 01760. (617) 655-1170. (A. Ross). (D,R) **Circle No. 368**

Cunningham, Sub. Gleason Works, 10 Carriage St., Honeoye Falls, N.Y. 14472. (716) 624-2000. (G. Appleton). (R) **Circle No. 369**

Custer Research Inc., P.O. Box 305, Fleetwood, Pa. 19522. (215) 376-2842. (L. Lewis). (R) **Circle No. 389**

Cycon Inc., 1080 E. Duane Ave., Sunnyvale, Calif. 94086. (408) 732-8311. (W. Peacock). (M) **Circle No. 370**

Data Control Systems, Commerce Dr., Box 584, Danbury, Conn. 06810. (203) 743-9241. (J. Lombardo). (D,M,R,S) **Circle No. 371**

Data General Corp., Rte. 9, Southboro, Mass. 01772. (617) 485-9100. (A. Ashton). (D) **Circle No. 372**

Data Graphics, 8402 Speedway Dr., San Antonio, Tex. 78230. (512) 342-9486. (J. Peddie). (D,S) **Circle No. 373**

Data Systems Engineering, 1620 E. Ball Rd., Anaheim, Calif. 92805. (714) 535-2894. (S. Reese). (D,S) **Circle No. 374**

Data Technology, 2700 S. Fairview, Santa Ana, Calif. 92706. (714) 546-7160. (D. Cappelletti). (D,M,S) **Circle No. 375**

Data Translation, 109 Concord St., Framingham, Mass. 01701. (617) 879-3595. (F. Molinari). (M,R) **Circle No. 376**

Datacom, Inc., Box 278, Fort Walton Beach, Fla. 32548. (904) 242-3113. (T. Jaye). (D,R,S) **Circle No. 377**

Datametrics Inc., 340 Fordham Rd., Wilmington, Mass. 01887. (617) 658-5410. (H. Grey). (D,R,S) **Circle No. 378**

Datascan, Electronic Prod., Box 785, Clifton, N.J. 07013. (201) 478-2800. (G. Moore). (M) **Circle No. 379**

Datel Systems Inc., 1020 Turnpike St. Canton, Mass. 02021. (617) 828-8000. (L. Copeland). (D,M,R,S) **Circle No. 380**

Datum Inc., 170 E. Liberty Ave., Anaheim, Calif. (714) 533-6333. (B. DeVito). (D,S) **Circle No. 381**

Delco Electronics Div., General Motors Corp., 700 E. Firmin St., Kokomo, Ind. 46901. (317) 459-2175. (J. Polhamus) (S) **Circle No. 382**

Design Automation, Inc., 809 Massachusetts Ave., Lexington, Mass. 02173. (617) 862-8998. (N. Sokal). (D) **Circle No. 383**

Digital Equipment Corp., Main St., Maynard, Mass. 01754. (617) 897-5111. (P. Connell). (D) **Circle No. 384**

Doric Sci. Corp., 3883 Ruffin Rd., San Diego, Calif. 92123. (714) 277-8421. (G. Shockey). (D,S) **Circle No. 385**

Dynalab Corp., 7808 Gloria Ave., Van Nuys, Calif. 91406. (213) 781-3151. (D. Espy). (M) **Circle No. 386**

Dynamic Measurements Corp., 6 Lowell Ave., Winchester, Mass. 01890. (617) 729-7870. (M) **Circle No. 387**

Dynamics Electronic Products, Inc., 12117 E. Slauson Ave., Santa Fe Springs, Calif. 90670. (213) 945-2493. (D. Cantrell). (R,S) **Circle No. 388**

EMR Telemetry, Box 3041, Sarasota, Fla. 33578. (813) 958-0811. (S. Bass). (D,S) **Circle No. 390**

Ectron Corp., 8133 Engineer Rd., San Diego, Calif. 92111. (714) 278-0600. (J. JaQuay). (D,R) **Circle No. 391**

Edmac Assoc., Inc., 333 W. Commercial St., East Rochester, N.Y. 14445. (716) 381-5472. (R. Boisvert). (D,S) **Circle No. 392**

Electronic Modules Corp., Box 141, Timonium, Md. 21093. (301) 666-3300. (A. Rutledge). (M,R,S) **Circle No. 393**

Esterline Angus Div., Esterline Corp., Box 24000, Indianapolis, Ind. 46224. (317) 244-7611. (R. Moore). (D,S) **Circle No. 394**

Fluidyne Instrumentation, 470 27th St., Oakland, Calif. 94612. (415) 444-2376. (R. Jennings). (D,S) **Circle No. 395**

Fogg Systems Co., 1380 S. Dahlia St., Denver, Colo. 80222. (303) 758-2979. (H. Fogg). (M,S) **Circle No. 396**

Foxboro Co., 38 Neponset Ave., Foxboro, Mass. 02035. (617) 543-8750. (D. Aiken). (D,S) **Circle No. 397**

Function Modules, Inc., 2441 Campus Dr., Irvine, Calif. 92664. (714) 833-8314. (S. Osgood). (M) **Circle No. 398**

G B Instruments, 2030 Coolidge, Hollywood, Fla. 33020. (305) 944-7144. (B. Richard). (D) **Circle No. 399**

General Automation, Inc., 1055 East St., Anaheim, Calif. 92805. (714) 778-4800. (D) **Circle No. 400**

General Devices, Inc., P.O. Box 253, Princeton, N.J. 08540. (609) 924-2500. (M. Medvin). (M) **Circle No. 401**

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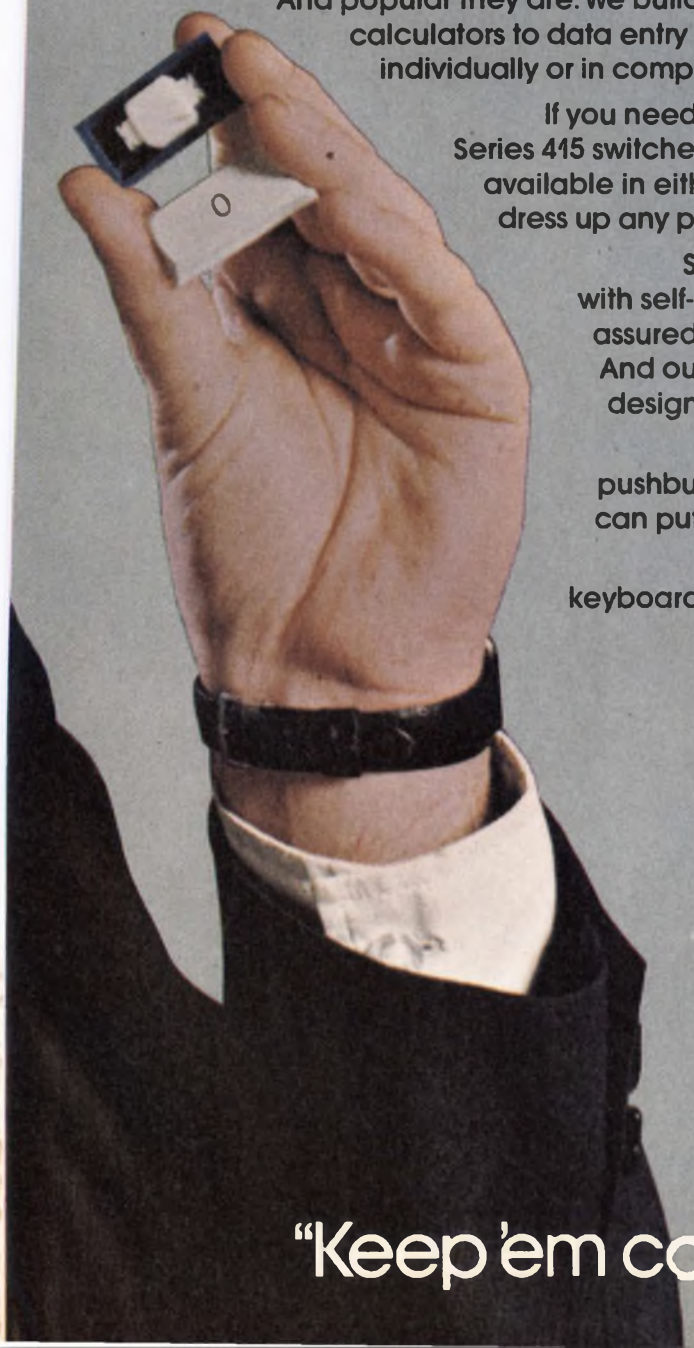

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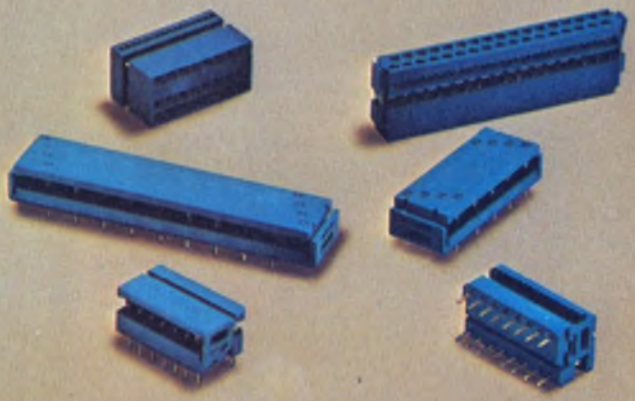

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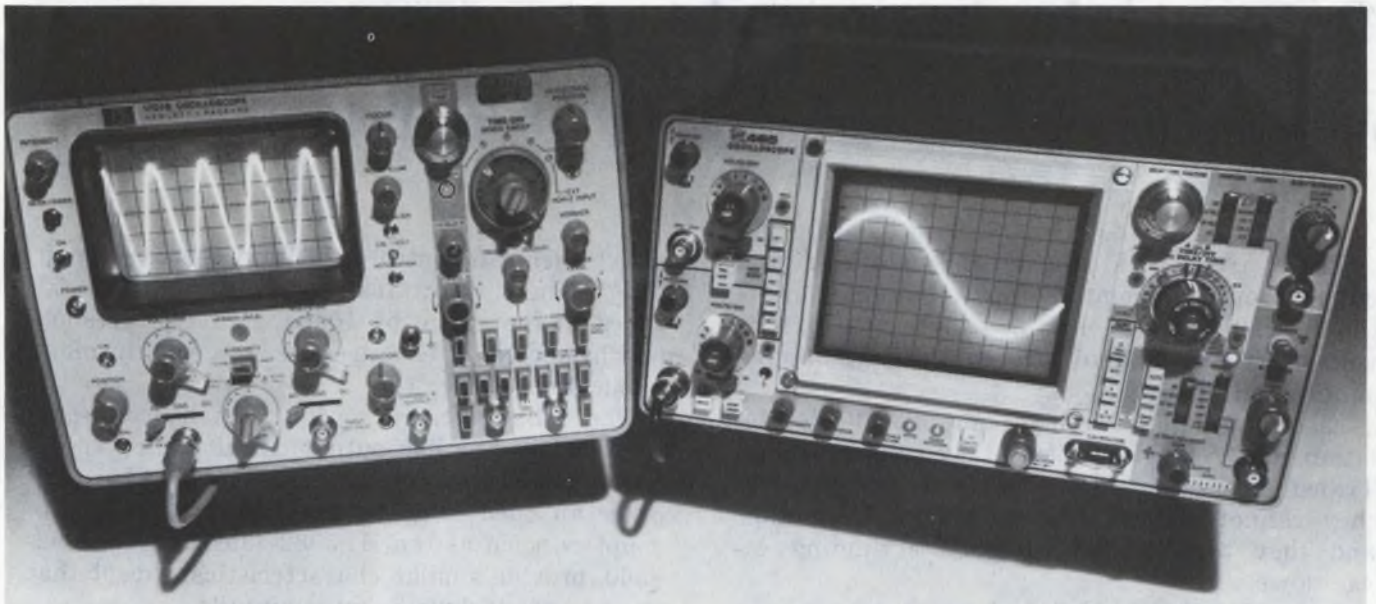

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INFORMATION RETRIEVAL NUMBER 42

Opto-isolator logic units add flexibility to digital design. They provide input-to-output isolation, low noise feedthrough and response to dc and fast pulses.

There are several ways to isolate a digital circuit's output from its input, but only one—the optically coupled isolator—gives you high dc voltage isolation and low capacitive coupling simply and directly.

Electromechanical relays can provide dc isolation, but relays are limited by slow response. Transformers can do the isolation job, too, but they cannot properly reproduce digital signals, and they tend to have high interwinding capacitance.

The optically coupled isolator, however, can provide up to 10^{12}-Ω input/output resistance and only 1 pF of capacitive coupling. It has rapid response and is particularly suited for coupling digital signals. In addition it provides high input-noise rejection capability.

An isolated digital coupler can be used for applications such as these:

- Coupling data to and from data-transmission lines.
- Controlling signaling attachments to telephone lines.
- Controlling switching in high-voltage and high-power circuits.
- Acting as a feedback element in regulated dc power supplies.
- Replacing polar relays in teletypewriter communications systems.
- Converting sine waves to square waves, and coupling logic circuits to power lines or other sine-wave systems for synchronization.

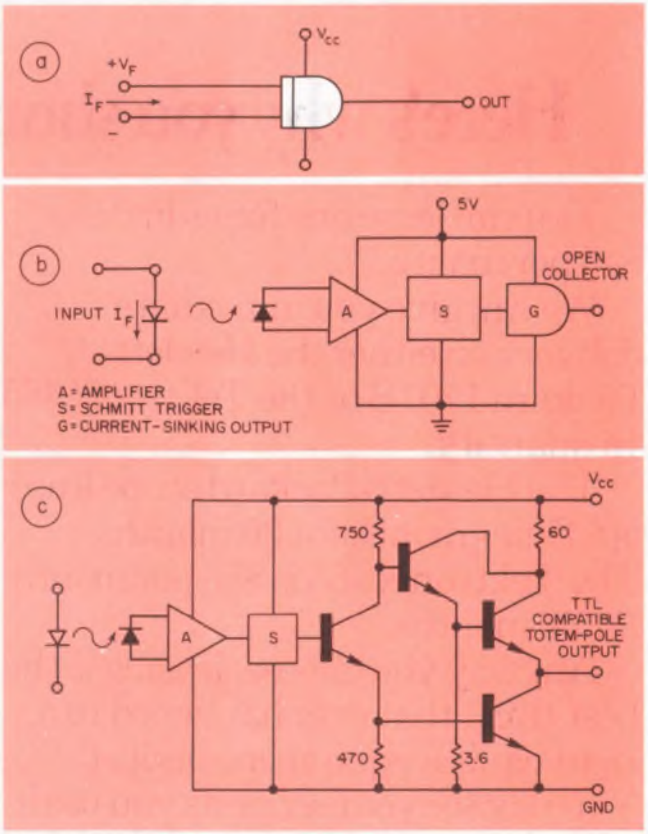
These digital circuits require dc isolation, which the ordinary solid-state circuit, with its common dc path between input and output, can't provide.

Light makes the connection

The basic opto-isolator combines a fast LED with an equally fast photodiode. Often the photodiode is coupled to a differential-input amplifier, which then can control a Schmitt-trigger circuit. The Schmitt circuit can provide rise and fall times in the range of 10 ns, and its threshold and hysteresis effects are advantageous in many applications (Fig. 1).

The Schmitt-trigger output can be connected to a TTL-compatible output circuit. One version has a totem-pole output circuit (MCL610), another an open collector (MCL611). Other opto-couplers, such as the HP5982-4352 and HP5082-4360, provide similar characteristics, except that they do not include Schmitt circuits.

Opto-isolation circuit design differs from ordinary methods, because the opto-isolator's input operates in a current mode while its output is a voltage response. The LED input dic-



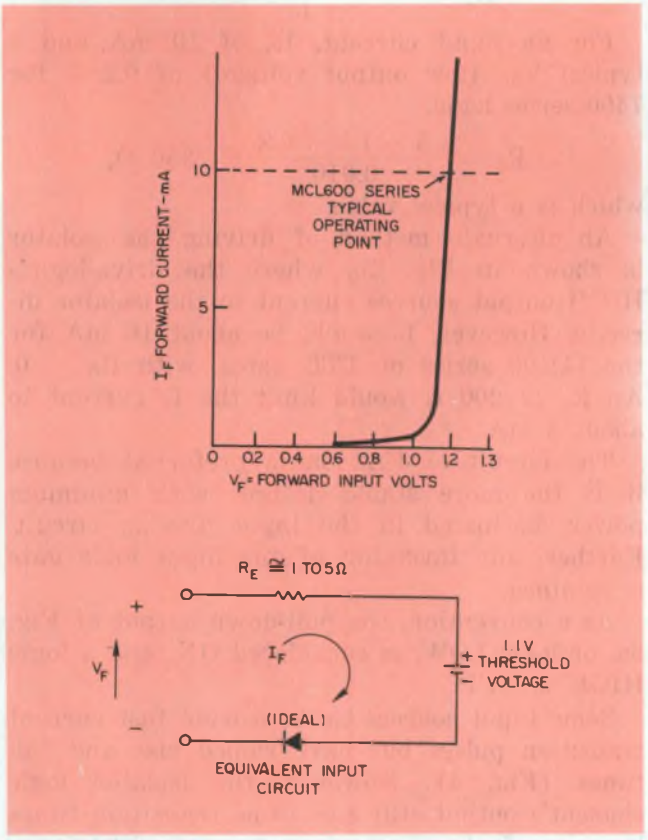
1. **Opto-isolator logic couplers** (a) can have an open-collector, current-sinking output (b) or a TTL-compatible, totem-pole output (c).

Grant C. Riddle, Applications Engineering Manager, Monsanto Commercial Products Corp., Palo Alto, Calif. 94304

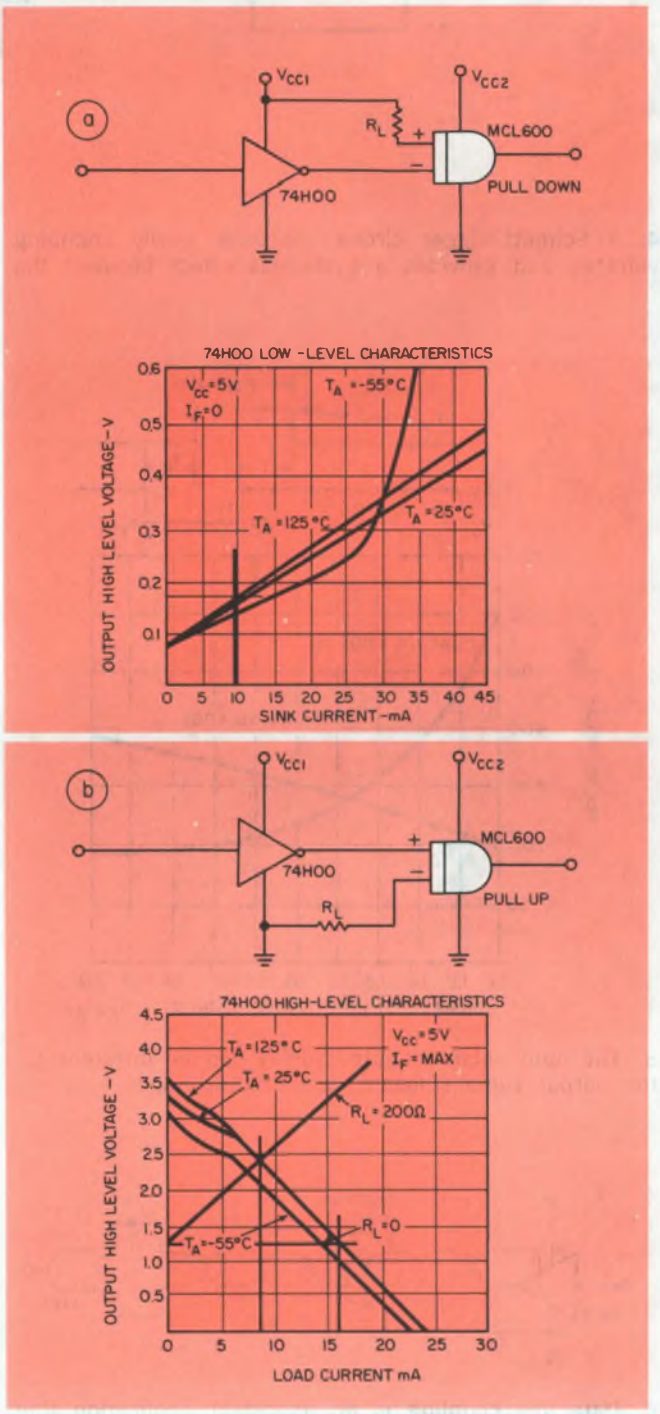
tates the use of the current input.

This is an important advantage, because common-mode noise voltages, which usually have little current capability, are easily rejected. Common-mode variations of hundreds of volts and even fast-rising noise spikes are easily handled.

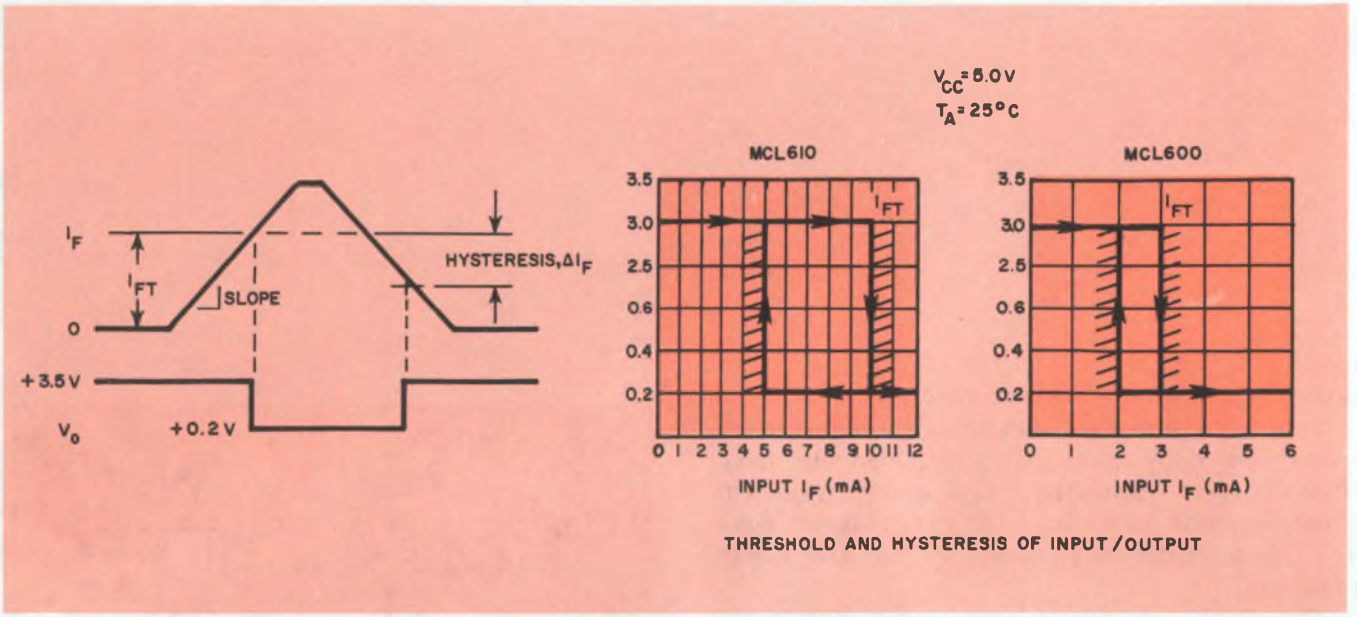
Therefore for direct-logic drive, the opto-isolator input isn't specified as HIGH or LOW, as in normal gate inputs. Instead the LED input is ON or OFF as determined by the current flow through the LED. The input LED is a forward-biased diode. It has a threshold voltage, V_{FT}, of about 1.1 V. At the operating point, $V_F = 1.2$ to 1.3 V, the typical current for an MCL-600 series unit is $I_F = 10$ mA. The diode's



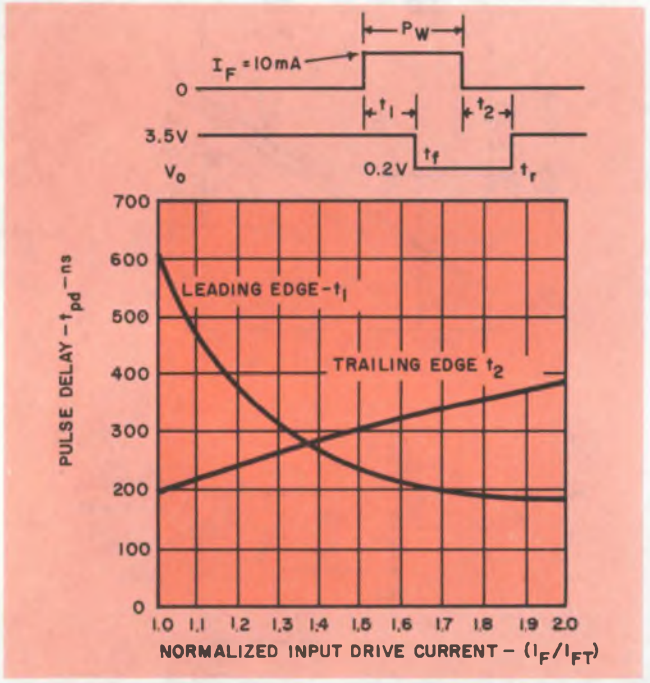
2. **The LED input of an opto-isolator** behaves as a diode with a threshold voltage of about 1.1 V and a dynamic resistance of between 1 and 5 Ω.



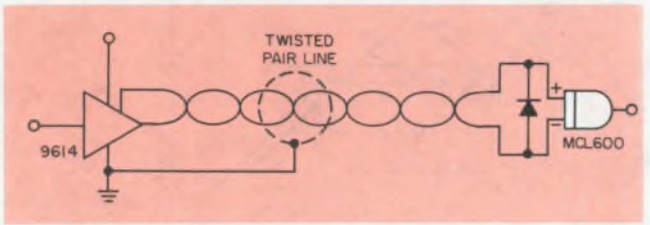
3. **The input current to the opto-isolator** can be derived from a TTL element and controlled by a resistor, R_L, in either a pull-down or pull-up configuration.



4. **A Schmitt-trigger circuit** sharpens slowly changing voltages and provides a hysteresis effect between the rise and fall of the signal edges. This squaring effect is useful in analog/digital interfacing.



5. **The opto-isolator's output delay can be different** for the output signal's leading and trailing edges.



6. **Data line coupling** is an important application that takes full advantage of an opto-isolator's input/output isolation and its pulse-sharpening and noise-rejection capabilities to couple lines to digital circuits.

equivalent dynamic resistance, R_E, is 1 to 5 Ω (Fig. 2).

When the input to the isolator is driven from a normal TTL output circuit, the drive circuit's logic LOW output (current-sinking state) is controlled by the value of R_L (Fig. 3a).

$$R_L = \frac{V_{CC} - V_F - V_{OL}}{I_F}$$

For an input current, I_F, of 10 mA and a typical V_{OL} (low output voltage) of 0.2 V for 7400 series logic,

$$R_L = \frac{5 - 1.3 - 0.2}{0.010} = 350\ \Omega,$$

which is a typical value.

An alternate method of driving the isolator is shown in Fig. 3b, where the drive-logic's HIGH output sources current to the isolator directly. However, I_F would be about 16 mA for the 74H00 series of TTL gates, with $R_L = 0$. An $R_L = 200\ \Omega$ would limit the I_F current to about 8 mA.

The circuit of Fig. 3a is preferred because it is the more stable design, with minimum power dissipated in the input driving circuit. Further, any inversion of the input logic gate is retained.

As a convention, the pull-down output of Fig. 3a, or logic LOW, is considered ON, and a logic HIGH is OFF.

Some input sources can't provide fast current transition pulses but have sloped rise and fall times (Fig. 4). However, the isolator logic element's output still has 10-ns transition times because of the unit's internal Schmitt-trigger circuit. Note that the two trigger levels differ because of the circuit's hysteresis. Thus this

opto-isolator is an excellent signal wave-clipping, or "squarer," circuit that can easily convert sine to square waves.

However, for fast rise-time inputs, the threshold levels and Schmitt circuit produce a time delay between input and output transition times (Fig. 5). The leading and trailing delay times, t_1 and t_2, are not necessarily equal. They both depend on the drive current that is delivered to the input LED in excess of the threshold current, I_{FT}. Though overdrive speeds the leading edge, it extends the trailing-edge time.

From the graph in Fig. 5, note the typical relationship between delay times and the ratio of I_F/I_{FT}. Equal delay on the graph occurs when the ratio I_F/I_{FT} equals 1.3. This ratio corresponds to values of I_F in the 10-to-12-mA range for the MCL600 opto-isolators. Equal delays distort the original pulse width least. A note of caution: The pulse width must always be greater than the leading-edge delay time, to allow time for the delays of the isolator circuits to stabilize.

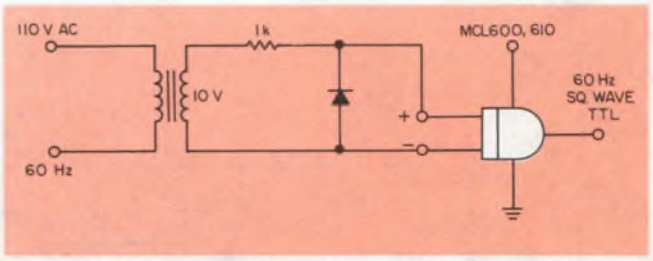
Also, when the opto-isolator is driven at the end of a long transmission line, a series resistance in the line is not recommended. Overvoltage would then be required. Higher voltages charge the line more, and this charge must then be discharged when the logic level reverses. For maximum line speed, it is best to allow the LED to function as a voltage clamp. A silicon diode, connected in parallel opposition to the LED, serves both to clamp negative voltage swings and to protect the LED from reverse-voltage breakdown (Fig. 6). Of course, because of its squaring ability, the opto-isolator will reconstitute any distorted input signals to TTL compatibility.

Another practical application of the device's squaring ability occurs in a sine-wave-to-TTL signal shaper for conversion of 60 Hz to accurate timing and synchronizing pulses (Fig. 7).

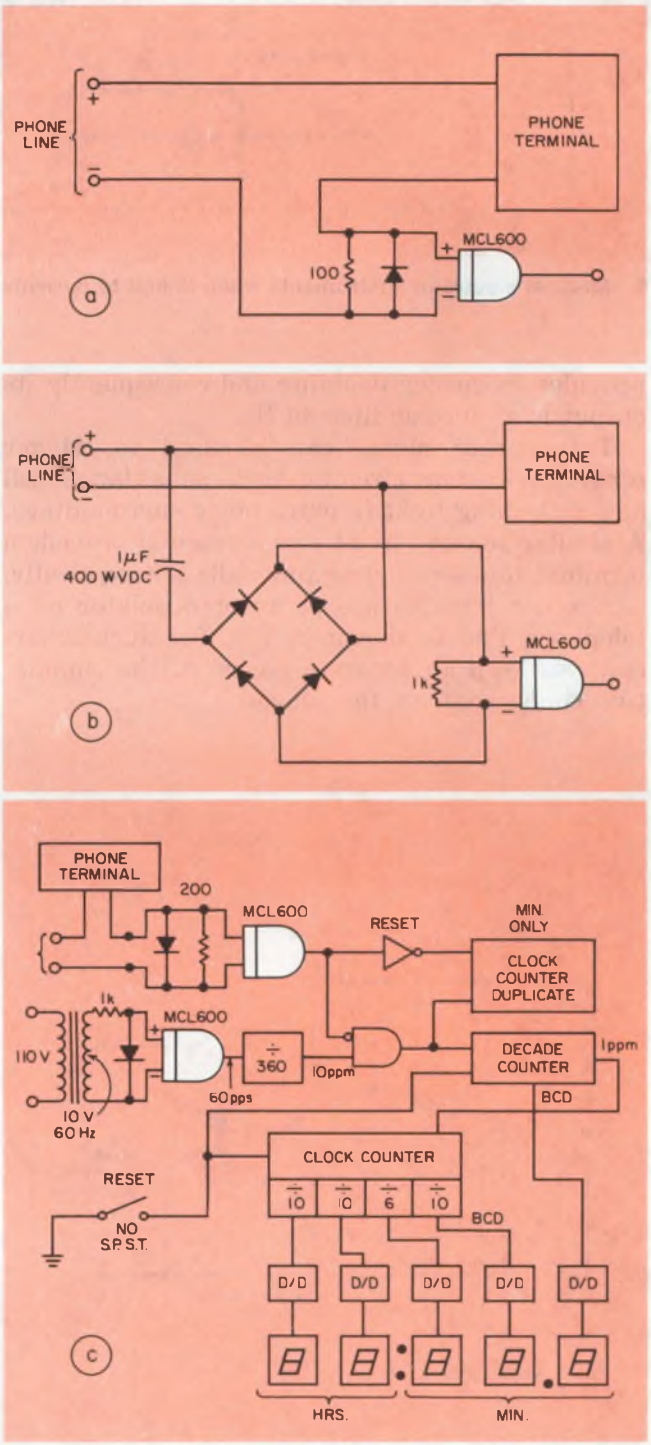
Coupling to phone circuits

The opto-isolator is particularly useful in telephone circuits. A series circuit can monitor and record dialing pulses and indicate on-line conditions without disturbing the system (Fig. 8a). The resistor, R, shunts most of the line current and provides line continuity for currents below the LED's threshold. The inverse parallel-connected diode conducts the reverse phase of the ac current used in the ring circuit.

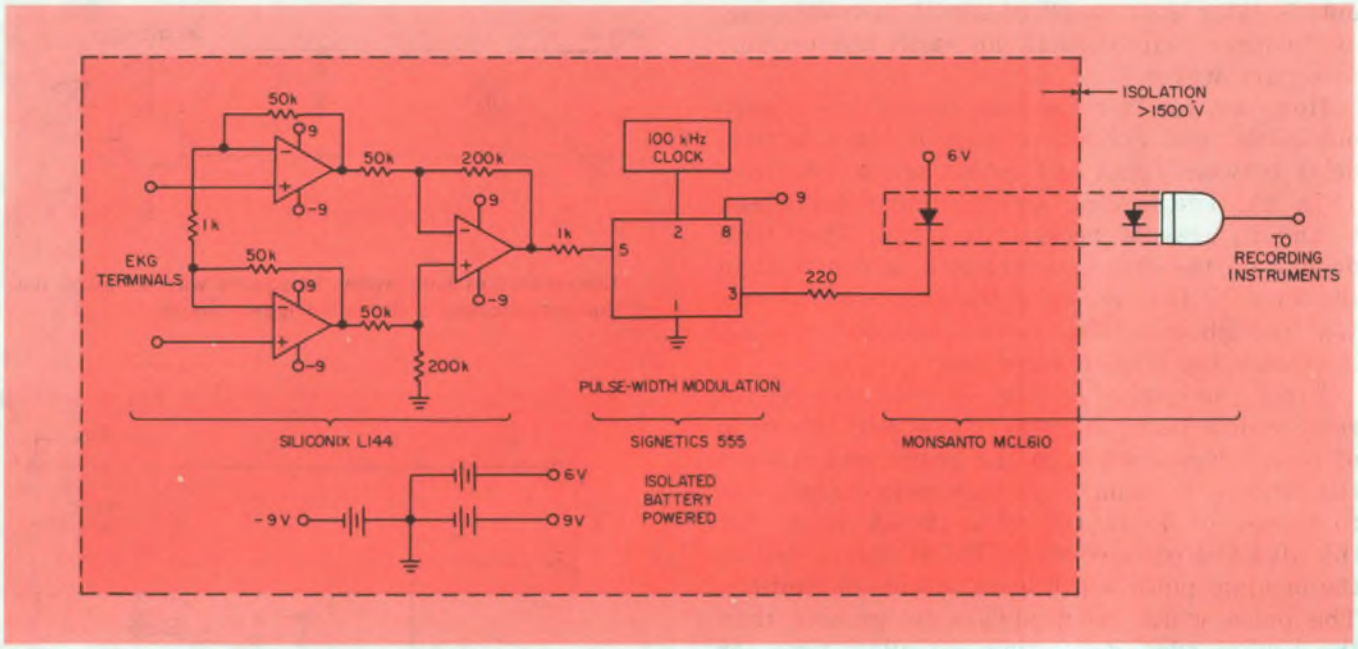
However, to detect the ringing condition of the phone, the cricuit in Fig. 8b would be used. The ring signal is 100 V rms at 20 Hz and activates a mechanical bell. The 10-mA load of the opto-isolator would not affect this ring voltage. The 1-μF capacitor presents a 10-kΩ impedance at 20 Hz and acts as the current-limiting device for the LED input. The bridge rectifier



7. **Conversion of sine waves to square waves** makes use of the opto-isolator's Schmitt-trigger circuit.



8. **The isolation of the optocoupler** is needed in phone-line circuits to detect the off-hook condition (a), the ringing signal (b) or to build a phone timekeeper (c).



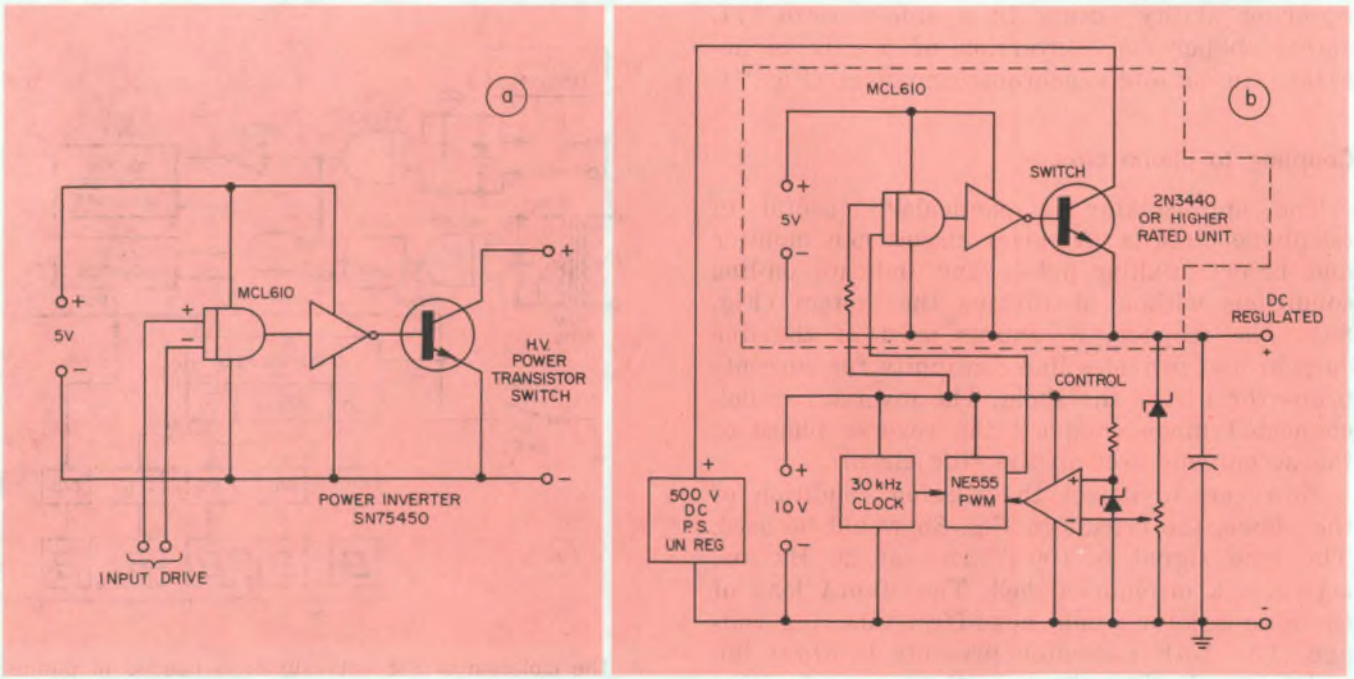
9. **Medical electronic instruments when linked to patients** need the high-isolation qualities of opto-isolators.

provides frequency doubling and consequently its output is a more audible 40 Hz.

This output signal can be used to trigger other devices or circuits, such as a large bell and a flashing light in extra-noisy surroundings. A similar sensor circuit can be used in a modem terminal to answer incoming calls automatically.

Another possible use of an opto-isolator on a telephone line is shown in Fig. 8c. Such a circuit can keep an accurate record of the cumulative time spent on the phone.

On-line phone current causes an opto-isolator, such as the MCL600, to enable an AND gate to pass 10-ppm clock pulses. The clock pulses are derived from the power line by counting down the 60 Hz after squaring with a second MCL-600. The gated signal is then counted by a decade counter in tenths of minutes, minutes and hours in a clock counter circuit, and displayed on seven-segment numeric devices. A duplicate counter with an automatic reset from the gating control can display the duration of



10. **Sensing and controlling** regulated high-voltage, high-power supplies require the isolation properties that the opto-isolator can provide. The isolator can couple a high-voltage level to a low-level control circuit.

any individual call.

One application where high isolation is absolutely essential is the monitoring of electrocardiograms. During EKG measurements without isolation, improperly grounded line-powered equipment can kill the patient.

In Fig. 9, the EKG voltage is converted to pulse-width modulation, which then powers the LED. The patient-connected system is powered by a battery pack, and the optocoupler provides 10^{12} Ω isolation that can withstand 1500-V-dc stress between the patient and the recording equipment.

Isolated power switch of many uses

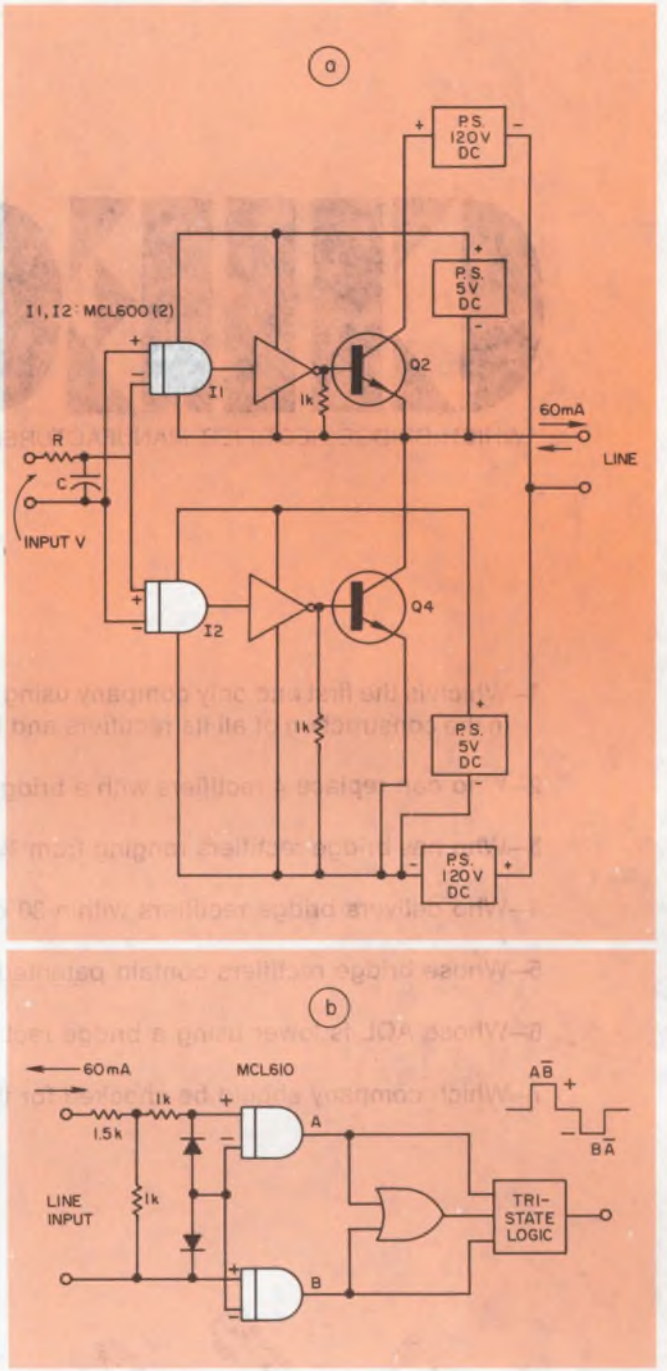
The opto-isolator's frequency response extends down to dc, so it can be used wherever long-term signal levels must be maintained. In Fig. 10a the logic isolator drives an SN75450 power inverter, which, in turn, drives a power-transistor switch. The power transistor can be a high-voltage unit. Since the 75450 can supply 500 mA into the power-transistor's base, the transistor can easily handle to 5 A in the saturation mode. In the turn-off condition, the inverter clamps the power-transistor's base to help reduce the transistor's recovery time.

This basic circuit has many applications. For example, in a switching-regulator power supply (Fig. 10b), the isolator circuit of Fig. 10a is used to couple pulse-width-modulated pulses from the low-level error-feedback circuits to the high-voltage, high-power switching device that controls the output. The isolator's low coupling input/output capacitance, typically 1 pF, prevents high-voltage spikes from feeding back and interfering with the modulator's operation.

Also, two power-switch circuits can be combined to make a dc teletypewriter polar-transmitter "relay" (Fig. 11a). In this circuit the input LEDs are connected in parallel but with opposite reversed polarity to sense the polarity of the input voltage.

Since MCL600 units provide a logic HIGH with no input current, both switching transistors (Q_2 and Q_4) are OFF for a no-input condition. Q_2 or Q_4 is turned ON only when its respective LED is ON, and only one LED can be on at a time. The input RC filter provides a time delay when the polarity changes to allow the conducting transistor to recover before the cut-off transistor starts to conduct. And the associated power sources are current-limited to 60 mA and adjusted for the particular line-load conditions.

A matching polar receiving "relay" is arranged with two LEDs connected in inverse-series. Opposing silicon diodes provide a current path until the threshold current of the LED



11. **Opto-isolator circuits can function as polar transmitter relays** (a) and polar receiver relays (b).

begins (Fig. 11b). The EXCLUSIVE-OR circuit provides an indication of an open-line condition when both opto-isolator units have logic HIGH outputs. Thus a three-state logic output can be obtained or the EXCLUSIVE-OR output can be used as an alarm signal for open-line conditions. ■■

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2. Cushman, R.H., "Designer's Guide to Optical Couplers," *EDN*, July 20, 1973, pp. 50-57.
3. Monsanto E.S.P., *Application Notes Series 500 through 520.*

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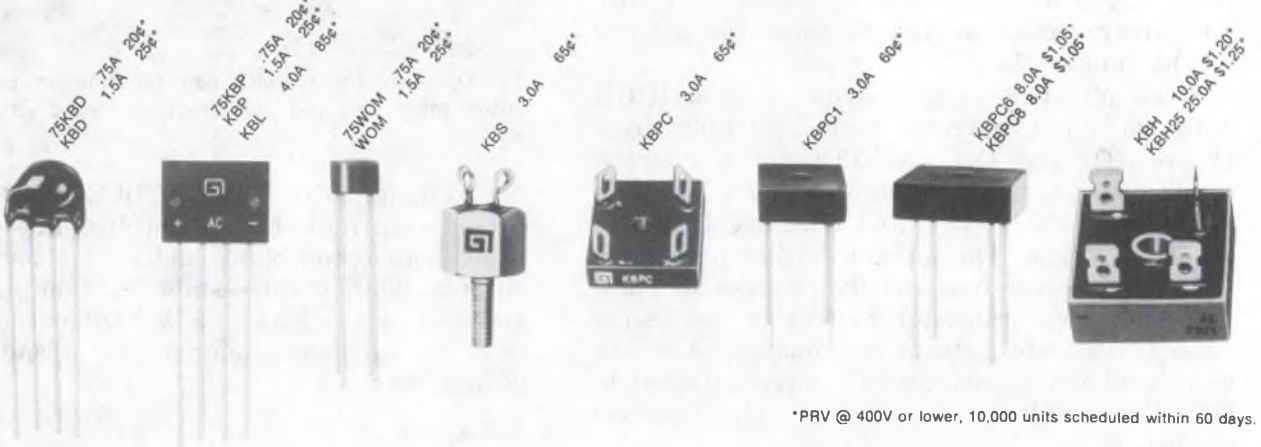

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INFORMATION RETRIEVAL NUMBER 43

MOS/LSI microprocessor selection: Here are basic hardware, software and design points to consider before you start a microcomputer design.

With the suddenly popular MOS/LSI microprocessor turning up in many new and intriguing applications, some down-to-earth questions are confronting designers: Is a microprocessor right for my application? If it is, which one should I choose?

Microprocessors are used primarily to replace or upgrade random-logic designs.[1] Selection problems can be simplified by careful analysis of hardware requirements, software capabilities and the design aids offered by manufacturers.

A microprocessor is more efficient than a random-logic design when the following conditions are present:

- About 50 or more ICs are used in sequential or combinational designs to perform many functions.
- Functional flexibility or expansion capability is desired.
- Random collection and routing of data are required.
- Complex, logic decisions must be made. (Array logic—in the form of ROMs, pROMs and PLAs, or programmable logic arrays—is another alternative for this condition.)
- Arithmetic computations are needed. (Bipolar 4-bit arithmetic logic units and some of the newer logic devices can also fulfill this need.)
- Speed requirements are not excessive. Although microprocessor speeds are not high, the use of wide-word, or multiple microprocessors, can increase throughput.

Microprocessors can be used in any quantity. For high-volume—more than 25,000 units—a small number of microprocessors can be used for prototyping or pre-production runs before you go to a custom LSI design.

A listing of some microprocessors and vendors appears in Table 1.

Alan J. Weissberger, Microprocessor Applications Engineer, National Semiconductor, 2900 Semiconductor Dr., Santa Clara, Calif. 95051.

What are the key features?

The importance of individual microprocessor characteristics depends heavily on the application. Here is a checklist of key features to consider before making a selection.

Table 1. Some microprocessors announced and expected

4 bit Structured chips, cards, systems	4 bit Building block chips	8 bit Chips, cards, systems	12 bit Chips	16 bit Cards	Custom Chips
*Rockwell PPS-4, 20102D02 *Applied Computing Technology PPS-4MP, CBC-4, prototyping systems (for PPS-4 and MCS-4) *Intel 4004, MCS-4, Intellec 4 *Fairchild PPS-25 National Semiconductor IMP-4, FILU	*National Semiconductor RALU, CROM Monolithic Memories bipolar LSI controller 6701	*Intel 8008, MCS-8, Intellec 8, 8080 *National Semiconductor IMP-8C, IMP-8P Signetics PIP Motorola M6800 RCA COSMAC DEC MPS, PDP-8A Pro-Log MPS-803, MPS-805 Rockwell PPS-8 General Automation (Rockwell circuits) LSI 12/16	Toshiba LCS-12 Intersil CMOS LSI PDP 8-A	*National Semiconductor IMP-16C, IMP-16L, IMP-16P Computer Automation Naked Mini LSI 1 Raytheon RP16 (bipolar LSI)	American Microsystems (used by Frigidaire) Western Digital (used by DEC) Mostek Rockwell (used by General Automation)

* Introduced commercially

- Word length.
- Architecture.
- Speed.
- Programming flexibility.
- Completeness. (How many additional circuits are needed to make it work?)
- Available design aids (both hardware and software).

Word length should be the first feature to consider (Table 2). The determining requirements are analog resolution, computational accuracy, character length and width of parallel digital inputs or outputs. Microprocessors are structured for fixed word lengths or for modular expansion by a parallel combination of building-block chips. In the latter category, National Semiconductor and Monolithic Memories have 4-bit "slices" of a CPU, or central processing unit. In some microprocessors the word lengths for addresses exceed those for instructions—for example, General Automation's LSI 12/26, Intersil's LSI PDP 8-A and Rockwell's PPS-4. A large address word eliminates the need to manipulate smaller—4 and 8-bit—data registers to obtain 12-to-16-bit addresses. Higher-speed parallel, rather than time-multiplexed serial, addressing is a resulting benefit. In general, longer word lengths for either addresses or instructions provide higher system throughput and more powerful memory addressing, while shorter word lengths require somewhat less hardware and smaller memories.[2]

Architectural features include general-purpose registers, stacks, interrupts, interface structure and choice of memories. General-purpose registers are used for addressing, indexing, status and as multiple accumulators. They simplify programming and conserve main memory by eliminating memory buffering of data. Multiple accumulators are especially important for ROM programs that have no writable memory.

Stacks can be used for nesting subroutines and interrupts and for temporary storage of data when programs reside in ROMs. Stacks consist of read/write (RAM) memory locations maintained by software—called a pointer stack—or by registers built into the processor chip—called a hardware stack. The pointer stack—found in the Intel 8080—offers size restricted only by the external RAM, but it must be maintained by software. The hardware stack—found in National Semiconductor's IMP, Rockwell's PPS-4, and Signetics' PIP—is faster, but its size is limited. An additional advantage of the hardware stack is that RAM is not required.

For applications where asynchronous or unpredictable events occur, an interrupt capability is valuable. Throughput increases, since the processor can perform useful work concurrent with I/O (input/output) operations. The major characteristics of this capability include interrupt latency (time to recognize the interrupt and branch to the service routine), response (time to identify the interrupted device and be-

Microprocessors: Some ABC's

All microprocessors use large-scale integrated-circuit technology. Silicon-gate, p-channel MOS is the most commonly used process. But manufacturers also employ n-channel MOS, silicon-on-sapphire MOS and bipolar processes for increased speed. And they use complementary MOS for lowered power dissipation.

Programmability—that flexible feature not found in random-logic designs—can be obtained on one of two levels. A very detailed level of control is provided at the *micro*-instruction level. These micro-instructions may be used to obtain a *macro*, or machine-language, instruction set, which is then used to write control programs for the microprocessor. New machine-language instructions may be defined by coding new micro-routines. In this way an instruction set can be tailored to an application.

Control programs can also be written in microcode. This provides increased execution speed and more detailed control at the expense of more difficult programming. Microprocessors that are not microprogrammable contain fixed, general-purpose instruction sets, which are often adequate for most applications.

Table 2. Applications and characteristics depend on word length

	4-bit Arithmetic or simple control functions	8-bit Controller	16-bit General Purpose	20, 24, 32-bit Special purpose
Typical applications	BCD display control or calculation Electronic cash registers Business and accounting systems Credit card verification Intelligent instruments Appliances Game machines	Intelligent terminals and instruments Data concentrators or front-ends (communications pre-processor) On-board computer (automobile) Process, numeric and machine control Text editing typewriters Traffic control Education—computer science courses or computer design projects Medical electronics Measurement systems	Data acquisition systems—a/d, d/a processing Process monitoring and alarm Supervisory control—gas, power, water distribution Navigational systems Automatic test systems (particularly in-house LSI testing by semiconductor manufacturers) Word processing systems Peripheral control	Digital signal processing—FFT, auto correlation Digital filtering Interfaces to larger computers (wider word length)
Key characteristics	Controller or arithmetic processor Simplified I/O BCD arithmetic instructions Address formation capability Small parts count for minimum systems Low cost and easy to use	Flexible I/O Hardware to reduce software overhead and simplify I/O Multiple addressing modes Interrupt feature Speed		Higher throughput and/or speed requirements Modular LSI building blocks Multiprocessor configurations Special math instructions or routines

gin execution of the device service code) and software overhead (to get to the service routine and return to the main program). Single line, multilevel and vectored interrupts offer various speed-hardware tradeoffs. Cascaded interrupt capability (interrupting an interrupt) is essential if slow and fast devices are to be mixed in a system. Interrupt enable flags are used to mask or unmask individual levels.

In a single-line interrupt system, all device-interrupt requests are ORed together to form one request line. The program must identify the device interrupting and resolve priority. This may be done by issuance of a device-select status order, in which all devices report their interrupt status on an assigned bit of the I/O bus. Multiple sense (multilevel) lines are sometimes provided for this function. These lines are interrogated by individual device-select status orders. A vectored interrupt offers very fast response by directly branching to a memory location that corresponds to a specific interrupt. Request/acknowledge and interrupt identification use external hardware, thus alleviating software overhead and increasing speed.

Consider the latency and response times of National Semiconductor's IMP-16C single-line and vectored interrupts (Table 3). The total time to get to the service routine for the device can be as high as 34.85 μs for single-line interrupts, but only 4.55 μs for vectored interrupts.

The choice of memories is important because the memory section often represents a major portion of hardware cost. Read/write memories are commonly used for variable data storage and for program storage during software development. Field-programmable ROMs have become quite popular for program storage in small and intermediate-volume systems and for high-volume prototype systems. MOS pROMs may be erased by ultraviolet light and then reprogrammed. For ease of design, memory modular blocks should be used; the memory-address bus width determines the upper limit of expansion (maximum number of addressable locations). Available microprocessor cards include ROM, pROM and RAM memories and eliminate the need to design or specify a memory system for limited storage requirements.

The interface structure should be easy to use for simple, low-cost applications (parallel or serial). Separate busses for data, addresses, memory and peripheral input and output are most appropriate in this case.

While the type of control depends on the processor, higher throughput results from the use of a direct-memory-access (DMA) bus. In this arrangement, a peripheral device communicates directly with memory without disturbing the CPU. Interfacing is more complex because request and acknowledge signals must be exchanged between the device and an autonomous bus controller. When a single bus is used, data and addresses must be time-multiplexed, and latches must be provided to hold the address stable while memory or a peripheral are accessed.

Provision for handshake I/O control allows convenient interfacing with peripherals of varying response time. Control flags and jump condition inputs are useful to reduce hardware decoding and software overhead. If multiple devices are to be connected over the same I/O lines, three-state or open-collector TTL logic is required to drive the bus. The microprocessor I/O circuitry should directly interface with these signals.

How do you measure speed?

Cycle time, state time, minimum instruction time, time to add two numbers, and interrupt response time have been given to measure speed. These numbers are rather meaningless, for they do not measure the power of the instruction set. Benchmark programs for a specific task should be coded and the execution times compared to determine which microprocessor meets the speed requirements.

The degree of programming flexibility can be determined from an examination of the instruction set.[3] Multiple addressing modes conserve main memory, simplify programming and increase speed through single-word memory-reference instructions. For programs stored in ROM or pROM, indexing or pointer addressing are the only means to access data tables in program loops. Other useful capabilities include bit and byte manipulation, multiply and divide, double-precision arithmetic, normalize and I/O control instructions.

Custom instructions through microprogramming can upgrade performance by optimizing the microprocessor architecture. In some cases other processors, including minicomputers, may be emulated with the microprogram control technique, thereby enabling software built for a larger machine to run on a microprogrammed microprocessor.

The number of additional IC packages required provides an indication of the completeness of the microprocessor set. For example, the Intel 8080, a one-chip microprocessor, requires six logic circuits, nine memory packages and two clocks for a minimum system. To drive more than one TTL load, address and data buffering must be supplied.[4] In many cases a more powerful multichip processor may be used with no increase in total component count.

Table 3. Latency and response times: Keys to speed

	*Latency time—μs	Response time—μs	Total interrupt overhead time—μs
Single-line interrupt	5.95	0-28.9 (1 to 16 devices)	5.95-34.85
Vectored interrupt	4.55	0 (independent of number of devices)	4.55

* Plus time to complete current instruction

Functions generally requiring additional components include clock generation and timing, memory and I/O control, data and address buffering, multiplexer inputs, interrupt control, and sometimes memory refresh control (for dynamic MOS RAMs) and additional power-supply voltages.

What support do you need?

In addition to the microprocessor itself, support should be provided by the manufacturer to simplify the application of the processor and the development and prototyping of the end product. This category includes documented manuals, application literature, area field specialists, prototyping systems—such as National Semiconductor's IMP 8P and 16P, Intel's Intellec 4 and 8 and Applied Computing Technology's PPS-4MP (for Rockwell PPS-4). Also generally useful are program-development software and the ability to fashion the microprocessor into different configurations.

Prototyping systems are essential to develop and debug hardware, firmware and software for the end product. The ingredients of such a prototyping system include expanded memory capability, a teletypewriter or card-reader interface, power supply, chassis, control panel and support software (assemblers, compilers, loaders, debug and edit packages). A pROM programmer provides very fast turnaround time when control programs are modified.

With a processor card, you get an assembled and tested microprocessor system, complete with memory. Cards are often more economical than chips for low-volume applications. They may be used for development of early production models for high-volume applications, before they are replaced by an in-house design.

Of course, chips represent the ultimate in low cost and small size, but the designer must interface them with additional components and perform the necessary tests. The components selected must meet exact speed, power and functional specifications.

Manufacturers often point to such features as the number of instructions and registers, memory bandwidth and speed to measure computing power. These criteria are often misleading because they are defined differently by various manufacturers. The only real way to determine the effectiveness of a microprocessor is to code benchmark programs or experiment with representative logic designs. ■■

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2. Reyling, G., "Microprocessors—Next Generation in Digital Design," *EE Systems Engineering Today*, November, 1973, pp. 86-90.
3. Weiss, D., "Software for MOS/LSI Microprocessors" (three-part series), *Electronic Design*, April 1, 1974, p. 50.
4. Mazor, S., "A New Single Chip CPU," *COMPCON 1974 Proceedings*, pp. 177-180.

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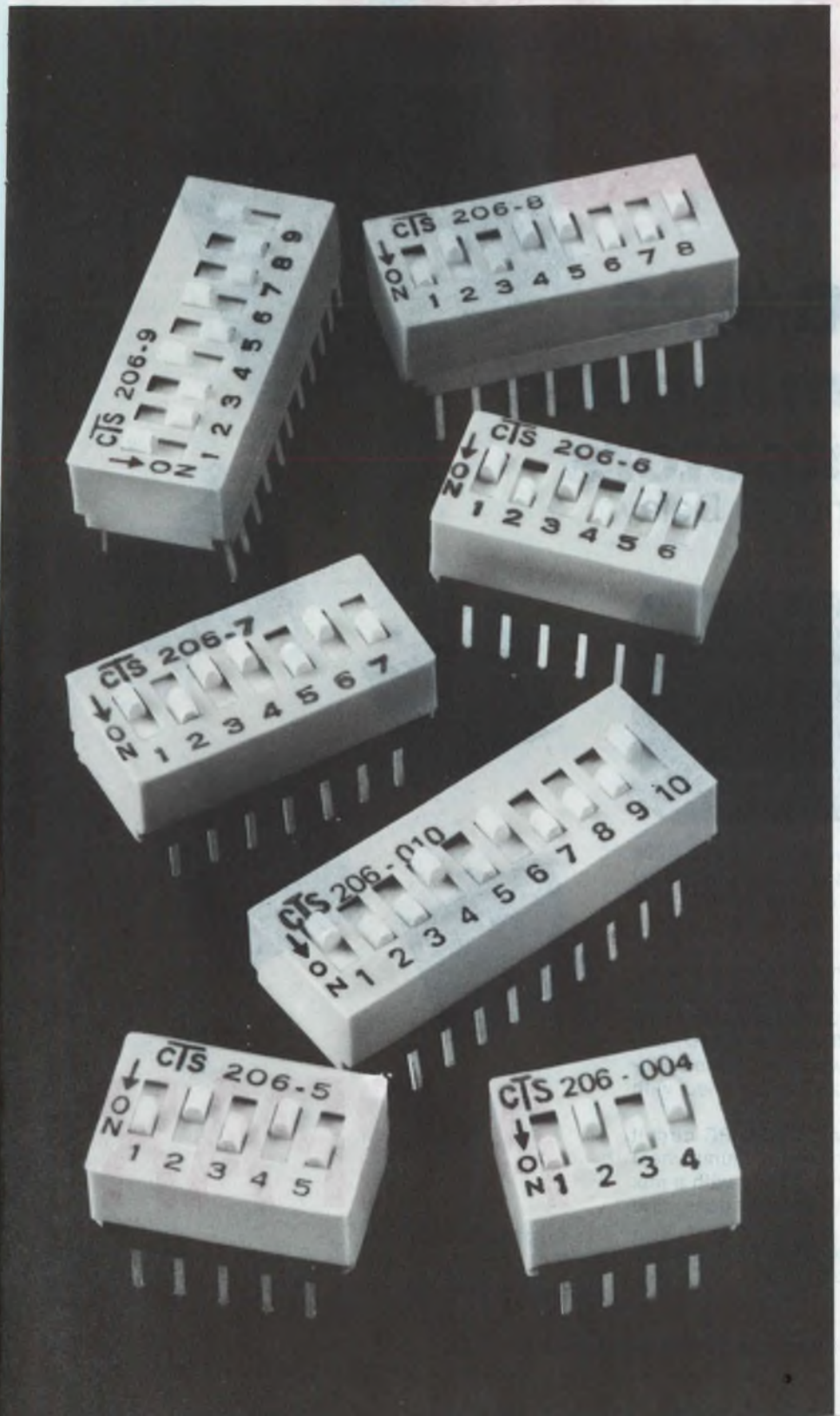

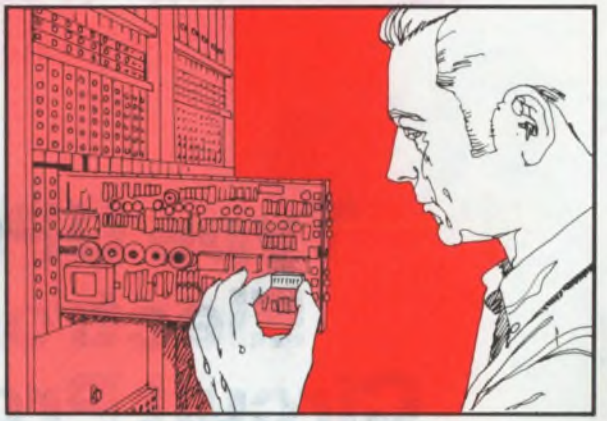

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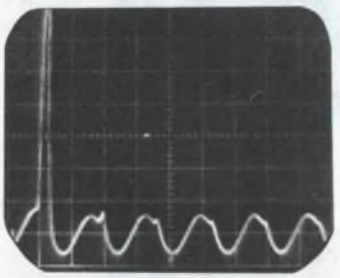

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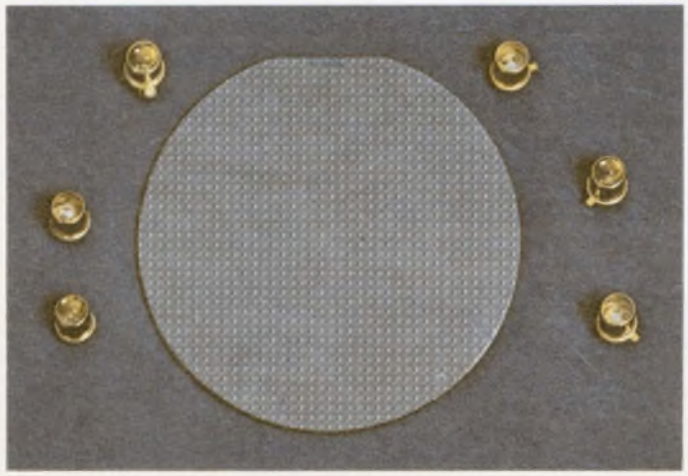
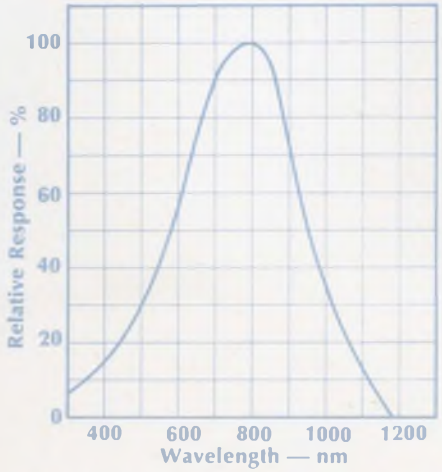
Vactec npn epitaxial large chip, high sensitivity phototransistor. An enlarged section of the wafer forms the colorful background.





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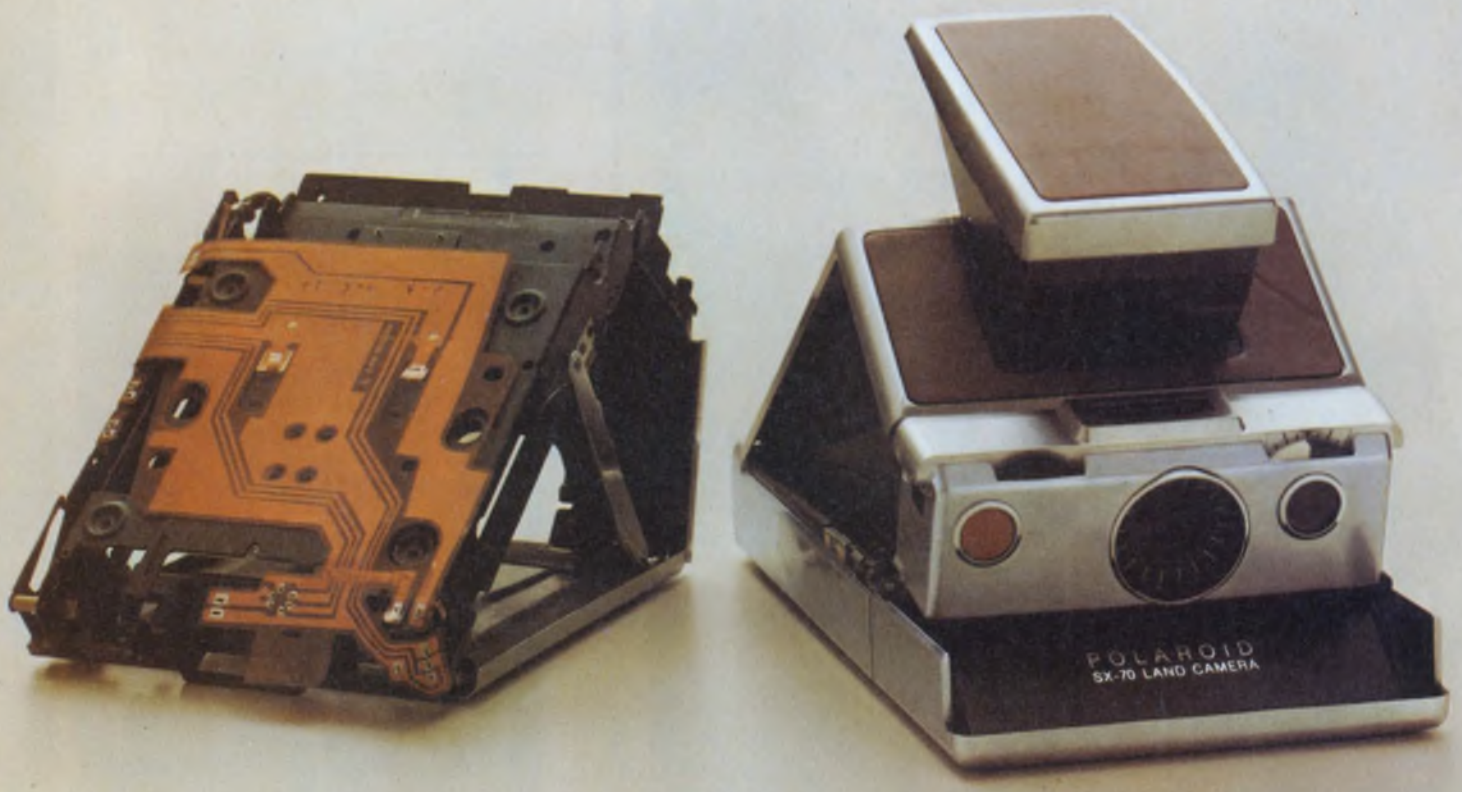

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A small, low-cost battery system can keep a large-scale-integrated memory nonvolatile if the power goes out or is reduced critically. The standby system will provide timed bursts of refresh cycles to keep the data intact for more than a month, while consuming a minimum of power from the battery.

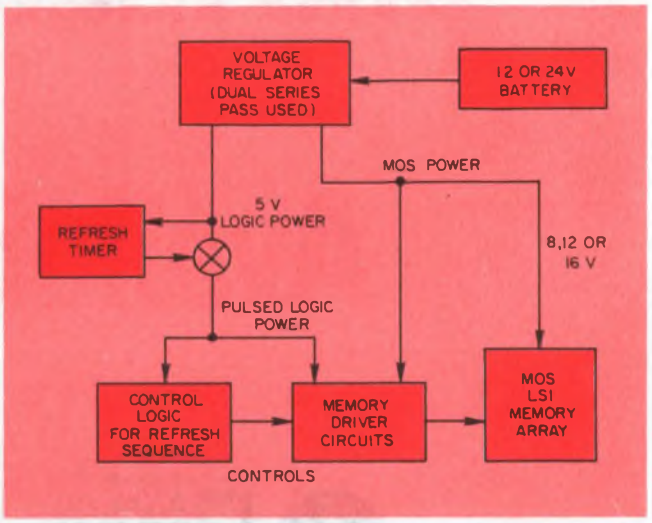
With the battery setup, LSI memories can compete fully with core on the basis of price and reliability—especially in view of the volume production promised by the recent introduction of 4-k RAMs.

The nonvolatile LSI memory system has two modes of operation. In the normal mode the memory operates on dc power derived from an ac power line. During this time the memory serves the central processing unit or another memory user. Manufacturers' spec sheets and applications notes adequately describe the device's operation in this mode.

In the standby mode, the memory system operates on a battery, and it performs only the refresh cycles required to maintain data integrity. Such a system has the following requirements:

- LSI memory arrays capable of operation at low power in a standby mode.
- A battery capable of supplying current for the duration of the nonvolatile period (see box).
- A voltage regulator to supply logic and MOS power from the battery.
- A power supply to charge the battery during the normal operating mode.
- Power-switching circuits to provide pulsed logic power.
- Control logic to perform the required memory refresh sequence.
- MOS driver circuits that can be operated on pulsed power.
- A refresh timing circuit that can operate at low power levels.

Unlike the operating mode, the standby mode is usually overlooked in the data provided by semiconductor houses. Consider the standby system in Fig. 1. Two power voltages are provided by the battery-regulator combination—logic power and MOS power. Logic power, typically +5 V, runs the standby refresh timer and, through a switch, the control logic and the interface drivers for the MOS arrays. MOS power, typically +12 or +16 V, runs the MOS LSI memory arrays and the interface drivers between the control logic and the memory arrays. Some MOS LSI memories require a third or fourth voltage for operation. These extra voltages are normally used only by the memory arrays.



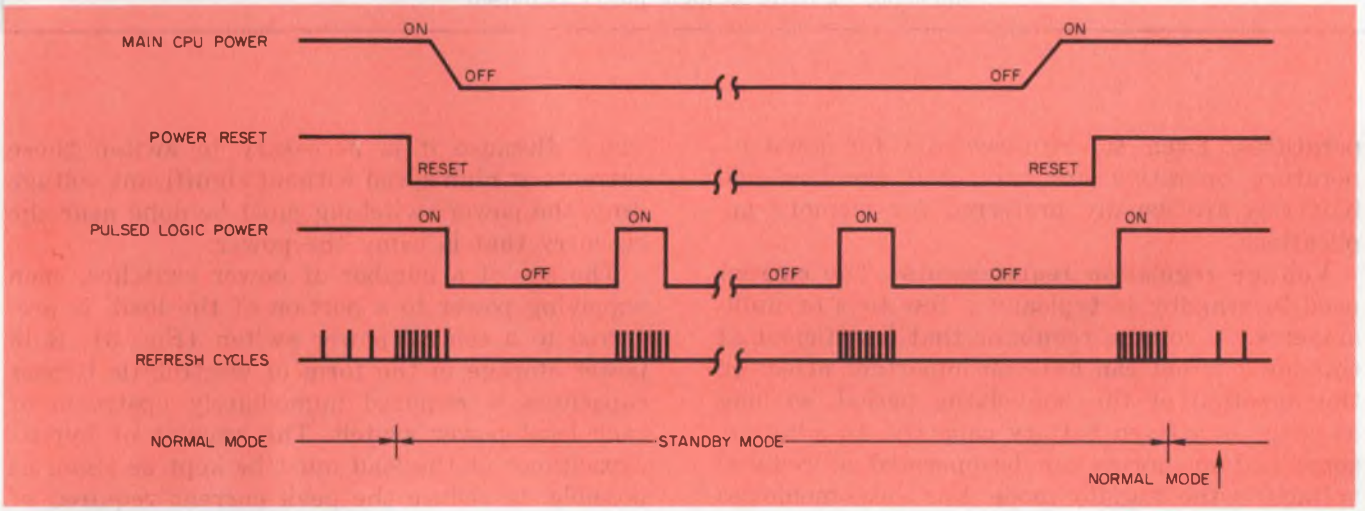
1. **Battery-regulator combination** furnishes logic power (5 V) and MOS power. The memory is refreshed in pulsed cycles by the timer to conserve the battery. Relatively simple circuits suffice.

Logic power for the refresh logic and for the driver circuits, in most cases, is pulsed on for a low duty cycle to minimize power consumption. The switch that applies the pulsed power is controlled by a timer. The pulse rate is such that the particular memory array type used maintains data integrity. When logic power is pulsed on, the control logic for the refresh sequence steps through a series of operations to refresh the data in the memory arrays. The refresh timer then turns off the pulsed logic power until it is time for the next refresh sequence.

Daren Appelt, Member of the Technical Staff, Texas Instruments, Inc., Digital Systems Div., P.O. Box 2909, Austin, Tex. 78767.

Most 1024-bit memory arrays require 32 memory cycles to complete memory refresh—that is, to address all 32 rows; 4096-bit arrays require 64 cycles. During the normal operating mode the refresh cycles are spaced evenly in time to create the least interference with the CPU. In the standby mode these cycles are performed in a burst, during the time when the standby pulsed logic power is on.

Transition between the two modes, operating and standby, is another aspect to consider. Fig. 2



2. **Control of the transition** between the memory's standby and normal operating modes is via a power-reset signal furnished by the main system supply. During the standby mode, refresh cycles are performed in bursts; in the normal mode they are spaced out to avoid interference with the CPU. The bursts continue until main power is restored which clears the power-reset signal. Normal operation begins after one last refresh burst.

shows the transitions from normal to standby and back to normal again. Control of the transitions is accomplished by a power-reset signal generated by the main system power supply to indicate when main power is unstable. When the reset signal is applied, the memory system immediately enters the standby mode, does a burst of refresh cycles and then switches off the pulsed logic power. The refresh bursts repeat, as determined by the standby refresh timer, until main power is restored. When main system power is restored and stable, the main system power supply clears the power reset signal. Upon completion of the next refresh burst, the pulsed logic power will stay on, and the memory system will re-enter its normal mode.

Design elements of standby mode

Each of the elements in the standby system has special design requirements for effective standby-mode performance (Table 1). The major design objective is to reduce the standby power consumption so that a small, low-cost battery will provide a long nonvolatile period.

There are eight subsystems that must be considered for a viable memory unit. The subsystem requirements include:

Memory array requirements—To be useful in a nonvolatile memory system, an LSI memory array must satisfy the cost/performance and reliability required of it in the normal operating mode in addition to providing low-power standby operation. The details of the standby mode are often hidden in the vendor's specification sheet. First, there must be a zero Q-current state (low quiescent current state) for the device, in which the current drawn from the power lead or leads is near zero. (Some 1103-type devices require one of the address leads to be pulsed to reach this state.) Second, the device should have reasonably low input capacitance, particularly if the inputs require large voltage swings. The power burned just driving the input capacitance can be a significant factor—CV^2 multiplied by the repetition rate, for resistive driver circuits.

Battery requirements—Batteries for application in nonvolatile LSI memory systems should be sealed, rechargeable cells that offer long service life. Five-year service without maintenance is a good goal. Standby memory power use is characterized by repeated periods of light discharge and long periods of slight overcharge. Under these conditions, most NiCd batteries cannot deliver their rated capacity on the first full-depth discharge. If the memory is being designed for more than a month of nonvolatility, the self-discharge characteristics of the NiCd system may also become significant. Some of the newer, sealed lead-acid batteries do not have these drawbacks. Their capacity, however, is greatly reduced at low tem-

Table 1. System design elements

Condensed design characteristics	
Memory component	Special requirements in nonvolatile system
LSI Memory array	Low power standby operation
Battery	3-5 Year service life, sealed, low self-discharge
Voltage regulation	Efficient at low supply currents
Main system power supply	Maintains battery charge, generates a power failure reset signal
Power switching	Provides pulsed logic power, has local energy storage distributed near loads
Refresh control logic	Low power, operates on pulsed power
MOS driver circuits	Zero quiescent-current operation with logic power off, must not "glitch" as logic power is pulsed

peratures. Even so, requirements for low-temperature operation are rare, and the lead-acid batteries are usually preferred for memory applications.

Voltage regulation requirements—The current used in standby is typically a few tens of milliamperes. A voltage regulator that is efficient at this low current can have an important effect on the duration of the nonvolatile period, so long as there is a fixed battery capacity. In addition, some LSI memories can be operated at reduced voltage in the standby mode. For these memories the standby voltage regulator can be designed to operate with a lower voltage battery in order to conserve power.

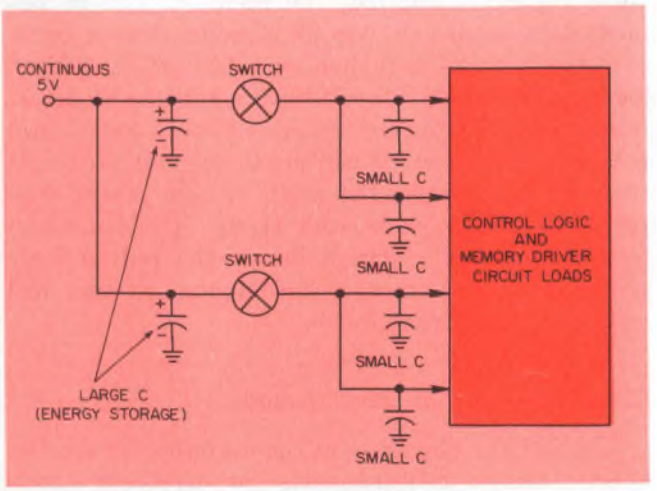
Main system power-supply requirements—The main power supply must provide power to charge the battery when ac power is on. This source can take the form of a simple trickle-charge circuit, unless ac power is expected to be off for most of the time. The main power supply must also generate a power failure reset signal, which is activated as soon as ac power failure is detected and then deactivated when power is restored and all derived dc power voltages are stable. This is the signal that causes the memory system to enter the standby mode. The importance of the correct sequencing of the power reset signal cannot be overstated.

Power-switching requirements—The power-switching circuitry applies the logic power from the standby regulator to the refresh control logic in pulses, as demanded by the standby refresh timer. This ability to switch off the power to the control logic and driver circuits reduces the power they require by a factor of 1000 in some cases.

But power switching is complicated by the fact that control logic (especially TTL) and driver circuits require bypass capacitors from power to ground. High peak currents result when power is switched on to capacitors from power to ground. In addition the MOS drivers draw high peak currents as they charge MOS circuit input capacitance. Because it is necessary to switch these currents at high speed without significant voltage drop, the power switching must be done near the circuitry that is using the power.

The use of a number of power switches, each supplying power to a portion of the load, is preferred to a central power switch (Fig. 3). Bulk power storage in the form of electrolytic bypass capacitors is required immediately upstream of each local power switch. The amount of bypass capacitance at the load must be kept as small as possible, to reduce the peak current required of the power switch and to reduce the power used in charging the bypass capacitance for each refresh event. Multilayer printed-circuit boards with ground and power planes provide an efficient power-switching system for this application.

Refresh control-logic requirements—The refresh-control logic performs a series of memory cycles to particular memory addresses. The sequence allows the dynamic cells of the MOS memory to be recharged. Power needed for this pur-



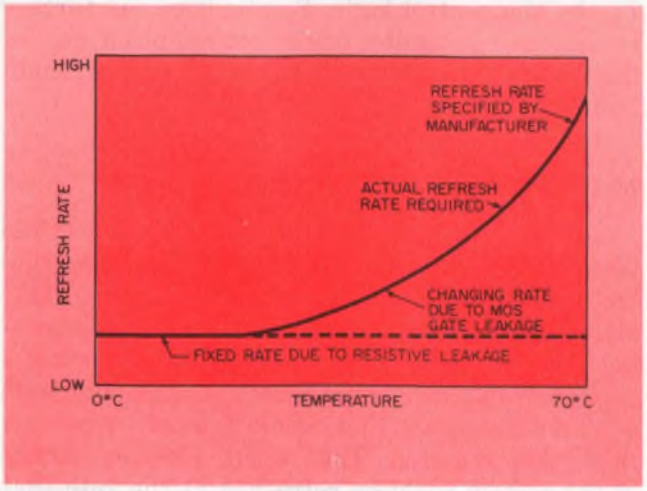
3. **The switched power is subdivided** near the loads to avoid voltage drops from the high peak currents drawn by bypass capacitors (with TTL logic) and MOS input capacitance. Simple transistor switches suffice for control of the dc power.

Table 2. Power budget for an 8-k memory

8k × 17 bit, 1103 memories used				
Function	Refresh rate dependent	Power at room temp	System percent	Percent of MOS
Control logic	Yes	3.8 mW	3.4%	9.5%
Driver circuits	Yes	5.7 mW	5.0%	14.2%
Clock capacitance	Yes	1.8 mW	1.6%	4.5%
Address capacitance	Yes	2.2 μW	—	—
MOS arrays	Yes	40.2 mW	35.5%	100.0%
Power switching	Yes	0.13 mW	0.1%	0.3%
MOS leakage	No	10.0 μW	—	—
Refresh timer	Yes	25.0 μW	—	—
Voltage regulator	Yes	61.7 mW	54.4%	153.5%
Battery power (total)	Yes	113.33 mW	100.0%	281.9%

pose may be reduced in several ways. Intelligent logic design can reduce the number of logic elements required. The technique used to generate memory timing signals is another factor. Delay-line or precision-RC timing are favored over digitally generated memory timing to reduce power consumption. Low-power logic elements, MSI counters, and even discrete components can often be used to advantage.

MOS driver circuit considerations—The memory driver circuits must have a zero Q-current state so they will not draw power between refresh cycles. In the zero Q-current state, the driver's output should be biased to maintain a ZERO signal to the memory arrays. Drivers must also be insensitive to their logic inputs when the control logic that feeds them is powered down. The insensitivity can usually be achieved by switching one or more of the driver supply voltages off during the interval between refresh events. When the supply voltages are switched, the drivers must not generate "glitches" on their outputs, since these will most probably affect the viability of memory data.



4. **To further decrease battery drain,** the refresh cycles are spaced in accordance with the memory temperature. Charge leakage decreases with temperature, but most manufacturers only guarantee the value at 70 C; so be sure to choose a conservative model.

Refresh timer considerations—The refresh timer is a key element of the standby system. It is the only circuit that operates continuously. It cannot use low duty-cycle switched power and therefore must be a very low-power design. The refresh timer should also sense the temperature of the memory, so that the refresh rate can be reduced at low temperatures. Fig. 4 shows the refresh rate requirement as a function of temperature for a typical MOS LSI dynamic memory. Most device manufacturers specify the refresh rate at 70 C.

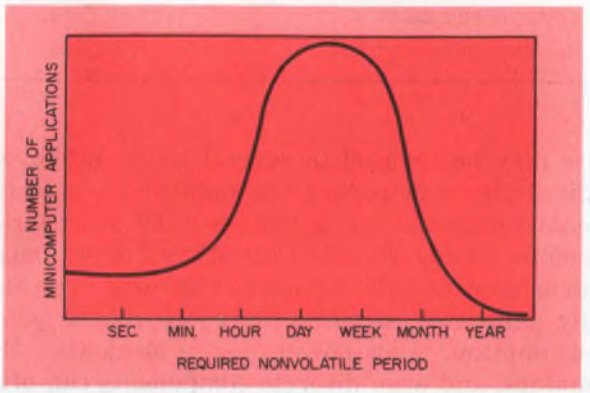
Because of the cost of testing at high temperatures, the devices are tested in production at room temperature at a low refresh rate. A refresh timer designed to sense temperature can reduce the refresh rate by a large factor. This can extend the nonvolatile period by a factor of 20 in some systems—a technique patented by Texas Instruments. In practice, the memory system designer must characterize the memory devices and apply a large measure of conservatism, because the LSI memory manufacturers do not currently specify or guarantee the entire temperature curve.

Standby power in the 960A mini

An example of how standby power can make an LSI memory nonvolatile is TI's 960A minicomputer. Table 2 shows the sample power budget in the standby mode of an 8 k × 17, Model 960A, minicomputer memory. A 4.5 A-h, 24-V battery is used. At room temperature the nonvolatile period is a little over a month. The memory is built

How long are data kept?

Just how long should a memory system be designed to operate without normal power? For some applications five minutes is sufficient. For others, a month or more of power outage must be tolerated. The plot shows the results of an informal survey of minicomputer applications. The number of computers in the field is plotted against the required nonvolatile memory time. Most minicomputer memory requirements are for between a day and a week of nonvolatility. Typical of these are data communication, process control, and automation applications.



of 1103-type devices.

Consider the power budget of the 960A standby system with a view toward reducing power consumption even further. The voltage regulation requires 54% of the power from the battery; a highly efficient regulator would double the nonvolatile period. Of the power not wasted by the regulation, 82% is used by the memory devices themselves, 11% by the MOS drivers and a mere 7% by the control logic. Possibilities for further reductions in standby power consumption lie, for the most part, with the LSI memory device manufacturers.

What's ahead for LSI memory

As advances are made in the memory devices themselves, the requirements for a complex control sequence for each refresh event will likely disappear. Refresh will involve no more than pulsing a single clock input to the memory device.

Conceivably memory devices could be built with extra storage cells that would indicate when refresh was required. Then every memory device in the system could be refreshed at the rate that its leakage required, thereby reducing refresh rates by a factor of perhaps 100. At such a low refresh rate, it would be easy to achieve many months of nonvolatility at very low cost. ■■

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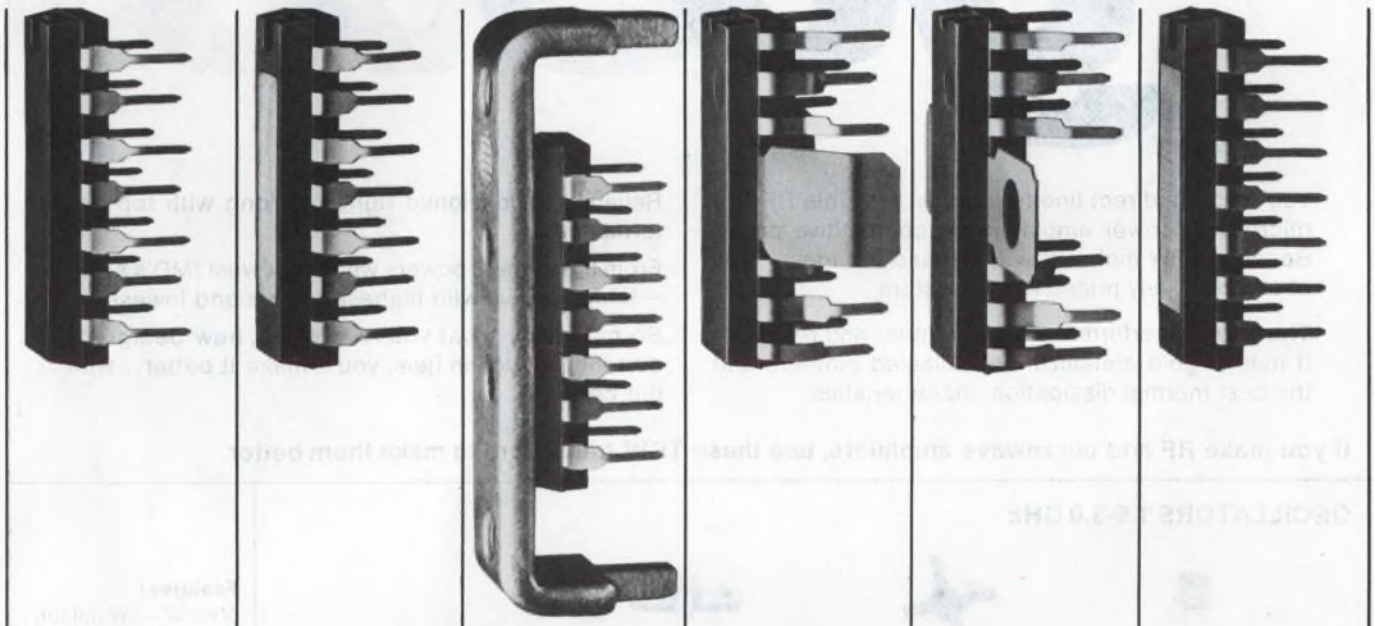

TBA 820
2W - 12V - 8Ω
0.75W - 6V 4Ω

TAA 621 A12
2.2W - 18V - 16Ω

TAA 611 B12
1.15W - 9V - 8Ω

TBA 641 B11
4.5W - 14V - 4Ω

TAA 621 A11
4W - 24V - 16Ω

TBA 810S
6W - 14.4V - 4Ω
Thermal shut-down

TBA 800
5W - 24V - 16Ω
4.7W - 18V - 8Ω

TCA 830
3.4W - 12V - 4Ω
2W - 9V - 4Ω
Thermal shut-down

TCA 940
10W - 20V - 4Ω
6.5W - 20V - 8Ω
Fully protected

TBA 810AS
6W - 14.4V - 4Ω
Thermal shut-down

TDA 2020
15W - ±15V - 4Ω
(THD = 1%)
10W - ±15V - 8Ω
(THD = 1%)
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—32 Db IMD
1.5-30 MHz

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1.5-30 MHz

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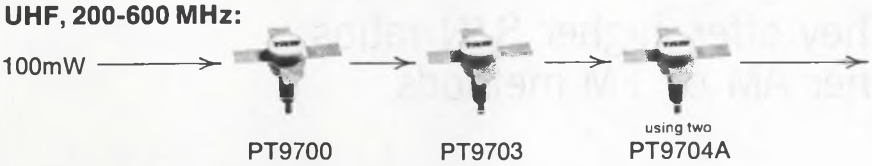

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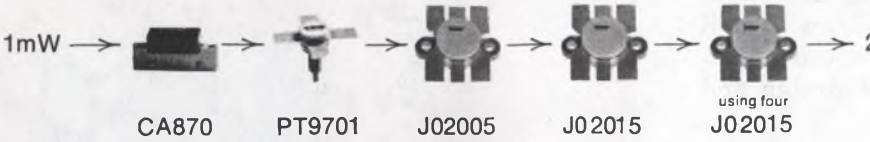
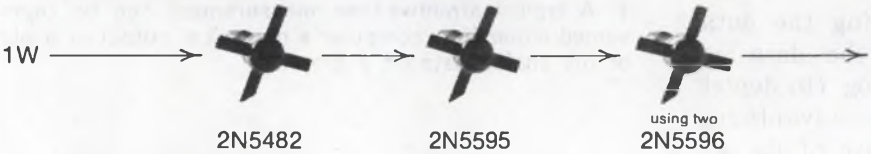
UHF TACTICAL RADIO—225-400 MHz broadband operation



For data sheets and broadband 120W/60W amplifier application note CT130, circle Reader Service Card number 214

Features: Designed for high power broadband operation. Drivers and finals input matched.* TRW gold system for reliability.

MOBILE BASE STATION—RADIO RELAY—ECM—600-1000 MHz (28V)



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Features: High gain. Ballasted for ruggedness. Gold metallized for long life. True hermetic package.

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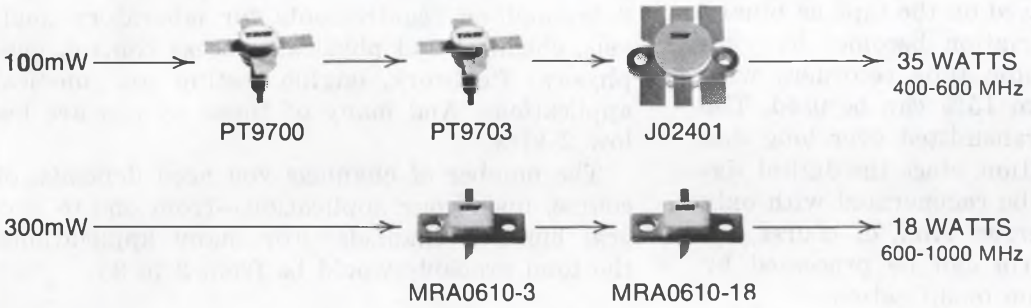

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Features: Broadband high power. Gold metallized. Ballasted for ruggedness. Internally matched final devices.*

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*TRW Patent 3,317,006

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Curb analog data errors with PCM

recording techniques. They offer higher S/N ratios and accuracies than either AM or FM methods.

Tired of errors in recording or replaying analog data? Try encoding the analog data with pulse-code-modulation (PCM) techniques. You'll bypass such problems as tape-deck speed variations, magnetic tape-head wear, tape stretch and head-alignment variations.

Alternatively, you can use the newer direct-recording AM units or the more complex FM units, but they'll only reduce, not eliminate, the problems.

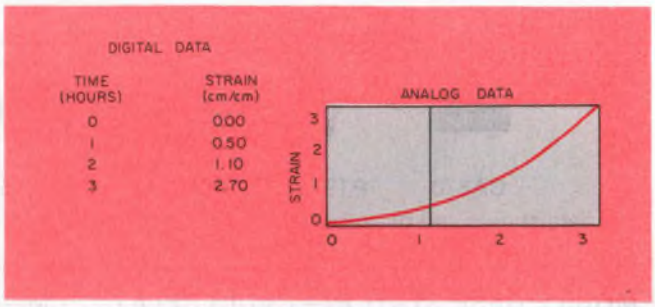
By directly encoding and recording the data in digital form, you can output the data as either digital (for analysis) or analog (to depict trends). PCM recording also has advantages over the FM or AM methods because of its accuracy, signal-to-noise (S/N) ratio, portability, reproducibility, ease of operation and competitive pricing.

Since the data are placed on the tape as binary bits, recorder speed variation becomes less important; inexpensive audio tape recorders with speed variations of up to 15% can be used. The digitized data can be transmitted over long distances without deterioration, since the digital signals, unlike analog, can be regenerated with only a small probability of error. And, of course, information in digital form can be processed by computers with almost no modifications.

With PCM, you get the best of two worlds—digital and analog. The technique requires analog signal sampling at regular discrete intervals and subsequent encoding of the signal amplitudes into a digital format. Although digital processing offers far greater accuracy, analog presentation has the advantage of descriptive clarity (Fig. 1). A glance at a graph clearly conveys meaningful trends.

What range of data?

Analog data often cover wide frequency and voltage spans. For ease of comparison, let's first consider the collection of a restricted range of data from sensors, especially those that have frequency outputs below about 5 kHz. This restricts the region covered to about 90% of the data-handling requirements for laboratory analysis, chemical and physical process control, geophysical fieldwork, engine testing and medical applications. And many of these signals are below 2 kHz.



1. **A typical strain-vs-time measurement** can be represented either by a computer's numerical output or a plot of the analog data on a graph.

The number of channels you need depends, of course, upon your application—from one to several hundred channels. For many applications, the total probably would be from 3 to 30.

The pros and cons

Of the three major recording methods (Fig. 2), AM has the lowest S/N ratio. Its only advantages are wide bandwidths and the simplicity of the equipment. For precision, AM recording doesn't work too well, since it can't reach dc.

FM systems offer high S/N ratios (50 dB) where voltage-to-frequency and frequency-to-voltage converters are used. These circuits fill the tape's dynamic range with the FM signal thus eliminating biasing problems, and providing a frequency response down to dc. But the limitation imposed on the S/N ratio by flutter or fluctuating speed can give the frequency-to-voltage converter false information (similar to Doppler shifting).

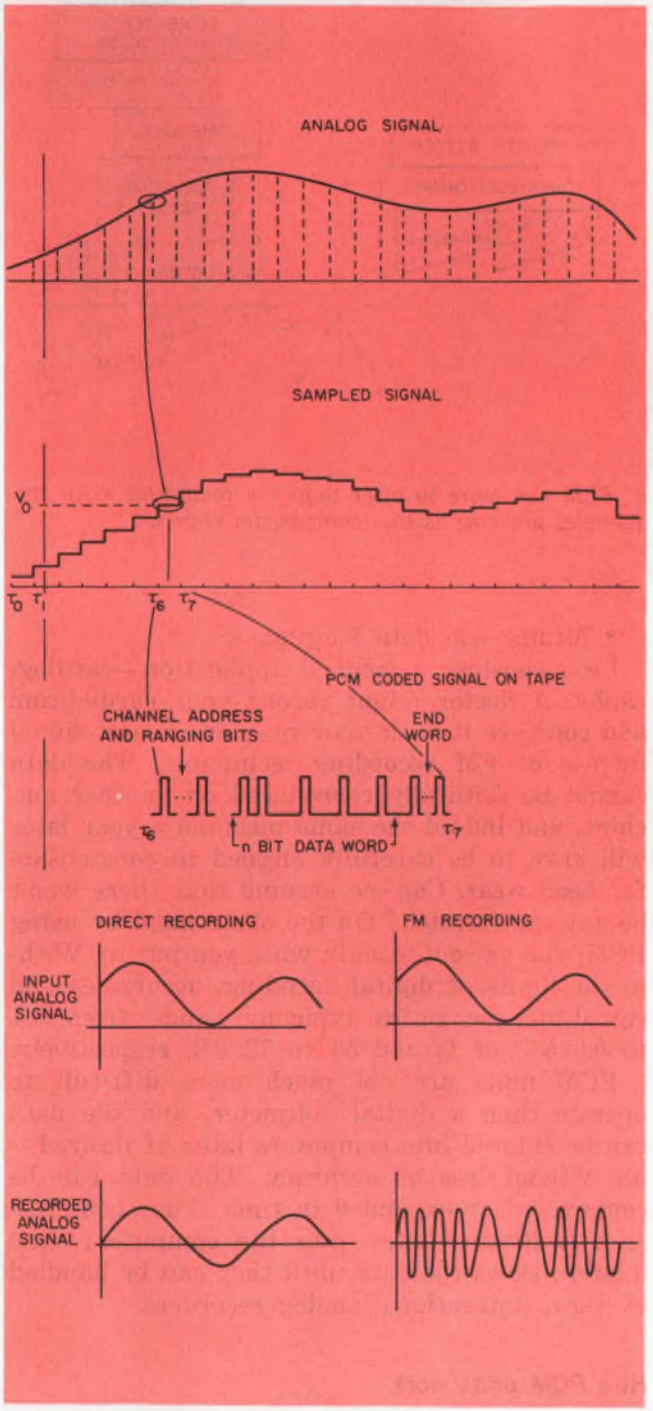
Most data-acquisition requirements for a good S/N ratio from dc to 5 kHz and for multichannel

Stan Yalof, President, and **Louis Shrinkle,** Design Engineer, Tetrahedron Associates, 7605 Convoy Ct., San Diego, Calif. 92111.

performance virtually rule out AM recording and leave only FM and PCM as possible techniques to work with.

For many circumstances, the choice is clear: If S/N ratio requirements are above 50 dB and high accuracies are required at any frequency, PCM recorders must be used.

The S/N ratios of PCM systems are about 74 dB, compared with FM ratios of about 50 dB (see table). With auto-ranging, the PCM dynamic range can be extended to more than 100 dB. However, if you can take a lot of noise and need many channels of data on tape at the high end of the frequency range, FM recording has a definite cost advantage; high-speed analog-to-digital converters for the PCM recording method are expensive.



2. **The three methods of data recording** differ in performance when they are all plotted on a signal-voltage-vs-time display and compared.

Comparison of the basic recording methods

	Bandwidth	Dynamic Range	Signal To Noise Ratio	Accuracy
PCM	DC → 2 kHz	72 dB	72 dB	±.025% of F.S.
FM	DC → 500 kHz	Depends upon S/N tolerance ratio	34-51 dB	±1% of F.S.
Direct	200 Hz → 2 MHz	Depends upon S/N tolerance ratio	23-38 dB	±3% of F.S.

You can get higher speed

To achieve higher input frequencies, you can increase the speed of the tape, but at the sacrifice of storage space. To do this, though, you must switch from incremental to continuous recorder drive.

The advantages of PCM over FM (Fig. 3) in bandwidths up to 5 kHz can be illustrated as follows: When you record two channels of data at a 1-kHz bandwidth, a serial PCM code can give a bit-packing density of 5 kbit/in. If each channel has 18 bits per word and the required sampling rate is 3000 ($3 \times f_{max}$), the minimum tape speed needed becomes

$$S = \frac{(2 \text{ words})\ (18 \text{ bits/word})\ (3000 \text{ words/s})}{(5 \text{ kbit/in.})}$$

$$= 21 \text{ in./s.}$$

A tape transport that has the industry standard speed of 30 in./s can easily handle this and still provide a 1-kHz bandwidth at a 74-dB S/N ratio. And if the word length is increased by three bits, the dynamic range of the system can be raised by more than 30 dB. This can easily be done with digitally controlled amplifier gains. On the other hand, if you use FM techniques at the same speed and bandwidth, you would get a 50-dB S/N ratio.

For high-performance PCM, let's consider a single system, assembled to Inter-Range Instrumentation Group (IRIG) standards.[1, 2] This system uses commercially available a/d converters and recorder mechanisms. It could use a 120 in./s, 12-track head and recorder with a 30-to-40 kbit/in. packing density (readily available with special coding). Performance can now be calculated as:

$$\frac{(120 \text{ in./s})\ (30 \text{ kbit/in.})\ (12 \text{ tracks})}{(16 \text{ bits/word})}$$

$$= 2.75 \times 16^6 \text{ conversions/s.}$$

With throughput this high, the a/d converter

must have a 0.3-μs conversion time and a bandwidth of

$$\frac{2.75 \times 10^6 \text{ conv/s}}{3 \text{ conv/cycle}} = 900 \text{ kHz}.$$

Depending upon the formatting, the S/N ratio can still be up around 74 dB[3]. If the number of channels is increased to 12, you have an approximate bandwidth per channel of 80 kHz with a 74-dB S/N ratio.

By comparison, a high-performance FM system that uses the same speed of tape equipment can provide dc-to-80 kHz performance with a 51-dB S/N ratio, or dc-to-500-kHz performance at a 35-dB S/N ratio.

Either system costs a lot if PCM techniques are used. For bandwidths above 80 kHz, FM is the best choice. And at or below 80 kHz, PCM has performance advantages, which, if required, would make it the better choice. Below about 5 kHz, PCM tends to have all the advantages.

A need for data scaling

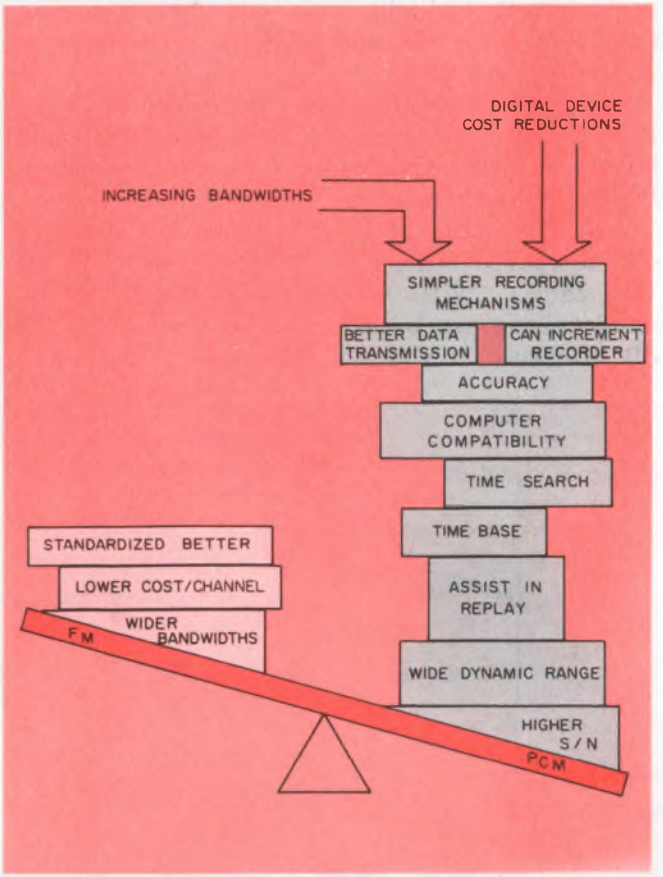
To store analog data correctly (Fig. 4), especially with AM or FM recorders, you must know beforehand approximately what the data will look like. This is essential for proper scaling to prevent distortion (such as that caused by clipping). Lacking knowledge of the data's characteristics, you must repeat test runs until the data are scaled correctly.

If after examining recorded data, you wish to compare the results with some other variable—time, temperature, frequency or stress—you usually have to set up or repeat a test. This is wasteful and not always possible.

For many mechanical, medical and geophysical tests, which usually have frequencies below 2 kHz, PCM recording techniques offer the most advantages. With PCM, you pay for bandwidth with data bits, although it is practical to push performance way up into the megahertz region.

For example, the French exhibited PCM television at Expo '67 in Montreal, NASA uses high-frequency PCM for telemetry, and Bell Telephone uses it as a carrier system. It also is employed in these applications:

- Automotive—for engine-combustion, shock and vibration monitoring.
- Aviation—in flight and wind-tunnel crash recording.
- Biological—for neurological signals.
- Chemical—for laboratory-instrument process monitoring.
- Structural engineering—for recording mechanical properties, shock and vibration.
- Geophysics—in seismic monitoring and data logging.
- Medical—in cardio-neurological and metabolic monitoring for patient care.



3. **PCM has more to offer** than FM recording when frequencies are low, as this comparison shows.

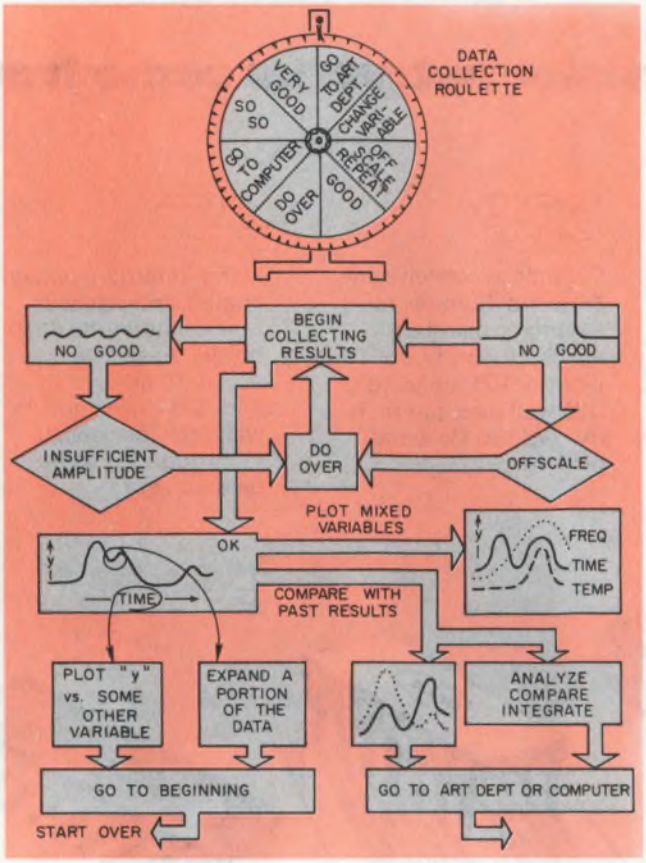
- Mining—in data logging.

Let's consider a medical application—cardiography. A doctor might record your cardiogram and compare it with your previous year's signal by use of FM recording techniques. The data cannot be faithfully reproduced on another machine, and indeed the same machine a year later will have to be carefully aligned to compensate for head wear. Can we assume that there won't be any tape stretch? On the other hand by using PCM, you get out exactly what you put in. Within the limits of digital encoding, accuracies and signal-to-noise ratios typically range from 0.1 to 0.025% of fs and 54 to 72 dB, respectively.

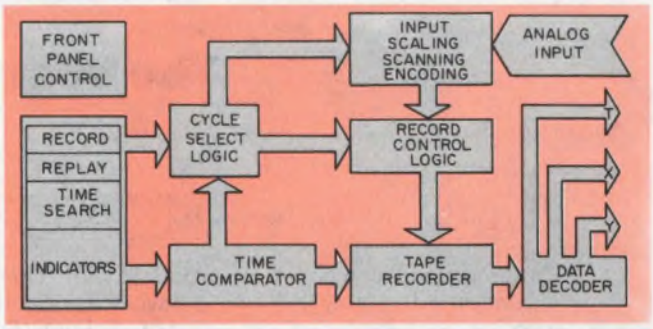
PCM units are not much more difficult to operate than a digital voltmeter, and the data can be entered into computers later, if desired—all without loss of accuracy. The data can be compressed or expanded in time. Time compression facilitates entry into the computer; time dilation slows the data until they can be handled by slow, conventional analog recorders.

How PCM units work

Several types of instruments are available for data collection and replay. Most take in multiple channels of analog data directly from other



4. The game of data collection is one of chance—unless you use the right system for your needs.



5. **Control and operating sections** of a recorder work together to acquire and scale data for analysis.

instruments, some can automatically switch gain range and all store the data digitally on magnetic tape. Then data can be delivered in either analog or digital form.

The sequence of operations and the controls for a typical system are shown in Fig. 5. The unit here uses a block-data sequence, while a much more simple PCM unit would trade the versatility of front-panel controls and autoranging for a larger operating bandwidth.

The various controls on the front panel direct digital and analog circuitry to perform recording, replay, time search and tape direction control. The circuitry consists of two networks: one for power and control, the other for conveying data signals. Since there is considerable interplay between many of these functions, it is difficult to segregate these into particular blocks.

The cycle-select logic synchronizes the activities of the various blocks, with sequencing assistance from the time comparator. The recording sequence begins with inputs from up to N channels of analog data through the input-scaling block. The inputs are scanned at selectable rates and translated into a digital word by an a/d converter. The converter assigns most of the bits to the value and sign of the analog input. The other bits are assigned for autoranging, for the channel address, and for parity to aid in error detection in the data words.

The digital words are passed through the signal network into the tape recorder. In this way up to a million coded words can be stored in block or on a tape cassette. On replay, the procedure is reversed, and the recorder can output (through the decoder) several channels of data and time in either analog or digital format. With this approach, data are inputted, stored and automatically outputted with no loss of accuracy.

Onward to the limit

Commercially available a/d converters have typical sample word rates from 20 kHz, with resolution up to 15 bits, to 100 MHz at four bits of resolution. Some researchers [4, 5, 6, 7] even claim to have attained 20-bit resolution at 100 MHz by use of an 84-track, 180-in./s recorder.[8, 9] The recorder has a bit-packing density of 40 kbits/in./track with a reported bit error rate of 5×10^6. The bandwidth and S/N ratio of a single channel work out to

$$\frac{(40\ \text{kbits/in.})\ (84\ \text{tracks})\ (180\ \text{in./s})}{(20\ \text{bits/word})\ (3\ \text{conv/cycle})}$$
$$= 10 \times 10^6\ \text{Hz}.$$

This bandwidth even exceeds that of FM and results in an S/N ratio greater than 100 dB. ■■

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2. Telemetry Standards," *IRIG Document #106-73.*

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5. "Magnetic Tape Recording Handbook," Hewlett-Packard *Application Note 89.*

6. Gili, Paul, "Getting the Drift of VCO Instability, *Microwaves*, Mar., 1974, pp. 42-45.

7. Review of specifications contained in data sheets supplied by: Ampex, Bell & Howell, Hewlett-Packard, Philips, Sangamo, Tandburg and Tetrahedron Associates.

8. Staff, "Analog-to-Digital Converter Survey," *Instrument & Control Systems*, Sept. 1969, pp. 115-138.

9. Spitzer, Charles F., "Digital Magnetic Recording of Wide-Band Analog Signals," *Computer Design*, Oct., 1973, pp. 83-90.

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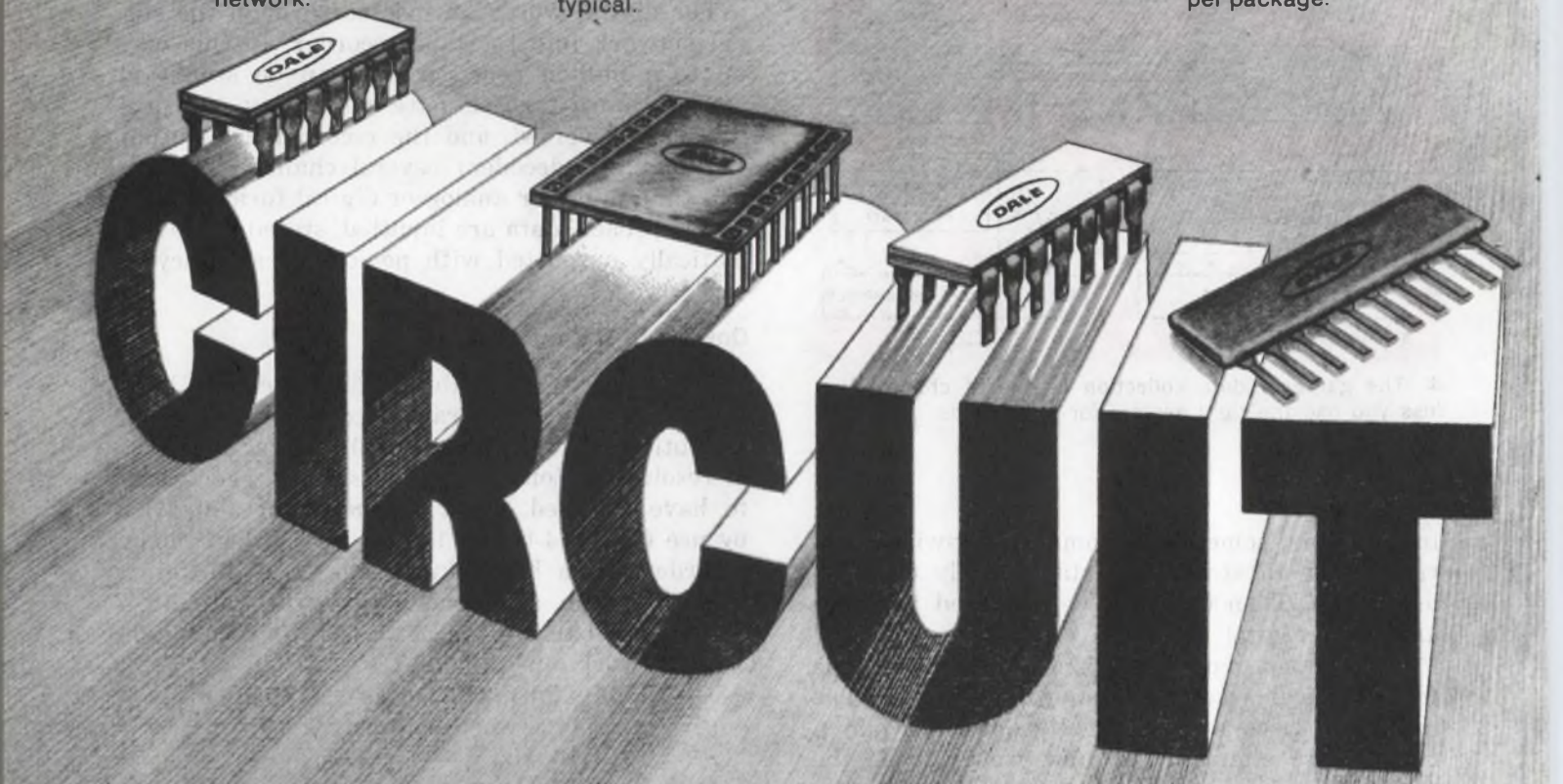

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Several companies offer suitable v/f converter modules. Or you can build your own.[1] The modifications that allow you to perform calculations stem from the basic operation of the converter (Fig. 1).

A voltage, V, at the input causes a current, I, to charge capacitor, C, and thereby vary the output voltage, V_o, of the integrator. When V_o passes a reference level, V_{ref}, a comparator triggers and, in turn, initiates a timing circuit.

The timing circuit controls a current generator whose output is a current pulse of length, T_d, and amplitude, I_d. Consequently during the cycling time, T, the capacitor discharges by an amount, $I_d \times T_d$, and collects a charge of $I \times T$.

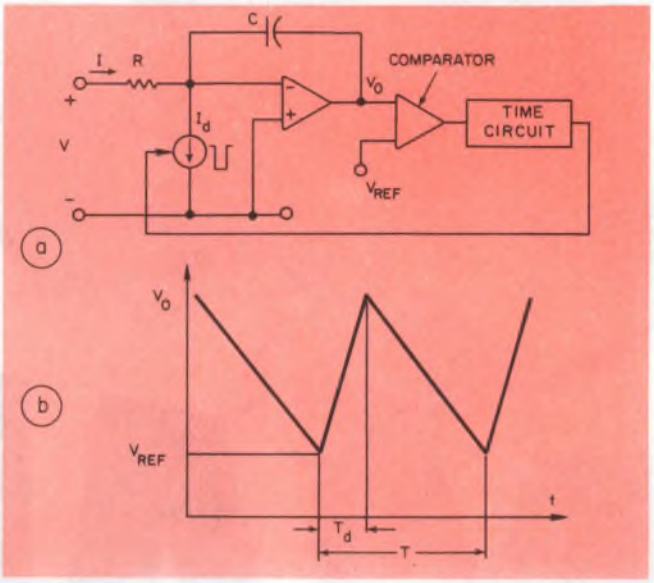
Since the input charge equals that put out (for full discharge), we get

$$I \times T - I_d \times T_d = 0.$$

Consequently the frequency of the output voltage is given by

$$f = \frac{1}{T} = \frac{I}{I_d \times T_d},$$

and the output frequency is proportional to the ratio of the two currents I and I_d.



1. **A linear, wide-range voltage-to-frequency converter** can be built by use of a constant-current generator, (I_d), to control the discharge of an integrating capacitor (a). The output voltage shows the capacitor charge/discharge cycle (b). Frequency depends on T_d.

Modifications yield arithmetic operations

If the converter is fitted with input circuits, so that currents I and I_d are proportional to two input signals, V_1 and V_2 (Fig. 2), then $I = V_1/R_1$ and $I_d = V_2/R_2$, and

$$f = \frac{R_2}{R_1 \times T_d} \times \frac{V_1}{V_2}. \qquad (1)$$

The ratio of two voltages is thus obtained. With a T_d of 100 μs (Fig. 3) and the component values shown in Fig. 2, ratios can be formed with less than 0.15% deviation (least mean square) over a one-decade range (Table 1). Since T_d is less than T, current I_d must be greater than I. This inequality sets the lower limit of V_2.

The v/f converter is also useful as an active component to obtain square roots and products. If the voltage at input 2 (V_2) is made proportional to the output frequency, f, then from Eq. 1,

$$f = K_1 \frac{V_1}{V_2}$$

$$= K_1 \frac{V_1}{K_2 f}$$

$$\therefore f \propto \sqrt{V_1}. \qquad (2)$$

To realize this relationship with hardware, first convert the output pulse train to a dc level, V. This is necessary because the v/f accepts only dc or a slowly varying voltage at input 2. A simple RC filter will perform the conversion adequately, provided that the amplitude of the pulse train is constant and that the change in output impedance of the timing flip-flop (CD 4013) is small compared with R_5 (Fig. 4).

The output voltage of the RC filter is then fed

Bengt Alvsten, University of Lund, Solvegatan 14, S-223 62, Lund, Sweden.

directly into input 2. With the values given in Fig. 4 for R and C, the output frequency is proportional to the square root of the input level over about a 10-to-1 span of input. Deviation from an ideal straight line is less than 0.07% over this span (Table 2).

Multiplication is also possible

It is well known that the inverse characteristic of an active circuit can be produced if the circuit is placed in the feedback loop of an amplifier. Thus if the v/f and low-pass filter combination connects the output of an op amp with its input (Fig. 5), we get

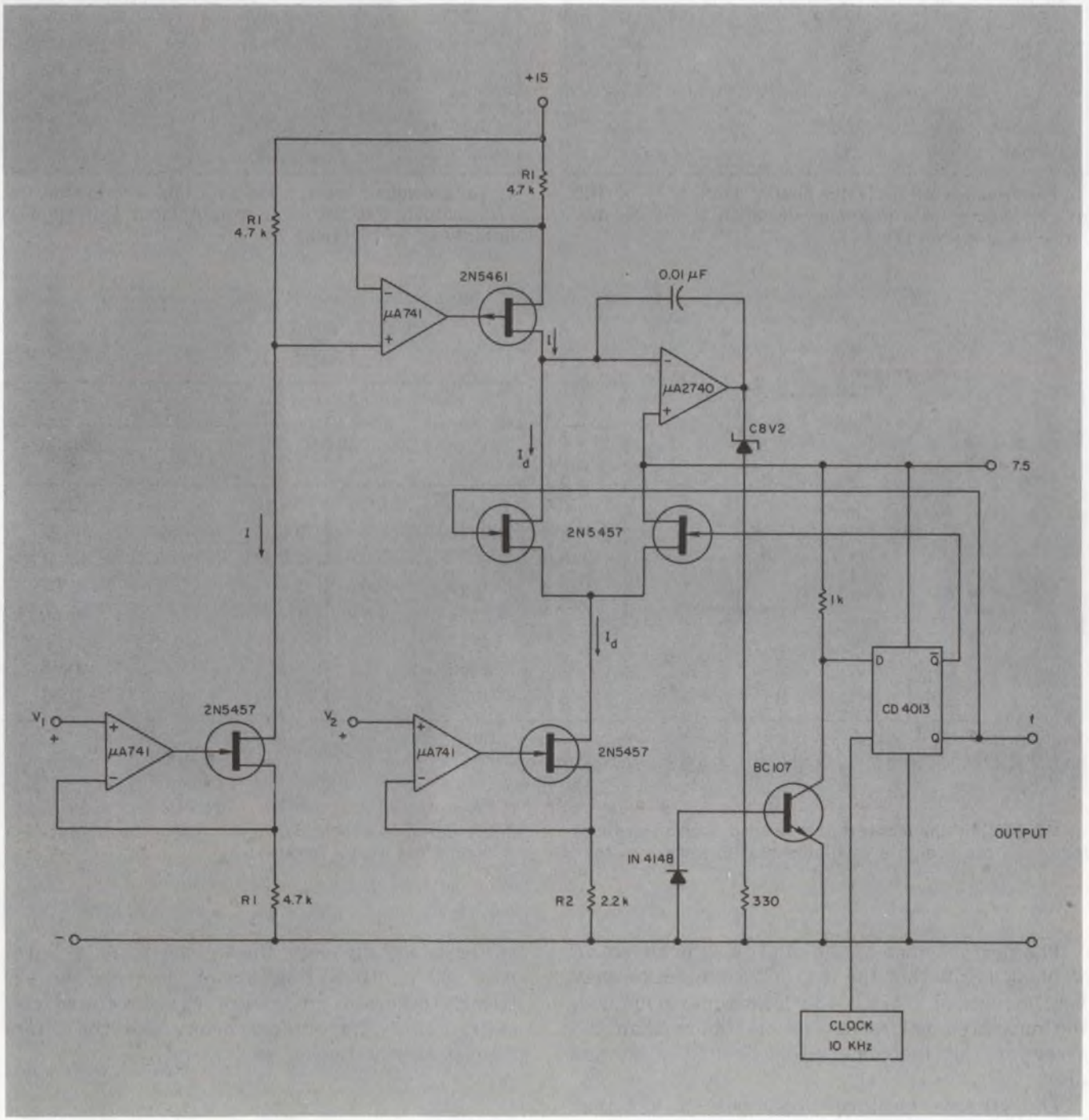
$$\frac{V_{in}}{R_6} = \frac{V}{R_6} .$$

But

$$V \propto \frac{V_1}{V_2} \propto \frac{V_{out}}{V_2} ,$$

so

$$V_{out} \propto V_{in} \times V_2 . \qquad (3)$$



2. **Modified v/f converter** accepts two input levels, V_1 and V_2, and outputs a frequency proportional to the ratio of the two inputs. The discharge period of the integrating capacitor is fixed by the clock.

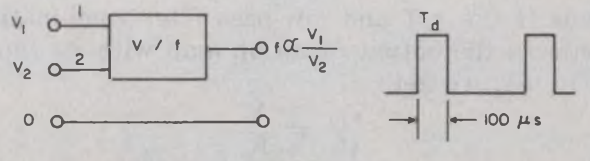


Table 1

V_2^{-1} (volt)$^{-1}$	$f_{measured}$ Hz	Deviation %
5.000	2394	0.02
2.500	1196	−0.06
1.667	796.8	−0.08
1.250	597.4	−0.05
1.000	477.9	−0.02
0.8333	398.2	0.01
0.7143	341.4	0.07
0.6250	298.7	0.10
0.5556	265.5	0.12
0.5000	238.9	0.15

3. **Performance of the ratio circuit:** With a T_d of 100 µs, the data show a maximum deviation of 0.15% over a one-decade span (Table 1).

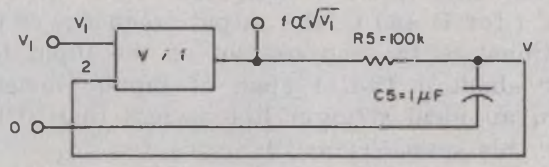


Table 2

$\sqrt{V_1}$ (volt)$^{1/2}$	$f_{measured}$ Hz	Deviation %
0.4472	1526	−0.20
0.6325	2153	−0.00
0.7746	2633	0.05
0.8944	3037	0.06
1.0000	3393	0.07
1.0954	3714	0.05
1.1832	4007	−0.02
1.2649	4282	−0.02
1.3416	4540	−0.03
1.4142	4784	−0.03

4. **To take square roots,** a low-pass filter is added at the v/f's output. Results of an output/input test show a linearity of 0.2% (Table 2).

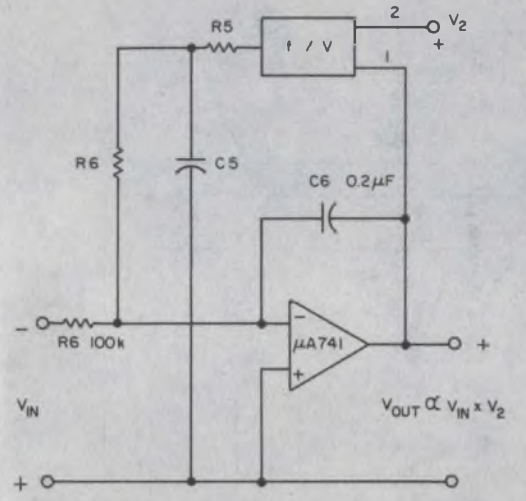


Table 3

V_1 = 0.250 V			V_1 = 2.000 V		
V_2 volts	V_{out} (volts)^2	Deviation %	V_2 volts	V_{out} (volts)^2	Deviation %
0.250	0.0355	0.14	0.250	0.2825	−0.3
0.500	0.0706	−0.02	0.500	0.5650	0.02
0.750	0.1057	−0.07	0.750	0.8471	0.05
1.000	0.1409	−0.03	1.000	1.128	0.07
1.250	0.1761	0.00	1.250	1.410	0.00
1.500	0.2114	0.06	1.500	1.692	0.03
1.750	0.2465	0.03	1.750	1.974	0.00
2.000	0.2815	−0.04	2.000	2.255	−0.03

5. **By placing the converter in an op amp's feedback loop,** you can design a multiplier that exhibits less than 0.3% deviation (Table 3). In this case, the output is a voltage rather than a frequency.

The performance of the multiplier is shown in Table 3. (Note that the $R_5 - C_5$ combination may not be needed.) With the least-square method, the measured values deviate not more than the error of the instruments used—0.3%, or one digit.

The circuits outlined presuppose a v/f that has two inputs—one to control the charge and the other the discharge process. Since such a converter is usually very linear, the ratio, square-root and multiplication circuits can also be extremely accurate. Of course, the associated circuitry—the voltage-to-converters and the filters—must also be linear. ■■

Reference

1. "Linearize Your V/F Converter, *Electronic Design*, No. 23, Nov. 8, 1973, p. 112.

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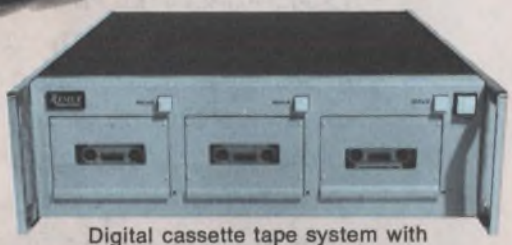

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INFORMATION RETRIEVAL NUMBER 62

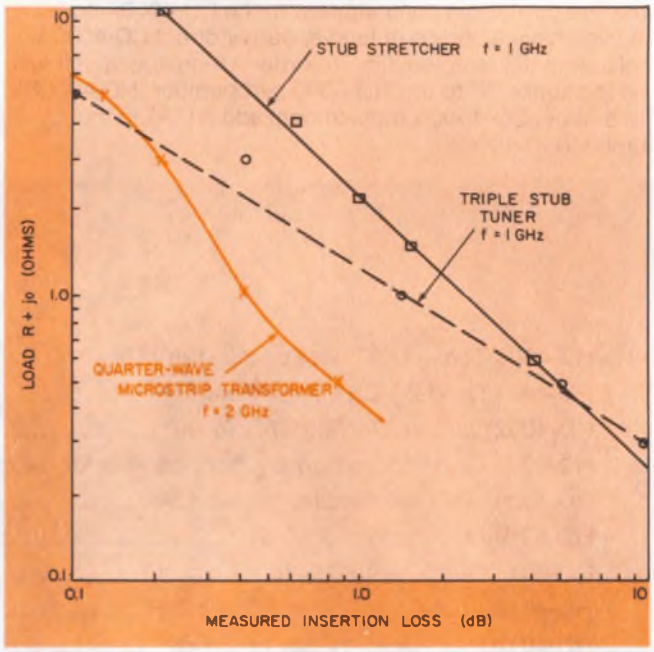
Match impedances with tapered lines

when you test microwave transistors, and you'll avoid the destruction of expensive devices.

If you're searching for a high-power microwave transistor, you'll find a growing number to meet your system needs. But mismatch the 50-Ω test equipment to the ohm-or-less input impedance of these new devices, and burnout may cost you hundreds of dollars. Microstrip exponentially tapered lines offer insurance against such losses by providing a near-perfect match over a wide frequency range.

The tapered lines have advantages over the conventional stub tuner and uniform microstrip transmission line. But they have a major drawback: They're bulky. This and other factors usually limit their use to transistor characterization rather than practical amplifier designs.

Let's compare stub tuners, uniform transmission lines and tapered lines and then examine how the tapered lines can be most useful in testing and in prototype designs.



1. **A quarter-wave microstrip transformer** offers less insertion loss than other approaches when an impedance of 3 Ω or less is matched to 50 Ω.

The ideal impedance-transforming network

Here are the requirements for an ideal impedance-transforming network:

- Wide bandwidth.
- Independent control of the real and imaginary parts of the impedances to be presented to the transistor under test.
- Limited range for real and imaginary components of impedance (to avoid the possibility of severe mismatch, which could destroy the transistor under test).
- Low loss.

Stub tuners are very popular and meet the wide bandwidth demand. However, both the real and imaginary components change simultaneously, and impedances can vary over a wide range with only a slight change in stub positioning. It is difficult to determine what impedances are presented to the transistor by observation of the physical settings alone. Finally, stub tuners become lossy at high transformation ratios. Fig. 1 shows the measured insertion loss in decibels in matching R + j0 to 50 Ω. Below 3 Ω the insertion losses for the triple-stub tuner and the stub stretcher far exceed the insertion loss of microstrip quarter-wave transformers.

Uniform microstrip transmission lines, combined with variable lumped element capacitors, offer less loss than stub tuners, but they are limited to a narrow bandwidth, often requiring more than one circuit to characterize a transistor over a wide frequency range.

Designing the tapered line

The exponentially tapered microstrip transmission line can supply a broadband match between two real impedances, if certain conditions are met.[1] The imaginary component of the device impedance can be tuned out by a series-tunable

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element—a series capacitor if that is required—or a variable capacitor in series with a small inductance, if a variable inductive reactance is required. A real impedance presented to the low-impedance end of the microstrip exponentially tapered line will then be transformed to 50 Ω.

The requirements for the tapered line are:[2]

- It must be operated above its cutoff frequency.
- Its characteristic impedance at the source end must be 50 Ω.
- Its characteristic impedance at the low-impedance end must equal the real impedance that it is required to transform.

The last requirement appears to rule out the tapered line. In practice, however, a variable shunt capacitor at the device input suffices to achieve the small transformation to match the real component of the input impedance of the transistor under test to the characteristic impedance of the tapered line at the low-impedance end.

The basic equations used to design the exponentially tapered line are

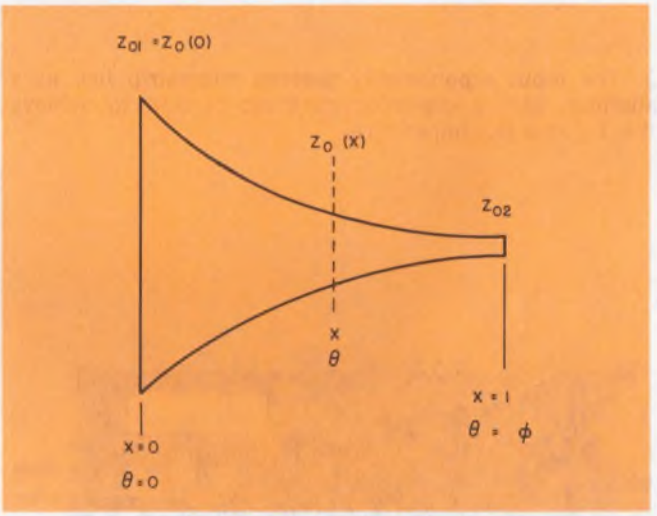
$$\frac{Z_o(X)}{Z_o(0)} = e^{\delta x} \text{ (Physical)} \qquad (1)$$
$$= e^{F\phi} \text{ (Electrical)},$$

where X is the distance from the low-impedance (wide) end, $Z_o(X)$ is the characteristic impedance at X, $Z_o(0)$ is the characteristic impedance at the low-impedance end, δ is the physical taper rate, and F is the electrical taper rate (Fig. 2). For W >> H (line width >> dielectric thickness), the two expressions in Eq. 1 are very similar. Then we can define the transformation ratio, T, by

$$T = \frac{Z_{02}}{Z_{01}} = e^{\delta \ell} = e^{F\phi}, \qquad (2)$$

where Z_{01} = line impedance at low-Z (wide) end,
Z_{02} = line impedance at high-Z (narrow) end (usually 50 Ω),
ℓ = total physical line length,
ϕ = total electrical line length.

Knowing the desired end impedances (hence T), we may calculate $\delta\ell$ or $F\phi$ from Eq. 2. Specification of the desired cutoff frequency and the



2. **In the exponentially tapered line** $Z_o(0)$ is the characteristic impedance at the low-impedance end.

material dielectric constant determines the taper rate δ by:

$$f_{cutoff} = \frac{\delta c}{4\pi \sqrt{\epsilon_r}}$$

or

$$\delta = \frac{4\pi \sqrt{\epsilon_r}}{c\, f_{cutoff}}, \qquad (3)$$

where c is the velocity of light. The cutoff frequency is chosen to be three or four times lower in frequency than the frequency of circuit operation. This ensures broad bandwidth and negligible loss. Combining Eqs. 2 and 3 yields the physical and electrical lengths

$$\ell = \frac{\ln T}{\delta}$$

and $$\phi = \frac{\ln T}{F} = \frac{\beta \ln T}{\delta},$$

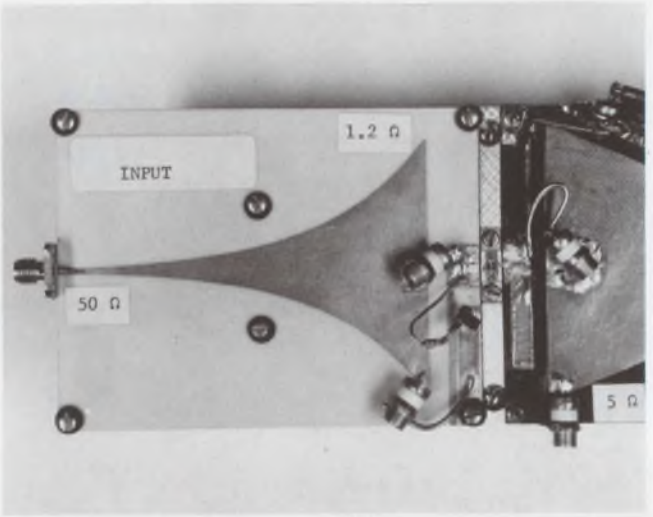
where $$\beta = \frac{2\pi f \sqrt{\epsilon_r}}{c} \text{ and } F = \frac{\delta}{\beta} \qquad (4)$$

The line widths are obtained from the well-known relationship

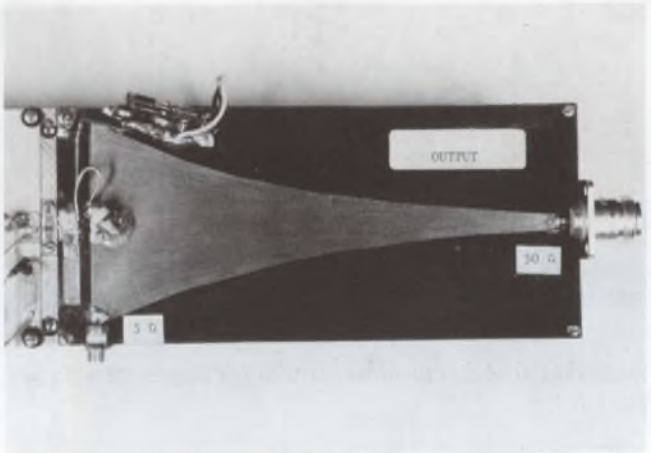
$$Z_o = \frac{377\, H}{\sqrt{\epsilon_r}\, W},$$

where H is the dielectric thickness.

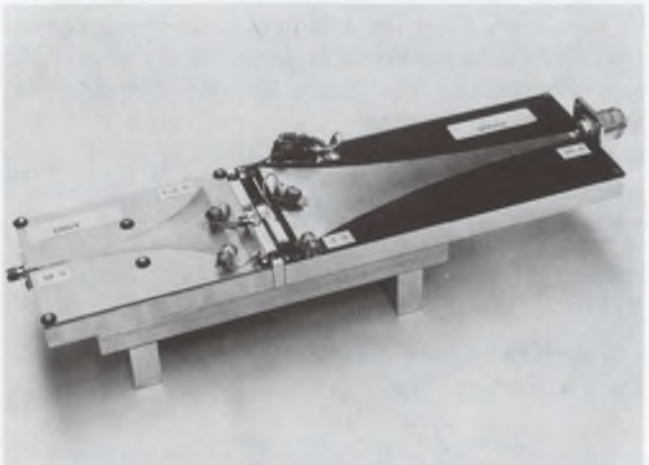
An example of the practical application of this



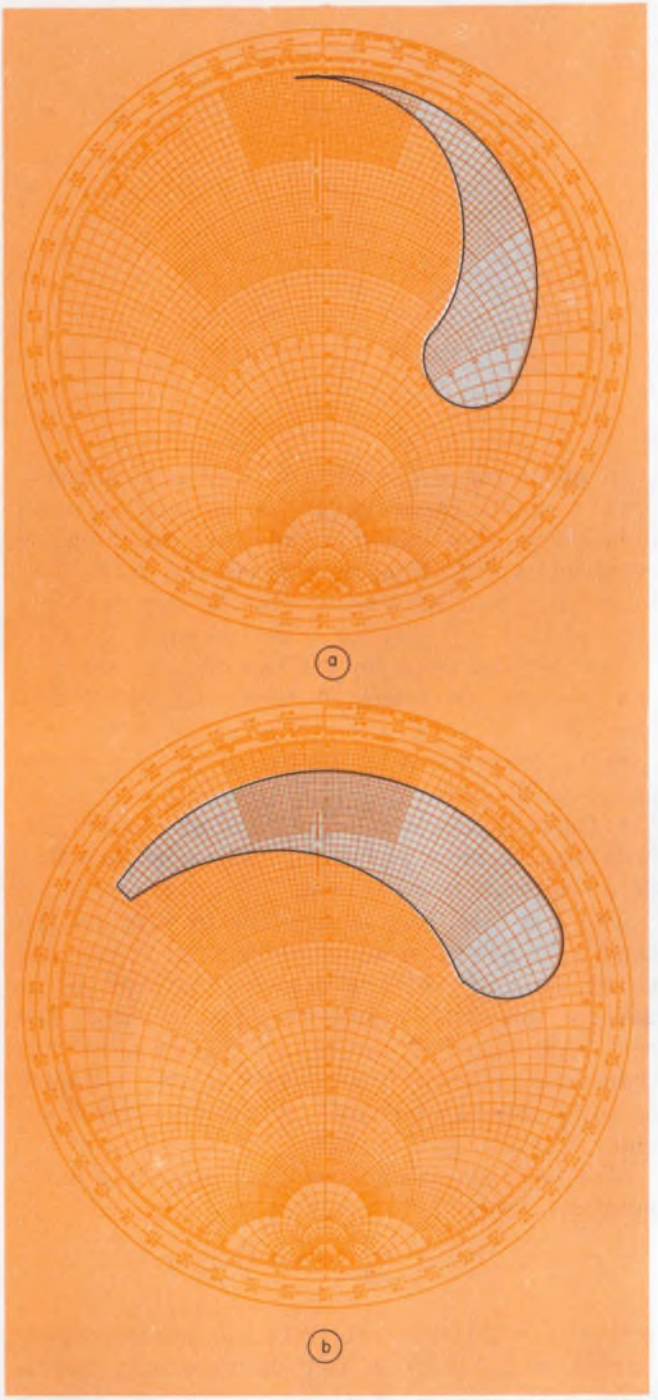
3. **The input exponentially tapered microstrip line uses alumina,** with a dielectric constant of 9.9, to achieve the 1.2-Ω input impedance.



4. **The output tapered line is constructed on Teflon-Fiberglas,** with a dielectric constant of 2.55, to match the transistor output to the 50-Ω load.



5. **The completed test setup is large,** but it reduces device burnout stemming from impedance mismatch.



6. **The tuning range** of the input stage (a) and the tuning range of the output circuit (b).

approach is shown in Fig. 3. The exponentially tapered microstrip line for the input matching circuit is constructed on 25-mil-thick alumina ($\epsilon_r = 9.9$) and transforms from 1.2 +j0 ohms to 50 + j0 ohms over a range of 700 to 1400 MHz. Alumina is used to restrict the width at the low-impedance end, to minimize spurious modes at the discontinuity. Specifically $W_1 = 2.4$ in., $W_2 = 24$ mils, $\ell = 3.5$ in., $\phi = 316°$ at f = 1 GHz, and $f_c = 318$ MHz.

The variable-shunt capacitor, shown connected to the tapered line at the low-impedance end, transforms the real component of the device in-

put impedance from 0.5 to 1.2 Ω. The series-variable capacitor reduces the imaginary component to zero. Fig. 4 shows a similar circuit (constructed on Teflon-Fiberglas $\epsilon_r = 2.55$) that is used to transform the 50-Ω load impedance to the value required by the output of the transistor for optimum performance. The circuit has $W_1 = 2.7$ in., $W_2 = 0.17$ in., $\ell = 6.2$ in., $\phi = 290°$ at f = 1 GHz, and $f_c = 219$ MHz. Although the advantages of the approach described here are of value particularly for input matching, it can be used in the output circuit also.[3] The over-all configuration is shown in Fig. 5.

Results prove the technique

This approach has proved valuable in the initial characterization of a number of microwave power transistors, and its advantages are as follows:

- The range of impedances that it presents to the transistor, particularly at the input, are limited to close to what is required, with little possibility of unintentionally high VSWR conditions being obtained (see Fig. 6a and b):
- The tapered line is continuously tunable over an octave bandwidth.
- The impedances can be varied in a controlled manner.
- For the high transformation ratios considered here, the losses are lower than those of typical stub tuners.
- In practice, the destruction of new devices was significantly reduced. (It is possible that this was due in part to the cutoff[4] characteristics of the tapers, which reduced the tendency toward low frequency oscillation.)

This method is not recommended as a replacement for conventional matching circuits when characterized devices are used. This is because 10% greater Class-C performance can be achieved by use of narrowband circuits. However, it has considerable advantage in the initial characterization of newly designed devices, where the impedances of the transistors are not yet known and the destruction of expensive experimental devices is rather serious. Also, one circuit can be applied over a large bandwidth. ■■

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Acknowledgements

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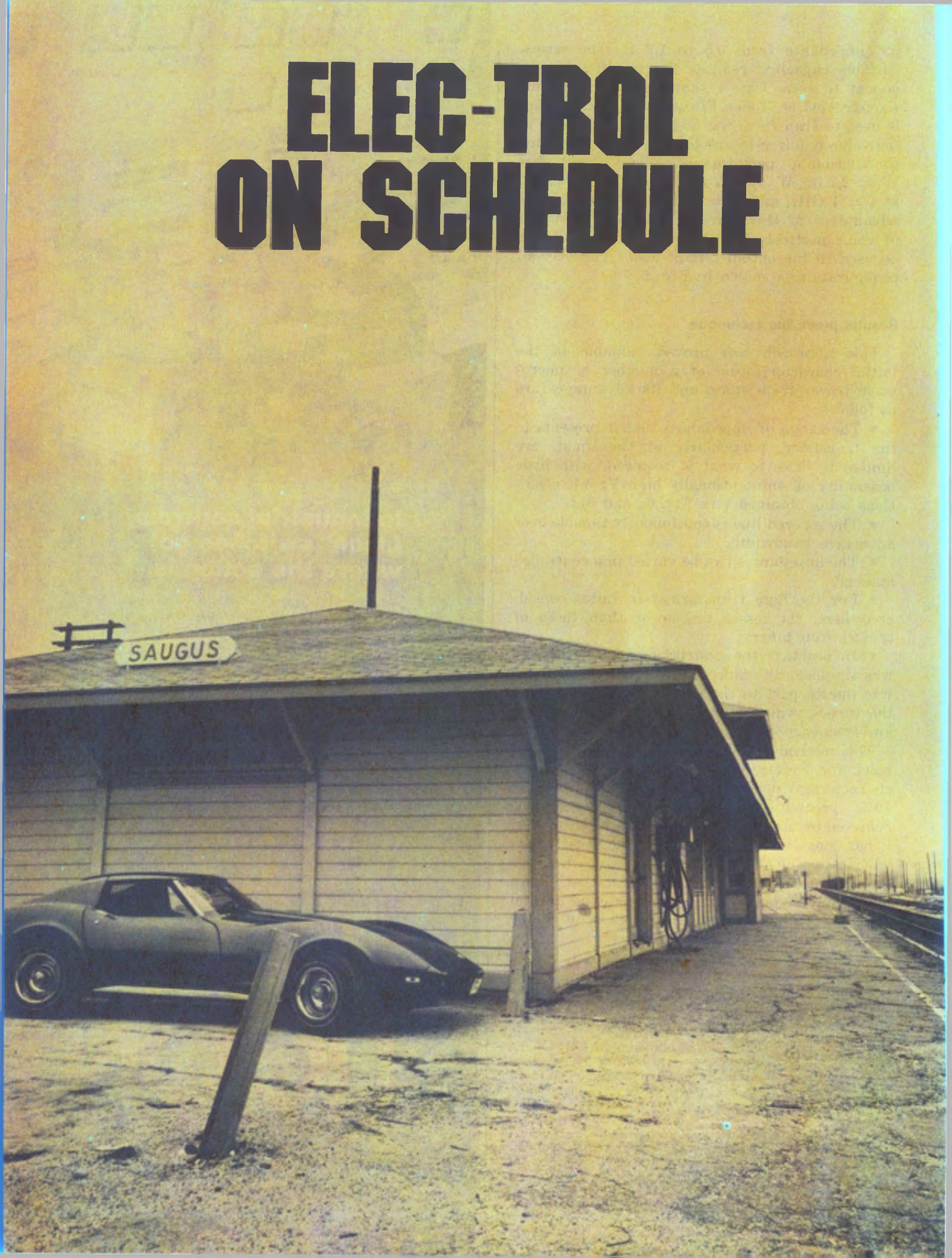

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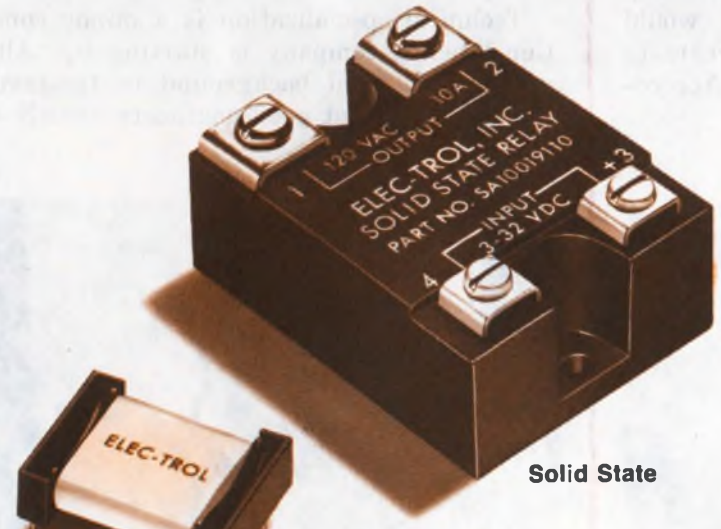

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INFORMATION RETRIEVAL NUMBER 64

Start your own electronics business –but look before you leap

Many engineers have thought about starting an electronics company. It's an exciting thought, because although many have failed in the attempt, others have prospered. Starting a company means understanding and applying some basic ground rules and then girding yourself for some very nasty surprises along with the welcome ones.

Seven years ago Donald Bruck founded Hybrid Systems Corp. in Cambridge, Mass., which now produces a range of products, from thick and thin film microelectronics to discrete component modules. Samuel Wilensky joined Bruck full time two years after the startup of the company and became a princal. Following are some ABC's for prospective electronics-company founders, based on the experiences of Bruck, now president of Hybrid Systems, Burlington, Mass., and Wilensky, vice president of modules. Here is their story:

By DONALD B. BRUCK

Seven years ago an engineer could go into a bank and, without any trouble at all, borrow $10,000, $20,000, and even $30,000 to start a company. Bankers thought that engineers were extremely ethical and hard-working, that they could always get a job, and that they would discipline themselves for X number of years to pay off the loan if they lost the money. According to my banker, those days are over.

By DR. SAMUEL WILENSKY

Starting a company isn't the result of spontaneous combustion; you have to set yourself on fire. Start a company because you want to run one and make money, not because you have a new product that will change the world.

Technical specialization is a minor consideration when a company is starting up. Although you need a good background in fundamentals, the feeling is that good engineers usually can be

Donald B. Bruck, *(continued)*

One of the reasons starting a company is different today is that investors no longer feel that electronics companies never go bankrupt. Seven years ago suppliers didn't bother to tell our company, for example, that we were four, five or even six months late in payment. We really had the use of their working capital to get started. They felt that if we got into a bind, we could always go public, give up some small fraction of our company and raise a considerable sum of money. The market for electronic company stock is not quite as favorable today, and you can no longer expect to obtain working capital from your suppliers.

Also, the electronics industry is so sophisticated now that it is far less tolerant of an amateurish startup. Seven years ago a group of amateurs could form a company and, through on-the-job-training, fumble their way to ultimate success.

Dr. Samuel Wilensky, *(continued)*

found. When we started, for example, I didn't know what an a-to-d converter was, and that's our main business; so I don't think technical experience is of vital importance. Being versatile and a fast learner is more important. Most important for the startup is finding a solid business to go into—one that has a market and needs a good, aggressive company.

Prove your commitment

After you've started a company, be prepared to sacrifice. Donald Bruck and I worked without salary for two years to finance our startup. But sacrifice means more than involvement; it means commitment.

If you have to ask investors for money to start a company, show them that you're committed to the task, by proving that you've got all of your

Do's and don'ts for prospective entrepreneurs

Here are some do's and don'ts that Samuel Wilensky recommends for engineers who want to start a company:

- **Don't ever think that you're smarter than the next guy.** Someone always knows something you don't. Be careful of the "not invented here" attitude. It's an easy bind to get into if you're from an academic or research background. If you see a good idea, use it. Even though you're convinced that a particular module construction is the way to go, be quick to change your mind if all the customers are buying another type.

- **Don't start a company alone.** In general, if two persons are involved, when one is down, the other is up. It depends on the personalities, of course, but if you're alone, you've got to be a very special person to pick yourself up and keep going when things look bleak.

- **Do keep the component count down.** When you're designing a one-of-a-kind item in a research lab, you can make it as complex as you want; the component count is not a factor. But when you're designing something for the production line, you've got to keep the parts count to a minimum, because it's less expensive, easier to assemble and usually more reliable. At first, Hybrid Systems found it difficult not to overdesign many of its circuits. Now there's a standing joke at the company: "When a new breadboard works, we cut out components until it stops working," Wilensky says. "Then we solder that one back and start cutting out some more. It's very easy to throw in a filter capacitor here and an unnecessary resistor there when you don't really need them."

- **Don't panic.** Hybrid Systems' first big job was a unit it built for Westinghouse. The company had invested a lot of time and money in the product. After about 40 units were shipped Westinghouse said it didn't like the way the equipment was being built. There was near panic at Hybrid Systems' headquarters, because the company had risked everything on one item, and if that was going to be rejected, the business could go under. Solution: We made suggested changes after talks with Westinghouse.

- **Do be open to suggestions, and look into alternatives.** For example, when you set up a production facility, you've got to convince yourself that it doesn't take a Ph.D to trim a module. At Hybrid Systems, the founders had thought it would take a highly trained person; it doesn't. It takes a trained person to write a test procedure. But there's not much that Hybrid Systems assembles that can't be done by the average person. If the person off the street can't do it, then it's too complicated and shouldn't be built that way.

- **Do remember that the customer is still the customer.** When he tells you that your product isn't performing, you can't just tell him that he isn't using it right. You've got to figure out how to build the circuit so he can use it.

Some advice on the business side

Engineers intent on starting their own companies are advised by Donald Bruck to consider these business tips:

- **Gain a competitive advantage:** In the electronics industry people often put together a team composed of extremely talented individuals who are qualified to compete against other talented and equally ambitious people. Then they all go to the market arena and fight over nanoseconds in performance.

In some cases, it might be a good idea to take your bright team to some industry other than electronics, where the team has an advantage over the competition and not just the qualifications for competing.

- **Increase your probability of success.** If your immediate goal is to achieve a $10-million company, there are two alternatives—10 $1-million projects or one $10-million project. If you do 10 $1-million projects, each project, by itself, is not large enough to attract the bigger companies with greater resources than your own company's. Therefore your competition is easier, and the cash required is smaller.

If you do the one $10-million dollar project, you'll have to bring in investors, leaving you with a smaller percentage, and your probability of success diminishes because of an increase in competition from larger established companies.

- **Avoid becoming a captive.** One of the most significant causes of the lack of growth with startup companies is that they take on custom, one-shot projects. There are always potential customers lurking around to lure you with these offers that the most successful companies won't accept. The one-shotters wave large purchase orders at you, but they won't buy in production quantities for years. Once the startup company takes on this carrot, it becomes a captive supplie of this manufacturer. The profitability for the product is never as good as you thought it would be, because your customer finds out what parts cost, and since he is essentially your only customer, he forces you to lower your prices at the threat of taking his business elsewhere.

When you finish shipping this marginally profitable job, you suddenly wonder what you're going to do next. That sends you after an even bigger carrot. You hop from carrot to carrot, never getting your original product ideas rolling, because you're putting your engineering efforts into these customized carrots rather than into products for the future. There are a lot of small companies that claim to have a large product line when, in reality, they are custom houses for a few large customers.

- **Pace the company's growth properly.** A design engineer who has never been in business before often comes to the rude awakening that successful companies do not always survive. From a cash-flow point of view, if the company grows too fast, it can just as easily become insolvent as it can by growing too slowly. In both cases you can assume a profitable operation. The cash demands—such as the increase in inventory, increase in receivables and the working capital requirements, in general outstrip your resources, even though, you're profitable. You can't depend on always having the minimum cash-flow requirement rate of growth.

Donald B. Bruck, *(continued)*

Now the competition is far keener; there is less room for mistakes.

The competition is tight

When our company started, the industry was expanding into many new product areas. Companies had their sights set on various markets that didn't significantly overlap. Today companies attack most new product areas systematically; your company won't be as immune from competition for as long as it might have been seven years ago.

If I were to start a company today, I'd pick a product area, talk to the leaders in that industry to find out who their best people were and see if I could lure those people together into a new company. The best way is to determine what products the market is buying and, if that market

Dr. Samuel Wilensky, *(continued)*

own money in it. If a company goes under, investors don't want to see any fat cats walking away from the ruins, particularly if they have their own $500,000 still invested in it.

Prospective backers also want to know if there's a large enough market to support the product. What they don't like is a new idea and the notion that you're going to *create* the market for it. They know that you never will; by the time you've created the market, the business will have gone under, and someone else who has learned from your mistakes will take advantage of the market you've established.

Prospective backers want to know if the company principals are competent in what they're doing. Consequently they want to back people who have good credentials—MIT, Harvard Business School, a Ph.D., a master's degree, experience in a variety of things, anything that will

Donald B. Bruck, *(continued)*
is big enough for your purposes, offer a better, cheaper line, or work harder than the competition.

There is an aspect of the present situation that actually works in favor of individuals attempting to start up a company at this time. There has been attrition of companies and of people with marginal capabilities and strategies. Hence the competition is much more realistic now in pricing. The previous situation—in which prices were lowered by some companies to whatever it took to secure and maintain ever-expanding sales, without due regard to costs and losses—has greatly diminished.

In short, the newly rediscovered importance of bottom-line profits has had the effect of weeding out the lunatics and perhaps of giving newly founded companies that employ sound business strategies a better chance of survival.

Organize your thoughts with a plan

But before you start a company, you should draw up a business plan.

A business plan tells the prospective investor where you intend to go and how you intend to do it. You have to describe the market you're going into and define the products, and then very carefully discuss the competition. Don't ignore a strong competitor, because you'll damage yourself more when the investor unearths that characteristic of the market. Face up to competition and explain why you think you can either compete with it or go around it.

If you can't cope with the competitor, perhaps you've chosen the wrong market. One of the best reasons for putting together a business plan is to organize your thoughts. When you put your plan on paper and you're faced with having to cope with the competition, finances, distribution systems and their bearing on sales, purchases and collection, you find those areas have meaning only with regard to each other in a time frame. You can see the impact of each on the others, and you start to get a better feel for what is necessary and what is practical to accomplish.

The biggest shock that engineers get from formulating profit-and-loss sales projections and cash-flow projections is learning that those two projections are different.

I've helped a couple of engineers get a business started, and I couldn't help but detect their disdain for accounting and finance. They seemed to think that if you have a company that's profitable, everything else falls into place. They soon learned that the presentation of numbers is not a casual exercise.

Business plans don't differ too much. If you know roughly what the gross margins are in a

Dr. Samuel Wilensky, *(continued)*
show them that you have a considerable technical and business experience. They like to see a business plan; they want to know that you're not just a part-time professor with a product. No matter how much money you think you're going to need, you're going to need more. If you're well financed and hire good people, you can usually survive long enough to get into some area where you can make money.

People-dealing a challenge

Being an engineer in a small company means that you've got to be a technician and also a salesman, because you're going to be out in the field talking to the customer and on the phone when he calls you for technical information. You've got to be an administrator, too, to pull all of these things together and make them work as an entity. You're the one who changes the toilet paper in the bathroom, because you're the only one who'll do that sort of task.

There are benefits—you are your own boss. But that presents its own special challenges. The two most difficult challenges for me as an engineer when we started the company were dealing with people and handling production and engineering simultaneously.

For me, dealing with people is the biggest headache of all. In starting a company, you meet more people than you do as an engineer. When I doubled as the purchasing agent, I had to learn to talk with salesmen, something I never did as an engineer. I have an academic background, and I worked with 10 to 20 people in a research lab, most of them on a peer level.

In a business it's a different story. There are personnel problems that never come up in the lab. A secretary comes to you in tears because one of the other girls looked at her wrongly. Or a guy says he has to have a raise or he's walking out the next day.

Hiring people is difficult, too. We try to hire a person who's working in the field now and who has experience and a good reputation. You've got to convince him that he can grow with a small company. If you give him an equity position in the company, you've got to be sure that he's as serious about the company as you are.

Whether I'm directing people, or hiring them, or buying from them or selling to them, for me honesty with people is probably the best policy. Whenever I tried to push the truth slightly, I never told a very good story.

Mixing production and engineering

Another difficulty for an engineer who starts a company is that there is always pressure to get

Donald B. Bruck, *(continued)*
particular field, there are certain inherent characteristics that force remaining numbers to come out somewhat similar. But the formulation of a plan is tremendously enlightening to the individual who does it. ■■

Donald B. Bruck and Dr. Samuel Wilensky study the assembly process in their Burlington, Mass., plant.

Dr. Samuel Wilensky, *(continued)*
the product out of the door. In a sense, you sometimes have to compromise your ideals of quality to push things out on time. It's very difficult doing both production and engineering. On the one hand you want to push products out the door and, on the other hand, you don't want to ship a defective item. Since you have to balance these two things, you've got to learn when the unit is good enough to ship. If my engineers finish 99% of the product and are still working hard on it, I tell them to stop. To get that extra 1% may take them the same amount of time it took to get the first 99%, and it's just not worth the investment in time and effort.

When you start a new product, find someone who has made it before; at least you won't repeat the same mistakes he made. It's worthwhile talking to someone or hiring an engineering consultant to show you the problems that you're going to run into. In a sense, you've got to divorce yourself from engineering and realize that you're in a business. ■■

Donald B. Bruck, Dr. Samuel Wilensky and Hybrid Systems Corp.

For a time one might have thought that Donald Bruck was going to become a professional student; he earned a B.E.E. at Renssalaer Polytechnic Institute; a Master of Science (electrical engineering) at MIT, a Master of Science (physics) at Northwestern University; and an MBA at Harvard.

But his education coupled with the business and technical experiences he picked up along the way helped him to found Hybrid Systems Corp., in 1967. His experiences included stints as sales director with Burr-Brown Research Corp.; Sales engineer at GPS Instrument Co.; computer programmer at Wolf Research & Development Corp.; and manager of systems development contracts and programs with the U.S. Air Force.

He incorporated Hybrid Systems in 1965 with a capital base of only $500.00. The mailing address was a post office box, the phone terminated only at an answering service, and the products were manufactured in the home.

From May 1967 sales doubled every year and the company has been profitable every year since 1970. In September, 1973, Hybrid Systems Corp. acquired the hybrid thin/thick film operation of Sprague Electric Company in Worcester, Mass. At the present time, Hybrid Systems Corp. employs over 200 persons and has a sales rate in excess of $7,000,000 per year. The company is privately held.

Dr. Samuel Wilensky had spent some of his engineering career teaching and some of it researching before becoming a principal of Hybrid Systems Corp. After he had earned his B.S. (electrical engineering) and his Ph.D at MIT, he taught nuclear physics courses at his alma mater, and, two years later taught a course in nuclear reactor engineering.

Sandwiched between Wilensky's teaching assignments were two research positions, one at MIT Rockefeller Accelerator, where he designed instrumentation for Van De Graaff Accelerators, the other at Massachusetts General Hospital and Harvard Medical School, where he was responsible for the instrumentation designs, and computer operation of Cyclotron.

He has published numerous articles and papers, including "SIGNMA: A Code to Change the Gain of a Multichannel Analyzer Output," Computation Center Final Report M2351, M.I.T., Cambridge, Mass.; "Hybrid Scintigram Display System," presented at the 16th Annual Meeting of Society of Nuclear Medicine, New Orleans, June, 1969; and "Computer Processing and Display of Positron Scintigrams and Dynamic Function Curves," *Medical Radioisotope* Scintigraphy, Vol. 1, (815-827) iAEA Vienna, 1969.

OUR 5V POWER MINI'S STACK UP LIKE THIS

OUTPUT VOLTAGE	OUTPUT CURRENT AMPS.	REGULATION LOAD ±%	REGULATION LINE ±%	RIPPLE MV RMS	PRICE	MODEL	SIZE INCHES
5	.250	.05	.05	0.5	$39.00	5E25	2.3 x 1.8 x 1.00
5	.500	.1	.05	1	49.00	5E50A	3.5 x 2.5 x 1.00
5	1.0	.2	.05	1	69.00	5E100	3.5 x 2.5 x 1.25
5	1.5	.3	.1	1	98.00	5E150	3.5 x 2.5 x 1.25
5	2.0	.15	.05	1	110.00	5E200	3.5 x 2.5 x 2.00
5	2.5	.15	.05	1	125.00	5E250	3.5 x 2.5 x 2.00

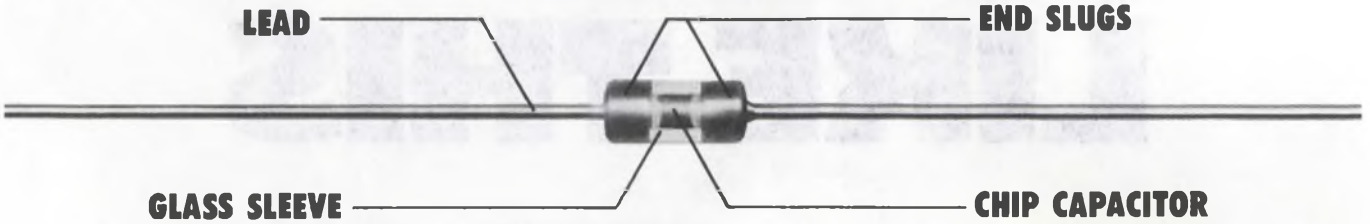
. . . and the model you choose will be shipped 3 days after Acopian receives your order. With a 105-125 VAC input, use it at full rated load to 71° C. Short circuits won't damage it. These mini-modules can be mounted on a printed circuit board in a space of only a few square inches. Generous quantity discounts are available. Or, if you're working with other voltages, choose from hundreds of other models. Single outputs from 1 to 75 volts.

Duals for op-amps with output currents from 25 to 500 ma. Even triple outputs. Complete details on these plus a comprehensive line of other power supplies and systems are included in the Acopian 73-74 catalog. Request a copy.

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

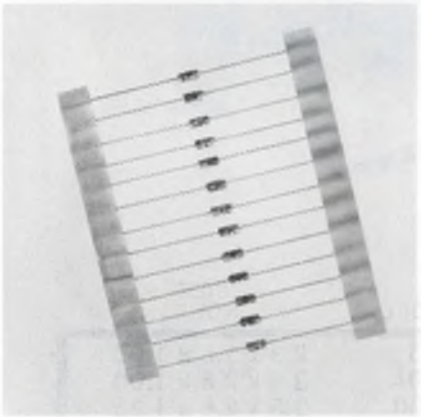
INFORMATION RETRIEVAL NUMBER 65

MONO-GLASS... A JEWEL OF A CAPACITOR



U.S. Capacitor Corp. has done something elegant for high volume capacitor users . . . MONO-GLASS.

This glass encapsulated monolithic ceramic capacitor offers something special: for the Design Engineer looking for cost reduction and dependability; for the purchasing agent looking for low price with fast delivery; for the incoming Q.C. inspector who is looking for reliability.



AUTOMATIC INSERTION:

If you use it, you know the substantial savings in time and cost. MONO-GLASS is designed for automatic insertion with the same equipment used for diodes and resistors. Reel packed and ready for your machines.

DURABILITY:

Our hermetically sealed, glass-to-metal construction offers these advantages: solderless internal contacts that won't reflow in your wave-soldering process; no glass fracturing during lead forming—stress is transferred to the end slugs rather than the glass sleeve.

HIGH VOLUME; LOW PRICE

USCC's production capability for chip capacitors is second to none. MONO-GLASS is produced by a simple assembly technique. Combine these two and you get the best possible delivery for high quantity requirements, at a budget price.

WIDE SELECTION:

Four case sizes are available . . . .200 x 100; .250 x .100; .300 x .150 and .400 x .150. The 50 and 100 WVDC units offer up to .01 mfd in COG dielectric, to .18 in X7R and up to 1.0 mfd in the Y5V dielectric.

RELIABILITY:

USCC is the proven leader in state-of-the-art, demonstrated on N.A.S.A. life support and guidance systems. Commercial as well as military aerospace applications benefit from the high reliability features of our products—the best available.

MONO-GLASS is our lowest priced ceramic axial lead capacitor, offering a new quality capability for communications, navigation and guidance, computer business machines or anywhere that high volume, low price is required.

Write or call for an evaluation sample, more technical data or applications help for your special requirements. Remember, USCC-Centralab.

USCC **USCC/Centralab**

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(213) 843-4222 ▪ TWX: 910-498-2222

INFORMATION RETRIEVAL NUMBER 66

Open a Savings Account with our new megapower SCRs

When you invest in IR's new Megapower SCR Family Savings Plan you start earning dividends three important ways.

First, you can eliminate over 70% of the devices and parts normally needed (see the 3-phase converter "savings account" below for full details). That gives you a lower total system cost, plus more reliability.

Second, having fewer parts cuts assembly time sharply, increases reliability and makes your field servicing that much easier, too.

Third, Megapower SCRs give you more production power with only a minimum change in your equipment size.

If you want to parallel Megapower SCRs, there's a special bonus. Our epitaxial process yields SCRs of virtually identical switching characteristics, so you eliminate expensive current balancing equipment. It also produces the high voltage SCRs you need. Specifically: 700A(av), 500 to 2100V; 850A(av), 500 to 2000V; 1000A(av), 500 to 1500V, and 1600A(av), 500 to 1200V.

IR'S 4800 Amp, 3-PHASE CONVERTER SAVINGS ACCOUNT

Parts Per Assembly	4800A Assy. Using 3-550A SCRs Per Leg	4800A Assy. Using 1-1600A SCR Per Leg	Parts Saved Per Assy.
1. SCRs	18	6	12
2. Heat Sinks	21	9	12
3. Clamps	18	6	12
4. Fuses	18	6	12
5. Balancing Reactors	18	0	18
6. Trigger Pulse Pwr. Amplifiers	6	0	6
7. Isolated Gate Drive Windings	18	6	12
Totals	117	33	84

There is also an extra dividend in overall productivity because Megapower SCRs will keep your equipment on line longer. Their surge capability is so high, they can ride through massive overloads without resorting to protective fuses.

Open a savings account today. Call your IR branch office, or bank headquarters (213) 678-6281: Telex: 67-4666. International Rectifer, 233 Kansas Street, El Segundo, CA

International Rectifier

International Rectifier, 233 Kansas Street, El Segundo, CA 90245. ***... the innovative power people*** I◎R

INFORMATION RETRIEVAL NUMBER 67

Current clamp blocks destructive discharges of large filter capacitors

A current-clamp circuit prevents damage from accidental fast discharge of large power capacitors.

As long as the power supply can furnish the necessary load current and voltage, CR_1 conducts and C_1 provides the requisite filtering. The auxiliary circuit supplies a portion of C_1's charging current, 1.2 A at 0.9 V.

When a short circuit occurs, point A is more positive than point B, and CR_1 blocks most of the discharge through the external circuit. Part of the energy is diverted through CR_1, which can handle large surge currents. Meanwhile the main breaker in the supply operates, and power is shut down. The circuit limits the capacitor dump current to 1.6 A at any load.

The components shown are for an HP 6274 A supply rated at 70 V/18 A. They also apply to Trygon MC 7C-150-20 supply rated at 160 V/16 A. With the Trygon supply operated at 70 V, 18 A, the peak current was 4 A and had a triangle-shaped decay curve that lasted 1 ms.

The ripple with both supplies used in conjunction with the circuit is

HP at 30 V and 10 A: 1 mV (rms),

Trygon at 70 V and 18 A: 20 mV (rms).

On the other hand, the supply specs were

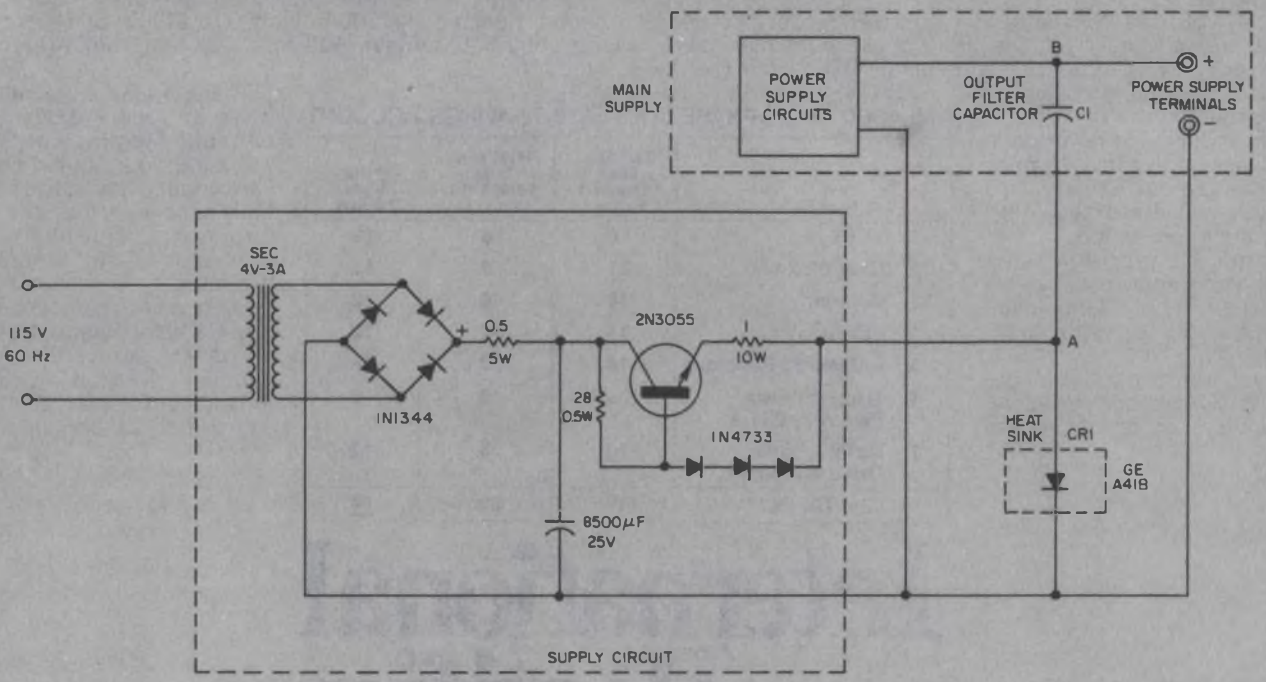
HP at 60 V and 16 A: 500 μV,

Trygon at 100 V and 16 A: 14 mV.

The circuit introduces little additional ripple.

John B. Ayer, Engineer, 2013 Deerhurst, Ottawa-K1J8H2, Ontario, Canada.

CIRCLE NO. 311



External circuitry limits current surges caused by a short circuit of an output filter capacitor.

The reader that can stay on, and on, and on. The 603.

The price of the Model 603 V-O-M is only $173.

The one V-O-M you can forget about forgetting to turn off. The incredible Model 603 FET V-O-M with exclusive Triplett Micro-Power™ draws only 10 uA, can stay on indefinitely without impairing performance. Ideal wherever frequent test changes, interruptions, distractions—or gremlins—keep your V-O-M working when you're not.

Truly outstanding features:

1. **Exclusive Triplett Micro-Power (TMP™) provides battery life in excess of a year for carbon batteries with unit left on continuously 24-hours a day.**
2. **Low-Power Ohms (LPΩ™)—6 ranges with 70 mV power source for in-circuit measurements without damage to components.**
3. **FET V-O-M with Patented Auto-Polarity—convenient and time-saving, always reads up scale.**

Accurately measures electric and electronic circuits on production lines, in quality testing, during maintenance, in service shops and on calls, in the laboratory or classroom, in the field.

One range selector switch operates the unit. One probe handles all functions—AC, DC, MA, Ohms—and a simplified scale utilizes only 4 arcs for all 44 ranges. The Low Power Ohm circuit permits fast circuit measurements without biasing semiconductor device junctions. The

Model 603 also has a unique, Patented Auto-Polarity circuit: push a button, measure either plus or minus voltages without switching leads. Make very fast voltage checks where polarity is known or doesn't matter.

For more information or a free demonstration, call your Triplett distributor or sales representative.

For the name of the representative nearest you, dial toll free (800) 645-9200. New York State, call collect (516) 294-0990. Triplett Corporation, Bluffton, Ohio 45817.

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INFORMATION RETRIEVAL NUMBER 68

A/d converter remembers signal peaks whose duration is less than 50 ns

Gerald C. Stoker, Senior Engineer, Sandia Laboratories, NDT Div. 9352, Albuquerque, N.M. 87115.

CIRCLE No. 312

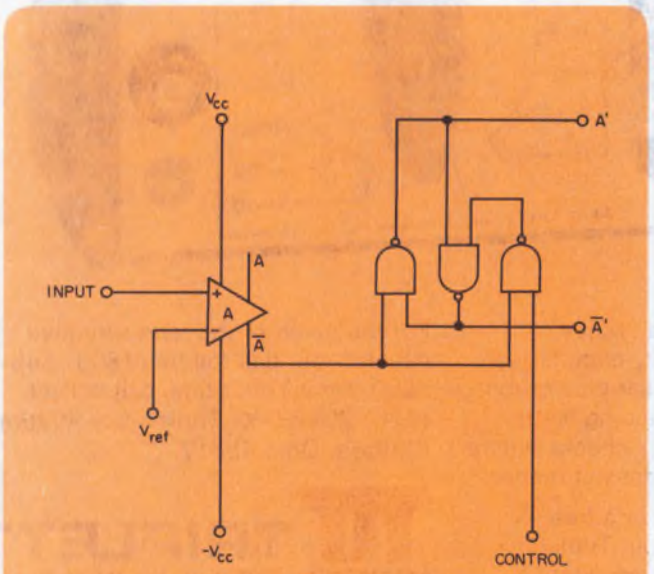
A parallel a/d converter plus some digital logic forms a circuit that can retain signal peaks of very short duration. The circuit includes externally controlled digital logic that either tracks the input signal or latches onto the high state.

The $\overline{A}$ output of each comparator is connected to an R-S flip-flop comprised of three, two-input NAND gates (Fig. 1). The $\overline{A}$ output remains high until the input to the comparator exceeds the reference level, V_{REF}. When this happens, the $\overline{A}$ output falls and the values of the A′ and $\overline{A'}$ outputs toggle—that is, A′ goes from low to high and $\overline{A'}$ goes from high to low.

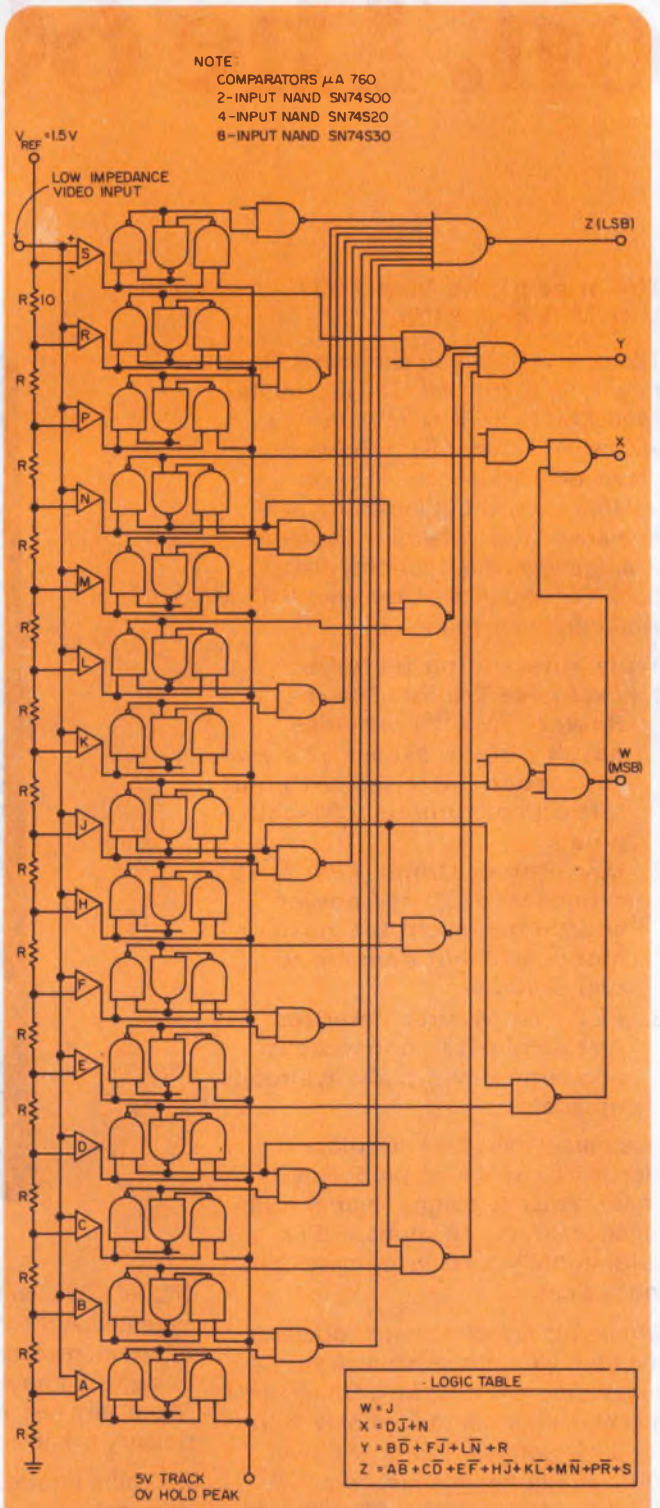
With the control signal at 5 V, the outputs A′ and $\overline{A'}$ toggle between states as the input goes above and below the reference level. If the control line is set to 0 V, the outputs latch when the input exceeds the reference voltage, and A′ remains high. However, the comparator output can still toggle between the high and low states.

A four-bit converter (Fig. 2) has 15 comparators and can output 16 states, zero included. Schottky-clamped TTL logic decodes the comparators. The reference voltage for each comparator is 100 mV more positive than the one below; the bottom comparator is referenced to 100 mV.

Some of the logic gates serve no purpose in decoding the comparator states. Their inclusion helps equalize the propagation delay to the decoded outputs. With the components shown, the circuit has retained peaks with less than 50-ns duration.



1. **R-S flip-flop logic follows the state** of comparator A if the control line is ONE. The logic circuit will latch on the high state of A when the control line is ZERO.



2. **A/d converter built with R-S logic** retains signal peaks when the control line is ZERO. The R-S logic remembers the high states that occur. The circuit follows the input when the control line is ONE.

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Need a special or unusual meter? Let Simpson help you custom design it. Send us your specs and we'll send you a quote. But check our catalog first—that "special" may be a standard Simpson stock item.

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INFORMATION RETRIEVAL NUMBER 69

Simplified biofeedback circuit detects alpha-wave activity

A simple circuit can detect alpha waves and provide feedback of alpha activity to the user.

The circuit provides high input impedance, high gain, selective alpha-wave filtering from 8 to 13 Hz and a time-averaged indication of activity. The tone produced by the speaker rises in pitch as alpha waves appear and falls off as the activity decreases.

The circuit is divided into three parts. The first stage, a high input-impedance differential amplifier, raises the level of the minute brainwave voltage about 2000 times. The second stage, an active filter for alpha-wave frequencies, rejects other classes of brainwave activity. The filter allows over-all gain control by means of a 10-k potentiometer.

The final stage, a voltage-controlled oscillator and speaker driver, examines the average level of alpha activity. The frequency of the tone at the speaker follows the averaged voltage at the output of C_5. Batteries are used because they are safer than line supplies, and provide less interference to the faint brainwave signal (5 to 50 μV).

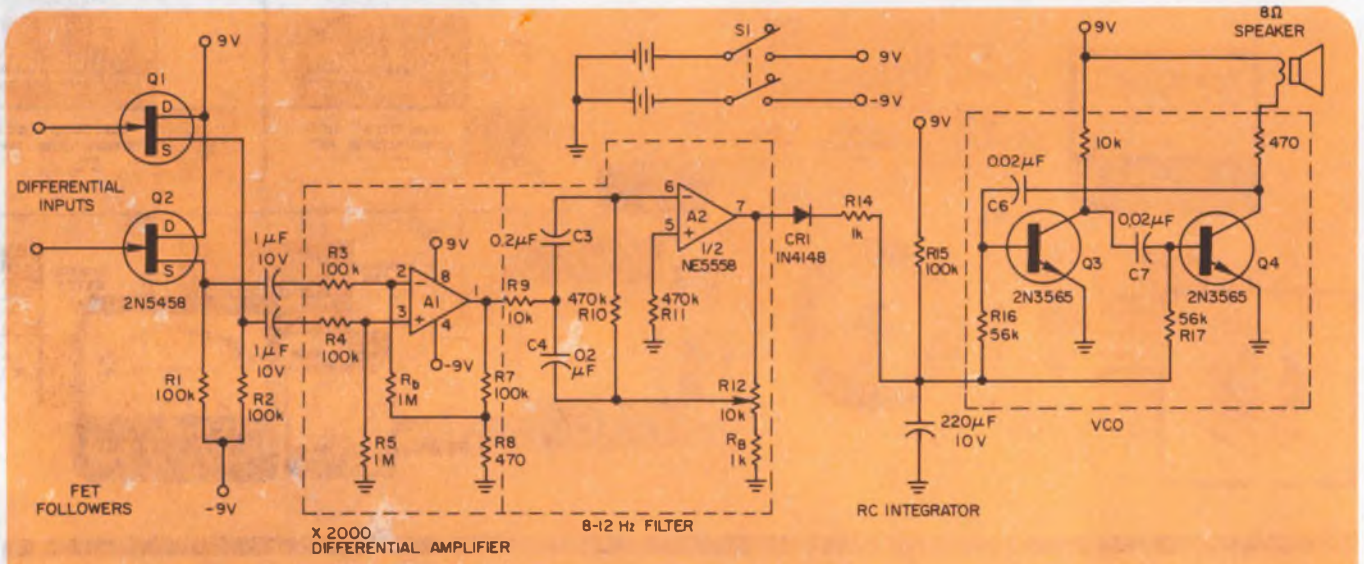
Electrode preparation and placement is covered in the reference, but note that a third or common electrode is also needed. The requirement is met if you mount the circuit in a metal box and hold it during use. The gain potentiometer R_{12} is adjusted to match the sensitivity of the circuit to the subject's specific alpha levels.

Paul Lutus, Design Engineer, Philips Broadcast Equipment Corp., Government Systems Div., One Philips Parkway, Montvale, N.J. 07645

Reference

Stoyva Johann (Ed.), "Biofeedback & Self-Control," Albine Publishing Co., New York, N.Y., 1971.

CIRCLE NO. 313



An aural indication of alpha-wave activity is provided by a selective amplifier and VCO combination. The frequency of the tone corresponds to the average level of alpha activity.

IFD Winner of February 1, 1974

P.R.K. Chetty, Indian Space Research Organization, A 3-6, Peenya Industrial Estate, Bangalore, India 560022. His idea "EXCLUSIVE-OR Circuit Handles Wide Range of Input Levels Without Power Supply" has been voted the Most Valuable of Issue Award.

Vote for the Best Idea in this issue by circling the number for your selection on the Information Retrieval Card at the back of this issue.

SEND US YOUR IDEAS FOR DESIGN. You may win a grand total of $1050 (cash)! Here's how. Submit your IFD describing a new or important circuit or design technique, the clever use of a new component or test equipment, packaging tips, cost-saving ideas to our Ideas for Design editor. Ideas can only be considered for publication if they are submitted exclusively to ELECTRONIC DESIGN. You will receive $20 for each published idea, $30 more if it is voted best of issue by our readers. The best-of-issue winners become eligible for the Idea of the Year award of $1000.

Watts New

Sorensen introduces the new, higher power density DCR-B series lab/system dc power supplies. Designed specifically as an extension of the popular single-phase DCR-A series. Minimum panel height is 3½". Power output is up to 2700 watts. Noise and ripple are 50% lower than in previous models.

Other DCR-B advantages: low cost-per-watt; fast response time; choice of 32 new versatile models to cover a broad range of applications; exceptional efficiency and dependability; and new, less expensive overvoltage protection option that can be installed at the factory or in the field. For complete data, contact the Marketing Manager at Sorensen Company, a unit of Raytheon Company, Manchester, N.H. 03103. (603) 668-4500.

Representative Specifications—DCR-B

Voltage Ranges: 0-10, 20, 40, 60, 80, 150, 300, 600 volts DC			
Efficiency: Up to 86% typical			
Panel Height	Cooling	Nominal Output Power (watts)	Price Range
3½"	convection	500	$400-475
5¼"	convection	1000	575-690
7"	convection	1800	775-975
7"	fan	2700	1075-1125

Sorensen
POWER SUPPLIES

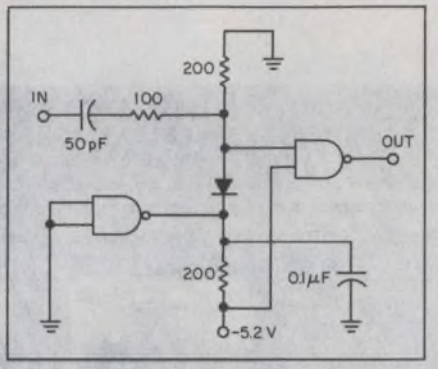
INFORMATION RETRIEVAL NUMBER 70

international technology

Subnanosecond transients detected with ECL logic

A tunnel diode, coupled directly to a gate of the emitter-coupled logic family detects subnanosecond transients with an output signal that is ECL-compatible.

Developed at Hull University in England, the circuit has a tunnel diode that is dc-biased at 8 mA through a 200-Ω resistor to ground. With the diode in its low state, the transient input voltage develops a current through the 100-Ω resistor. Provided that this current is large enough, the tunnel diode switches to its high state.



During the switching the tunnel diode has an effective load of 100 Ω in parallel with 200 Ω, or 6 Ω. The switching time is directly proportional to the total capacitance across the tunnel diode, which is the sum of the junction capacitance, the logic-gate input capacitance and any stray capacitance. A typical junction capacitance is 1.5 pF and, for a logic-gate value of 3 pF, the total capacitance across the diode is about 6 pF. With a bias current of 8 mA, the predicted diode switching time is 0.35 ns. With a 0.5-ns-duration pulse, the circuit operates satisfactorily down to 0.5 V, at which point the switching becomes erratic. The addition of inductance between the diode and the gate input can improve the switching speed by removal of the shunt-capacitance effect of the logic gate.

Phase shifter holds amplitude within ±0.4%

A German phase shifter for the 0-to-5000-Hz range has been designed to maintain amplitude deviations within ±0.4%. The phase angle can be varied between 0 and 180° with infinite resolution.

Developed at the Institut Für Nachrichtentechnik in Braunschweig, West Germany, the shifter is being used to set up the calibration equipment for a magnetometer.

Three operational amplifiers are used in the shifter—one as the main phase shifter and two as input and output buffers. For stability, metal-film resistors and low-loss, low-inductance capacitors are used in the feedback loops.

The variable, phase-angle potentiometer control presented problems because parasitic inductances and capacitances greatly influence amplitude stability. The combination finally chosen—a 24-pole ceramic switch with a series of 2-kΩ metal-film range resistors, switched in series with a 2.7-kΩ single-turn Cermet potentiometer—is described as superior to a wire-wound potentiometer and a conductive-plastics type. The phase-shifting capacitance is switched in steps, to linearize the phase control over three decades.

Anisotropic conductors herald new devices

A new class of anisotropic conductors, which conduct electricity in one plane only, is under development at Brown Boveri in Switzerland. The substances are said to be perfect insulators for voltages perpendicular to the conducting plane.

The anisotropic properties are induced by long chains of platinum atoms in substances such as potassium-platinum-cyanide. Such properties are expected to be useful in microwave-cavity technology and optics. For example, since the electrical vector of visible light is also short-circuited along the conducting plane, transparent layers of anisotropic conductors are suitable for polarized filters.

A flight simulator for the Concorde due

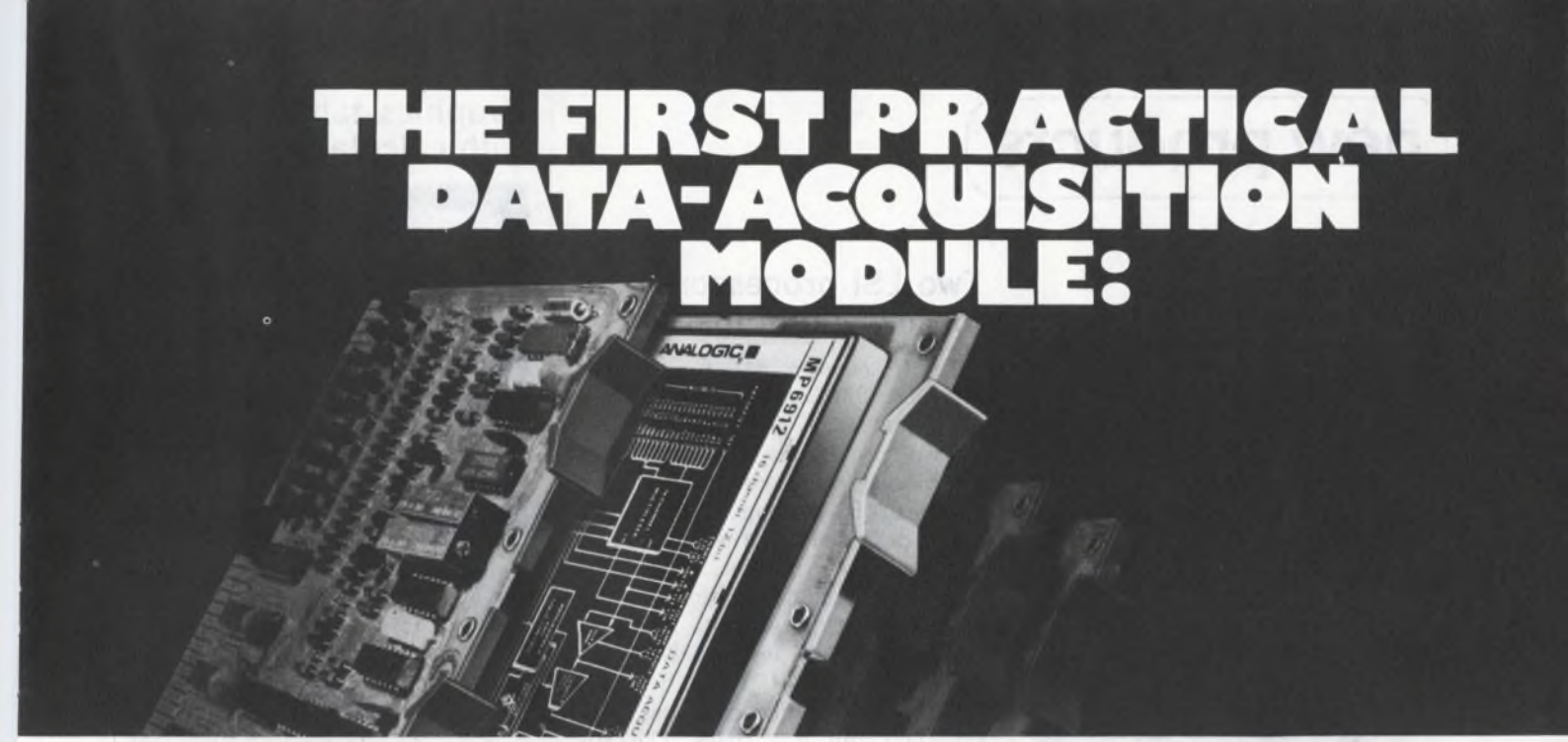
A supersonic flight simulator for the Concorde SST will be built by Redifon Flight Simulation, in Crawley, England, in collaboration with the British branch of Link-Miles (Singer Co.). A contract, awarded by the British Aircraft Corp. calls for use of a Link six-axis motion system, a Redifon Duoview color closed-circuit TV display, and Redifon R200A computers and interface equipment.

4-k-bit core memory to go into solar probe

A 4-k-bit ferrite core memory, to be incorporated in the Helios solar-probe spacecraft, has been designed through the cooperative efforts of Siemens, in West Germany, and the Braunschweig Technical University.

Total mass of the unit is 42 grams. Mechanical stability is 38 g for vibrations between 50-to-200 Hz, and 6 g in the 200-to-2000-Hz range. The temperature range is between −55 and +110 C.

THE FIRST PRACTICAL DATA-ACQUISITION MODULE:



Complete 12-bit, 16-channel system fits 0.5" card spacing--anywhere. Better performance, at lower cost, than individual module combinations.

On a minicomputer motherboard, medical instrument or process control system . . . mounted on a single small card . . . plugged directly into a card-cage connector—there's always room for the 0.375"H x 4.6"W x 3.0"L Model MP6912: With space at a premium, this remarkable plug in, easily serviceable high-performance / low-cost system is your first really practical alternative to either in-house design or larger more costly systems. Particularly since you'd actually pay *more* to get comparable performance from individual modules that need 3-5 times the "real estate".

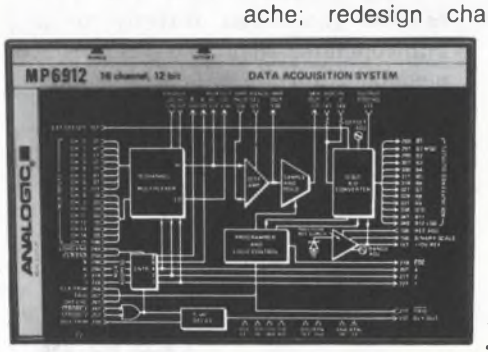
You get a 16-channel multiplexer (expandable to 256 channels), fast sample and hold, and a 12-bit A/D converter (accuracy ±0.025% at a 100kHz thruput rate), integrated with complete programming, control, and timing logic. (That's what we call the first *practical* data acquisition module.)

What you don't get is equally important: error accumulation; module interconnection costs and headache; redesign challenges every time the application changes; and testing, documenting, and quality-controlling at the module level.

The MP6912 is an optimized design: 100% shielding on all six sides to minimize interference; minimum parts count for inherently high reliability; an exceptional 100kHz basic throughput rate that can be "short cycled" up to 450kHz; buffered outputs for trouble-free digital interconnection.

A companion D.C. to D.C. converter, the MP3020, which is powered by the +5V logic supply is also available to provide all the power needed for the MP6912 in a compatible 0.375" thin package.

Write for our 16-page designer's guide to the MP6912—applications and timing diagrams, set-up and calibration procedures, etc. and see why the Analogic alternative makes sense. Analogic, Audubon Rd., Wakefield, Mass. 01880; phone (617) 246-0300.



Northeast, 617-235-2330, 203-966-2580, 315-466-0220, 201-652-7055, 212-947-0379
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Midwest, 314-895-4100, 913-362-0919, 216-267-0445, 513-434-7500, 313-892-2500, 412-892-2953, 312-283-0713, 414-476-1500, 317-844-0114
South, 713-785-0581, 214-620-1551, 305-894-4401, 919-227-3639, 205-534-9771, 305-773-3411, 813-867-7820
West, 303-744-3301, 505-523-0601, 602-946-4215, 505-292-1212, 714-540-7160, 415-398-2211, 206-762-7664, 503-643-5754,
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INFORMATION RETRIEVAL NUMBER 71

new products

Desk-top terminals have advanced features

Car-Mel Electronics, 2218 Cotner Ave., Los Angeles, Calif. 90064. (213) 477-4216. $1110 (100 quan); stock.

The compact D-302 CRT terminal can be used to enter information on a screen and transmit the data at high speed (up to 9600 baud) to a polling computer. The terminals also include the protected field feature. Up to 128 terminals may be connected to a single computer port—directly or by use of a modem—since each terminal may be daisy-chained to the next one in the line and has its own specific address.

CIRCLE NO. 253

Interface card links HP 2100s at 25 Mbit/s

Hewlett-Packard, 1501 Page Mill Rd., Palo Alto, Calif. 94304. (415) 493-1501. Stock.

A high-speed series interface links HP 2100 computers. The hardwired interface card, designated the HP 12889A, enables asynchronous data transfer at 2.5 Mbits/s at distances up to 1000 feet and up to 1.25 Mbit/s at distances up to 2000 feet. The device plugs directly into the I/O structure of each 2100 to be linked. Also supplied is a software driver that is compatible with HP's disc-operating system, DOS-III.

CIRCLE NO. 254

Two LSI processors aim for low end of market

Digital Equipment Corp., 146 Main St., Maynard, Mass. 01754. (617) 897-5111. See text.

Two processors—an 8-bit LSI Microprocessor Series (MPS), and a 12-bit MSI version of the PDP-8—are designed for the low end of the computer market. The MPS with a basic configuration of CPU plus 1 K of RAM sells for $745 in single quantities and $445 for 1000 units. The PDP-8/A will sell for $895 in single units and $537 for 1000 unit quantities. The Microprocessor Series consists of five modules that include CPU, RAM and pROM. The CPU module communicates over an 8-bit data and memory bus, and contains an 8-bit parallel arithmetic unit. All program preparation is performed on a 4-k, PDP-8. The 12-bit PDP-8/A miniprocessor is a two module configuration. The CPU can address up to 32-k words. The unit allows for efficient use of memory and has a cycle time of 1.5 μs. The PDP-8/A is fully compatible with existing PDP-8s in hardware and software and can execute all existing PDP-8 programs.

CIRCLE NO. 255

Modular CRT terminal offers 64-color graphics

Cybernex Corp., 922 Industrial Ave., Palo Alto, Calif. 94303. (415) 328-8470. From $5120.

The AS103 is a vector programmed CRT terminal that provides high speed graphics in up to 64 colors. Plug in function generators are available for vectors, characters and circles. The unit can be interfaced directly to a minicomputer and uses the host's memory for refresh or can be supplied with a list processor that provides a local refresh buffer and data formatting capabilities. The AS103 has a 10 × 8-in. viewing area with 1024 × 1024 addressable points. Interfaces and software are available for popular minis.

CIRCLE NO. 256

Graphics tablet mated with calculators

Summagraphics Corp., 398 Kings Highway, Fairfield, Conn. 06430. (203) 384-1344. See text.

An interface is available to connect the manufacturer's Data-Tablet/Digitizer with the HP-9800 Series of calculators. The Data Tablet digitizes graphical source data, thus enabling the calculator to compute distances, perimeters, areas, regressions, and other factors from source material. Prices for digitizer and interface range from $1750 to $4400, depending on the useful working area and quantity ordered.

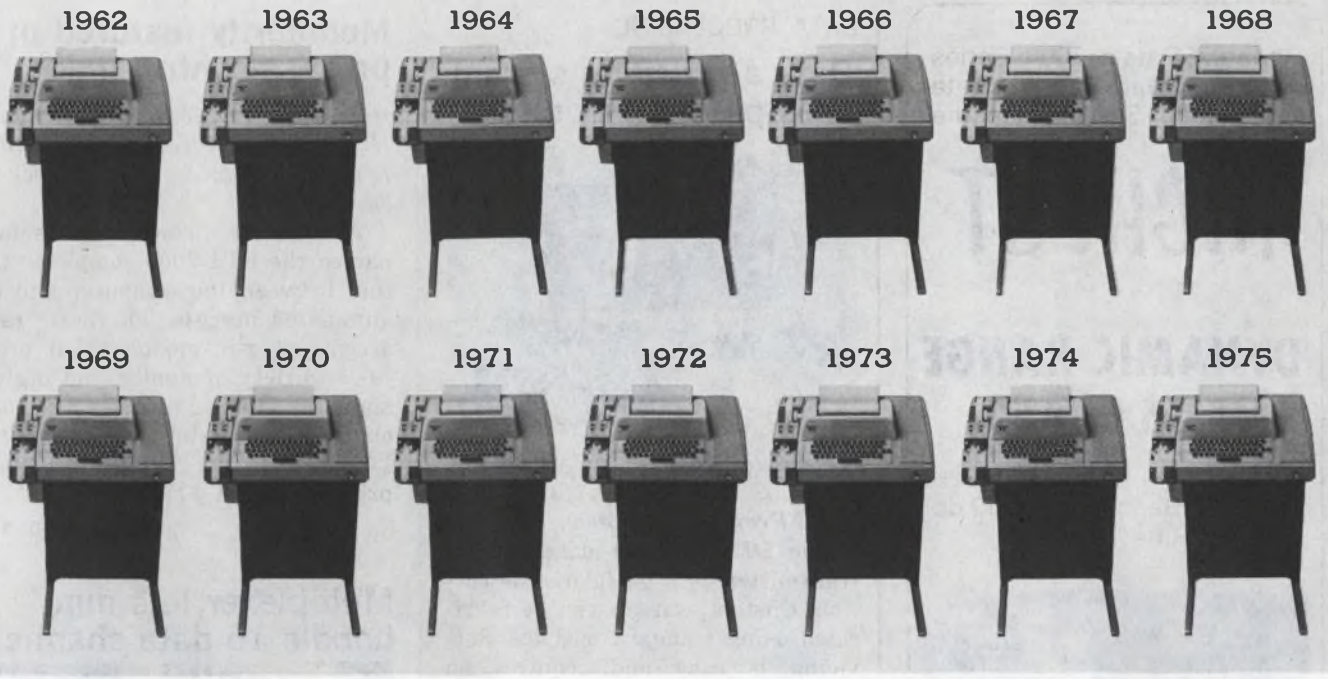
CIRCLE NO. 257

Tablets add free-hand graphics input

Tektronix, P.O. Box 500, Beaverton, Ore. 97005. (503) 644-0161. August.

The graphics tablet line includes two standard sizes. The 4953 is 11-by-11 in., has a 10-bit format, and is intended primarily for use with the 4010, 4012 and 4013 terminals. The 4954 tablet is 40-by-30 in., has a 12-bit format, and is intended for use with the larger Tektronix 4014 and 4015 terminals. Each of the tablets, however, will work with any of the terminals. The tablet converts the position of a pen on a writing surface into the digital information required to position the writing beam on the screen of a terminal. Graphic data can be simultaneously transmitted to the computer and the terminal to provide a local display, or it can bypass the terminal if no local display is wanted. The smaller tablet has a 1024 × 1024 point grid with 0.01-in. spacing. The larger tablet uses a 4096 × 4096 point matrix with 0.01-in. spacing.

CIRCLE NO. 258



Just how much longer will the model 33 be around?

The moment economy, reliability and versatility in data communications go out of date, the model 33 will become obsolete. But the more we look at today's business and economic environment, the more it seems the model 33 will live forever.

Because where else can you get so much for so little?

When the model 33 was first introduced, it was a bargain. Today, it's still a bargain. But it's hardly the same machine.

We've got a team of engineers assigned to the model 33 and their job is to keep making it better. Every year, they come up with a number of new features and improvements. Some improvements make the 33 more dependable and versatile. Others make it easier and more economical to manufacture.

Because of these changes, the model 33s we're building today are standard-duty terminals instead of light-duty units. And our manufacturing changes have enabled us to stay ahead of rising costs.

Since we feel the model 33 is going to be around for a long, long time to come, our parts support, quality service and continued product improvement programs are as strong as ever.

It takes more than manufacturing facilities to build the terminals Teletype® Corporation offers. It also takes commitment. From people who think service is as important as sales. In terminals for computers and point-to-point communications.

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INFORMATION RETRIEVAL NUMBER 72

DATA PROCESSING

Data acquisition system uses plug-in modules

Metrodata Systems, P.O. Box 1307, Norman, Okla. 73069. (405) 329-7007. From under $4000.

The DL640 series data logger/transmitter uses modular construction. Custom systems can be fabricated using standard modules. Servicing is easy and requires no special tools. The standard DL640 accepts one to 24 analog inputs, expandable up to 72. In addition, 12 digital BCD inputs can be provided. Data are recorded on 0.5-in. computer compatible magnetic tape or on the company's TD-60 tape deck using a 0.25 in. × 1200 ft. endless loop tape cartridge. Time data are automatically entered in each data scan in days, hours, minutes, and seconds and are set by front panel switches. The unit also has selectable scan rates, scan lengths, and 17 scan intervals. Data in any channel may be selected and displayed on the front panel. The system uses either 12 V dc or 115 V ac with stand-by dc capability in case of line failure.

CIRCLE NO. 259

Floppy disc is also IBM compatible

Control Data Corp., Box 0, Minneapolis, Minn. 55440. (612) 853-4094.

The CDC 878 flexible disc is interchangeable with the IBM 3540/3740 product family, as well as the manufacturer's 9400 and equivalent drives. Preformatting makes the CDC 878 compatible with the IBM Diskette. The format includes 77 tracks with 26 sectors per track and a maximum of 128 bytes per sector. The disc is shipped error-free, but the format allows for two spare tracks should noncorrectable errors occur during usage.

CIRCLE NO. 260

Modularity featured in process-control link

Process Computer Systems, 5467 Hill 23 Dr., Flint, Mich. 48507. (313) 744-0225. See text; stock to 90 days.

A process control interface named the GPI 2000 completes the link between the computer and an automated process. The basic rack accepts plug-in modules that process a variety of analog and digital signals. Other modules provide channel addressing and computer I/O interfacing. Typical interface prices begin at $1790.

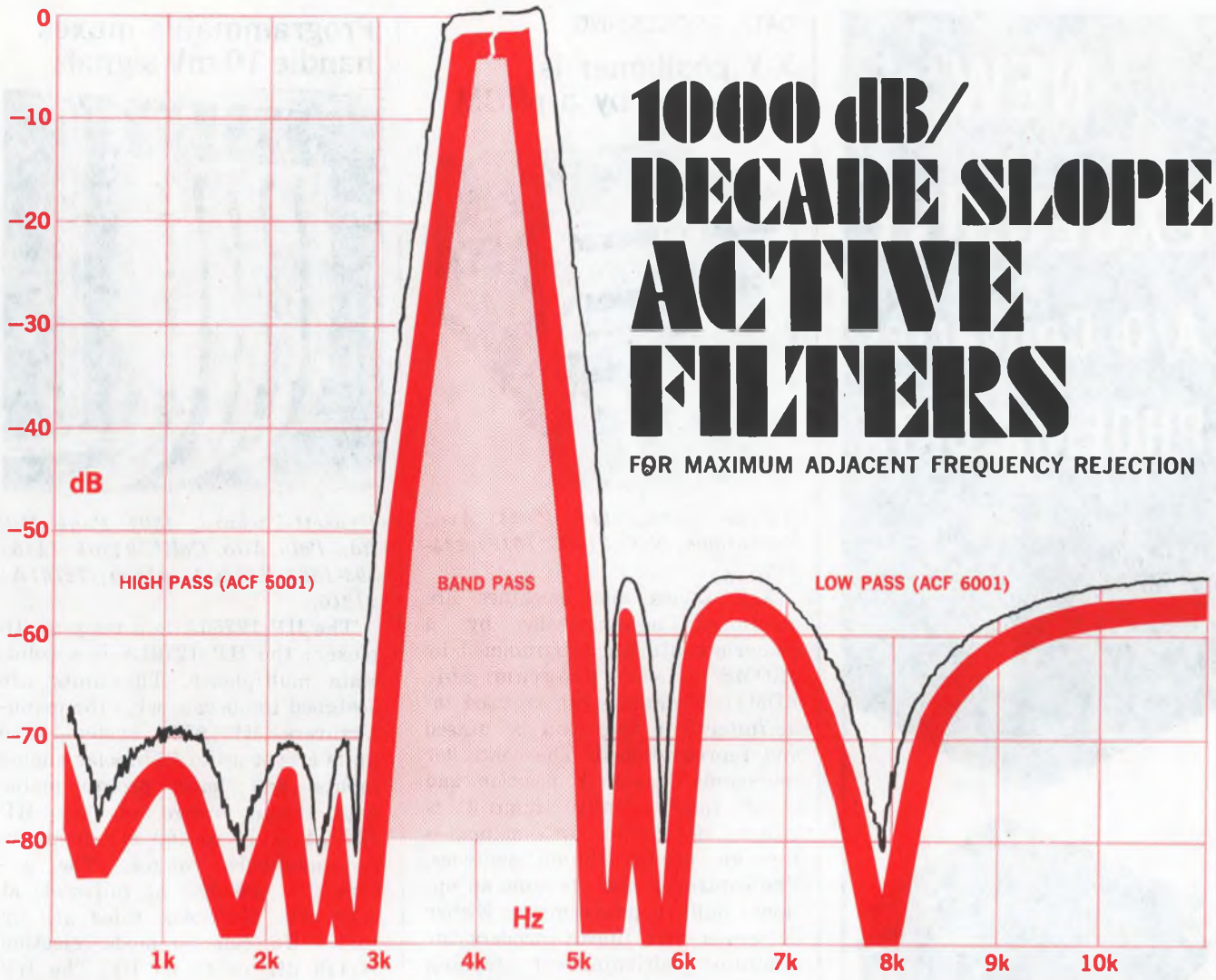
CIRCLE NO. 261

Multiplexer lets mini handle 16 data channels

Hewlett-Packard, 1501 Page Mill Rd., Palo Alto, Calif. 94304. (415) 493-1501. $2200; stock.

The 12920A, a high-performance multiplexer, enables signals from up to 16 communication lines to be channeled through the HP-2100 computer's I/O system. The asynchronous 16-channel unit operates at programmable data rates from 57 to 2400 baud per channel and can interface with asynchronous devices that are hardwired locally or connected remotely through a 103-type data set. The basic 12920A kit consists of three interface cards, a connector panel and cables and is installed into existing I/O slots of the 2100 central processing unit. The system offers several programmable features such as character length (from 5 to 12 bit); full-duplex, half-duplex, or echoplex-mode transmission; speed and break detection, parity generation and checking; and variable-length stop code. An automatic answering feature is also included. An optional control interface, priced at $800, allows the connection of up to 16, 202-type data sets.

CIRCLE NO. 262



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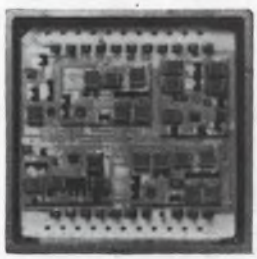
FOR MAXIMUM ADJACENT FREQUENCY REJECTION



General Instrument's new state-of-the-art active filters are designed for use in telecommunications systems, data and signal processing, biomedical, navigational, seismographic and other applications . . . wherever critical frequency rejection is a must.

Available in both high pass (ACF 5001) and low pass (ACF 6001) versions, these filters can be used together as a band pass filter. Each is packaged in a 1.6" x 1.6" x .25" hermetically sealed metal plug-in case.

Both filters are 8th order Cauer Elliptical in design with characteristics in the 3 to 6 kHz range.

For complete information on these, or any other General Instrument hybrid active filter, fill in and mail the adjacent coupon, or call (516) 733-3243.

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General Instrument Corporation,
Hybrid Division,
600 W. John St., Hicksville, N.Y. 11802

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- ☐ Chebyshev
- ☐ Bessel
- ☐ Bi-Quad
- ☐ Linear Phase
- ☐ Cauer
- ☐ Universal
- ☐ C-Message
- ☐ 1000 Hz Notch
- ☐ 50 or 60 Hz Rejection
- ☐ Comb
- ☐ Leap-Frog
- ☐ Custom

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GENERAL INSTRUMENT CORPORATION
HYBRID DIVISION

INFORMATION RETRIEVAL NUMBER 74

DATA PROCESSING

X-Y positioner is controlled by a pROM

Anorad Corp., 115 Plant Ave., Smithtown, N.Y. 11787. (516) 234-1824.

X-Y tables and machines are positioned automatically by a numeric controller programmed by pROMS (field programmable ROMs). Programs can be used indefinitely, or they can be erased and reprogrammed. The controller commands X and Y position and speed independently. Control is either automatic or manual—through digital thumb switches. The controller also contains an optional built-in programmer. Either dc servos with linear encoders for accurate positioning, or stepping motor drivers for less stringent requirements can be used.

CIRCLE NO. 263

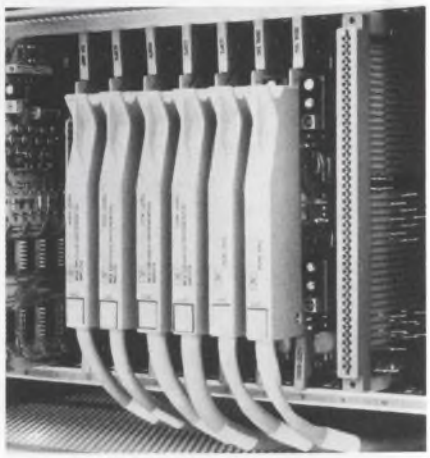
Remote data logged and formatted to tape

Memodyne Corp., 369 Elliot St., Newton Upper Falls, Mass. 02164. (617) 527-6600. See text; 2-4 wks.

The 4000 data logging system gathers remote data for processing at a central facility. The heart of the system is a standard Philips tape cassette. Data are recorded incrementally, bit-by-bit on a low-power cassette transport. The tapes are later converted to IBM tape format or serial ASCII. Prices range from $325 for a transport to $7459 for a complete IBM-compatible tape converter.

CIRCLE NO. 264

Programmable muxes handle 10 mV signals



Hewlett-Packard, 1501 Page Mill Rd., Palo Alto, Calif. 94304. (415) 493-1501. 12760A: $1600; 12761A: $1240.

The HP 12760A is a relay multiplexer; the HP 12761A is a solid-state multiplexer. The units are designed to operate with the manufacturers HP 9600 system. The units accept up to 16 bipolar analog inputs and have programmable gain. Input range of the HP 12760A is 10 to 400 mV in seven programmable ranges. The accuracy is ±0.29% of full scale at ±10 mV. Multiplex rates are up to 150 Hz; common-mode rejection is 115 dB, dc to 60 Hz. The HP 12761A offers eight programmable ranges. Its accuracy is ±0.33% of full scale with ±10 mV input at 20 Hz sample rate. Common mode rejection exceeds 100 dB, dc to 60 Hz.

CIRCLE NO. 265

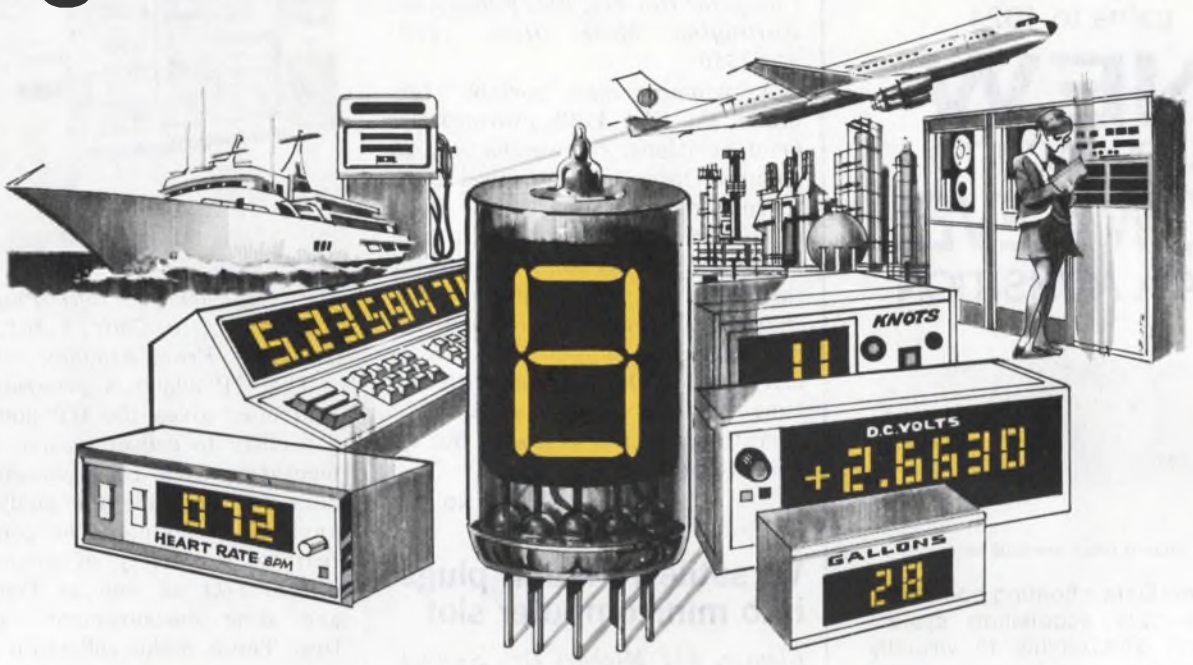
External memory board helps debug programs

Douglas Electronics, 718 Main Blvd., San Leandro, Calif. 94577. (415) 483-8770. $175; stock.

A Memo and Register board named the 101-DE-8 is compatible with PDP-8/e computer system. The board provides four MQ-like registers for temporary storage of repetitive data values and eight memo flip flops to control program flow. The registers permit an accumulator value to be stored and retrieved without first clearing the accumulator. The memos permit the programmer to set up program branches in advance and provide ready access to decision points.

CIRCLE NO. 266

When your design calls for the brightest readout...



consider all the advantages of RCA NUMITRON Display Devices.

In applications where brightness is critical RCA NUMITRON devices meet your most exacting requirements. They don't wash out, even in direct sunlight!

But brightness is just one important feature to think about when selecting display devices. Consider all the features that RCA NUMITRON devices have to offer:

- Unlimited color filter selection because of wide-spectrum light emission.
- Brightness is completely controllable — the device maintains uniform brightness, from segment-to-segment, even when operated at reduced voltages.
- High reliability and rugged construction. Life expectancy is more than 100,000 hours.
- Low-voltage operation (4.5 volts or 2.5 volts nominal).
- Compatible with IC decoder/drivers such as the RCA CD2500E family.
- Freedom from induced or radiated interference.
- Planar construction offers uncluttered, wide-angle viewing.
- Operating temperature range from -50°C to +125°C.

RCA NUMITRON devices are rugged! The DR2200 Series can withstand shock of 200g and vibration of 20g max. over a 60 to 500 Hz frequency range. NUMITRON displays are flexible, too. Solderable base pins permit direct PC board mounting. The DR2000 series of devices fit low-cost 9-contact miniature sockets. DR2100 and DR2200 Series fit TO-5 10-contact sockets.

Bright, sharp, dependable — RCA NUMITRON devices offer many important performance advantages to designers of readout equipment for industrial, commercial, or military applications.

Ask for RCA's NUMITRON Display Devices Designer's brochure (NUM-421A). You'll get the latest application information and data. Contact your RCA representative or RCA NUMITRON Device Distributor, or write, RCA Commercial Engineering, Sec. 57F7 415 S. 5th St., Harrison, N.J. 07029.

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INFORMATION RETRIEVAL NUMBER 76

DATA PROCESSING

Portable terminal now has 132 print positions

Computer Devices, Inc., 9 Ray Ave., Burlington, Mass. 01803. (617) 273-1550.

A wide-carriage portable terminal, the CDI 1132, provides 132 print positions, yet weighs only 25 pounds. Output is furnished by a thermal printer at selectable rates of 10, 15 and 30 char/s in both upper and lower case. The operator can select line widths of 80 or 132 characters from the keyboard. An integral acoustic coupler allows direct use of the terminal with any time-sharing system. The CDI 1132 operates with ASCII codes, but an APL version is available.

CIRCLE NO. 267

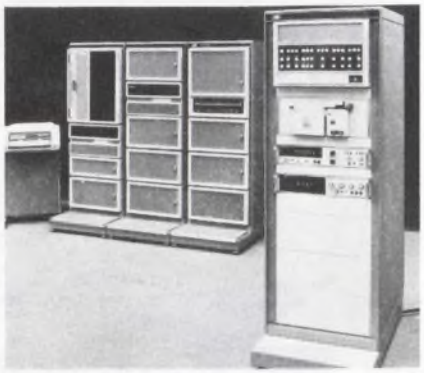
Versatile FFT unit plugs into minicomputer slot

Elsytec, 212 Michael Dr., Syosset, N.Y. 11791. (516) 364-0560. $6000; 60 days.

The 306/MFFT consists of one card, which plugs directly into any Data General Nova computer. The unit performs Fourier transform related operations that include forward and inverse FFT, spectral magnitude, Hanning weighting and complex multiplication. When used with a NOVA 800, a 1024 real-sample time series can be Fourier transformed and the magnitude of the spectrum formed in 139 milliseconds. Time domain signal processing functions such as correlation and convolution can be rapidly calculated at a rate of 2.8 μs per multiply-accumulate. The 306/MFFT is also capable of performing hardware single precision and some double precision arithmetic operations. The unit automatically carries out an arithmetic operation on a complete array with hardware that advances the addresses, counts and number of points processed and checks for the end of the array. In a Nova 800, the 306/MFFT performs single precision adds, subtracts, multiplies, divides and square roots of arrays in 2.8 μs per array element. This is equivalent to reducing the cycle time of the Nova 800 from 800 ns to 150 ns.

CIRCLE NO. 268

Controller lets user put instrumentation on-line



Hewlett Packard, 1501 Page Mill Rd., Palo Alto, Calif. 94304. (415) 493-1501. From $18,000; 90 days.

The HP 30300 A programmable controller gives the HP 3000 user a facility to collect on-line instrumentation data. Once collected, the data are available for analysis on any 3000 terminal. The controller features a variety of analog and digital I/O as well as frequency and time measurement capabilities. These make collection of instrumentation data an easy task. The controller based on the HP 2100 mini, is a CPU with 8-k words of core and has a dual port controller.

CIRCLE NO. 269

Lab instrument counts and logs random events

Columbus Instruments, P.O. Box 5244, Columbus, Ohio 43212. (614) 488-6176. $4700.

Model TMC-6 helps automate long duration laboratory experiments in which event counting is used. Six individual counters (five digits) log the events. At the end of a timing cycle, a multiplexer circuit scans the counters and prints the information on a TTY. At the same time, the TTY furnishes a punched tape. The cycle is adjustable from 1 s to 99 min by front panel controls. An optional a/d converter allows the user to record analog signals. The counters furnished operate at a maximum rate of 1 MHz. Slower units can be furnished at the customer's request.

CIRCLE NO. 270

Ferrite power supplies are more efficient and cost less.

Inverter-Rated ferrites™ end the guesswork.

Replace metal laminations with ferrite components and get a lot of trade-offs going in your direction. Less weight. Higher efficiency. Smaller size. Better regulation. And lower system cost.

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High frequency, low loss ferrites from Indiana General have improved the efficiency of inverters and power supplies in everything from computers to portable test equipment.

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We specify and guarantee inductance and core loss under maximum and recommended conditions to end guesswork. By giving you circuit performance data instead of routine magnetic parameters, we make your design task easier and more precise.

Inverter-Rated components are tested under square wave drive so the performance you design in —stays in.

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INFORMATION RETRIEVAL NUMBER 78

Honeywell computer family announced

Honeywell, c/o Carl Byoir & Associates, 40 Walnut St., Wellesley, Mass. 02181. (617) 237-4100.

A new family of computers, the Series 60, comes in seven models that ranges from small systems, that rent from under $5000 a month, to large ones for $100,000 a month. The machines are byte oriented. The smallest machine, Model 66/20 handles up to 131 kbytes of MOS memory with 1.4 μs cycle time. The top-of-the-line unit handles 8 Mbytes of MOS memory and can address 6-billion bytes of virtual memory. Memory access is on a word basis—the smallest machine accesses two bytes at a time the largest eight bytes. An interesting feature is the use of an electrostatic printer that can produce the equivalent of 18,000 lines/min.

CIRCLE NO. 271

Computer breadboards hf circuit designs

Hewlett Packard, 1501 Page Mill Rd., Palo Alto, Calif. 94304. (415) 493-1501. $3000.

BAMP (Basic Analysis and Mapping Program) is a computer-aided design procedure to model high-frequency circuit designs that run on the HP-2000 Series time-share systems. The system can be used simultaneously by as many as 32 design engineers, each as if he had the system to himself. The system exploits the S-parameter characterization of active circuitry. The software includes a library of S-parameter data on commercially available active high-frequency components. One can ask the system to optimize for gain, power, bandwidth, for example, and quickly see the available tradeoffs. One can also call up plots of time delay as a function of frequency, for full information on FM or PM circuit distortion before any hardware is ever assembled.

CIRCLE NO. 272

Graphics system works with IBM 360/370

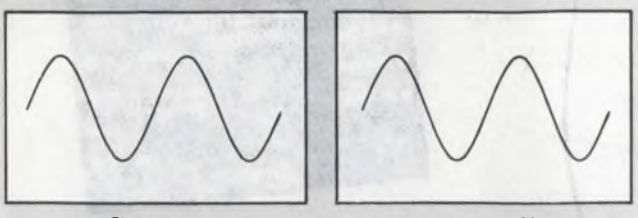
Gould Data Systems, 20 Ossipee Rd., Newton Upper Falls, Mass. 02164. (617) 969-6510. $20,400-$39,700; 60 days.

According to the manufacturer, the Plotmaster system breaks the bottleneck in existing computer-generated graphics and allows IBM 360/370 computers to plot data up to 400 times faster than with pen plotters. A specially designed controller transfers data from the computer to Gould's 4820, 5000 or 5100 series electrostatic printer/plotters. In the on-line mode, the controller operates on the computer's selector, byte-multiplexer or block-multiplexer channels. In the off-line mode, a nine-track, 800 or 1600 bit/in read-only tape drive is used for data input to the printer/plotter unit. All software is written in assembler language to conserve internal storage and make efficient use of the main computer. Each subroutine package, however, is callable from Fortran programs.

CIRCLE NO. 273

Undistorted truth

from the new Weston 4445 DMM with true RMS capability.



Can your present average-reading DMM tell the difference between these two computer-generated sine waves? Probably not.

But the Weston new model 4445, a low-cost, 3½-digit RMS-responding DMM can. It can seek out and detect the 1% distortion in the third harmonic of the wave on the right. And it could do the same even if the wave were square, triangular or odd-shaped.

So don't depend on just any DMM for those critical AC voltage readings. Stop guessing at those last one or two digits. Get a Weston model 4445 with RMS capability and read every wave to a guaranteed ± 0.5% accuracy ± one digit across ranges from a low 200mV to a full 1000V with 100uV resolution.

For only $450 you get all this, plus 5 DC voltage ranges, 200mV to 1000V; 6 resistance ranges, 200 ohms to 20 megohms; 2 DC current ranges, 200uA to 2mA; plus 2 AC RMS current ranges, 2uA to 2mA—all fully over-load protected.

And you get it all inside a fully portable, shock-resistant case measuring only 2.25" x 5.45" x 7". Weighs only 2.5 lbs. Comes complete with four nickel cadmium batteries for up to 10 hours continuous operation, and AC line converter for bench-work. Fuses, probes, and carrying case are included, of course.

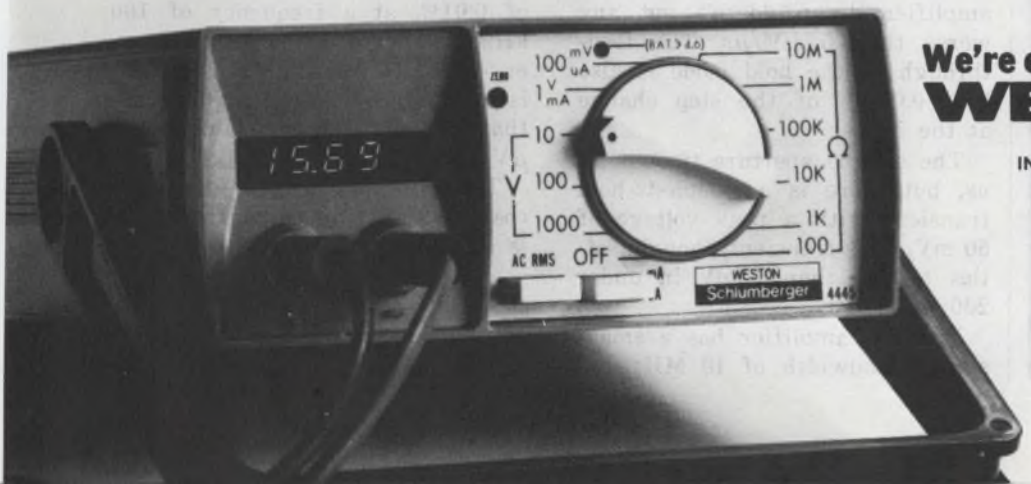
9744 Transducer adds RMS to any one-volt digital instrument.

If you already use a digital voltmeter with 1-volt DC range, you can add RMS with the new Weston 9744 Transducer.

Model 9744 can be ranged to accept AC input from 100mV through 700V. It converts the input to a 1-volt DC output signal for the full-scale RMS value of the AC signal. Will also scale AC current input from 1uA to 1mA. Operates on either 115V or 230V, 50-60 Hz line.

List price only $150 with case.

See both these exciting new examples of WESTON leadership in test equipment at your nearby distributor today. Or, write direct to Weston Instruments, Inc., 614 Frelinghuysen Ave., Newark, N.J. 07114.



We're either first or best. Or both.

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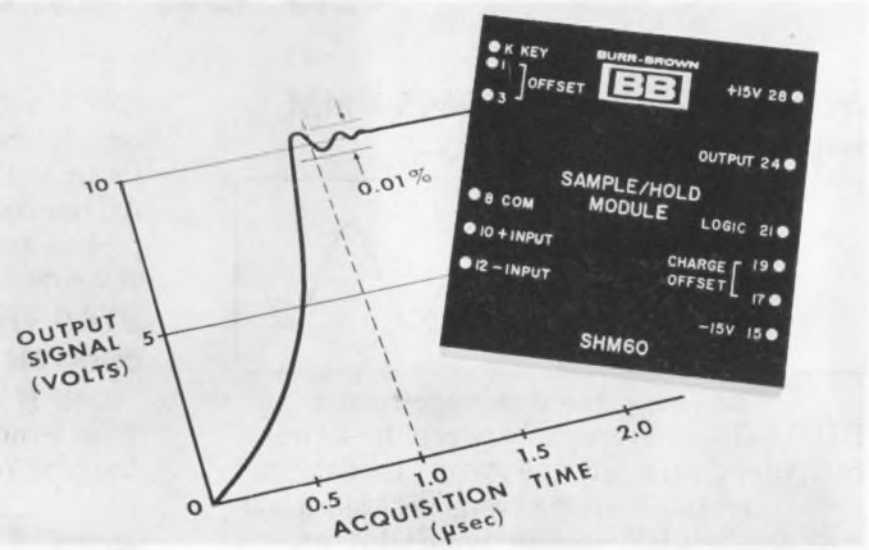
INFORMATION RETRIEVAL NUMBER 80

High-speed s/h circuit gives gain up to 1000



Burr-Brown, International Airport Industrial Park, Tucson, Ariz. 85706. (602) 294-1431. P & A: See text.

Sampling a signal at high speeds isn't unusual, but getting a high gain at the same time is. Burr-Brown's SHM60 sample-and-hold amplifier provides gains from ±1 to ±1000—set by external resistors. Also, it works at system throughput rates from 50 kHz to 1 MHz.

The amplifier has a full-scale voltage range of −10 to +10 V. Its acquisition time for a 10-V step is 1 μs, while for a 20-V step it increases to only 1.5 μs. The s/h circuit gain error, guaranteed for either step input, is a low 0.01%. Errors in gain caused by changes in temperature are kept to below ±2 ppm/°C.

When put into the hold state, amplifier droop doesn't get any worse than 5 μV/μs. The feedthrough in the hold mode is also low—0.005% of the step change at the input.

The sample aperture time is 12 ns, but there is a sample-to-hold transient with a peak voltage of 50 mV. This transient, though, settles to less than 1 mV in under 200 ns.

The s/h amplifier has a small-signal bandwidth of 10 MHz and a slew rate of 25 V/μs maximum. The input impedance of 10^{11} Ω keeps the input bias currents to about 50 pA typically.

The SHM60 competes with many other s/h circuits. Two of the closest competitors are the SHM-2 from Datel (1020 Turnpike St., Canton, Mass. 02021) and the SH730 from Hybrid Systems (87 Second Ave., Northwest Park, Burlington, Mass. 01803).

Both of these units cost $89 in single quantities, but they have quite different characteristics. The Datel circuit has no input buffer amplifier, and its small-signal bandwidth is only 500 kHz. It also has a fixed gain of +1 and a rather high droop rate of 50 μV/μs.

The Hybrid Systems unit offers variable gains from ±1 to ±100 and a 5-MHz small-signal bandwidth. But it has a feedthrough of 0.01% at a frequency of 100 kHz. Its aperture time is also longer—about 50 ns. And its gain drift is more than 10 times higher than that of the SHM60—almost 25 μV/°C.

The Burr-Brown s/h circuit costs $99 in single quantities and is available from stock.

Burr-Bown	CIRCLE NO. 250
Datel	CIRCLE NO. 251
Hybrid Systems	CIRCLE NO. 252

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Rate ITT by its accomplishments. Take a look at our 3701 — it's a complete monolithic 2-watt FM sound system for TV, radio and other FM sound communications. It is packaged in a 14-pin power DIP. It eliminates shielded volume control cables and is impervious to output short circuits. It drastically reduces your total component requirement while providing limiting with less than 100 μV input. It's only one in a line of ITT devices that includes the popular 1330, 1352, 3064, 3065 (plus several proprietary circuits), as well as double-plug diodes, glass rectifiers, zeners and other consumer-oriented components. Tune in to ITT now!

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INFORMATION RETRIEVAL NUMBER 82

"Okay, okay. You tell me where we can find twenty thousand RAMs a week for that much less than the 2102 and I'll tell you where to find the Easter bunny."

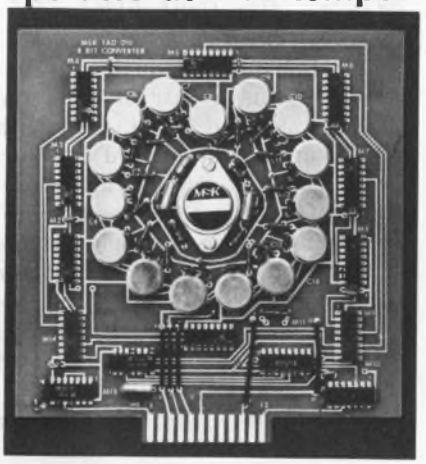
Give him the good news:

You can find all the 1K RAMs you need right now—right here at AMI. We have 4006, 4008 and 4008-9 RAMs ready for immediate delivery. They're pin-for-pin with Mostek's. But you can get more of ours—faster. (Stands to reason that when you have larger production facilities you can produce more.) The price is right, too. For example, the 4008-9 is yours for just $3.50 in quantities over 1000. You get the advantages of a 2102 system, while saving a bundle with our 4006 family. You can get an application note on how to do it, and a free sample, by writing to Frank Rittiman, AMI, 3800 Homestead Road, Santa Clara, CA 95051. Phone: (408) 255-3651. Or ask your distributor.

AMI
AMERICAN MICROSYSTEMS, INC.

INFORMATION RETRIEVAL NUMBER 83

High speed a/d operates at MIL temps



M. S. Kennedy, Pickard Dr., Syracuse, N.Y. 13211. (315) 455-7077.

The T.A.D.C. series of a/d converters can work over either the commercial (0 to 70 C) or MIL (−55 to +125 C) temperature ranges with temperature drifts of less than 1 bit over the entire range. Hybrid and modular construction allows a variety of bit and speed combinations. Model and speed combinations are as follows: 8-bits at 10 MHz, 9-bits at 2 MHz, 5-bits at 20 MHz and 4-bits at 20 MHz. All units are mounted on a 6 × 6 in. PC card.

CIRCLE NO. 274

Fast settling DACs resolve 8 or 10-bits

Analog Devices, Rte. 1 Industrial Park, P.O. Box 280, Norwood, Mass. 02062. (617) 329-4700. $119 (8-bit), $139 (10-bit); stock.

Model DAC1106 is a high speed, current output digital-to-analog converter with either 8 or 10-bit resolution that settles to 10-bit accuracy in 50 ns. The unit is packaged in a 2 × 2 × 0.4 in. module and has fully DTL/TTL compatible positive-true logic inputs. The settling time to ±1/2 LSB is 25 ns for the 8-bit version, 50 ns for the 10-bit. Both units have ±1/2 LSB linearity, ±10 ppm/°C gain temperature coefficient, and ±0.002%/V power supply rejection. A single ±15-V-dc power supply is the only power required. The unit is specified for operation over the 0-to-70-C temperature range.

CIRCLE NO. 275

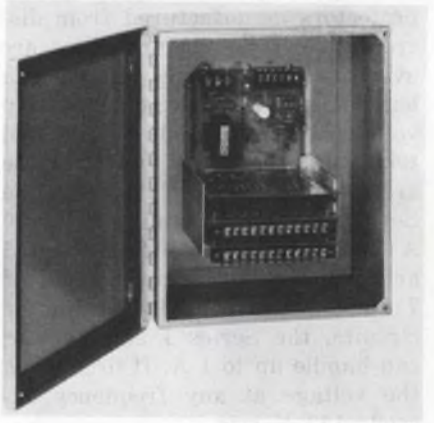
12-bit d/a converter settles to 0.1% in 25 ns

Datel, 1020 Turnpike St., Canton, Mass. 02021. (617) 828-8000. $149.

Model DAC-HI12B high resolution d/a converter will settle within 25 ns to 0.1% of full scale. This unit also has a linearity of ±1/2 LSB and a temperature coefficient of ±20 ppm/°C. The DAC-HI2B has output flexibility. The current-type output supplies 5 mA which can be fed directly into an external resistor to give a 1.2 V maximum output. By external pin strapping, a bipolar output of ±1.2 V can be generated across the output load resistor. Data inputs are TTL/DTL compatible and straight binary coded for a unipolar output. Coding for bipolar outputs may be either offset binary or 2's complement. Input power requirements are +15 V dc at 40 mA and −15 V dc at 20 mA. The power-supply rejection ratio is 0.0085%/V.

CIRCLE NO. 276

Parallel pulses changed to serial by converter



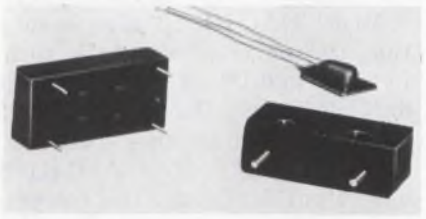
Sys-Tec, 877 Third St., S.W., New Brighton, Minn. 55112. (612) 636-6373.

The CS-181 pulse count summer converts parallel coincident input signals to serial output pulses equally spaced in time. Its four or eight inputs feature optical isolation, thus permitting the unit to operate in electrically noisy industrial locations, and at input speeds greater than mechanical contacts can provide. The output may be either relay or solid state. The unit is housed in a 12 × 10 × 6 enclosure and requires either 117 V ac, 60 Hz or 18 V dc. Output capability is 2500 counts/s.

CIRCLE NO. 277

MODULES & SUBASSEMBLIES

Over/undervoltage protectors handle 30 A



Heinemann Electric, Trenton, N.J. 08602. (609) 882-4800.

A line of overvoltage protection devices is made for use in semiconductor circuits. The smallest device is a 5-A hybrid unit. It contains a sense amplifier, control circuit and an SCR crowbar. A voltage transient or overvoltage causes the SCR to fire, shunting the line to ground within 500 ns. An external device, such as a circuit breaker, removes the load from the line about 10 ms later. Standard trip voltages for the hybrid protectors are 16.5 and 6.5 V dc. Protectors with trip voltages of 7 and 5.5 V dc are available on special order. For operating currents higher than the capability of the 5-A hybrid, protectors manufactured from discrete electronic components are available. The Series 10 dc can handle up to 10 A; standard trip voltages are 6.5 and 16.5 V dc, and trip voltages of 5.5 and 32 V dc are available on special order. The Series 30 dc can handle up to 30 A; standard trip voltages are 6.5 and 16.5 V dc, and trip voltages of 7 and 32 V are available. For ac circuits, the Series 1 ac protector can handle up to 1 A. It fires when the voltage at any frequency exceeds 143 V rms.

CIRCLE NO. 278

Opto isolators reduce delays to under 50 ns

Hewlett-Packard, 1501 Page Mill Rd., Palo Alto, Calif. 94304. (415) 493-1501. $9.90 (100-up); stock.

Model 5082-4364 dual opto isolator contains a pair of inverting optically isolated gates, each with a LED and an integrated detector. Delay times of 50 ns can be obtained with this high-speed device. The unit requires a supply voltage of 5 V and the input current for an eight gate fan-out (13 mA) is 5 mA. Common-mode rejection is 20 V at 1 MHz. Performance specs are guaranteed over 0 to 70 C.

CIRCLE NO. 279

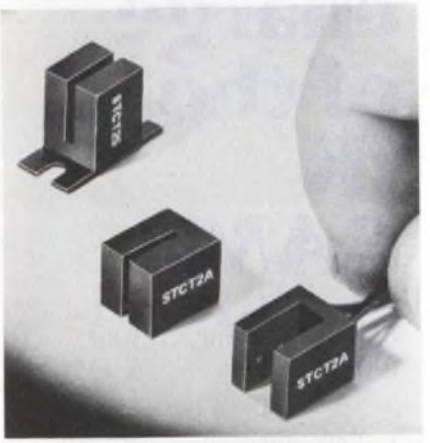
Single module performs v/f or f/v conversion

Datel, 1020 Turnpike St., Canton, Mass. 02021. (617) 828-8000. $59 (10K), $79 (100K); stock.

The VFV series of converters operates as either voltage-to-frequency or frequency-to-voltage converters. You can select the function just by external pin connection. In addition, these units have voltage inputs of 0 to +10 V or 0 to −10 V, current inputs of 0 to +1 mA or 0 to −1 mA, positive or negative going output pulses and DTL/TTL or CMOS compatibility, all by external pin connection. The 0.005% or 0.05% linearity (10 or 100 kHz unit, respectively) holds down to zero input voltage. As an f/v converter, full-scale output voltages of 0 to +10 or 0 to −10 V may be selected by external pin connection. There is also provision for an external integrating capacitor to reduce output ripple.

CIRCLE NO. 280

Optical switches come in 64 different models



Sensor Technology, 21012 Lassen St., Chatsworth, Calif. 91311. (213) 882-4100. $12; 30 day.

The solid-state Opto-Switch, an optoelectronic control switch, is available in 64 standard models. There are 16 models in each of four basic electrical configurations. The Opto-Switch comes in either single or dual-channel models, with a choice of sensing gaps of either 0.06 or 0.2-in. Mounting options include standard DIP pins with or without base, or wire leads with or without a base. The units measure 0.4 × 0.4 × 0.5 in. Each switch contains a GaAs infrared LED and a photodetector, packaged in a plastic case. Designs include a choice of four combinations of emitter and sensor circuitry: LED-phototransistor pair; LED-phototransistor plus amplifier; LED-photo-Darlington transistor; and LED-photo-transistor plus amplifier and Schmitt trigger. The latter units can be used directly with TTL/DTL/MOS logic-level circuits.

CIRCLE NO. 281

Our motors do the things most motors can't do

Precise positioning / Precise speed regulation / Precise tension control

Only a DC servo motor can respond in milliseconds to rapidly programmed commands. It'll stop, go, accelerate or decelerate, reverse direction at full speed, maintain constant speed under variable torque load or hold constant tension under variable speed . . . precisely as you want it to.

That's the kind of performance you can expect from all Inland Motor DC servos with temperature-stable magnets and rugged, high-duty-cycle capability. They'll give precise control of position, rate or tension in computer peripheral sub-systems like magnetic tape drives, incremental transport drives, capstan drives and high speed printout systems.

Thirty-two off-the-shelf models range from tiny "inch-cube" size to a fist full of power . . . from 7 to 300oz. in torque . . . speeds to 8,000 RPM . . . as low as 20.6 watts at peak torque . . . and less than $25 in quantity lots.

For specifications or technical data, call your local Inland Motor Representative or contact us direct.

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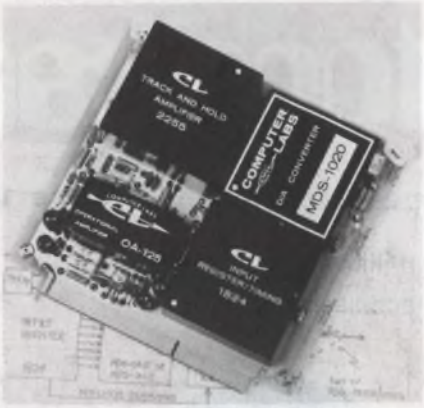
INLAND MOTOR DIVISION Kollmorgen Corporation
501 First St., Radford, Va. 24141, Phone: (703) 639-3973, TWX: 710 875-3740

INFORMATION RETRIEVAL NUMBER 86

High speed DAC has 15 MHz word rates



Computer Labs, 1109 S. Chapman St., Greensboro, N.C. 27403. (919) 292-6247. From $850; 8 to 10 wk.

The RDA series of d/a converters is made for reconstructing TV and other video signals. The 8 and 10-bit converters include a deglitching circuit to remove spike discontinuities from the analog output. Input word-rates of 15-MHz are possible, with optional output amplifiers for applications requiring greater drive. The units are mounted on 5.5 × 6 in. edge-connector PC cards.

CIRCLE NO. 282

High speed FET op amps slew at 400 V/μs

Analog Devices, Rte. 1 Industrial Pk., P.O. Box 280, Norwood, Mass. 02062. (617) 329-4700. $99 (A), $119 (B).

The Models 51A and 51B differential FET-input op amps provide ±100 mA minimum output current over a 6 MHz minimum full-power bandwidth. The units have a 400 V/μs minimum slew rate and a 250 ns maximum settling time to 10-bit accuracy (0.05%, or 140 ns maximum to 8-bit accuracy or 0.1%). The Model 51 has a CMRR of 60 dB minimum for a ±10 V common-mode voltage and an 80 MHz small-signal unity-gain frequency response. The Model 51 is a MIL-type design that uses hermetically sealed semiconductors and operates over −55 to 100 C. The Model 51A has a voltage drift of ±50 μV/°C maximum and the Model 51B has ±20 μV/°C. Both units are packaged in 1.82 × 1.22 × 0.61 cases.

CIRCLE NO. 283

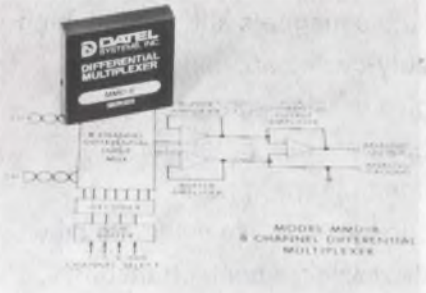
Sine wave oscillator keeps distortion low

Frequency Devices, 25 Locust St., Haverhill, Mass. 01830. (617) 374-0761. $25 (100-up); 2 to 4 wk.

The 450 Series of modular sine wave oscillators are low distortion (0.1%) units. They are amplitude stable to within 0.1 dB and are packaged in a low profile 1.5 × 2 × 0.4 in. case. The oscillators are available in any frequency specified by the customer in the range from 100 Hz to 10 kHz. Other features include an accuracy of ±1% (externally adjustable ±5%), a stability of 0.02 %/°C, an output amplitude of 20 V pk-pk, an output impedance of less than 10 Ω and a dc offset of under 5 mV. Power requirements of the circuit are ±15 V at ±8 mA.

CIRCLE NO. 284

Differential multiplexer handles ±10 V signals

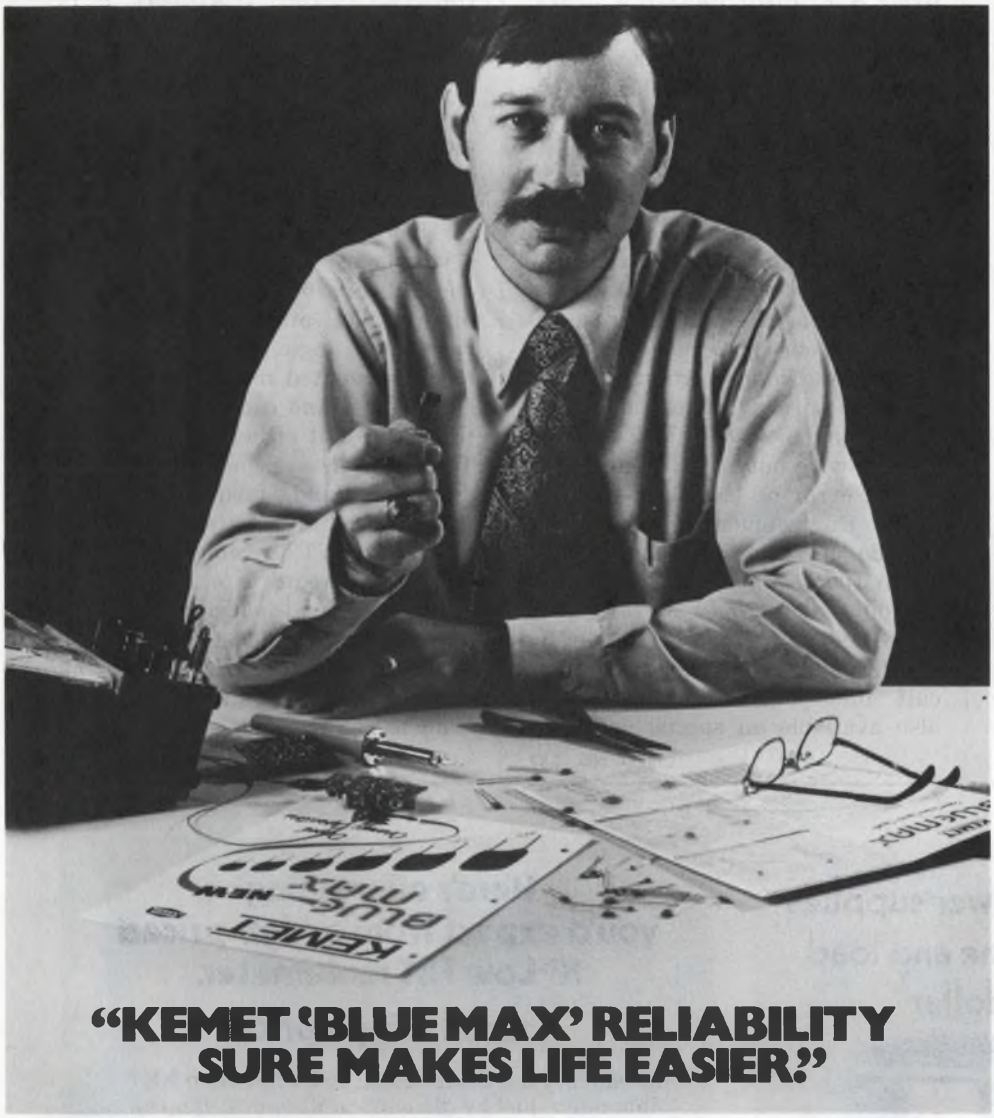


Datel, 1020 Turnpike St., Canton, Mass. 02021. (617) 828-8000. $169 (1 to 9).

The Model MMD-8 differential multiplexer consists of eight pairs of analog switches. A channel select inhibit (all channels off) is provided so that two MMD-8's can be stacked to provide 16 channels of differential analog multiplexing. Differential input signals up to ±10 V can be handled. Without the amplifiers, switching time is typically 500 ns, while the output settling of the amplifier is 4 μs. The differential output amplifier will deliver ±5 mA with a linearity of 0.01%, an offset adjustable to less than 1 mV, and a temperature coefficient of 60 μV/°C. The amplifier has a slew rate of 100 V/μs. The unit is housed in a 2 × 2 × 0.375 in. encapsulated module with dual-in-line pinning (0.1 in. grid) and requires only ±15 V at ±20 mA.

CIRCLE NO. 285

KEMET® CERAMICS:



"KEMET 'BLUE MAX' RELIABILITY SURE MAKES LIFE EASIER!"

When I breadboard a new system, I use reliable components. Right from the start.

Take capacitors, for instance. KEMET "Blue Max" Capacitors give me the reliability I need. And total design flexibility, too.

That's a combination that can really make your life a lot easier.

What do you need in your capacitors? Size? Lead spacing? Choice of dielectrics? Capacitance range? Voltage? Price and delivery?

You get all of these with "Blue Max" Capacitors—the maximum CV range, miniature, precision epoxy dipped, monolithic ceramic capacitors from KEMET.

They're built on fully automated lines. So you get uniform dielectric thickness, electrode integrity, and consistent electrode-to-termination continuity.

And talk about solid quality! "Blue Max" Capacitors are the same inside as KEMET high-volume molded Military CKs. They stay tough and dry inside a shield of precision-dipped epoxy that even meets the UL Standard 492 flame test.

Beginning to sound good? Then you'd better look into it. You'll be surprised how much more you can get done—and easier, too—by standardizing on "Blue Max" Capacitors.

They're available now in three dielectrics—COG Ultra-Stable, X7R Stable, and Z5U General Purpose—in six precision case sizes.

And you can pick from more than 350 CV values in a capacitance range from 2.2 pF to 4.7 uF for operation on 50, 100 and 200 VDC working voltages.

What more can I tell you?

Try 'em out yourself. Write to Union Carbide and ask for free engineering samples and a specification guide.

Be sure to get the name right. KEMET "Blue Max"—the maximum CV range, precision dipped, ceramic capacitors.

You'll be surprised how easy they can make your life!

UNION CARBIDE COMPONENTS DEPARTMENT

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Mail to:
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P. O. Box 5928, Greenville, S. C. 29606

Sure, I'd like to take it easy—and get total design flexibility, too. Send me specification information and free engineering samples of KEMET "Blue Max" Capacitors!

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INFORMATION RETRIEVAL NUMBER 88

Pwr transducers handle watts, vars, pf and more

E.I.L. Instruments, 1830 York Rd., Timonium, Md. 21093. (301) 252-1260.

Custom solid-state power transducers are designed for use in alarm, indicating and recording systems. These watt, vars, frequency and power factor transducers are used along with digital and analog meters from all major manufacturers. In-house calibration facilities are available for variable frequency, variable power and variable phase angle.

CIRCLE NO. 286

Synchro amplifier has 1 MΩ input impedance

Singer, Kearfott Div., 1150 McBride Ave., Little Falls, N.J. 07424. (201) 256-4000.

The Model C70 3718 005 synchro amplifier can drive multiple synchro loads with Thevenin equivalent impedances as low as 50 Ω line-to-line. The amplifier has an input impedance greater than 1 MΩ thus minimizing loading and error factors. The synchro amplifier requires power of 115 V, 400 Hz and generates all other necessary power requirements. The input/output configuration consists of three-wire synchro inputs and amplifying them (at unity gain) to a three-wire output with an input/output error of less than six minutes. Environmental capabilities include operation in temperatures up to 100 C and relative humidity of 100% at altitudes up to 70,000 ft. Other units that accept 60 Hz synchro inputs and have short-circuit input/output protection are also available on special order.

CIRCLE NO. 287

Tracking s/d converters are accurate to ±4 min.

Computer Conversions Corp., 6 Dunton Ct., East Northport, N.Y. 11731. (516) 261-3300. Under $400; 4 wk.

A series of small 14-bit synchro-to-digital tracking converter modules provides accuracies of ±4 min. of arc, ±0.9 LSB. These units are 2.6 × 3.1 × 0.82 in. and are made for PC board mounting. They convert synchro inputs of 11.8 or 90 V, 400 Hz, or 90 V, 60 Hz, into 14-bit parallel binary outputs that represent angle. The converters have an isolated reference and synchro inputs and can track rates up to 1800 °/s at either 60 or 400 Hz. They are also insensitive to input amplitude and frequency variations. The digital output is buffered and DTL/TTL compatible. Part No. SDC40 requires a 26 V or 115 V ac reference input and ±15 V at 50 mA, −15 V dc at 30 mA, and +5 V dc at 350 mA. Operating temperature ranges are 0 to 70 or −55 to +85 C.

CIRCLE NO. 288

Ever have the feeling your biggest connector problem is trying to tell your connector suppliers what your problem is?

We may be the best listeners in the connector business.

We've listened so well over the past 23 years and come up with so many right answers that we now have one of the broadest lines of P/C connectors around.

Tell us your design needs and chances are we'll have the answer right on our shelf.

If we don't, we also have one of the best design engineering departments (not the biggest, by any means, but the best, we think). And our P/C Connector Product Manager has absolutely nothing better to do than listen to your needs.

Call him. Right now. He'll start listening –before he starts to answer.

Call (213) 341-4330.

Ask for the P/C Product Manager

Viking
CONNECTORS

Viking Industries, Inc./21001 Nordhoff St./Chatsworth, Calif. 91311

INFORMATION RETRIEVAL NUMBER 91

Design refresher on Metal Glaze™ resistors

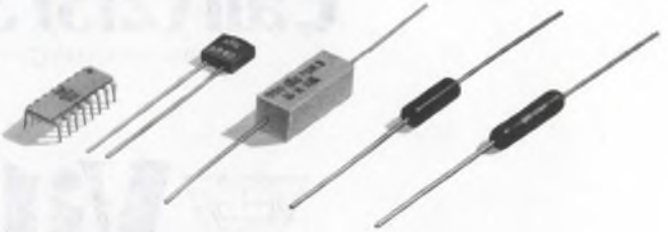
1. Solid ceramic substrate for maximum heat conductivity, superior strength.
2. High-temp. soldered (not crimped) termination gives optimum electrical contact, 20-lb. pull strength.
3. Automated helix with 100% electrical test.
4. Molded jacket protects against breakage during machine insertion.
5. Metal Glaze thick-film element fused to core at 1000°C. Provides a tough resistor system that withstands overloads, environmental extremes.

An all-purpose resistor? Not *quite*. But if you're designing any type of low-power circuitry, it usually pays to look at Metal Glaze.

Mechanically, these resistors are nut tough. Electrically, they offer excellent load life stability. And thermal characteristics are outstanding, giving you lower operating temperatures, greater reliability. In fact, you can often *double-rate* Metal Glaze resistors. So you can use smaller resistors, save board space.

The quality and cost effectiveness of Metal Glaze resistors have been proven *billions* of times over—in all types of electronic equipment, worldwide. Available in ratings $\leq$ 5 watts, $\geq$ 1% tolerance, and ranges as low as 1 ohm.

Complete resistor choice. TRW offers you a total resistor capability—carbon comp., thin-film, Metal Glaze, wirewound, networks. For complete specs and application data on Metal Glaze, contact your local TRW sales representative (or TRW/IRC's Boone, N.C., plant—(704) 264-8861). Or *write* TRW/IRC Resistors, an Electronic Components Division of TRW, Inc., 401 N. Broad St., Philadelphia, Pa. 19108.



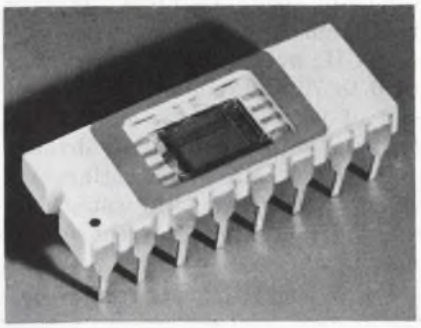
TRW® IRC RESISTORS

™Metal Glaze is TRW/IRC's trademark for its thick-film resistors.

INFORMATION RETRIEVAL NUMBER 92

INTEGRATED CIRCUITS

4-k RAM comes in 16-pin DIP



Mostek Corp., 1215 W. Crosby Rd., Carrollton, Tex. 75006. (214) 242-0444. $45 (100); 6-8 wk.

A 4096-bit dynamic n-channel MOS RAM, called the MK 4096P, comes in a standard 16-pin ceramic package. The new RAM features 350-ns access time and single-transistor cell design. The RAM offers read and write cycles of 500 ns. All inputs and outputs including clocks are directly TTL-compatible, and voltage pins are located on package corners to simplify board layout. Power supplies required are 12, 5 and −9 V. Active power is under 100 μW per bit, while standby power is under 2.5 μW per bit. Refresh time for each of the 64 row addresses is 2 ns. All specs apply over a temperature range of 0 to 70 C.

CIRCLE NO. 289

ICs contain logic for clocks and timers

National Semiconductor Corp., 2900 Semiconductor Dr., Santa Clara, Calif. 95051. (408) 732-5000. $14 (100); stock.

Two digital alarm-clock circuits, intended for use with gas-discharge displays, contain all of the logic required to build a variety of clocks and timers. The new ICs, called the MM5370 (for 60-Hz operation) and the MM5371 (for 50-Hz operation), interface with seven-segment displays to exhibit three modes—time, alarm set, and sleep time. The display format may be either 12 hours with leading zero blanking and AM/PM indication, or 24 hours. The circuits operate from voltages in the 8-to-29-V range, and they don't require a regulated power supply.

INQUIRE DIRECT

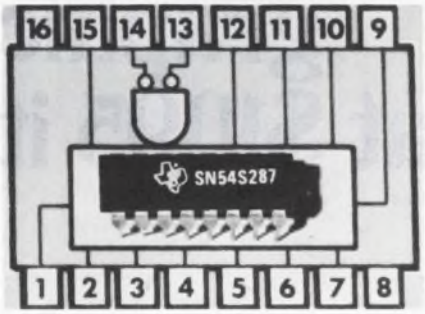
IC quad op amp uses single supply

RCA Solid State, Route 202, Somerville, N.J. 08876. (201) 722-3200. CA3401E: 75¢.

The CA3401E quad op amp operates from a single positive power supply. The monolithic circuit requires no external compensation and has a 3-pF on-chip capacitor to maintain closed-loop stability in each amplifier. The CA3401E features a supply range of 5 to 18 V, unity-gain bandwidth of 5 MHz typical, bias current of 50 nA typical and open-loop gain of 60 dB typical.

CIRCLE NO. 290

1024-bit pROMs feature 15-ns access



Texas Instruments, P. O. Box 5012, M/S 308, Dallas, Tex. 75222. (214) 238-2894. $17.52 (100); stock.

Two ROMs, called the SN74S287 and SN74S387, feature a typical enable access time of 15 ns. The 'S287 memory has a three-state output; the 'S387 features an open-collector output. Operation of the pROMs is guaranteed over the 0-to-70-C temperature range. Each pROM comes in a 16-pin plastic DIP.

CIRCLE NO. 291

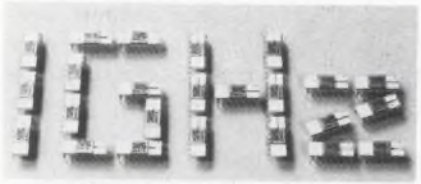
FET op-amp drift drops to 5 μV/°C

Intersil, 10900 N. Tantau Ave., Cupertino, Calif. 95014. (408) 257-5450. $9.50 to $49.50 (100).

The 8007 series of low-drift FET-input op amps combines a bias current of 10 pA with drifts as low as 5 μV/°C (8007-1). Offset voltage ranges from a high of 10 mV down to 2 mV. Other 8007 specs include a 6-μV/sec slew rate, ±12-V input range and a 90-dB common-mode rejection. The ICs come in TO-5 cans and operate over the 0-to-70-C temperature range.

CIRCLE NO. 292

Counters operate up to 1 GHz

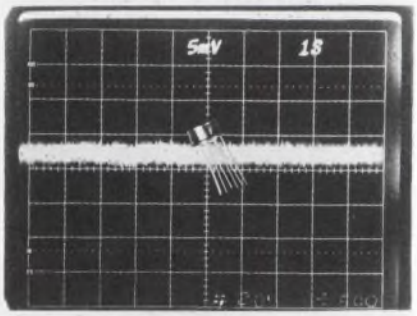


Plessey Semiconductors, 674 McGaw Ave., Santa Ana, Calif. 92705. (714) 540-9979. $96 to $120 (100-999); stock.

The SP613 through 616 series divide-by-four counters provide maximum operating frequencies up to 1 GHz over a temperature range of 0 to 70 C. Counter outputs consist of complementary emitter-followers, both capable of driving 100-Ω lines. Maximum ratings include a power-supply voltage of 8.5 V and output current of 15 mA.

CIRCLE NO. 293

Op amp features 5-μV noise and 15-pA bias

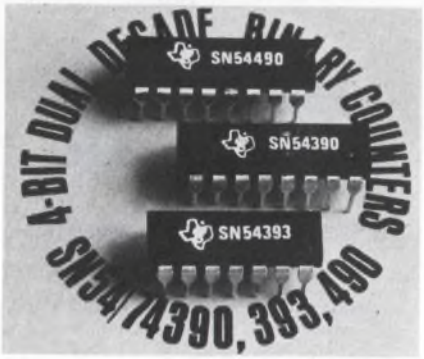


Analog Devices, Route 1 Industrial Park, P. O. Box 280, Norwood, Mass. 02062. $5.90 up (100).

The AD514 FET-input op amp guarantees a maximum noise level of 5 μV pk-pk in a 0.1-to-10-Hz bandwidth. The IC also combines a maximum bias current of 10 pA with offset voltages below 20 mV and an open-loop gain above 50,000. The AD514 comes in a TO-99 package.

CIRCLE NO. 294

Dual counters replace single units



Texas Instruments, P.O. Box 5012, M/S 84, Dallas, Tex. 75222. (214) 238-3741. $1.76 up (100); stock to 12 wk.

Three dual 4-bit TTL counters —the SN54/74390, SN54/74393, and SN54/74490—are dual versions of the popular SN54/7490A and SN54/7493A 4-bit counters. All three counters incorporate full parallel outputs from each 4-bit section. They accept count frequencies from dc to typically 35 MHz. The '390 BCD circuit has both divide-by-two and divide-by-five clock inputs as well as individual direct clear inputs. The '490 BCD counter features a divide-by-10 clock, direct clear, and a preset-to-nine input for each 4-bit stage.

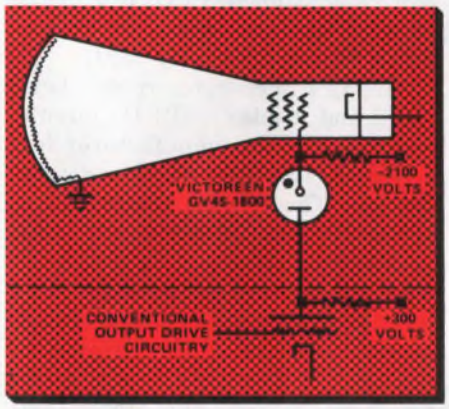
CIRCLE NO. 295

Problem solving... with Victoreen High Voltage Technology

1 UNORTHODOX CRT DRIVE

How did we meet ever-expanding requirements for increased bandwidth and lower power consumption, coupled with the availability of high-voltage zener-type diodes (Victoreen Corotrons)? With an unorthodox drive scheme for CRT's.

Basically, this scheme is a mirror-image of the conventional method. Instead of supplying the CRT anode with very high voltage, we ground the anode and supply a drive signal, riding at approximately — 1800 volts, to the grid. The advantages? Being direct-coupled there are no reactive components to limit high-end frequency response or cause roll-off



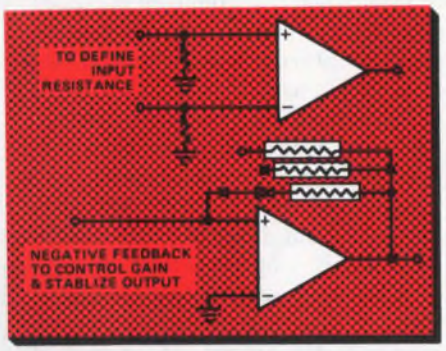
at the low end. Second, the face plate of the CRT does not build up static charges which can distort the display.

Even though the Corotron operates in the corona mode of discharge, it has no voltage jumps or jitters. Corotrons are not tied to "natural" operating voltages and are adjustable in manufacture from 350 to 30,000 volts. Corotrons also have a positive regulation curve eliminating possible relaxation oscillation.

2 FROG MUSCLES TO BRAIN WAVES

Colleges and universities, medical research laboratories and a number of R&D firms are faced daily with the need for controlled high-amplification of a wide variety of extremely low level signals. Such signals are derived from frog-muscle experiments, brain-wave measurements, cardiac research, avalanche-breakdown, currents in ionization chambers as well as from a range of constant-current sources.

The operational amplifier provides the amplification required because of theoretical infinite-gain characteristics. However, at full gain an op-amp tends to be unstable and go into oscillation; further, amplified signals are difficult to fully analyze if the gain is unknown.



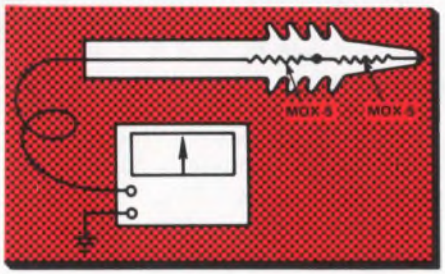
Victoreen MINI-MOX resistors are used widely to modify op-amp characteristics to: 1. Stabilize output and eliminate oscillation. 2. Define gain so measurements can be quantified. 3. Restrict bandwidth to the region of specific interest.

Smaller than a conventional resistor and compatible with a TO-3 can, MINI-MOX resistors are ideal for highly-stable, low-level, miniature electronic circuitry.

They typically have a voltage coefficient of −5 ppm/volt, full-load drift of less than 2% in 1000 hours, temperature coefficient of 100 ppm, and a Quantech noise of less than 1.5 μV/volt at 20M ohms. They are available in values from 100K to 10,000M ohms in 1, 2, 5 and 10% tolerances.

3 A PROBE FOR HIGH POTENTIAL

Two Victoreen MAXI-MOX resistors used in series can serve as a probe in radar circuitry capable of measuring voltages up to 60,000 volts. The probe, compatible with a number of voltmeters of different manufacture, has both short- and long-term stability. Short-term stability assures negligible drift and fluctuation



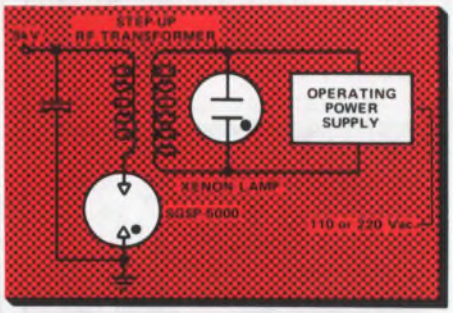
during measurement, while long-term stability maintains the original calibration accuracy of the probe.

Each MOX-5 resistor used in the probe has a maximum operating voltage of 37,500 volts with a power rating of 12½ watts. The voltage coefficient is 1 ppm/volt over the complete voltage range of the MOX-5, while the temperature coefficient is better than 300 ppm from −55° to 125°C.

MAXI-MOX resistors have full-load drift less than 1% in 2000 hours of operation, and are available in tolerances of 1, 2, and 5% in values from 10K to 2,500M ohms. A silicone varnish conformal coating provides environmental protection while allowing a maximum hot-spot temperature of 220°C. In addition, it is compatible with commonly-used potting compounds.

4 SPARK GAPS SPARK INTEREST

Victoreen SGSP spark gaps normally protect electrical circuits from damage from transient voltage spikes; however, Optical Radiation Corporation, Azusa, Ca. uses them to ignite a Xenon lamp in a theatrical lamphouse to project motion pictures. Xenon lamps provide two



advantages; one, being very small and brilliant, light radiation is easier controlled; second, efficiency is higher, so smaller lamphouses with greater output result. The design won the company an Academy Award in technical achievement.

In operation, the capacitor is charged until the SGSP-5000 breaks down. The stored energy is released through the transformer primary, producing a very high voltage pulse in the secondary which ignites the Xenon lamp. This provides an extremely reliable method of starting the lamp. Once ignited, operation is sustained by a lower-voltage line operated power supply.

Victoreen Instrument Division of VLN Corp.
10101 Woodland Avenue
Cleveland, Ohio 44104

VICTOREEN

INFORMATION RETRIEVAL NUMBER 94

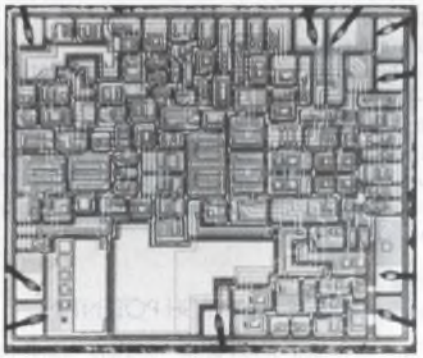
Bipolar ICs modulate, demodulate

Plessey Semiconductors, 1674 McGaw Ave., Santa Ana, Calif. 92705. (714) 540-9979. $2.50 (100-999); stock.

Two bipolar IC doubled-balanced modulators, the SL 10001A and B, contain internal bias which allows direct balanced transformer input or single-ended capacitor drive. The new modulators/demodulators feature a carrier and signal suppression of 50 dB, low noise level of −112 dBm, intermodulation suppression of −58 dB, supply current of 4 mA and unity conversion gain. The circuits have a two-stage common-collector output, and a pair of diodes are provided for optional limiting of the carrier input.

CIRCLE NO. 296

IC performs sample/hold function



Harris Semiconductor, P. O. Box 883, Melbourne, Fla. 32901. (305) 727-5407. $14.85 (100); stock.

Monolithic sample-and-hold amplifiers make their debut with the company's introduction of the HA-2425. The new IC has a slew-rate-to-droop-rate ratio of 5×10^6 and requires an external holding capacitor. Other features include TTL/DTL-compatible control input, 2-MHz bandwidth, 50-ns aperture time and a 5-V/μs slew rate. The new circuit consists of an op amp with its output in series with an analog switch that has a 1-nA maximum leakage current. The switch is buffered by a MOSFET-input unity-gain amplifier. The HA-2425 comes in a 14-pin, hermetically sealed DIP, and it operates over the 0-to-75-C temperature range.

CIRCLE NO. 297

256-element CCD operates at 10 MHz

Fairchild Semiconductor, 464 Ellis St., Mountain View, Calif. 94042. (415) 962-3816. $125 (100-999).

The company's latest charge-coupled device, the CCD 110, is a 128/256-element linear sensor. A two-phase device, the new sensor can be operated with standard TTL-level clocks at data rates in excess of 10 MHz. Other features include on-chip preamplifier and compensation amplifier, and a dynamic range of 200:1. The device comes in an 18-pin DIP with a glass window.

CIRCLE NO. 298

Microprocessor system gets new IC

Microelectronic Device Div., Rockwell International, P. O. Box 3669, 3430 Miraloma Ave., Anaheim, Calif. 92803. (714) 632-2321.

An LSI general-purpose keyboard and display (GPKD) circuit is offered by the manufacturer for use with its PPS microprocessor system. The GPKD permits an automatic scan of keyboards with as many as 64 keys. It also provides multiplexed outputs for displays that have up to 32 digits and optional discrete status indicators. Included in the circuit is a nine-key first-in, first-out stack that provides nine keys of buffering.

CIRCLE NO. 299

64-bit RAMs access in 10 ns

Signetics, 811 E. Arques Ave., Sunnyvale, Calif. 94086. (408) 739-7700. $12.95 to $13.70 (100).

Three 64-bit ECL RAMs are offered for computer applications including scratch pads and buffers. The 10140 and 10148 memories combine a typical access of 10 ns and write cycle of 18 ns with a typical power dissipation of 420 mW. The 10140 drives 90-Ω lines; the 10148 is designed for 50-Ω lines. The third memory—called the 10151 and originated by the company—has a latch circuit on the data output line. Otherwise, the characteristics of the 10151 are the same as those of the 10140 and 10148.

INQUIRE DIRECT

Thinking about Microcomputers?

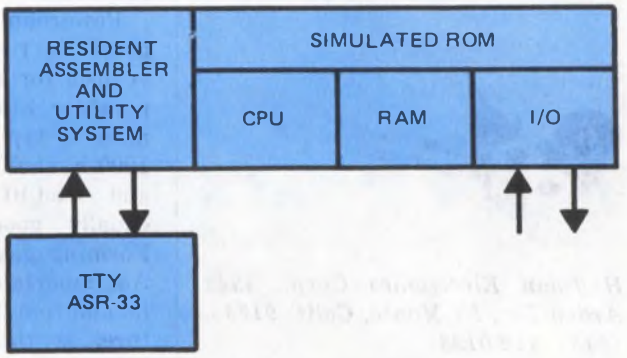
After selecting the microcomputer for your job, how are you going to integrate it into your product or system?

Applied Computing Technology's series of ASSEMULATORS (assembler-simulators) offer a complete stand-alone microcomputer development capability. Applied Computing Technology builds ASSEMULATOR development systems for the Rockwell International and Intel series of 4 bit and 8 bit microcomputers.

The ASSEMULATOR features real-time microcomputer simulation including ROM simulation up to full system capacity. A resident assembler transcribes machine language directly into the ROM simulator memory from mnemonic instructions inputted via the teletype.

A resident utility system allows quick display and change of simulated ROM and RAM. Input-Output channels within the ASSEMULATOR provide for interface with external electronics.

Integral programmers allow direct memory transfer to Programmable-Read-Only-Memories.



APPLIED COMPUTING TECHNOLOGY INCORPORATED
17961 Sky Park Circle
Irvine, CA 92707
(714) 557-9972

INFORMATION RETRIEVAL NUMBER 96

SIGNAL CONDITIONING for all types of Transducers

All solid state 3KHz Carrier System For Variable Reluctance, Strain Gage or LVDT Transducers

MC1 Module case can house up to 20 plug-in units . . provides carrier & DC operating voltages.

Input power: 105 to 125 V

Size: MC1—10 5¼" x 19" x 12" Price: $730.
MC1—20 8¾" x 19" x 12" 910.

Interchangeable plug-in units available

CD90 Very high gain carrier demodulator for use with strain gage bridge variable reluctance transducers, differential transformers (LVDT) and others.
Input Sensitivity: 0.1 mv/V for 10 VDC output
Output A Signal: ±10 VDC at 100ma, short-circuit proof
Output B Signal: Standard provides ±1 VDC
Price: $350 (from stock)

SG71 A signal conditioner and power supply for strain gage bridge circuits. Provides buffered, short-circuit proofed DC excitation to the bridge.
Input Sensitivity: 1 mv/V
Output A: ±10 VDC at 10ma
Output B: ±100ma maximum
Price: $225 (from stock)

CD90

Other special purpose plug-in units available.

Validyne ENGINEERING CORPORATION
WRITE FOR CATALOG
19414 Londelius Street
Northridge, Calif. 91324
Phone (213) 886-8488
Telex 65-1303

INFORMATION RETRIEVAL NUMBER 97

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costs, get proven performers and realistic delivery... you didn't figure on

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MX SERIES
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INFORMATION RETRIEVAL NUMBER 98

Cable stripper handles wide range of sizes

Hoffman Electronics Corp., 4323 Arden Dr., El Monte, Calif. 91734. (213) 442-0123.

The Hi-Peeler cable stripper features hardened, heat-treated-steel cutting blades, made of nickel-plated, drop-forged steel and comfortable plastic hand grips. The stripper handles wire sizes from 6 AWG to 400,000 cmil and it is easily pre-set with its graduated setting screw. The unit can be used to strip the ends of wire or in-line for splicing.

CIRCLE NO. 300

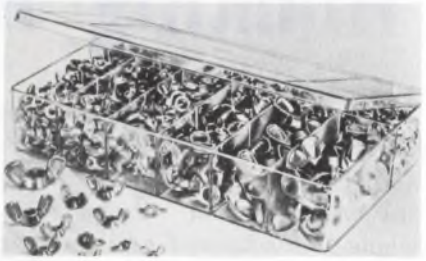
Thick-film resistor paste fires at 780 C

Thick Film Systems, Inc., 324 Palm Ave., Santa Barbara, Calif. 93101. $45 per oz; 10 days.

Powerohm, 780 Series, screen-printable resistor pastes were developed for a low 780-C firing temperature. Stability after laser trimming is typically about 0.05% for 1000-h shelf, thermal, hot-column and load-life tests. Stability is equally good after exposure in Forming gas at 150 C for 10 min. An important cost saving feature, in addition to low firing temperature, is that the paste requires only a 25-min. firing cycle. Thus, energy consumption is low and over twice the number of circuits, or discrete components, can be fired in the same time that higher-priced, higher-firing temperature systems require. The 780 Series formulas are available with resistivities from 50 to 1,000,000 ohms per square and with TRCs of 0 to ±200 ppm.

CIRCLE NO. 301

Assortment of wing nuts handy to have around



Product Components Corp., 36 Lorraine Ave., Mount Vernon, N.Y. 10553. (914) 699-8640. $36 per box.

There are hundreds of everyday uses in the shop, factory, lab and in the field for this all-purpose, 825-piece, wing-nut assortment. Twelve most popular wing-nut sizes are packaged in a see-through box with a separate compartment for each size. The nuts are a nickel-plated, die-cast, zinc alloy that is rustproof and corrosion resistant. They will not freeze on bolts. Their accurate threads are tapped square to the face and they have washer-like bosses.

CIRCLE NO. 302

CELCO makes "Above-Average" YOKES for "Above-Average" CRT Displays

Need a deflected CRT spot as small as 0.00065"?

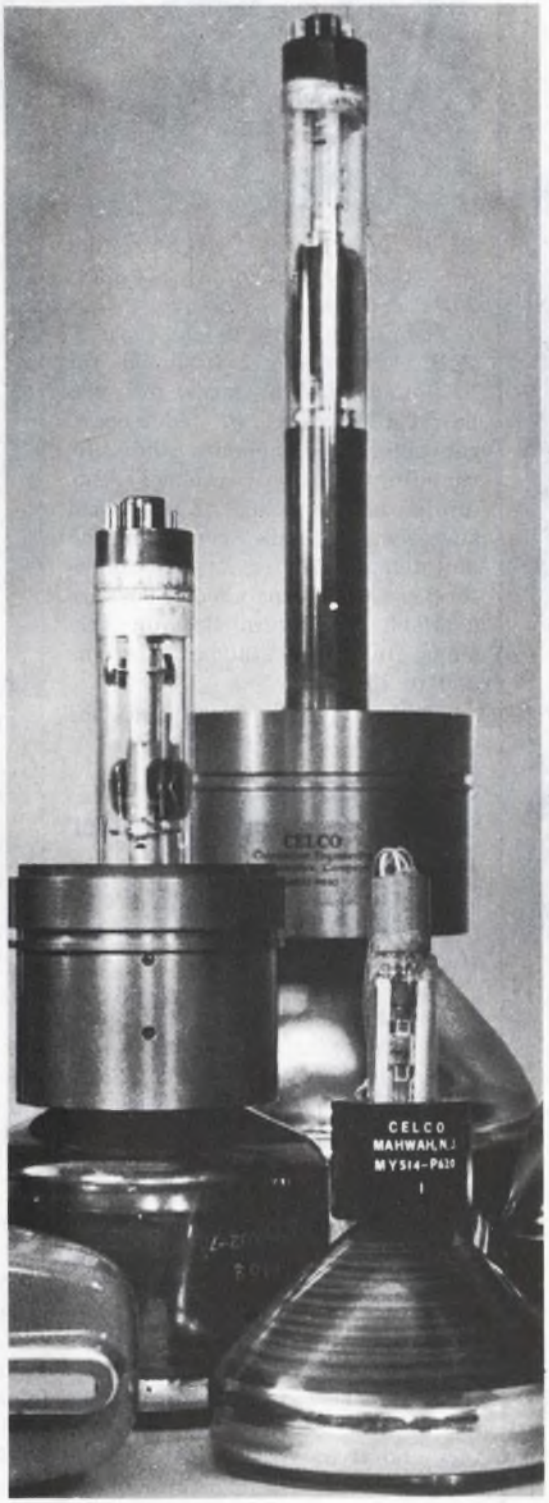
The CELCO HDQ High-Resolution Deflectron for Satellite Photography Read-out was the choice of one of our customers for their "Above-Average" display requirements.

You can get performance like that with a CELCO YOKE optimized on your CRT for your "Above-Average" display. (measured with a CELCO CRT Spot Analyzer.)

Or YOUR "Above-Average" display may require fast Zero-approach settling time, as required in a Fingerprint Scanning job where CELCO HDN Deflectrons are specified to recover to 0.01% in 25μs.

Precision Linearity on the final film plane or work surface, in Integrated Circuit Mask-Generator Displays enables producers of LSI technology to make low-cost computers for all of us. CELCO Special Deflectrons and Linearity Correctors LC123 are being used by several equipment builders for their "Above-Average" displays.

For PEPR, a system for reading Bubble Chamber photographs, developed by a few individuals at MIT and refined and expanded by others at leading universities throughout the world, CELCO was asked to provide special Low Residual Yokes for their project. CELCO produced their HD Deflectron with special 0.003% residual, and GFJ irrotational Focus Coils to help achieve the performance of these "Above-Average" displays. CELCO DAPP2N-7 Amplifiers drive the Dynamic Focus Coil; a CELCO DAPP2N-5 Amplifier was selected by another PEPR group to drive the CELCO B1700 Di-Quadrupole which produced the rotating high-resolution scanning line!



"Above-Average" YOKES for "Above-Average" CRT Displays.

"Above-Average" Recording Storage Tube displays with 1 7/16" neck scan converters and storage tubes need CELCO QY and QD Recording Storage Tube Yokes.

CELCO electronics and magnetics were integrated into a CELCO "DS" Special Display System for Oil Exploration and Data Reduction where "Above-Average" Linearity, Spot Growth, Zero-approach, Bandwidth, and Residual performances were required. Our customer decided to use CELCO's unique display experience to achieve his "Above-Average" display.

CELCO "Above-Average" deflection yokes, focus coils, beam-centering and aligners, astigmatic correctors, and pincushion correctors applied to your specific requirement will help you produce YOUR "Above-Average" Direct-View Display.

REMEMBER CELCO YOKES, whether you want to send a man to the moon, a probe to Jupiter or Mars, investigate chromosomes or trophoblast for cancer research, or build a large format scanner to generate typesetting masters, X-Ray enhancement, or data digitization.

- CELCO CRT Mounts, coil positioners, holders and magnetic shields will enable you to get everything together to achieve your "Above-Average" display.
- Write for CELCO YOKE BROCHURE and your FREE CELCO CRT Display Computer Slide Rule to compute the CELCO YOKE you need for your "Above-Average" CRT Display.

UPLAND CA 714-982-0215
MAHWAH NJ 201-327-1123

(average is so . . . ho-hum to us.)

CONSTANTINE ENGINEERING LABORATORIES COMPANY
1150 E. Eighth Street, Upland, CA 91786 — 70 Constantine Drive, Mahwah, N J 07430

Celco

INFORMATION RETRIEVAL NUMBER 101

Card ejectors reduce stress on connectors

Bivar Inc., 1500 S. Lyon St., Santa Ana, Calif. 92705. (714) 547-5832. $0.18 (1000 up); stock.

The family of nylon Card-O-Pull card ejectors, designed for 1/16 and 3/32-in. cards, prevents harmful stresses on edge-board connectors, components and surrounding support systems. Also, minimized handling of PC-board surfaces prevents contamination and damage to circuitry. The ejectors are easily installed. They are available in several locking versions, in eight standard designs and in 13 colors.

CIRCLE NO. 303

Solder pot features safety, removable heater

Plato Products, Inc., 4357 N. Rowland Ave., El Monte, Calif. 91731. (213) 283-0466. $54 (unit qty); stock.

The Plato Model 100 solder pot can make soldering areas much safer. All parts of the Model 100, except the crucible and dross tray, are safe to touch—even when the operating temperature reaches 975 F. In addition, the Model 100 has a 3-wire-grounded, UL-listed, 6-ft. cord with a NEMA 5-15 connector and receptacle. And should the sealed-disc heating element ever need replacing, it can be done easily by removing four nuts. The pot has a removable dross tray for easy cleaning, thermostat control from 500 to 975 F, adjustable leveling feet and it operates on 110 V, 60 Hz and uses 350 W. The crucible is 1-1/2-in. deep by 2-1/2-in. diameter. Over-all dimensions are 7-1/2-in. high by 6-in. diameter.

CIRCLE NO. 304

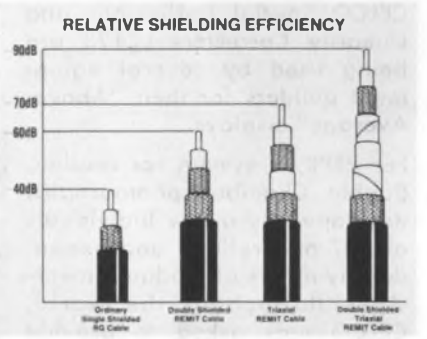
Crimping kit is handy around the lab or shop

Electrical Construction Products, Hackettstown, N.J. 07840. (201) 852-1122.

A new kit of Buchanan copper and steel crimp connectors, splice cap insulators, terminal lugs and a C24 hand crimping tool enables electronics personnel to splice or terminate virtually any wiring job. Its metal box has individual partitions to separate the parts and a parts location chart allows easy identification. Parts are available to restock the kit.

CIRCLE NO. 305

Multishielded cable reduces noise pickup



Times Wire & Cable Co., 358 Hall Ave., Wallingford, Conn. 06492. (203) 269-3381.

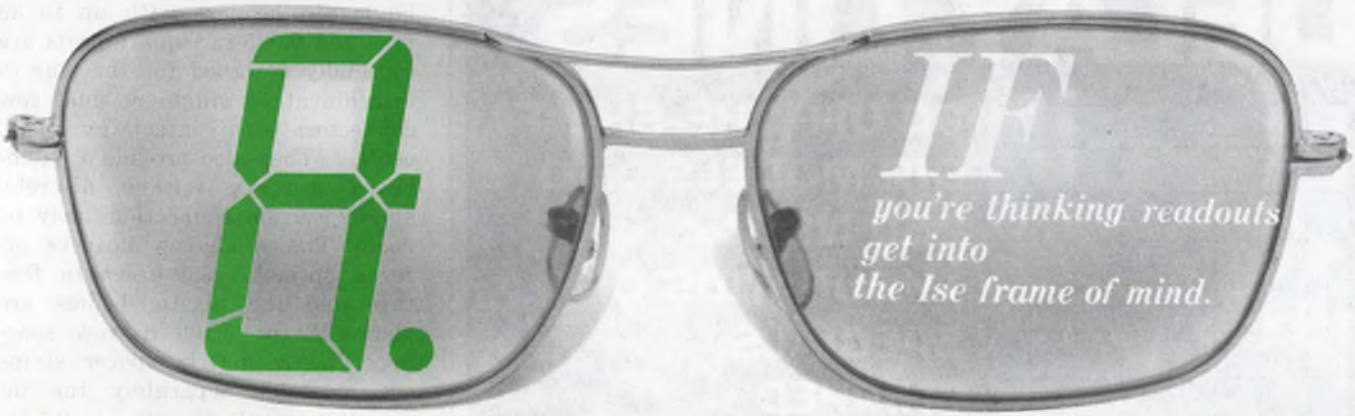
Called Remit, for reduced electromagnetic interference, these flexible cables were developed to give from 20 to 50-dB better isolation than standard single-shielded RG cables. Remit RDT-178, for example, is a double-shielded-triaxial cable that performs to the same electrical characteristics as RG-178B/U, but it offers 50 dB more isolation. The cables are available in double-shielded, triaxial and double-shielded-triaxial constructions.

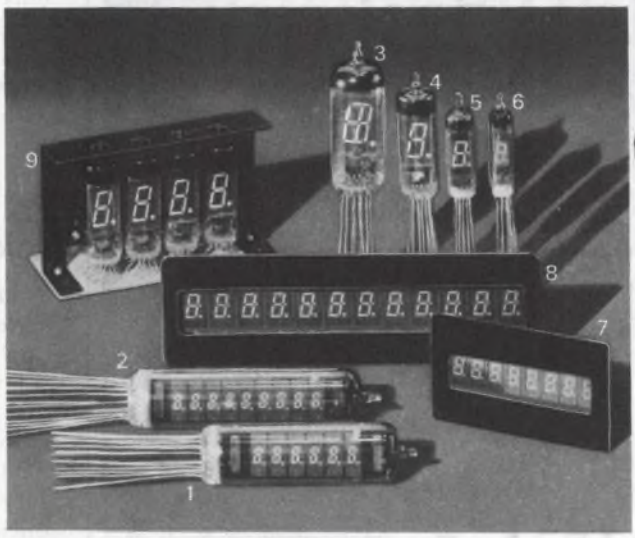
CIRCLE NO. 306

Frame them any old way

Or any new way.

Then sit back and watch your Ise display electronics get your ideas across. Beautifully.
In an eye-easy fluorescent green glow.
At the same time, they're low on voltage and current drain.
High on stability.
Pick the readouts that offer more of everything, including variety, for a whole host of digital display ideas.
They're a difference you can see.





1. DP60A
2. DP90A
3. DG19E
4. DG12H
5. DG10F1
6. DG 8F
7. DP 89A
8. DP127F
9. DMCL12H (NEW)
   Display module w/counter & latch
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Tel: (213) 532-0470 Telex: 230674910

Representative: Paris, Munich, Amsterdam, Stockholm, Vienna, Milan, Bombay, Hong Kong, Taipei.

INFORMATION RETRIEVAL NUMBER 103

Magnet wire operates at 1500 F, 1×10^{15} RADS

Gulton Industries, Inc., 6400 Roland Ave., Buena Park, Calif. 90621. (714) 523-3480.

Durock-insulated magnet wire will operate at temperatures to 1500 F and in nuclear-power generator applications where the radiation levels reach 1×10^{15} RADS. The insulation is a flexible silico-ceramic compound that is applied in ultra-thin layers of 0.0003 to 0.0005-in. The insulation is available on all types of wire, including nickle-clad copper, nickle-clad silver and stainless steel-clad copper wire. The wire can be bent around a mandrel only seven times the wire diameter without damage.

CIRCLE NO. 307

Headers with square posts attach to plugs

A P Products, Inc., 72 Corwin Dr., Box 110, Painesville, Ohio 44077. (216) 354-2101.

Molded, straight and right-angle pin headers with up to 36 pins and 0.025-in. square posts are especially designed for the plug-in attachment of single or dual row connectors with contacts on 0.1-in. centers. They also provide a patchboard matrix where discrete, single-position connections may be made. The single-row headers offer a special break-to-length feature and the plastic bodies are stackable for 0.100-in. row spacing. Plastic matrix spacer strips are available separately for increasing row spacing in 0.1-in. steps. Double-row headers are available in any lengths up to 36 pins per row. They are made up of single-row headers, either straight or right-angle, which have been ultrasonically welded together.

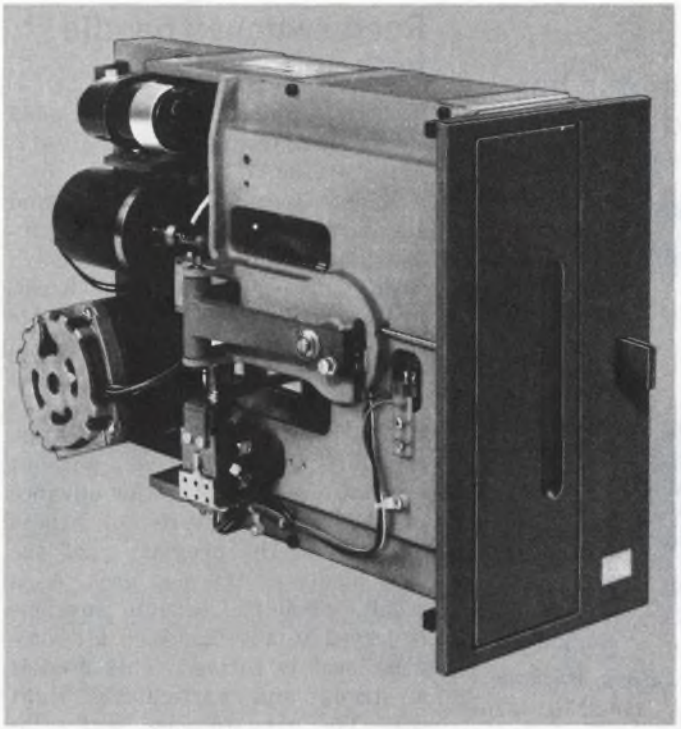
CIRCLE NO. 308

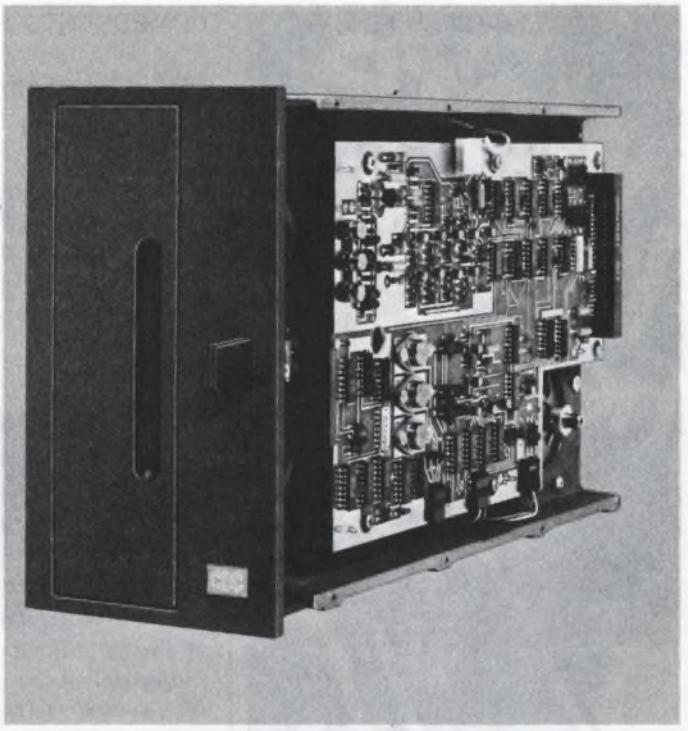
Polyimide-glass resists solder temperatures

Sanders Associates Inc., Grenier Field, Manchester, N.H. 03103. (603) 885-2810.

Multilayer PC wiring boards that are made with polyimide glass enable the fabrication of up to 17 conductor layers and 3500 holes on an 8 × 7-in. board only 0.125-in. thick. Polyimides are heat-resistant materials that can withstand soldering temperatures almost indefinitely. Bond strength doesn't degrade during the heat process, soldering doesn't lift off pads and measling doesn't occur.

CIRCLE NO. 309





The CONTROL DATA® 9400 Flexible Disk Drive is read/write/media compatible.

Technical sophistication and design simplicity best describe the Control Data Model 9400 Flexible Disk Drive. A low cost, 3 megabit, random access information storage device utilizing a removable, flexible, mailable 7.88-inch magnetic disk compatible with diskettes in the 3740. Weighs just 12 pounds. Can sit on a desk top or be mounted in an equipment cabinet. Data transfer rate is 249,948 BPS. All this, designed for a 5 year product lifetime. We invite you to send coupon, or contact your Control Data OEM Representative nearest you.

CONTROL DATA
CORPORATION

Control Data Corporation
Tom Farrell, OEM Marketing Manager,
Hawthorne Operations, 2815 W. El Segundo Blvd.,
Dept. ED-64, Hawthorne, CA 90250

Name_____

Title_____

Company_____

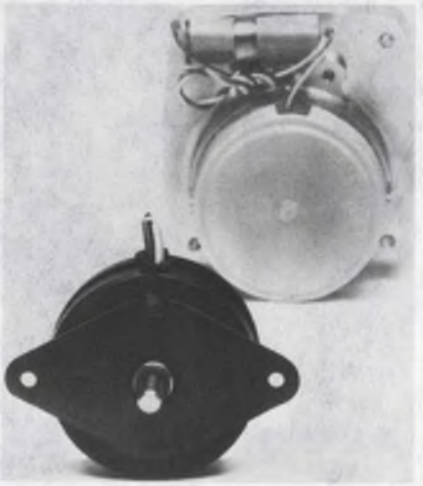
Address_____ Phone_____

City_____ State_____ Zip_____

☐ I want to see a demonstration of the Control Data Model 9400 Flexible Disk Drive. Have my Representative call.

INFORMATION RETRIEVAL NUMBER 105

PM stepper motor has 1-1/2-oz-in. detent



Molon Motor & Coil Corp., 3737 Industrial Ave., Rolling Meadows, Ill. 60008. (312) 259-3750. $10 (5000 up).

Molon's new PM stepper motor, only 2-1/2 D × 7/8 L in., replaces higher-priced stepper motors in business machines, computer peripheral and communication equipment. The simplest excitation mode uses a unipolar four-phase power supply. For this mode, the motor is constructed with center-tapped windings. Standard voltages are 6, 12 and 24 V. The motor's step angle is 7-1/2 degrees; its running torque is 4 oz-in. at 100 pps; and its static torque is 10 oz-in. The maximum no-load response rate is 260 pps. In addition, the rotor exhibits a detent-torque of 1-1/2 oz-in. The motor is available with a gearbox.

CIRCLE NO. 310

Microphone operates on electret charge

Thermo Electron Corp., 101 First Ave., Waltham, Mass. 02154. (617) 890-8700.

Model 5336 TELectret condenser microphones are very small (0.280-in. square by 0.160-in. deep), and low in cost (not supplied). They offer a smooth, extended frequency response from 50 to 16,000 Hz, and they are completely sealed. An IC hybrid preamplifier is built into the unit. TELectret microphones are powered by a permanent electric charge built into the diaphragm.

CIRCLE NO. 511

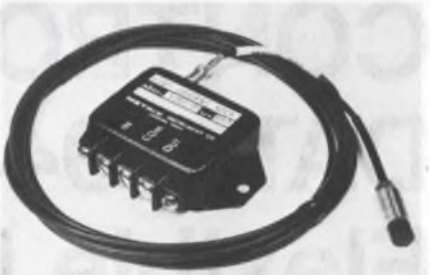
Reed switches handle high voltages

Current Industries, Inc., 3359 Ocean Ave., Oceanside, N.Y. 11572. (516) 678-3895.

A new line of subminiature and standard reed switches have unusually high voltage breakdown ratings. The subminiature (0.098-in. dia) switches are available with ratings up to 1000 V dc and the standard (0.177-in. dia) switches are available with ratings to 3600 V dc. This high-voltage capability is achieved without evacuation stems. A major advance in the manufacture of these switches is the preglazing of the reed blades at the seal area. As a result, when the capsule envelope is joined to the blades, a glass-to-glass seal is formed. This creates a strong and particularly tight seal. The glass-to-glass seal technique also enables the envelope material to be lead-free borosilicate glass. Thus, the switches also feature excellent thermal-shock characteristics, as well as the high open-contact resistance.

CIRCLE NO. 512

Sensor measures radial or axial movement



Metrix Instrument Co., P.O. Box 36501, 5760 Rice Ave., Houston, Tex. 77036. (713) 668-2386.

Model 5265 noncontact proximity sensor measures radial vibration or axial position of machinery shafts and other metallic objects. Operating on the eddy current principle, the sensor can detect either a static change of position or vibrations to 10 kHz. Motions as small as 40 μ-in. and up to 0.05 in. can be measured. The sensitivity can be adjusted to 0.1 V/mil. The unit operates on 12 V dc. The temperature range of the driver unit is −20 to 65 C and the probe −20 to 100 C.

CIRCLE NO. 513

Voltage sensor has repeatability of 0.1%

Time Mark Corp., P.O. Box 15127, Tulsa, Okla. 74115. (918)939-5811. $23 to $27 (100 up); stock.

Series 260 solid-state sensing relays for over or undervoltage detection are housed in standard eight-pin octal relay cases. Models cover the range of 4 to 500 V ac or dc. The ac models can operate at from 25 to 2000 Hz. Adjustment of the voltage set-point is made with a small screwdriver through a hole in the rear of the case. The output is a SPDT contact rated at 2 A. Hysteresis between pull-in and drop-out is typically 0.3% of the monitored voltage. Repeatability for fixed conditions is less than 0.1%.

CIRCLE NO. 514

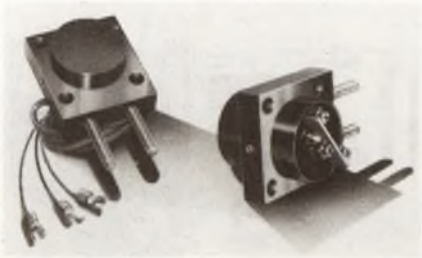
PC-board relay mounts with daughter board

Executone, Inc., 29-10 Thomson Ave., Long Island City, N.Y. 11101. (212) 392-4800. 24BW2G: $1.73 (5000 up).

A low-cost PC-board relay for use in rf or thermocouple circuitry uses a PC daughter board that becomes an integral part of the relay. The daughter board can have intricate conductor patterns that serve both as fixed contacts and also provide special characteristics for these applications. Patterns and ground planes can match the characteristic impedance of attached transmission lines in the range of 50 to 75 Ω and achieve crosstalk isolation of 70 to 50 dB over a frequency range of 50-250 MHz with acceptable VSW ratios. For thermocouple switching, the copper conductor pattern is first plated with a nickel barrier, and then, hard gold. This pattern, when mated with the gold contacts of the swinger blades of the relay, maintain the thermal emf under 2 μV. A bead-pin header also allows you to unplug the relay. Relays are supplied with coils of 6 to 24 V dc, either magnetic latching or nonlatching and with contact configurations to 4PDT, or an 8-pole combination of 4PNO and 4PNC. Contacts are rated to 0.5 A.

CIRCLE NO. 515

Proximity switch comes in several packages



Electro Corp., 1845 57th St., Sarasota, Fla. 33580. (813) 355-8411. 55501-3: $8; 55501-7: $9 (unit qty); stock to 30 days.

Completely sealed and shock resistant metal sensing devices are available in two package configurations: three models (Series 55501-3) with screw terminals for external connection, featuring an operating check LED; and three models (Series 55501-7) with an integral three-wire cable. All have a universal three-axis mounting bracket. The sensing circuit is designed to provide a stable and fixed sensing distance of 0.625 in. for steel, and 0.2 in. for aluminum targets. The switching circuit has an operating range of 0 to 10,000 impulses-per-second. Output for all models is 200 mA dc with supply voltages of 5, 12 and 24 V dc.

CIRCLE NO. 516

Gas filled relays defibrillate hearts

Kilovac Corp., P.O. Box 4422, Santa Barbara, Calif. 93103. (805) 684-4560. $125 (1-9); stock to 30 days.

Model KM-14, a DPDT gas-filled relay, designed specifically for use in heart defibrillator instruments, also has a broad range of other applications. The relay is capable of switching up to 500 W-s of pulse energy. In defibrillator applications, its DPDT contact arrangement allows the patient to be completely isolated from the voltage source. The gas filled relay provides "soft" switching to reduce transients that could have a detrimental effect on the patient and the associated circuitry. The glass envelope is encapsulated in plastic to reduce handling damage. The standard relay has a 12-V-dc coil, but other coil voltages are available on request.

CIRCLE NO. 517

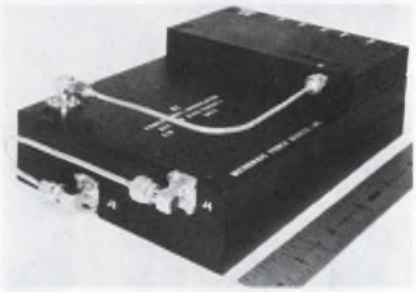
Cascade TO-8 amps up to four stages

Watkins-Johnson Co., 3333 Hillview Ave., Palo Alto, Calif. 94304. (415) 493-4141. $99 up (1-9); stock (small quantities).

The WJ-A5 and WJ-A7 amplifiers are cascadable 5-to-500 MHz units. Up to four stages can be cascaded to achieve typically 58-dB gain and ±0.5-dB flatness. The amplifiers are supplied in hermetic 4-pin TO-8 packages and operate from 15 V (WJ-A5) and 24 V (WJ-A7) dc supplies. Noise figure is 4 dB (A5) and 5 dB (A7).

CIRCLE NO. 518

Tacan mod/amp outputs 100 W peak



Microwave Power Devices, Adams Ct., Plainview, N.Y. 11803. (516) 433-1400. 90-120 days.

The Model PWA9612/1489, a broadband solid-state modulator/amplifier, delivers 100 W peak Gaussian-shaped pulses (MIL-STD-291B) over the 960-to-1215 MHz range. The unit weighs only 2-1/4 lbs and measures 4-1/4 × 6-1/4 × 1-13/16 in., and it doesn't require tuning or Gaussian-shaping adjustments over the full frequency range and over the −55 to 85 C temperature range. Other features include an rf gain of 40 dB, circulator protection against load mismatches, second harmonics under 45 dB below the carrier and an over-all average power consumption of 17.5 W.

CIRCLE NO. 519

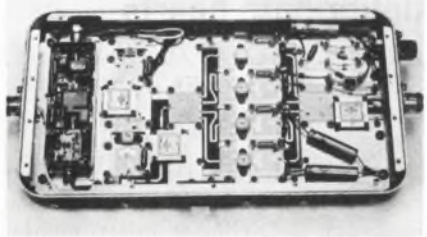
Digital power meter handles 18-GHz signals

Systron-Donner Corp., 735 Palomar Ave., Sunnyvale, Calif. 94086. (408) 735-9660. $1725; stock.

A digital power meter for measurement of cw and swept rf power covers the 1-to-18,000-MHz frequency range. Called the Model 4020, the new meter has a dynamic range of +10 to −40 dBm without autoranging. The four-digit display provides direct readout of power in both 50 and 75-Ω systems in dBm, with a linearity of ±0.04 dB for any 10-dB range. Resolution is 0.01 dB over the full dynamic range. Other features include high stability—no zero drift at −40 dBm—field replaceable power sensing element and self-calibration.

CIRCLE NO. 520

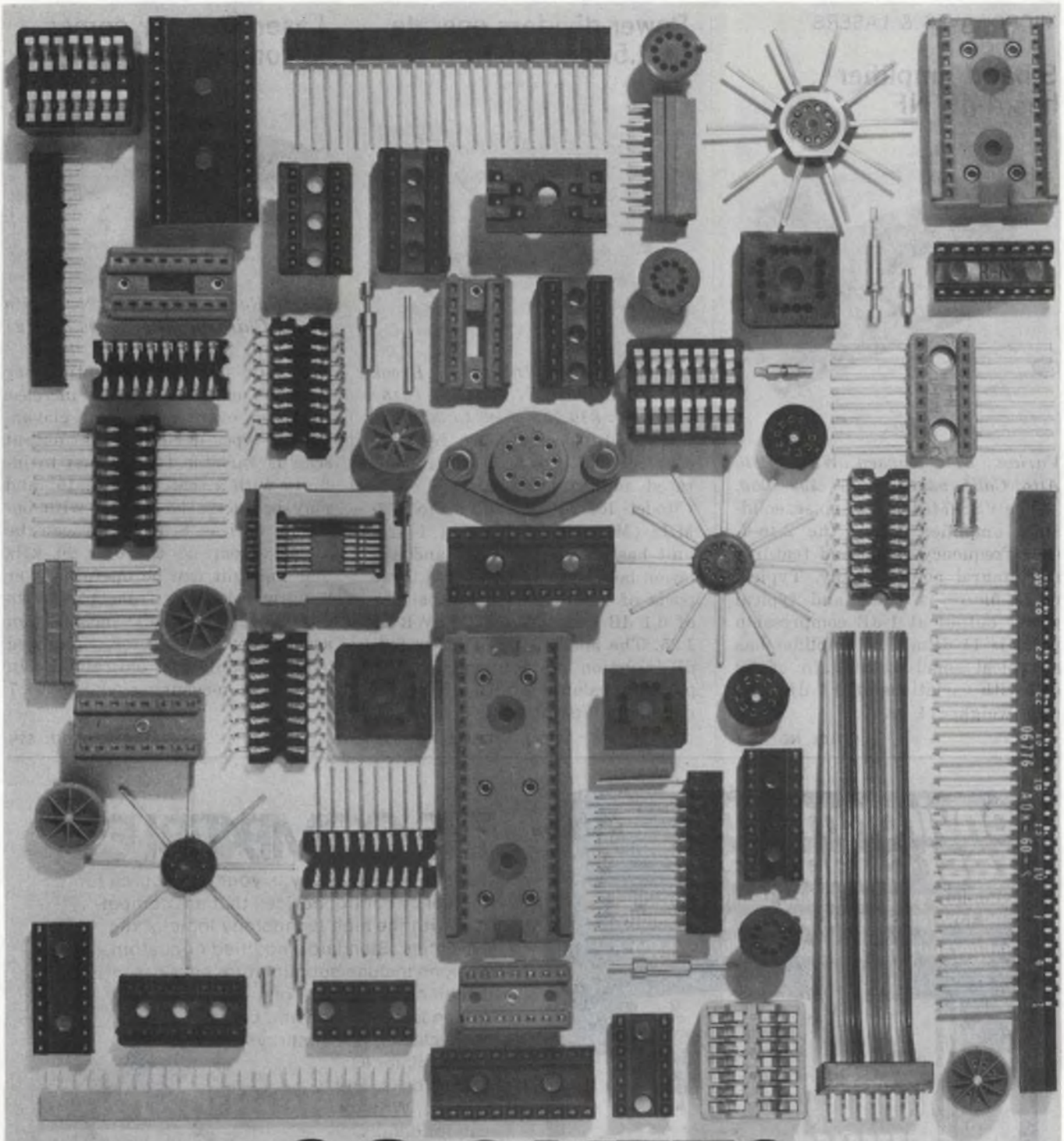
100-W L-band amp has 15-ns rise, fall



Trak Microwave Corp., 4726 Eisenhower Blvd., Tampa, Fla. 33614. (813) 884-1411. $3800; 135 days.

Use of microstrip, thin-film hybrid and miniature ferrite technology results in a 150-W pulsed L-band solid-state amplifier with 15-ns rise and fall times. Minimum output power is 100 W, and peak input power can be 1 to 4 mW. At 1300 MHz, the amplifier has a 110-MHz bandwidth with a gain flatness of ±0.5 dB maximum in any 30-MHz band from 1250 to 1350 MHz. The unit operates on a 0.002 duty cycle.

CIRCLE NO. 521



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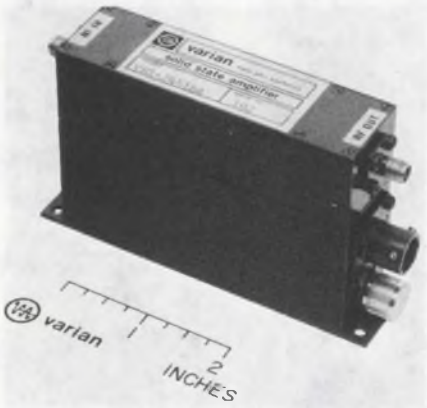
INFORMATION RETRIEVAL NUMBER 114

S-band amplifier has 4-dB NF

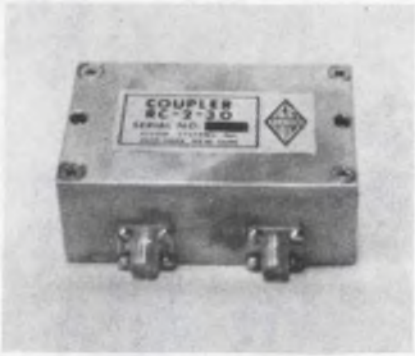


Varian, 611 Hansen Way, Palo Alto, Calif. 94303. (415) 493-4000.

The VSS-7451JP low-noise, solid-state amplifier covers the 2-to-4-GHz frequency range and features an integral power supply. Typical noise figure is 4 dB and typical power output at 1-dB compression point is 11 dBm. The amplifier has a typical small-signal gain of 30 dB, with variations of ±1 dB. The unit weighs 11 oz.

CIRLCE NO. 522

Power dividers operate at 0.5 and 1 GHz



Elcom Systems, Inc., 127F Brook Ave., Deer Park, N.Y. 11729. (516) 667-5800. $39.50; stock to 30 days.

Two 50-Ω coaxial SMA resistive coupler and power dividers are rated for at least dc to 1 GHz (Model RC-2-30) and dc to 500 MHz (Model RC-3-30). The 1-GHz unit has an insertion loss and isolation between any two of its three ports of 6.25 dB. It has a balance of 0.1 dB and maximum VSWR of 1.35. The 500-MHz unit has a 9.6-dB insertion loss between any four ports, a balance of 0.2 dB and a maximum VSWR of 1.65.

CIRCLE NO. 523

Laser scanner comes in compact package

Zenith Radio Corp., 1900 N. Austin Ave., Chicago, Ill. 60639. (312) 745-5035. $7950.

A solid-state acousto-optic laser scanner provides a 10-20 increase in speed over commercial glavanometer-type devices. The output scan is variable from 6 mm to infinity with a scan angle of 15° and may be increased to 40° with optional optics. Scan rates can be varied from dc through 20 kHz and the unit can be operated over laser wavelengths from 4416 Å to 10,600 Å. The unit includes an acousto-optic deflector, required optics, mounts and optical rails in a package measuring 31-1/2 × 7 × 7 in.

CIRCLE NO. 524

A BETTER METER.

Data Precision's newest multimeter — the 5½ digit MODEL 3500 — is a second generation instrument that combines the best of both worlds.

More features.
For less money.

MODEL 3500 incorporates all of the proven circuitry advances that made our 2500 Series the internationally accepted price/performance leader.

Tri-phasic™ auto-zero, Ratiohmic™ 2- and 4- wire resistance, and Isopolar™ high stability referencing.

With a 6 month basic DC accuracy of ±0.007% of reading ±0.001% of full scale ±1 LSD, full autoranging from 1 microvolt to 1000V (DC or AC peak) and 1 milliohm through 12 megohms resistance, 20% overranging, DC Ratio, isolated BCD output, remote triggering and remote ranging, it represents the most sophisticated lab-quality multimeter you can buy for less than $1000.

$995. complete

MODEL 3500 features the industry's most reliable, field proven circuit technology packaged behind a big, bright and easy-to-read ½ inch planar gaseous display. And none of the bugs of an unproven design.

MODEL 3500 measures DCV, 1 microvolt to 1000 Volts; ACV, 1 microvolt to 700V RMS, 30 Hz to 100KHz; Resistance, 1 milliohm to 12 megohms; and Ratio.

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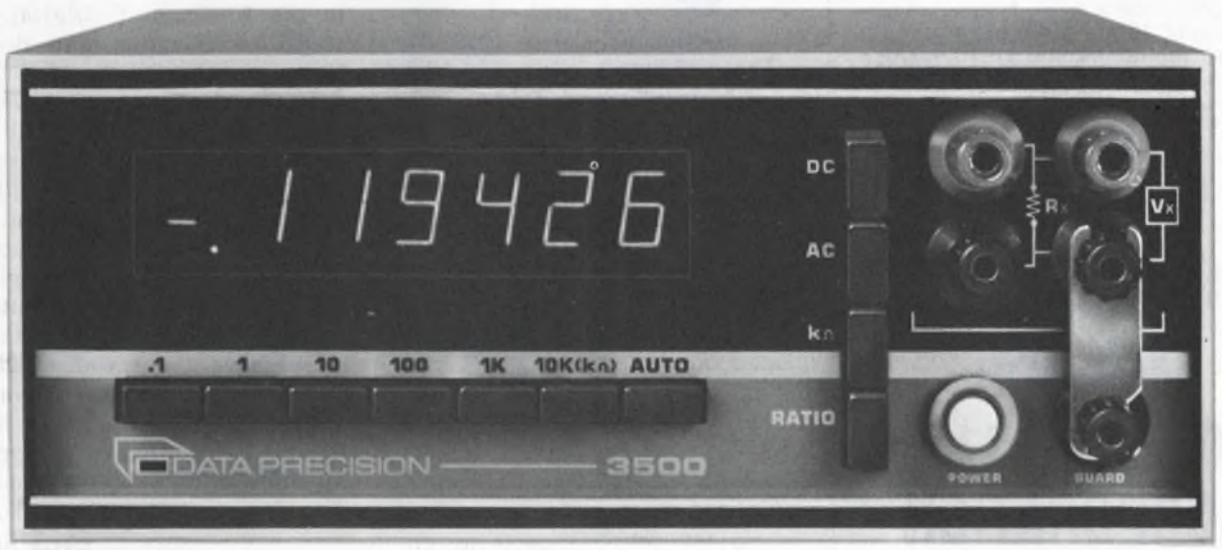


INFORMATION RETRIEVAL NUMBER 117

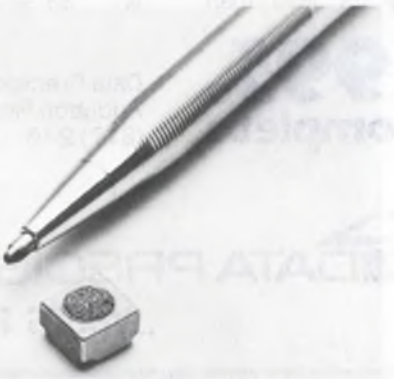
Tunnel-diode amp forms transponder front end

Aertech Industries, 825 Stewart Dr., Sunnyvale, Calif. 94086. (408) 732-0880.

The T6699 tunnel-diode amplifier, a transponder front end, operates over the 5.4-to-5.9-GHz frequency range and provides an over-all rf gain of 14 dB maximum. Noise figure is 7 dB maximum and 1-dB output compression is at least −18 dBm. The T6699 can transmit 800 W peak at a 0.001 duty cycle. Maximum VSWR at rf ports is 1.35.

CIRCLE NO. 530

Test module signals at high and low levels



Trak Microwave Corp., 4726 Eisenhower Blvd., Tampa, Fla. 33614. (813) 884-1411. $600; 60 days.

A series of thin-film hybrid test modules, the Model 5040-1004, contains internal gating in a shielded case and offers a high and low level test signal for dynamic tests. The unit operates over the 100-to-150-MHz frequency range and it features rise and fall times of 0.2 μs. The module measures 1.33 × 1.33 × 0.49 in, and the circuit operates from a 12-V-dc supply, drawing 80 mA maximum.

CIRCLE NO. 531

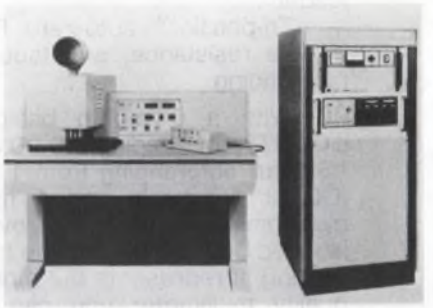
Gunn-diode line lists 400-mW output

Alpha Industries, Inc., 20 Sylvan Rd., Woburn, Mass. 01801. (617) 935-5150. $8.90 to $300; stock to 4 weeks.

A line of Gunn-effect diodes, called the DGB-6800 series, offers a range of cw output power from 25 to 400 mW at discrete frequencies between 4 to 18 GHz, and 25 to 250 mW between 26.5 to 40.0 GHz. The diodes are available with a choice of four standard ceramic/metal case styles. The diodes operate from supplies in the 5-to-15-V range.

CIRCLE NO. 532

Laser scriber handles 100 wafers per hour



Electroglas, 2901 Coronado Dr., Santa Clara, Calif. 95051. (408) 246-6500. $63,500.

A laser wafer scriber for semiconductor and IC production provides throughputs of up to 100 wafers per hour. The throughput rate, reportedly the highest available, is achieved through use of a proprietary X-Y motion system. Called the Model 1400AX, the new scriber uses a vacuum wafer chuck in the forcer unit. Digitally controlled acceleration and deceleration achieve accuracies of 0.0005-in. over the total area of travel. The area of the wafer to be cut is exposed to a finely focused beam of Q-switched YAG laser radiation with a wavelength of 1.06 μ. Pulsing action is created by an acousto-optic Q switch, providing high peak power pulses at selectable intervals ranging from 5 to 50 kHz. The pulses have a duration of 250 ns. The new scriber has a variable scribing speed of 0.5 to 10 in. per second. Scribe depth is typically 2.0 mils at 10 in. per second, and it is deeper at slower speeds.

CIRCLE NO. 533

INFORMATION RETRIEVAL NUMBER 119 ►

If you're into control applications, We'll give you one-million good reasons to spend 19¢.

Here they are. MA47110s, MA47111s and MA47120s. Hermetically sealed glass packaged PIN diodes from Microwave Associates. 19¢ apiece in quantities of 1,000,000.

These rugged, application-oriented diodes are designed for use as switches and current controlled attenuators in constant impedance AGC circuits, such as those found in CATV and other communications systems. But the MA47111 gives you even lower intermodulation products than the MA47110.

The MA47120 is what you're looking for if you work with modulating circuits and matrix switching at frequencies as low as 1 MHz.

And all three of them give you uniformity and repeatable performance. Even under extreme environmental conditions.

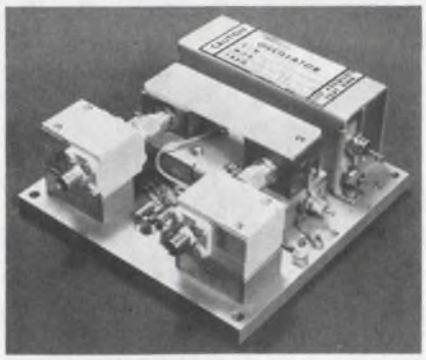
That means they're ideally suited for control applications. Like RF switching, limiting, duplexing, phase shifting, variable attenuation, modulation and pulse forming.

If you have a prototype to test, we'll be glad to send you some free samples. Because we're sure you'll be more than satisfied with what you can get for 19¢.

Microwave Associates, Inc., Northwest Industrial Park, Burlington, Mass. 01803, 617-272-3000; Dunstable Woodside Estate, Dunstable, Beds., United Kingdom, Tel: Dunstable 601441.

MICROWAVE ASSOCIATES

11-GHz varactor Gunn osc delivers 13 dBm



Omni Spectra, Inc., 1040 W. Alameda Dr., Tempe, Ariz. 85282. (602) 966-1471. $2750; 3 weeks.

The Model A30463 dual-channel varactor-tuned Gunn oscillator spans the 10.8-to-11.35-GHz range, delivering +13 dBm. The oscillator also has a high modulation capability of 50 MHz in 3 ns. The unit includes an output isolator and a 115-V heater.

CIRCLE NO. 525

2-GHz transistor outputs 1 W

RCA, Route 202, Somerville, N.J. 08876. (201) 722-3200. $52 (25-99); stock.

The RCA2001 transistor, for the 500-MHz to 2-GHz range, yields 1 W with 7 dB gain at 2 GHz when used with a 28-V supply. The new transistor is designed for various applications involving stripline, microstripline or lumped-constant circuits. The transistor comes in the company's HF-46 flanged ceramic-metal package, which features low inductance and low parasitic capacitance.

CIRCLE NO. 526

42-to-50-GHz Gunn osc supplies up to 150 mW

Varian, 611 Hansen Way, Palo Alto, Calif. 94303. (415) 493-4000. $900; 30-60 days.

The VSQ-9021 series of Gunn-effect oscillators delivers 5 to 150 mW in the 42-to-50-GHz frequency range. The oscillators are factory adjusted to operate at a specified frequency and output power, with standard models tunable ±100 MHz. Units weigh 4 oz and they use conduction cooling. Heat-sink temperature range is 0 to 50 C.

CIRCLE NO. 527

Power sweepers compete with BWOs

Weinschel Engineering, P. O. Box 577, Gaithersburg, Md. 20760. (301) 948-3434. $2745 up; stock to 60 days.

The series 430AP solid-state power sweeper, for the 1-to-18-GHz frequency range, reportedly provides performance characteristics previously available only from BWO sweepers. The sweepers have a leveled power of 30 mW in C band, 25 mW in X band and 20 mW in Ku band. Sweep speeds reach 10 ms per sweep for a flicker-free display without the use of long persistence scopes. Also available are digital frequency programming and pulse-modulation options with rise times under 50 ms.

CIRCLE NO. 528

1-to-18-GHz detector senses —50 dBm

Microphase Corp., Box 1166, Greenwich, Conn. 06830. (203) 661-6200.

The Model CSM-3118 detector covers the 1-to-18-GHz frequency range with a tangential sensitivity that is better than —50 dBm (2-dB video noise figure and 2-MHz bandwidth). The detector has a 0.807-in. "insertion length" and features a response that is flat with ±1.2 dB (±1.5 dB maximum). It uses a silicon Schottky chip.

CIRCLE NO. 529

Fast pulse-laser xmtr yields 6 W at IR

EPI Corp., 1241 Birchwood Dr., Sunnyvale, Calif. 94086. (408) 734-8235. Under $1000 (complete system).

A self-contained injection-laser system, for optical receiver tests, produces 5-ns pulses with less than 1-ns rise times and 6 W peak at rates to 20-k pulses per second. The light is infrared at 905 nm and divergence angle is only 10 milliradians. The hand-held laser can operate from self-contained batteries.

CIRCLE NO. 534

Module forms doppler sensor

General Electric, 316 E. 9th St., Owensboro, Ky. 42301. (502) 683-2401.

With an antenna, a microwave-circuit module—called the C-2126A MCM—forms a complete doppler-motion detector sensor. The unit limits spurious and harmonic-related outputs to meet Part 15 FCC regulations. The sensor operates at 10.525 GHz and from bias supplies of 8 V dc and 120 mA. The unit has a —30 to 70 C temperature range, and it specs an harmonic output of 2500 μV/m at 100 feet. The module measures 2.5 × 1.62 inches.

CIRCLE NO. 535

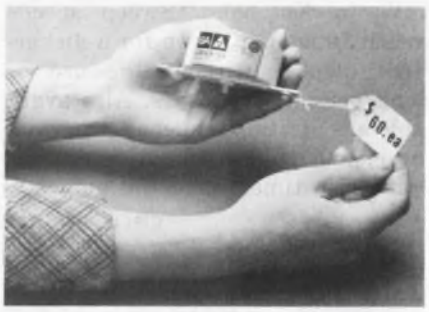
Ku-band switches offer 100-dB isolation

Hyletronics Corp., Newton Rd., Littleton, Mass. 01460. (617) 486-8911. 60 days.

The Model SK-606N Ku-band (12 to 18 GHz) switch provides a minimum isolation of 100 dB and specs insertion loss at 3.5 dB. The switch can handle up to 3 W of cw power, and it has a switching time of about 100 ns. Units are designed to meet environmental MIL specs.

CIRCLE NO. 536

2 to 12.4-GHz spiral antenna costs $60



Sanders Associates, Microwave Div., Grenier Field, Manchester, N.H. 03102. (603) 669-4615. $60.

A spiral antenna that sells for only $60 operates over the 2-to-12.4-GHz and has a beamwidth of 70°. Called the AS-212, the new antenna includes an SMA connector, weighs only 3 oz and has circular polarization with a typical axial ratio of 1.5 dB. VSWR is 2.5:1 and gain is 0 dBI.

CIRCLE NO. 537

Laser trimmer costs 10¢/hour to operate

GTE Sylvania, 1 Stamford Forum, Stamford, Conn. 06904. (415) 966-2452.

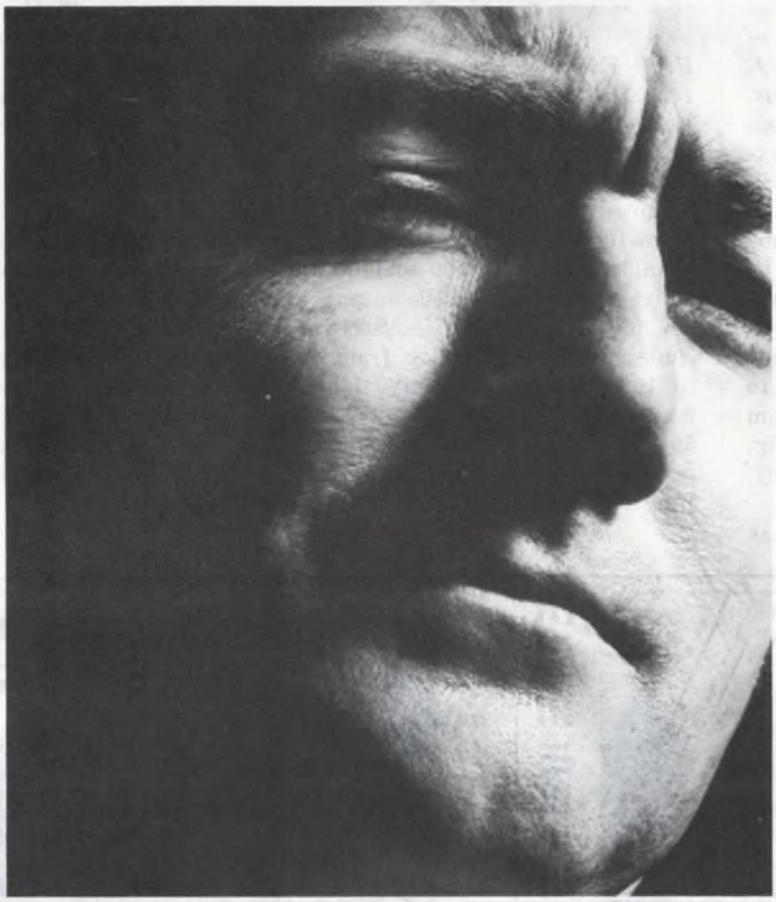
A low-cost thin-film resistor laser trimmer, called the Model 607, produces 1-1/4 W output power in a single-transverse mode. The Q-switch Neodymium:YAG device uses air-cooled tungsten-halogen lamps that cost 10¢ per hour to operate. No additional power is needed because the 607 operates from any 115-V receptacle.

CIRCLE NO. 538

If you're using Pertec or Wangco tape transports today, you can be saving money tomorrow.

You have a right to be skeptical. You've heard the claim before. But Microdata backs it up.

Microdata tape transports are priced lower than any other major manufacturer. Because we're plug-compatible with your OEM product, it's also extremely easy for you to take advantage of the savings we offer.



When you put Microdata 8.5″ or 10.5″ tape transports into your systems, you get all the performance and reliability you demand. At the same time, you pick up some very attractive sales features to build a strong competitive edge into your product. These include such welcome additions as dynamic braking. Full 200 inches per second fast forward and rewind. Trouble-free direct drive. The security of file protection. The accuracy of a forward and reverse electronic deskewer. With the added convenience and economies of a Microdata formatter readily available.

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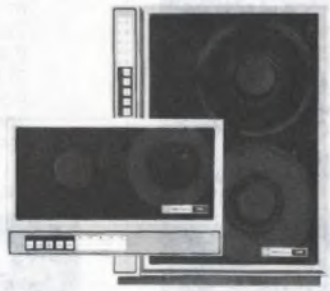

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INFORMATION RETRIEVAL NUMBER 124

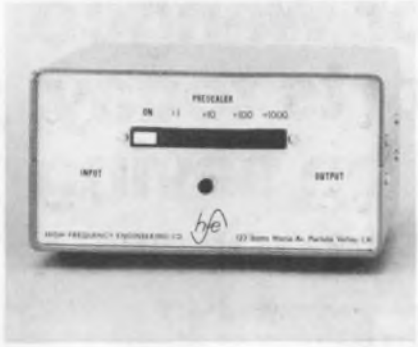
Option converts DMM to true-rms reader

California Instruments, 5150 Convoy St., San Diego, Calif. 92111. (714) 279-8620. $575; 30-45 days.

This true-rms converter is optional with the DMM 50 and extends the capability of the 5-1/2-digit multimeter. The option—which provides both ac and ohms functions—offers rms ranges of 1, 10, 100 and 1000 V fs with 20% overrange on all but the 1000-V range, which has 10%. Frequency response is from 10 Hz to 100 kHz, with accuracies from ±0.15% to +1.0% of reading, depending on input frequency, and crest factor is 7:1.

CIRCLE NO. 539

Unit prescales by 100 or 1000



High Frequency Engineering Co., 123 Santa Maria Ave., Portola Valley, Calif. 94025. (415) 851-8108. $455; stock.

Model PS-1000 frequency-counter prescaler divides an incoming 20-to-1000-MHz frequency by selectable factors of 100 to 1000 and delivers the processed output as 2-V pk-pk square waves. Specs include: Input sensitivity from 100 to 1000 MHz of 100 mV typical; maximum input signal of 3 V rms, 50 V dc; input and output impedance of 50 Ω; and output rise time of 20 ns.

CIRCLE NO. 540

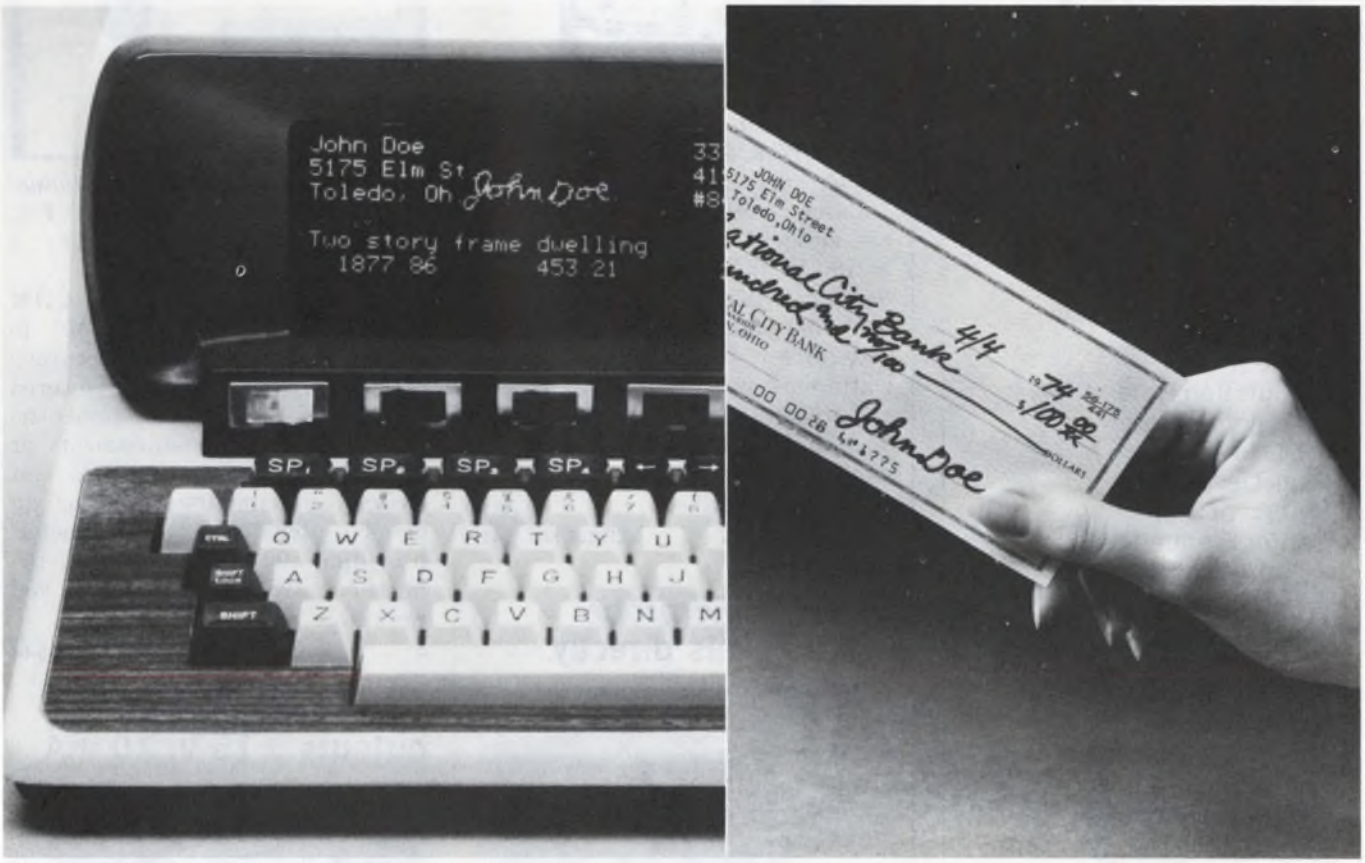
Pulser outputs 10 MHz, costs just $470

Interstate Electronics, 707 E. Vermont Ave., P. O. Box 3117, Anaheim, Calif. 92803. (714) 722-2811. $470.

P12 pulse generator outputs pulses from 10 MHz down to 0.01 Hz and features calibration-free circuitry. The unit offers simultaneous positive and negative pulses at less than 5-ns rise/fall times, square waves, single and double modes, and a special normal/complement selector. Each channel has individually adjustable amplitude from 1 to 10 V. One-decade pulse width, delay, and rate adjustments are further refined with continuously adjustable 10:1 verniers.

CIRCLE NO. 541

Digivue®- a better way to look at it.



Digivue 80-33 in demonstration unit, showing high-contrast display for use in signature verification.

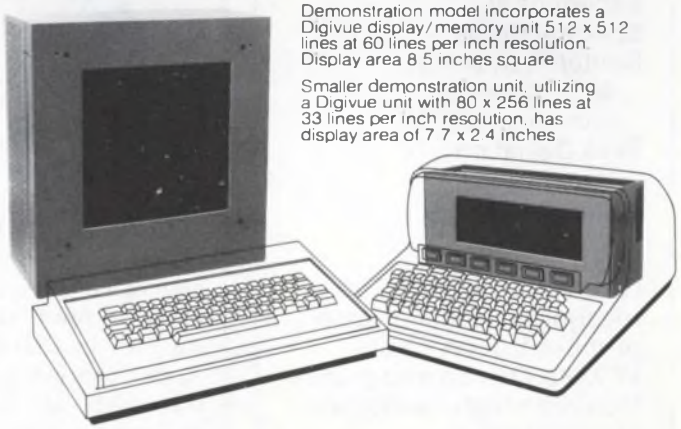
Because computer time is valuable to your customers, Digivue display/memory units offer an unforgettable advantage.

The advantage is inherent memory and it's an inherent part of every Digivue unit. This makes Digivue units especially useful for graphic presentations like signature verification since refresh is not required.

And Digivue units offer a high-contrast, flicker free display for precise readings with less chance of eye fatigue for people who spend long periods referring to data displays and computer terminals.

There's a lot more to Digivue, too. Our 512-60 models have hard copy and rear projection capabilities. And Digivue panels are flat and thin, allowing precise display and broad equipment design parameters.

As you may have guessed, Digivue display/memory units currently cost more than CRT's. But then, they offer a lot more. For a booklet that explains Digivue more fully, call (419) 242-6543, Ext. 66-415. Or write Electro/Optical Display Business Operations, Owens-Illinois, Inc., P.O.Box 1035, Toledo Ohio 43666



Demonstration model incorporates a Digivue display/memory unit 512 x 512 lines at 60 lines per inch resolution. Display area 8 5 inches square

Smaller demonstration unit, utilizing a Digivue unit with 80 x 256 lines at 33 lines per inch resolution, has display area of 7 7 x 2 4 inches

OWENS-ILLINOIS

Toledo, Ohio

INFORMATION RETRIEVAL NUMBER 127

Meter measures laser power to 250 W

International Light, Dexter Industrial Green, Newburyport, Mass. 01950. (617) 465-5923. $772.

Laser power meter, Model IL500, can measure power levels from 2.0 × 10^{-7} W up to 250 W with neutral-density attachment. Features include illuminated dial for darkroom use, direct readout in watts or watts/cm² and three chart-recorder outputs of 10, 100 and 1000 mV. The unit can also be used as a nanoammeter. Spectral range is 200 to 800 nm.

CIRCLE NO. 542

CMOS logic probe reads levels directly

Kurz-Kasch, David K. Burhap Bldg., Dayton, Ohio 45439. (513) 298-9971. $89.00; stock.

Model LP-575 CMOS logic probe offers a direct-reading LED display of logic-level information. The probe is for 5 through 15-V logic supplies in CMOS digital circuits. A new concept maintains the logic thresholds at nominally 70% of the supply for a logic ONE, and 30% of the supply for a logic ZERO. Deadband is approximately equal to 30% to 70% of V_{dd} and is indicated by no display. Pulse trains or single-cycle pulses (negative or positive) of 100-ns duration or greater are indicated by a red LED display.

CIRCLE NO. 543

Portable unit measures to 10-million MΩ

Eltec Instruments, Central Industrial Park, Daytona Beach, Fla. 32014. (904) 252-0411. $225; 2 weeks.

Model 600 HIGH MEGOHM meter measures from 0.1 MΩ to 10-million MΩ, with an accuracy of ±5%. The battery-powered solid-state FET circuit needs no warm-up time. No adjustments or calibration are required. A test switch acts simultaneously as an on-off switch for the entire meter, providing 400 hrs battery life. Dimensions are 8 × 5 × 6 in. and weight is 5 lb.

CIRCLE NO. 544

5-V-powered DPM outputs ±15 V, 10 mA

Analog Devices, Route 1 Industrial Park, P. O. Box 280, Norwood, Mass. 02062. (617) 329-4700. $122 (100); stock.

The AD2006/D is a 5-V-powered version of the recently introduced line-powered AD2006, a 3-1/2-digit DPM featuring Sperry displays. By offering a ±15-V at 10-mA output, the AD2006/D provides sufficient output power to drive many of the circuits that it measures. Like its line powered counterpart, the AD2006/D offers a differential input and ratiometric operation as standard features. With a full scale of ±1.999 V, the unit has a maximum error of 0.05% reading ±1 digit. Tempco is less than 50 ppm/°C.

CIRCLE NO. 545

RF Microwattmeters– Analog and Digital– FS Sensitivities from 10 nW to 10 mW

MODEL 42B/42BD

Boonton rf microwattmeters offer unrivalled sensitivity: 10 nW fs to 10 mW fs; from 200 kHz to 18 GHz, at highest stability ever attained at these sensitivities. Analog (42 B) or digital (42 BD) versions, both with linear DC outputs and logic-level programmability. BCD outputs are standard on digital version, autoranging and dB display (0.01 dB resolution) optional. Boonton Electronics, Parsippany, N.J. 07054

INFORMATION RETRIEVAL NUMBER 221

Wide-Range Programmable Capacitance Meters

MODEL 72B/72BD

Boonton analog (72B) and digital (72BD) provide rapid, accurate, 3-terminal and differential measurements, at 1 MHz, from 1 pF fs. Measures semiconductor-junction capacitance at low (15 mV) test level, with provision for external DC bias. Phase-sensitive detector measures accurately even at Q=1. Logic-level range programmability and fast-tracking DC output are ideal for ATE. Model 72BD has standard BCD output and autoranging. Boonton Electronics, Parsippany, N.J. 07054

INFORMATION RETRIEVAL NUMBER 222

Direct Capacitance Bridge 0.00005 to 1000 pF and 0.01 to 1000 mho

MODEL 75D

Boonton Model 75D Direct Capacitance Bridge is designed for 1 MHz capacitance and loss measurement. Capacitance range, 0.00005 pF to 1000 pF; basic accuracy, 0.25%. Conductance range: 0.01 mho to 1,000 mho, basic accuracy, ±5%. Internal bias from –6 V to +150 V. Adjustable test level, 1 mV to 250 mV, at 1 MHz. Two modes of operation allow either conventional capacitance and loss measurements or one-control balance for capacitance only. 3-terminal input configuration. Boonton Electronics, Parsippany, N.J. 07054

INFORMATION RETRIEVAL NUMBER 223

Why buy the HP 8640B at $5,400 when $2,205 less will get you Boonton's competitive 102A signal generator?

Our Model 102A, at $3,195, has everything you need for just about any AM/FM application — *plus* seven performance and convenience features you won't get in the HP $5,400 design.

What did we leave out?

Phase-lock synchronization, for one (but our dc-coupled FM channel can be externally locked if you need better stability than our typical 4 ppm); and narrow-pulse modulation (belongs in a different class of generators).

What did we add?

Four different signal-generation techniques — for optimum performance in *each band*, from 4.3 to 520 MHz, without the usual compromises in noise, stability, or residual-distortion characteristics.

The most logical panel layout and convenient control setup you've ever seen. And a unique adjustable "feel" main drive mechanism for narrow-band receiver setting with ease — even without our electrical vernier.

Separate meters for modulation and output — no annoying autoranging or out-of-range annunciators . . . we don't need them.

15 minute warmup to typically meet 10 ppm/10 minute stability — made possible by low internal dissipation (only 30 watts; no fan!)

Wider FM deviation at low carrier frequencies than any other design in this class (how does 2 MHz peak-to-peak grab you?)

A detected-AM-output option, to verify our negligible phase-shift for VHF-omni testing.

Versatile modulation features— like five internal frequencies, 30% and 100% AM scales, and true-peak-responding AM and FM metering.

All these performance pluses are coupled with low spurious and close-in noise, excellent low-frequency phase integrity, really effective leveling, a low and flat VSWR curve, accurate wide-range attenuation, high output power . . . all of it buttoned up tight for low leakage in a lightweight 30 pound package.

. . . and it's all yours for $3,195. Get the full specs today — before you spend 70% more . . .

For complete data or a demonstration write or call Boonton Electronics Corp., Rt. 287 at Smith Road, Parsippany, N. J. 07054, (201) 887-5110.

BOONTON

INFORMATION RETRIEVAL NUMBER 224 ►

50-MHz pulser offers variable delay, width

Alpha Systems, Neumuller GMBH, 8 Muchen, 2 Karlstrasse 55.

Model 120 pulse generator features repetition rates of less than 1 Hz to greater than 50 MHz, rise and fall times of less than 3.5 ns, and simultaneous positive and negative outputs. Pulse amplitude is variable from less than 200 mV to greater than 10 V into 50 Ω. Rep rate, delay and width jitter are less than 0.1% of setting or 50 ps, whichever is greater, and waveform aberrations (undershoot, overshoot and top slope) are less than 5% of amplitude.

CIRCLE NO. 546

Low-frequency analyzer offers built-in counter

Hewlett-Packard, 1501 Page Mill Rd., Palo Alto, Calif. 94304. (415) 493-1501. $2600; stock.

Model 3581A 15-Hz-to-50-kHz Wave Analyzer has a built-in counter that displays the tuned frequency with 1-Hz resolution on a LED digital readout. Accuracy is 3 Hz. Signal amplitude is read on a four-scale analog meter. Sensitivity is 100-nV full scale, dynamic range is 85 dB and max input is 30 V. Bandwidths are selectable from 3 to 300 Hz.

CIRCLE NO. 547

Build your own sweep generator

MITS Inc., 6328 Linn, N.E., P.O. Box 8636, Albuquerque, N.M. 87108. (505) 265-7553. Kit: $119.95; Assembled: $149.95.

Model SG 1900 Audio Sweep Generator can be used as both a fixed-frequency (cw) and a sweep generator, and has adjustable logarithmic and linear sweep modes from 10 ms to 100 s. Three waveforms are outputted: sine, square and triangle. Specs include a range of 1 to 100 kHz; response of ±0.1% to 20 kHz and ±0.15% to 100 kHz, with average distortion for the sine wave of 1.5% over 10 Hz to 20 kHz.

CIRCLE NO. 548

Sometimes a digital computer gets so trapped in detail, it takes an analog to get things moving

Choosing the right iron is an exercise in logic—work for a digital computer. Plotting the optimum path for the ball is done by processing all the variables in parallel fashion—as an analog computer does. But we can't carry two computers to the links. Or can we?

Current theory says the human brain is like a hybrid computer. One half does sequential calculation; the other, parallel processing. The interaction of the two produces some pretty flashy results.

So do EAI PACER™ systems. Because they're hybrids, too. They blend analog and digital computing techniques to solve enormous problems with speed and efficiency that are not possible otherwise.

They will, for instance, complete large-scale simulations in one-hundredth the time that it would take even the largest digital—and at a small fraction of the cost.

That's why EAI PACER systems can be found at work in scientific and engineering organizations wherever speed and price/performance ratios are considerations. For more facts from the world's largest manufacturer of hybrid computers, write Electronic Associates, Inc., West Long Branch, N.J. 07764. Or call (201) 229-1100.

EAI
Electronic Associates, Inc.

INFORMATION RETRIEVAL NUMBER 132

Microwave counter handles pulsed signals

Hewlett-Packard, 1501 Page Mill Rd., Palo Alto, Calif. 94304. (415) 493-1501. $3450.

This plug-in counter, Model 5345A, needs just 1 s to measure any frequency from 1 Hz to 500 MHz with 9-digit resolution. The unit resolves one-shot time intervals to 2 ns, measures the frequency of rf pulses as brief as 50 ns and can resolve repetitive time interval measurements to 1 ps. The counter is available with full digital output, input programming capability, calculator interface and accessories to 18 GHz.

CIRCLE NO. 549

On-line unit measures FET specs

Lorlin Industries, Inc., Precision Rd., Danbury, Conn. 06810. $56,300; 90 days.

The PICOFET-100 system provides total on-line control in the testing of FETs; n or p-channel devices in enhancement or depletion modes, single gate, dual gate or dual FETs in array or discrete package form and vacuum tube replacements. In addition to measuring leakage currents in the low picoamp range, the standard PICOFET-100 can run a gamut of tests which include breakdowns up to 500 V, output admittance and resistance, plus forward currents up to 2 A. The standard unit also measures ac parameters.

CIRCLE NO. 550

Impedance bridge works from batteries

Tucker Electronics, P.O. Box 1050B, 1717 S. Jupiter Rd., Garland, Tex. 75040. (214) 348-8800. $525; stock.

The 610A is a 5-digit nulling-type impedance bridge that measures resistance (0 to 12 MΩ in seven ranges), capacitance (0 to 1200 μF in seven ranges), inductance (0 to 1200 H in seven ranges), conductance (0 to 1.2 mhos in seven ranges), storage factor (0.1 to 1000 at 1 kHz in two ranges), and dissipation factor (0 to 1.05 at 1 kHz in two ranges). Accuracies are: 0.25% of reading on all R&G ranges, 1.0% of reading on all C&L ranges and ±5.0% on all Q&D ranges. Resolution is ±0.001% of range.

CIRCLE NO. 551

4-digit DMM operates from line or batteries

Data Technology, 2700 S. Fairview St., Santa Ana, Calif. 92704. (714) 546-7160. $399; stock.

Called the Model 45, this 10,000-count (4-digit) DMM operates from either line or battery power. The unit has five ac and five dc voltage ranges with 10-μV resolution, six resistance ranges with 10-mΩ resolution and five ac and five dc current ranges with 10-nA resolution. Battery charge life is 10 to 12 hours, power consumption is 3 W and size is 2.5 × 6.25 × 9 in. Weight is 2.3 lb.

CIRCLE NO. 552

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MODEL 2000

- ☐ Basic main frame is adaptable for rack mount or bench or specialized system configuration.
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INFORMATION RETRIEVAL NUMBER 134

Power transistors handle peak currents of 20 A

Solitron Devices, 1177 Blue Heron Blvd., Riviera Beach, Fla. 33404. (305) 848-4311. 301: $10, 201: $30 (large quantity); 3 to 4 wk.

A series of high current, fast switching npn silicon power transistors has a peak current capability of 20 A. They are available in two packages, the isolated TO-61 (SDT 13201-SDT 13205) and the standard TO-3 (SDT 13301-SDT 13305). Typical specs include V_{CEO} (sus) from 300 to 500 V, I_C (continuous) = 10 A and I_C (peak) = 20 A, with 125 W power capability at 100 C. The thermal resistance is typically 0.8 C/W and f_t = 15 MHz (minimum). V_{CE} (sat) = 1 V (maximum) and V_{BE} (sat) = 1.4 V (max). Typical switching times are t_{on} = 0.25 μs, t_s = 1.6 μs and t_f = 0.35 μs (typical).

CIRCLE NO. 553

High V power transistors handle up to 350 V

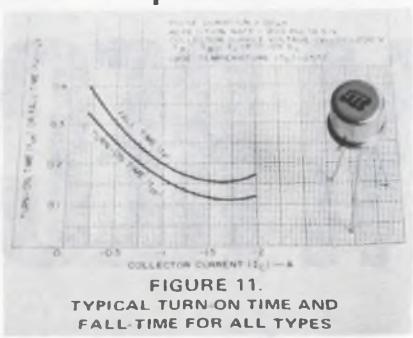


FIGURE 11.
TYPICAL TURN-ON TIME AND FALL-TIME FOR ALL TYPES

Silicon Transistor Corp., Katrina Rd., Chelmsford, Mass. 01824. (617) 256-3321. From $0.87 (100-up); stock.

Four complementary high voltage power transistors, 2N3439 and 2N3440 (npn), 2N5415 and 2N-5416 (pnp), are specified for gain over a 50 mA current range. They have V_{ceo} ratings from 200 to 350 V. These transistors are housed in hermetic TO-5 packages and can handle up to 10 W at 25 C or 1 W at 50 C. Other characteristics include a 20 pF maximum C_{ob} and a 5 MHz min. cutoff frequency.

CIRCLE NO. 554

Microwave transistors operate at 2.3 GHz

TRW Semiconductors, 14520 Aviation Blvd., Lawndale, Calif. 90260. (213) 679-4561. From $27.55 (100-up); stock.

A line of microwave transistors is rated for operation at 2.3 GHz and has a mismatch tolerance of infinite VSWR for any phase at full rated power output. The TRW 2001 is rated for power output of 1 W and gain of 9 dB, the 2003 for 3 W and 8 dB, the 2005 for 5 W and 8 dB and the 2010 for 10 W and 7 dB. Devices rated for 20-W operation and higher will be available soon. The units offer a minimum collector efficiency of 40%.

CIRCLE NO. 555

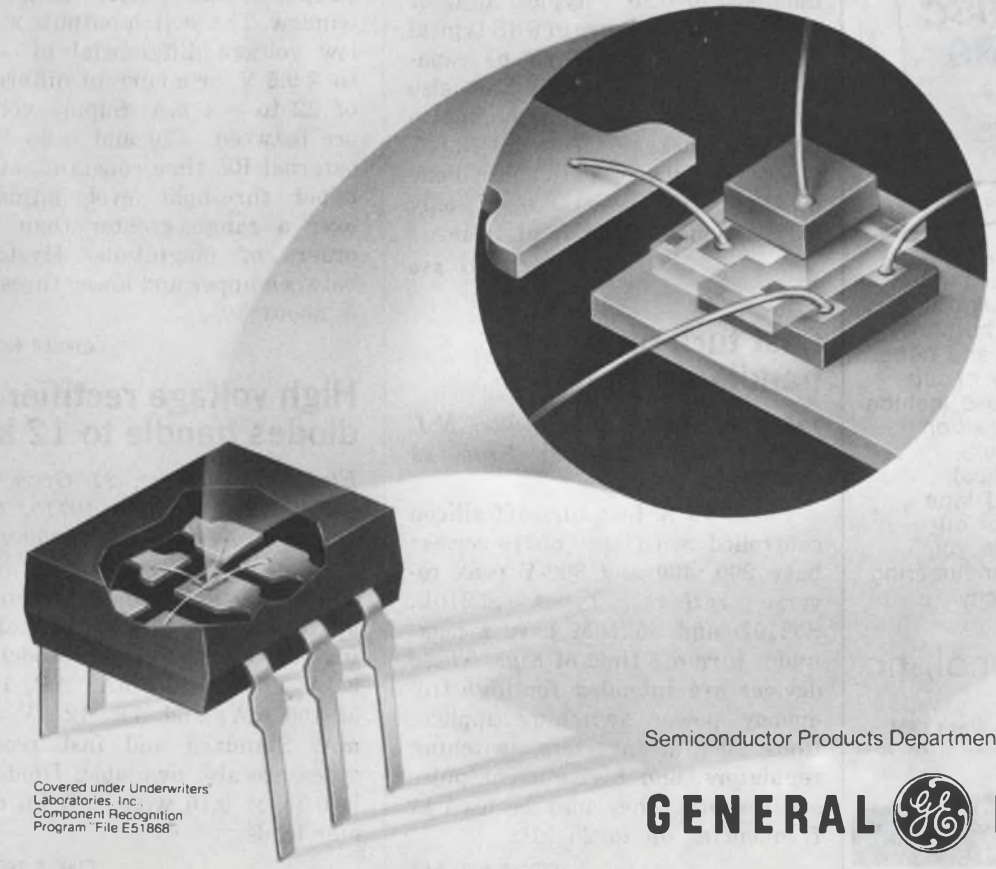
3,500 VOLT ISOLATION
100% CURRENT TRANSFER
OPTO COUPLER

HOW GENERAL ELECTRIC DOES IT

General Electric's unique glass isolation produces precise alignment and controlled spacing between the LED and the silicon detector thus optimizing photon coupling...minimizing the effect of the inverse relationship of isolation voltage and current transfer ratio...and yielding optoelectronic couplers with BOTH high isolation voltage and high current transfer ratios.

3 new models 4N35, 36, 37 are characterized for high isolation voltage and high current transfer ratios. 4N35 offers 3,500 volts (peak) and 100% transfer ratio for $1.85 each in 1,000 lot quantities.

Available now from any authorized GE Semiconductor distributor or GE Electronic Components Sales Office.



Covered under Underwriters' Laboratories, Inc. Component Recognition Program "File E51868"

Semiconductor Products Department, Syracuse, New York.

GENERAL ELECTRIC

Tuning diodes have a 6:1 capacitance change

Motorola, P.O. Box 20912, Phoenix, Ariz. 85036. (602) 244-3466. From $10 (100 up); stock.

The MV205 hyper-abrupt tuning diode offers a guaranteed minimum tuning ratio of 4.5 C3/C25 at 1 MHz, and a minimum Q of 225 at 9 pF at 100 MHz. Typical capacitance variation from 2 to 25 V is 12 to 2 pF. The MV206 is similar but with relaxed specifications for less critical applications. Guaranteed tuning ratio C3/C25 is 4, while minimum Q is 150 at 100 MHz. The MBD103 silicon hot-carrier mixer (Schottky) diode has a high forward conductance of 0.35 V typical at I_F of 100 μA, a noise figure of 6 dB typical at 1 GHz and less than 1 pF capacitance at 0 V. The MBD103 also has a low series inductance due to its pill package. The MPN3601 p-i-n microwave switching diode has a series resistance of only 0.34 Ω typical at an I_F of 10 mA.

CIRCLE NO. 556

Fast turn-off SCRs handle up to 600 V

RCA, Box 3200, Somerville, N.J. 08876. (201) 722-3200. From $3 (1000-up); stock.

Three 10 A fast turn-off silicon controlled rectifiers (S5210 series) have 200, 400 and 600-V peak reverse ratings. Types S5210B, S5210D and S5210M have a maximum turn-off time of 8 μs. These devices are intended for high-frequency power switching applications, such as inverters, switching regulators, and high-current pulse applications. They may be used at frequencies up to 25 kHz.

CIRCLE NO. 557

Abrupt junction tuning diodes guarantee specs

KSW Electronics, S. Bedford St., Burlington, Mass. 01803. (617) 273-1730. From $0.90 (100-up).

Abrupt junction tuning diodes in the KV620-666 series offer guaranteed tuning ratios and temperature coefficients. Tuning voltages should not exceed 15 to 20 V. The series has 4-V capacitance values of 6.8 to 300 pF. The KV-620-666 series diodes are directly interchangeable for many 1N, MV, PC and V prefix diodes sold by other manufacturers.

CIRCLE NO. 558

Light activates MOS switches

Integrated Photomatrix Inc., 1101 Bristol Rd., Mountainside, N.J. 07092. (201) 233-6010.

The IPI-15/17 series of light-activated switches combines a photodiode, buffer and Schmitt trigger on a single MOS chip. Packaging consists of 4-lead TO-18 (Type IPI-15) and 6-lead TO-71 (Type IPI-17) style with glass window. The switch outputs a high-low voltage differential of -0.25 to -9.5 V, or a current differential of 22 to -4 mA. Supply voltages are between -20 and -30 V. An external RC time constant sets the upper threshold level, adjustable over a range greater than three orders of magnitude. Hysteresis between upper and lower thresholds is about 3%.

CIRCLE NO. 559

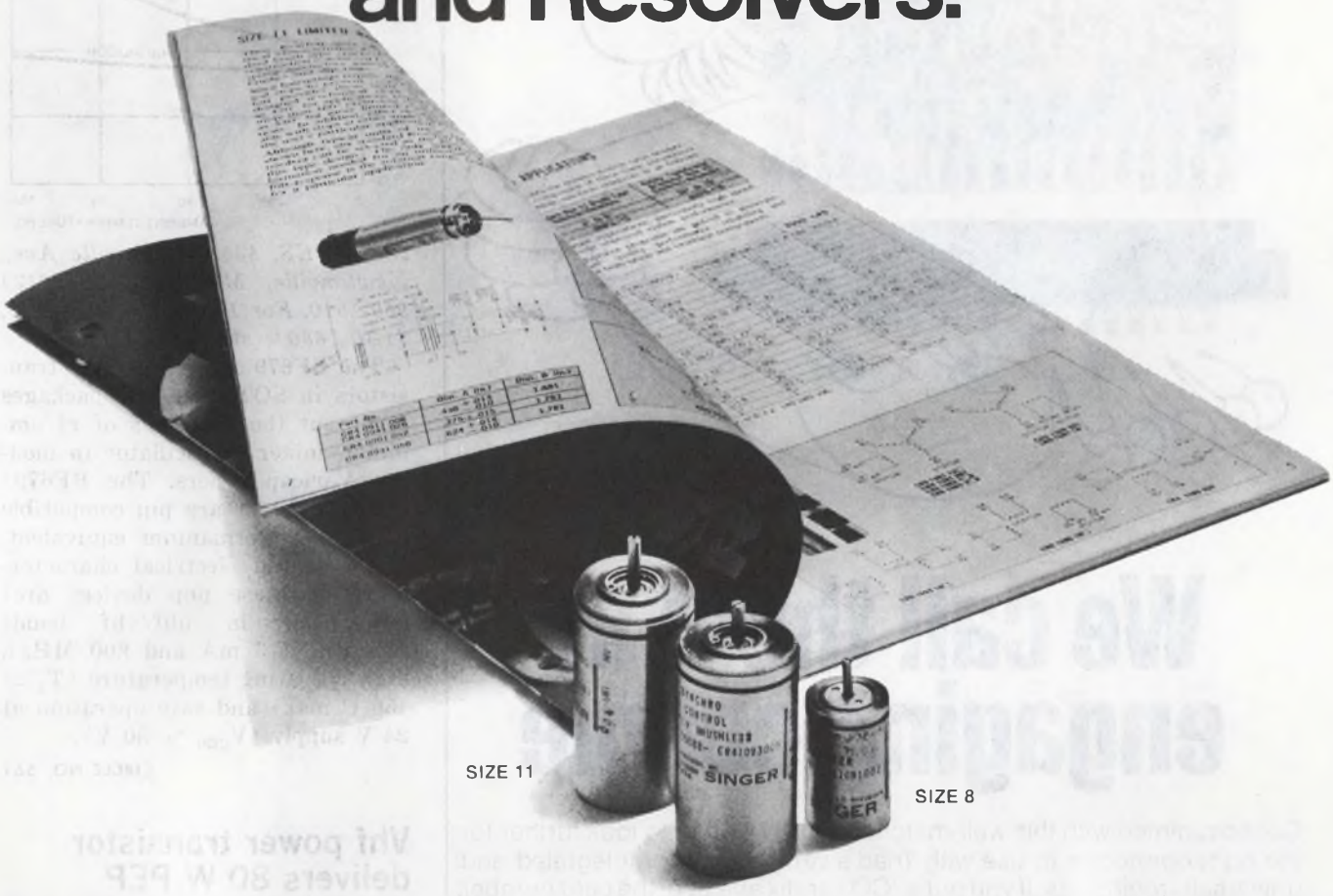
High voltage rectifier diodes handle to 12 kV

Electrical Devices, 21 Gray Oaks Ave., Yonkers, N.Y. 10710. (914) 965-4400. From $1.70 (1000-up).

A line of 8-to-12-kV miniaturized, silicon diodes handles currents of up to 125 mA. The electrical ratings of the diodes are: Model AM, 8 kV PIV at 125 mA; AP, 10 kV at 100 mA; and AR, 12 kV at 80 mA. Standard and fast recovery types are also available. Diode size is 0.38 $\times$ 0.16 with 0.03 in. diameter leads.

CIRCLE NO. 560

Send for our brushup course on Brushless Synchros and Resolvers.



Faced with applications where synchros and resolvers have to be driven at extremely high speeds? Or where brush wiping contact can't be permitted?

Kearfott Brushless Components provide system performance advantages. (Instead of standard brushes and slip rings, rotary transformers couple power into the synchro motor.) And extra-wide bearings give you increased reliability and load-carrying capacity.

Our Brushless Synchros offer you a number of other benefits, too. Longer life, since there's nothing to wear but the bearings. No spurious signals from high-speed brush bounce which Digital Computers can interpret as a command input. Elimination of brush friction for Indicators that require the ultimate in minimum loading. And an end to RFI noise.

Kearfott Brushless Synchros and Resolvers also serve as excellent low cost Brushless Encoders when used in combination with Kearfott TRIGAC I S/D converter cards.

Like to know more? Write for our 36-page brochure on Synchros and Resolvers. It's packed with facts and figures on Brushless Synchros for limited and continuous rotation applications—plus our full line of Synchros and Resolvers. The Singer Company, Kearfott Division, 1150 McBride Avenue, Little Falls, New Jersey 07424.

SINGER

AEROSPACE & MARINE SYSTEMS

The Singer Company, Kearfott Division
1150 McBride Avenue
Little Falls, New Jersey 07424

Gentlemen:

☐ I want to know more about Brushless Synchros. Rush me your 36-page booklet on Synchros and Resolvers.

☐ I have an application for Brushless Synchros. Have a company representative call.

Name_____

Title_____

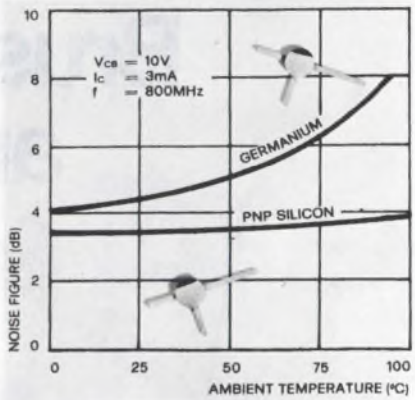
Company_____

Address_____

City_____ State_____ Zip_____

INFORMATION RETRIEVAL NUMBER 139

Pnp rf transistors have 3 dB noise at 800 MHz



SGS-ATES, 435 Newtonville Ave., Newtonville, Mass. 02160. (617) 969-1610. For 100 up: $1.20 (679), $1.10 (680); stock.

The BF679 and BF680 pnp transistors in SOT-37 plastic packages carry out the functions of rf amplifier, mixer or oscillator in modern Varicap tuners. The BF679/680 transistors are pin compatible with their germanium equivalent. The essential electrical characteristics of these pnp devices are: low noise in uhf/vhf bonds (3.5 dB at 3 mA and 800 MHz), high operating temperature (T_j = 150 C max) and safe operation at 24 V supply (V_{CEO} > 30 V).

CIRCLE NO. 561

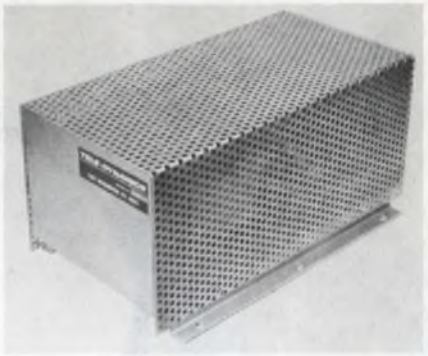
Vhf power transistor delivers 80 W PEP

RCA, Box 3200, Route 202, Somerville, N.J. 08876. (201) 722-3200. $36 (100-up); stock.

Type 41042 vhf power transistor can deliver 80 W of peak envelope power at 136 MHz. It is intended for use in amplitude-modulated amplifiers operating in the frequency range from 118 to 136 MHz. At 136 MHz, it provides 20 W of cw power with a 13-V supply, and 80 W PEP with a 26-V supply. It can withstand an infinite load mismatch at the 80-W PEP level. The device is an epitaxial silicon npn planar transistor with overlay emitter-electrode construction. Integral silicon emitter-ballasting resistors are used for ruggedness and overdrive capability. It is supplied in a HF-44 package.

CIRCLE NO. 562

Line-voltage regulators protect against brownout



Telé-Dynamics/Wanlass, 525 Virginia Dr., Fort Washington, Pa. 19034. (215) 643-6161. $150 to $190; 6 wk.

This patented series of line-voltage regulators is used to protect motors, controls and other instrumentation sensitive to under or overvoltage line conditions—such as summer "brownouts." Called Varax Line Voltage Regulators, the new devices are for use in 115 or 230-V applications. Five series are rated 500, 1500, 3000, 5000 and 10,000 VA. Output is constant for input variations from 90 to 125 V on 115-V nominal lines, or 180 to 250 V on 230-V nominal lines.

CIRCLE NO. 563

Seven computer supplies offered

Lambda Electronics, 515 Broad Hollow Rd., Melville, N.Y. 11746. (212) 371-8800. $535; stock.

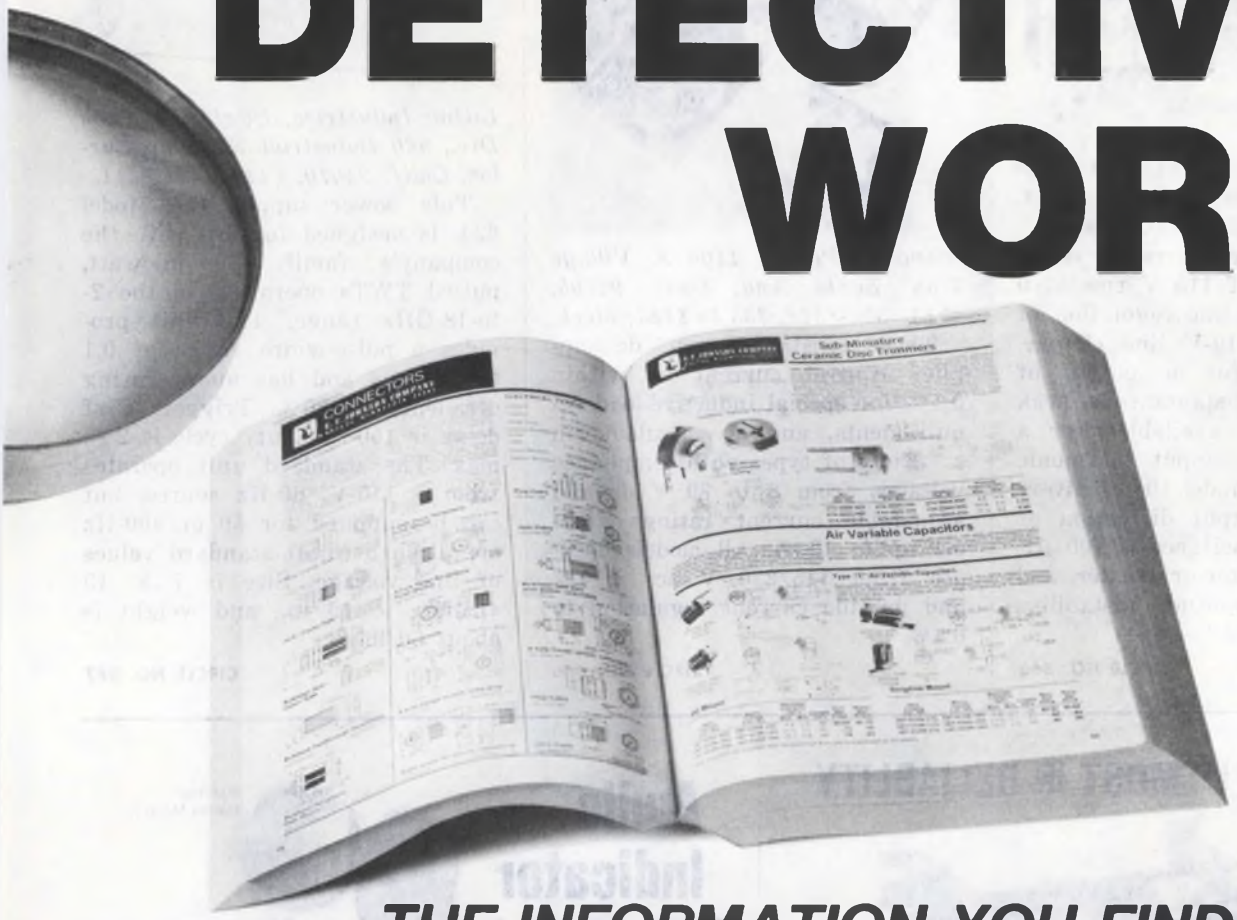
Called the series LX-7, this 4-15/16 × 10-1/8 × 16-1/2-in. power supply is built with adjustable overvoltage protection, is convection cooled, and requires no blowers. Seven, single-voltage output models are available: 5, 6, 12, 15, 20, 24, and 28 V, all ±5%. Currents at 40 C for these voltages, respectively, are 65, 59, 40, 36, 28, 25 and 22 A.

CIRCLE NO. 564

CUT

Electronic Design's

DOWN YOUR DETECTIVE WORK



THE INFORMATION YOU FIND HERE WILL SAVE YOU TIME AND MONEY

When you see *Electronic Design's* GOLD BOOK you'll wonder how you ever got along without it. You don't have to be a super-sleuth to find out who makes what or where to find it.

For example, there are almost 300 catalog pages on Monolithic ICs alone; almost 300 pages on Power Supplies; over 250 catalog pages on Instruments; almost 200 pages on Semiconductors — approx. 4,000 pages of directory data and technical material in all.

And the Directories — they're the most complete and comprehensive, the most thorough and useful reference sources ever compiled. Almost 7,500 manufacturers are listed with *complete* address, zip and phone. In most cases (where applicable) you also get 800 (toll-free) numbers, Telex, TWX, cable address, facsimile equipment with make and number, plus QPL and FSC designations, financial data and names of key officers.

5,000 distributors are listed — with both alphabetic and geographic access — in the *Distributors Directory*.

See how often *Electronic Design's* GOLD BOOK will answer your questions before you even pick up the phone. Keep the manufacturer's tech pages in front of you when you call — it can speed the discussion and help you communicate your needs quickly and easily.

GOLD BOOK

COMING JULY, 1974

Line corrector regulates to 0.025%

California Instruments, 5150 Convoy St., San Diego, Calif. 92111. (714) 279-8620. $1495; 30 days.

Model 1060 line corrector delivers an output of 115 V rms at 0 to 10 A with a line regulation of 0.025% for a 10-V line change. Though rated for an output of 1000 VA, an instantaneous peak of 5000 VA is available. For a maximum 10% input harmonic distortion, the Model 1060 delivers a maximum output distortion of 0.2%. Load capacitance is 100 μF at 0.1 power factor or greater, and peak output amplitude instability is ±0.01% cycle-to-cycle.

CIRCLE NO. 565

Constant-current units output to 12 A

Standard Power, 1400 S. Village Way, Santa Ana, Calif. 92705. (714) 558-8512. $55 to $125; stock.

These constant-current dc supplies control current to within 0.1% for special inductive-load requirements, and are available in a variety of types with compliance voltages from 8 to 30 V dc and adjustable current ratings from 0.1 up to 12 A. All models operate from 115/230 V ac, ±10% and provide current regulation to 0.1%.

CIRCLE NO. 566

Lab supply pulses TWTs to 18 GHz

Litton Industries, Electronic Tube Div., 960 Industrial Rd., San Carlos, Calif. 94070. (415) 591-8411.

This power supply, the Model 624, is designed for use with the company's family of kilowatt, pulsed TWTs operating in the 2- to-18-GHz range. The unit provides a pulse-width range of 0.1 to 15.0 μs and has an operating efficiency of 80%. Trigger to rf delay is 150 ns; duty cycle is 2%, max. The standard unit operates from a 115-V, 60-Hz source, but can be supplied for 50 or 400-Hz operation at most standard values of line voltage. Size is 7 × 19 (panel) × 18 in., and weight is about 60 lb.

CIRCLE NO. 567

Op amp supplies output to 2000 V

Kepco, Inc., 131-38 Sanford Ave., Flushing, N.Y. 11352. (212) 461-7000. $483; 90 days.

OPS-IXB group of high-voltage operational amplifiers is rated for 20 W, with 500, 1000 and 2000-V output. The new models feature a low drift, integrated front end for stability, and have a built-in "free amplifier" for low-level programming by passive devices. A simple 0-to-5-kΩ rheostat, supporting just 0 to 5 V, will program the Model OPS 1000B over its entire 0-to-1000-V, 0-to-20-mA range. OPS-IXB models feature a 12-terminal front-panel patch board for dc output, with signal input and feedback connections superimposed over a schematic representation of the circuit.

CIRCLE NO. 568

High-voltage units hook up to CRTs, PMTs

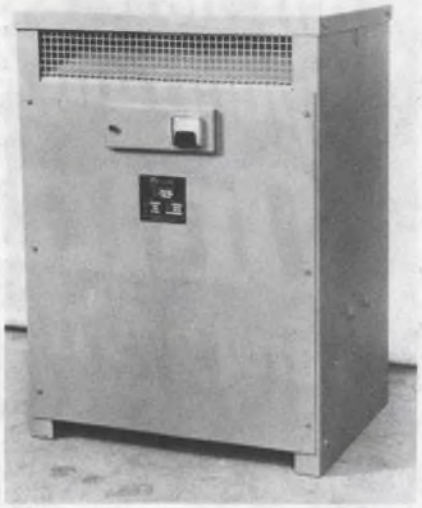
Spellman High Voltage Electronics Corp., 1930 Adee Ave., Bronx, N.Y. 10469. (212) 671-0300. Begin at $85; 3-4 wks.

This line of high-voltage units is divided into two categories: FWRM and WRM. FWRM consists of slot supplies with output voltage variable over a narrow range. The WRM models are fully adjustable from near 0 to maximum rated output voltage. Both FWRM and WRM units are available with output ratings up to 30 kV and 30 W. Featuring both remote voltage and remote resistance programming, all models are available with either positive or negative output polarity with respect to ground. Line regulation for all modules is ±0.01%, load regulation is 0.05% for full-load change. Ripple is 0.01%/W pk-pk.

CIRCLE NO. 569

INFORMATION RETRIEVAL NUMBER 144 ►

Line-voltage regulators keep output to ±1%



Electro Engineering, 401 Preda St., San Leandro, Calif. 94577. (415) 653-5990. $970 to $31,500; 8 to 14 wks.

LVR Series is a line of single and three-phase automatic LVRs in the power range of 3 to 2500 kVA. The electromechanical units combine a variable auto-transformer with an all-solid-state control device to reduce line-voltage fluctuations of ±10% to within a ±1.0% bandwidth, with no waveform distortion.

CIRCLE NO. 570

Switching modules give efficiencies to 80%

Abbott Transistor Laboratories, 5200 W. Jefferson Blvd., Los Angeles, Calif. 90016. (213)936-8185. $245 (1-4); stock.

Hi-efficiency series of power modules converts 47 to 440-Hz lines to 50 W of regulated power. Model "VN50" series uses a new approach in switching technology to provide a line of 21 high-efficiency (up to 80%) power modules. Any output voltage between 4.7 and 50 V dc is available in a package that measures only 3-7/8 × 6-1/4 × 2-3/4 in. Line and load regulation are held to 0.4% and ripple to 30-mV rms maximum. Baseplate temperature range is 0 to 71 C and maximum tempco is 0.03%/°C.

CIRCLE NO. 571

PC-mount unit gives triple output

Lambda Electronics, 515 Broad Hollow Rd., Melville, N. Y. 11746. (516) 694-4200. $70; stock.

The company has added a new triple-output model to the LZ series. The new model is the LZT-36, a 5-V dc, 500-mA; ±15-V dc, 50-mA unit. This addition makes a total of 26 single, 19 dual and one triple-output models in the series. The models in this PC-mount series have continuously adjustable voltages, are field repairable and foldback-current limited. They have a wide input voltage range (105 to 132 V ac), are short-circuit proof, have a vacuum-impregnated transformer and are designed for series operation.

CIRCLE NO. 572

Dc inverters operate from 350 to 600 V

Nova Electric, 263 Hillside Ave., Nutley, N.J. 07110. (201) 661-3434. Approx. $600 to $4500; 60 days.

These high-dc-input voltage inverters—the SD, SSD, SSDD series—include 18 models that operate from voltage levels of 350, 450 and 600 V dc. The fully transistorized, modular units provide 115 V, 60 Hz at power levels from 125 VA to 3 kVA. Specs include sine wave output, short-circuit and overload protection and voltage regulation of 1%. Input transient protection is optional up to 4 kV for 10 ms. 50 and 400-Hz outputs are available on special order. Typically, the 250-VA unit measures 16-3/4 × 9 × 6-3/4 in.

CIRCLE NO. 573

RCA introduces the "easy way" to buy test equipment.

RCA's new Easy Payment Plan makes it possible for you to own . . . *immediately*, any of the electronic instruments shown in the table below for just a small down payment and only four additional easy payments.

No interest . . . no special charges to worry about. Just meet your local participating Distributor's credit criteria.

So check off the instruments you need and visit your nearest participating RCA Electronic Instruments Distributor. Or write to RCA Electronic Instruments, 415 S. Fifth St., Harrison, N.J. 07029. A distributor will contact you. He'll show you the quick and easy way to own the best in RCA test equipment.

But hurry. This great offer ends on July 31, 1974.

Model WO-33B

New "super" portable 3" Oscilloscope
$229.00 **$71.00 Down**

Model WO-505A

DC to 10 MHz 5" Oscilloscope
$329.00 **$101.00 Down**

Model WV-98C

Senior VoltOhmyst®
$99.95 **$30.00 Down**

Model WV-532A

Relay-protected VOM
$99.95 **$30.00 Down**

Model WR-514A

TV Sweep Chanalyst
$380.00 **$114.00 Down**

Model WR-538A

Super Chro-Bar Generator
$129.95 **$39.00 Down**

Model WT-524A

Dynamic Transistor/FET Tester
$159.00 **$47.00 Down**

Model WO-535A

Triggered sweep DC to 10 MHz 5" Oscilloscope
$349.00 **$104.00 Down**

Model WV-510A

Master VoltOhmyst®
$135.00 **$40.00 Down**

Model WV-500B

Portable Solid-State VoltOhmyst®
$99.95 **$30.00 Down**

Model WA-504B/44D

Audio Sine/Square-wave Generator
$109.50 **$36.00 Down**

Model WR-515A

Master Chro-Bar Generator
$189.00 **$56.00 Down**

Model WT-333A

Picture Tube Tester/Rejuvenator with "SIMUL-TEST"
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Model WP-702A

Dual Output DC Power Supply
$99.00 **$30.00 Down**

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Specialists demand the best tools of their trade.

RCA Electronic Instruments

INFORMATION RETRIEVAL NUMBER 146

application notes

Analog networks

"Circuit Design and Network Analysis" describes Electronic Engineering Pac Volume 1. This software package is used with the HP 9820 or 9821 calculators and contains programs in five categories: network analysis, filter design, transfer function analysis, component design and digital logic minimization. Hewlett-Packard, Palo Alto, Calif.

CIRCLE NO. 646

Permanent magnets

Magnet fundamentals and specific design considerations are outlined in a 16-page summary of design techniques for magnet systems. Indiana General, Valparaiso, Ind.

CIRCLE NO. 647

Filter measurements

Data on how to use tunable notch and peak filters to facilitate telephone line measurements and tests for data transmission are given in a four-page brochure. All measurements are referenced to Bell technical reference guidelines, PUB 41009. SEG Electronics, Jamaica, N.Y.

CIRCLE NO. 648

Waveform recorder

An application note describes how waveform (transient) recorders have been powerful new tools for studying fast chemical reactions. Biomation, Cupertino, Calif.

CIRCLE NO. 649

Dry photoresist stripping

Use of plasma instrumentation for removal of photoresist from aluminum substrates is described in an application note. The note describes the advantages of using the dry plasma technique as compared with organic stripping. Tegal, Richmond, Calif.

CIRCLE NO. 574

Spectrum analyzer

How to use on-line real-time spectrum analysis to test and service high-quality tape recorders is described in a four-page technical paper. Federal Scientific, New York, N.Y.

CIRCLE NO. 575

Variable angle techniques

Variable angle attenuated-total-reflectance (ATR) techniques to simplify surface studies are illustrated in a 16-page booklet. These techniques can be used in analyzing plastics, rubber, paper, resins, ink, fiber, wax, blood, multilayered films and coatings of almost any type. Barnes Engineering, Stamford, Conn.

CIRCLE NO. 576

Magnetic sensors

A report covers design criteria and application requirements for obtaining precision synchronous timing with the use of analog (passive) and digital (active) magnetic sensors. Electro Corp., Sarasota, Fla.

CIRCLE NO. 577

design aids

Flame-retardancy charts

An easy-to-follow product performance chart identifies at a glance which flame retardant and/or UL tests have been passed by Scotch-brand electrical tapes, ScotchTite tubings, 3M tubings and Scotchcast resins. A second chart, a UL recognition guide, includes file numbers and guide numbers for tapes, resins, tubings, thermal cutoffs and Scotchpar-brand film. 3M.

CIRCLE NO. 578

Thumbwheel switches

"Our Codes Are No Secret" is the theme of a 22 × 34 in. thumbwheel switch wall chart. Included with the 79 switch code charts are photographs, dimensions and descriptions, plus features and options covering all series. The Digitran Co.

CIRCLE NO. 579

Zener voltage regulators

A product locator for zener voltage regulators lists power ratings, voltage ratings, tolerance range, case style and data sheet number. The literature shows 12 photographs of various devices with their dimensions. International Rectifier, Semiconductor Div.

CIRCLE NO. 580

Metric conversion aids

A catalog offers a variety of metric educational aids, such as a wall chart, three-dimensional mechanical devices, slide-rule type converters and color and sound films. Millimeter Industrial Supply.

CIRCLE NO. 581

4-color LED kit

Designer kits contain 15 different light-emitting diode lamps in four colors—red, green, yellow and orange. All are in 0.125, 0.160 and 0.200-in. diameter package sizes. They may be purchased at an introductory price of $7.95 each. Cramer Electronics, 85 Wells Ave., Newton, Mass. 02159.

INQUIRE DIRECT

new literature

Power supplies

A 196-page power supply catalog and application handbook is subdivided into these sections: power components, power kits, standard power supplies, custom power supplies and power instruments. Data include available models, sizes, electrical specifications and prices. Dimensional mounting drawings, photos of the packages and connection diagrams are supplied. Lambda Electronics, Melville, N.Y.

CIRCLE NO. 582

Sliding potentiometers

General construction details and a model selection chart for the PL40 series sliding potentiometers are shown in a four-page catalog. Mounting styles, housing dimensions and shaft configuration details are given for the PL60 series as well as a selection chart and mounting hole pattern. Piher, Des Plaines, Ill.

CIRCLE NO. 583

Magnetic tape I/O system

A 12-page catalog describes magnetic tape I/O systems for minicomputers, cassette transports and systems and precision timing instrumentation. Also included are sections on the optical mark reader, complete computer systems and graphic arts tape systems. Datum, Anaheim, Calif.

CIRCLE NO. 584

Automatic test processor

A six-page pocket guide describes the Datatester 400 automatic test equipment processor. The guide includes an operational diagram of the system as well as a complete instruction set. Data Test, Concord, Calif.

CIRCLE NO. 585

Laser system

An eight-page brochure features a design-it-yourself "building block" concept incorporated in the company's K1 series solid-state laser system. Korad, div. of Hadron, Santa Monica, Calif.

CIRCLE NO. 586

Programmer

A stepping drum programmer for controlling sequential operations is described in a four-page bulletin. Tenor, New Berlin, Wis.

CIRCLE NO. 587

Heat dissipators

Heat sinks, heat dissipators, dissipator/retainers and other thermal management devices for electronic circuits and components are described in a 68-page catalog. IERC, Burbank, Calif.

CIRCLE NO. 588

Schottky diodes

A power Schottky diode, believed to be the first such device rated for a junction temperature of 125 C, is described in a data sheet. Device ratings, characteristics and curves are included. TRW Semiconductor, Lawndale, Calif.

CIRCLE NO. 589

IC sockets

A four-page brochure shows 14, 16 and 24-pin IC sockets including one, two and three-level wrapped wire styles with gold or tin-plated leads. Solder tail models are shown for providing IC plugability on soldered boards. Features and specifications including dimensions and material characteristics are pointed out. Scanbe, El Monte, Calif.

CIRCLE NO. 590

SIGNAL CONDITIONING

for all types of Thermocouples in Data Acquisition Systems

Validyne TR41 Thermocouple Reference Junction offers low cost heated reference with complete isolation for up to 100 channels. Low induced noise & stability maintained through the use of a proportional heating circuit whose temperature accuracy exceeds that of the common ice bath.

TR41 designed for single circuit thermocouple input with choice of terminals or thermocouple jacks. Additional circuit available for terminating or carry-thru of shield wire.
Temperature stability: ± 1/10°F long term unattended operation.
Junction Temp: 150°F standard. Optional temperature from 10°F above ambient to 250°F.
Power Requirements: 105-125 volts, 50 to 400 Hz, Standard 28VDC optional.

TR42 provides for the alternate use of different thermocouple materials with the output pair for each channel.

TR43 offers 5 or more input terminals for use with 3 or more types of Thermocouple pairs for each output circuit.
Units available with special panel configurations and optional features.

Price & Delivery $250 Base all models 4 weeks
Plus $10/channel TR41 $15/channel TR42 $18/channel TR43

Validyne ENGINEERING CORPORATION

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Northridge, Calif. 91324
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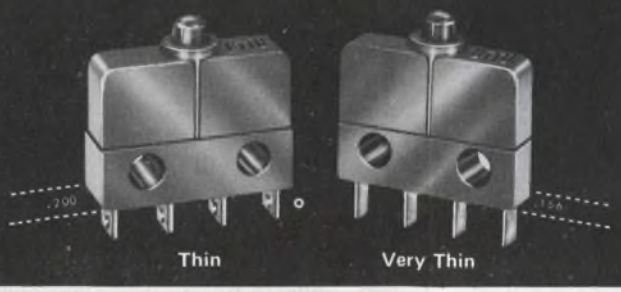
Telex 65-1303

INFORMATION RETRIEVAL NUMBER 152

OTTO®

Sub-subminiature Switches



snap-action • precision • 8 A. to dry circuit!

Less than 10 milliohms contact resistance in a ten million cycle switch! That's the OTTO B3 series with patented* design featuring high contact force and minimal contact bounce. Commercial or military, your options include "thin" and "very thin" sizes, contact arrangements to form Z, terminals, and contact materials. Load ratings to 8 A. resistive. Actuators available, too.

For full details including prices and local distributors, write for Bulletin B3.

*U.S. Pat. No. 3,612,793

OTTO CONTROLS *Division, OTTO engineering, Inc.*
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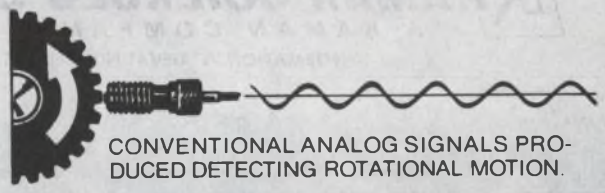
INFORMATION RETRIEVAL NUMBER 153

DI-MAG®

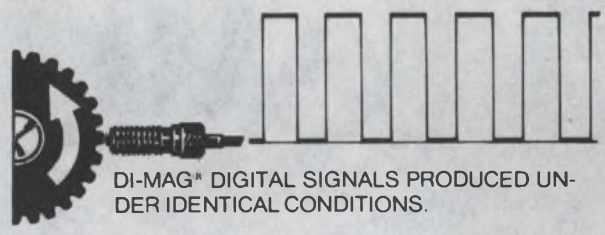
...SUPER SENSORS

THE SENSIBLE CHOICE...

- **DIGITAL OUTPUT — Constant amplitude pulses independent of surface speed or air gap.**
- **COMPATIBILITY — Direct interface with TTL, DTL or HTL logic.**
- **NOISE IMMUNITY — High signal-to-noise ratio not achievable in analog sensors.**



CONVENTIONAL ANALOG SIGNALS PRODUCED DETECTING ROTATIONAL MOTION.



DI-MAG® DIGITAL SIGNALS PRODUCED UNDER IDENTICAL CONDITIONS.

DI-MAGS® work particularly well in these computer peripheral functions and applications:

- ☐ **FEED RATE CONTROL**
- ☐ **PRINT HAMMER SYNCHRONIZATION**
- ☐ **DISK POSITION INDICATION**
- ☐ **DISK AND TAPE DRIVE RPM MEASUREMENT**
- ☐ **INDEXING CONTROL**
- ☐ **CONTROL SIGNAL FOR CLOSED-LOOP SERVO SYSTEMS.**

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INFORMATION RETRIEVAL NUMBER 154

NEW LITERATURE

Digital oscilloscopes

"The general purpose, high precision, digital oscilloscope," a 12-page brochure, discusses the design philosophy, operation, mid-signal trigger, display capabilities, accuracy, resolution and interfaceability when digital techniques are used in an oscilloscope. Nicolet Instrument, Madison, Wis.

CIRCLE NO. 591

Rf tuning diodes

Specifications and application data for variable capacitance tuning, band switching and afc diodes are given in a six-page brochure. Charts of diode capacitance vs reverse voltage, outline drawings of the five different package configurations, and a sample schematic diagram of the front end of an FM auto radio are included. Amperex, Slatersville, R.I.

CIRCLE NO. 592

Aluminum heat sinks

A bulletin profiles extruded heat sinks. Printed on one side, this 8-1/2 × 11 in. bulletin opens out to a 48-1/2 in. wall chart. Featured are 101 aluminum extrusion shapes, scaled 1/4 to 1 in. Wakefield Engineering, Wakefield, Mass.

CIRCLE NO. 593

Monolithic circuits

An eight-page brochure describes standardized custom monolithic circuits. Interdesign, Sunnyvale, Calif.

CIRCLE NO. 594

Buy the Ballantine 3/24 DMM

24 Ranges — 3 Full Digits

- AC Volts, AC Current, Ohms, DC Volts, DC Current
- Fully Overload Protected
- 300 Hour Dependable Battery Life
- Pocket Size — Weighs Under 2 Pounds
- 0.2% DC Accuracy — AC to 20 kHz

Available from Stock Factory/Distributor **$195** complete

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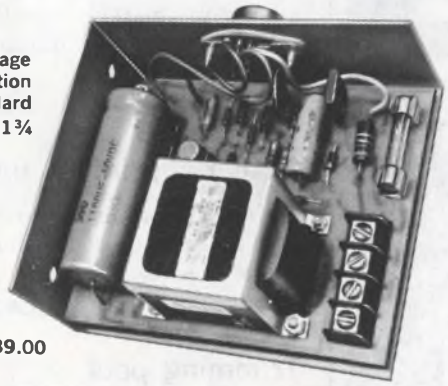
P.O. Box 97, Boonton, New Jersey 07005
201-335-0900, TWX 710-987-8380

INFORMATION RETRIEVAL NUMBER 157

Power Modules 400 Series

Overvoltage Protection Standard
4 x 4½ x 1¾



$39.00

MOD	VOLT	AMPS
86-401	5	1.5
86-402	6	1.3
86-403	10	1.0
86-404	12	0.8
86-405	15	0.75
86-406	24	0.4

Small, open frame, power modules, economical but without any compromise with quality. Connections are by screw type barrier terminals. Foldback current limiting and overvoltage protection are standard protective features.

REQUEST BULLETIN PS-401
115 Marine St., Farmingdale, N.Y. 11735 • (516) CH 9-2336

VOLTEX

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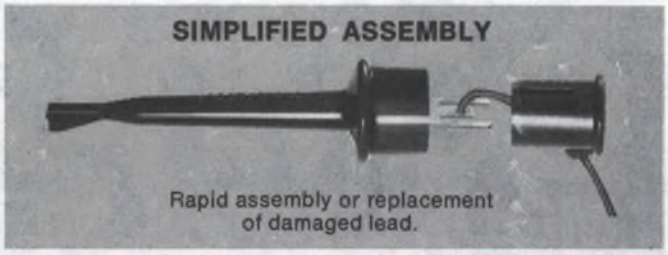
DO-IT-YOURSELF grabber

NEW

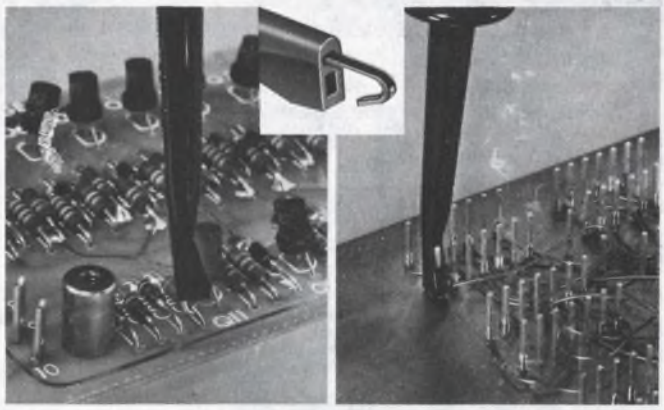
- **Simplified Assembly**
- **Versatile**
- **Comfortable Finger Grip Action**
- **Completely Field Serviceable**
- **Molded of Tough Lexan***

Model 3925
Mini Test Clip
Shown Actual Size

This test clip with gold plated hook is excellent for rapid testing of components and Wire Wrap† pins. Clip is completely insulated to point of connection. Build any combination of test leads with wire up to .090 dia. Easy and comfortable to operate. Molded of rugged Lexan to resist melting when soldering. Write for literature and prices.



MODEL 3925
hooks onto components or slips over square Wire-Wrap pins

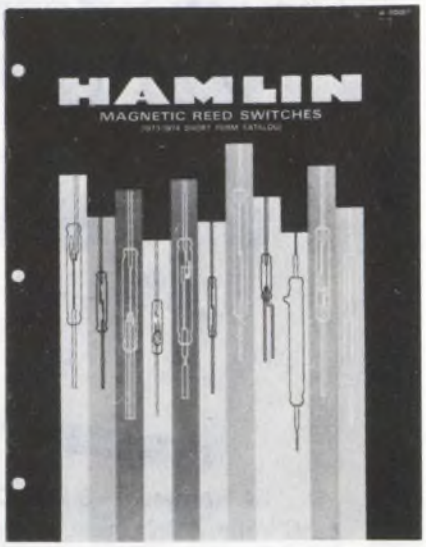


*Lexan is a General Electric trade-mark. †Registered trade-mark of Gardner-Denver Co.

POMONA ELECTRONICS
A Division of ITT
1500 East Ninth St., Pomona, Calif. 91766
Telephone (714) 623-3463

INFORMATION RETRIEVAL NUMBER 159

NEW LITERATURE



Reed switches

An illustrated catalog aids in the selection and application of reed switches. The catalog covers various forms of actuation, including proximity switching with permanent magnets, bias switching, shielding and electromagnetic actuation. Hamlin, Lake Mills, Wis.

CIRCLE NO. 595

Infrared thermometers

An energy-saver booklet gives examples showing how infrared thermometers have saved energy and scarce materials while increasing product yield. Raytek, Mountain View, Calif.

CIRCLE NO. 596

Numeric printing unit

The 4508 numeric printing unit is illustrated in a brochure. Facit-Addo, Secaucus, N.J.

CIRCLE NO. 597

Trimming pots

A 12-page bulletin, "Cermet Trimming Potentiometers," includes six key parameter tables which allow comparison of specifications such as power, size, turns and maximum operating temperature. Specification tables for military and industrial models present available sizes, pin spacings and performance characteristics for all standard trimmers. Beckman Instruments, Helipot Div., Fullerton, Calif.

CIRCLE NO. 598

EMI SHIELDING

- Knitted wire shielding strip gaskets and special shapes.
- Wire mesh and elastomer seal/shield gaskets.
- Thin elastomer filled meshes for shielding/sealing.
- Honeycomb, screen and mesh shielded vent panels.
- Shielded optical viewing windows.
- Metal or carbon filled conductive elastomers.
- Conductive paint, adhesives, epoxies and caulking compounds.

These and more in TECKNIT's Design Guide.

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INFORMATION RETRIEVAL NUMBER 162

HECON predetermining counters do more than count for you!

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- Measure
- Mix
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- Regulate
- Position
- Guide
- Program
- Inspect
- Analyse
- Turn
- Shift
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Make them count for you today. Call or write for free 36 page catalog – includes comprehensive application section.

HECON CORPORATION 890

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27

INFORMATION RETRIEVAL NUMBER 163

Check in one direct move with Brandenburg's new HV meter

We thought it was about time somebody supplied *direct reading* meters for high voltage, so we've produced three—one for up to 5kV, one for 15kV and one for 30kV to complement our range of HV power supplies.
The meters are operated by two 9V internal batteries (800 hours life) linked with a built-in checking facility. Positive or negative ground is available, selected by a front panel switch. And, as with all Brandenburg products, there is a 12 months unconditional guarantee.

- **Accuracy of 1% fsd over voltage range of 0.30kV d.c.**
- **Less than 1 μA drawn at 30kV d.c.**
- **4.5in (114 mm) scale mirror-backed meter.**
- **Temperature range 5-35°C.**
- **Dimensions only 7 x 8 x 5½in high (200 x 145 x 178mm).**
- **Recorder output.**

Yet another Brandenburg piece in the high voltage game

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INFORMATION RETRIEVAL NUMBER 164

NEW LITERATURE

Log video amps

Four models of standard direct coupled log video amplifiers designed to provide wide dynamic range logging with low-frequency response (dc to 5 MHz) and a capability to process pulsed data at duty factors up to 25% are described in a brochure. American Astrionics, Costa Mesa, Calif.

CIRCLE NO. 599

Compact relay

The compact industrial RY relay is illustrated in a six-page brochure. The booklet shows ease of contact conversion (18 s without rewiring) and the simplified coil-changing procedure, again without wiring changes. Variations of the relay for a number of applications are described, and four accessories are illustrated. Micro Switch, Freeport, Ill.

CIRCLE NO. 600

Microwave diode chips

Microwave semiconductors available in chip and beam-lead form for microstrip and stripline applications are specified in a 14-page catalog. A special section details the methods for handling and bonding both beam-lead devices and semiconductor chips. It gives recommendations on use of equipment, substrates, wire or ribbon attachment, metalization and materials. Alpha Industries, Woburn, Mass.

CIRCLE NO. 601

Semiconductors

A 56-page book, printed in two colors, provides a quick reference guide to discrete power devices, hybrid power regulators and Schottky diodes. Package illustrations and dimensional drawings are provided. Solitron Devices, Riviera Beach, Fla.

CIRCLE NO. 602

Dc power converter

A two-page bulletin covers the MP3020 dc/dc power converter. Analogic, Wakefield, Mass.

CIRCLE NO. 603

Microwave p-i-n diodes

A six-page catalog contains specifications and mechanical outlines of microwave p-i-n diodes. Outline drawings of 26 standard packages are included plus typical examples of the company's custom package capability. Unitrode, Watertown, Mass.

CIRCLE NO. 604

Liquid-crystal displays

A 12-page brochure describes liquid-crystal displays. The brochure includes a description of nematic-liquid crystals, applications information, turn-on, turn-off curves, drawings and circuit diagrams. Siemens, Iselin, N.J.

CIRCLE NO. 605

Noise analysis equipment

A 16-page short-form catalog describes and illustrates instruments and systems for spectrum analysis and processing. Products range from tracking filters to real-time spectrum analyzers and digital signal processors and systems. Spectral Dynamics, San Diego, Calif.

CIRCLE NO. 606

Lasers

Helium-neon lasers, education packages, holography systems and optical benches and accessories are described in a 16-page catalog. Metrologic Instruments, Bellmawr, N.J.

CIRCLE NO. 607

ISA publications

The 1974 ISA catalog lists 235 current publications and educational aids on instrumentation, measurement and automatic control. The catalog contains descriptions, prices and ordering information for reference books and proceedings of ISA sponsored or co-sponsored conferences and symposia, videotape training program, audio cassettes, films, study guides, standards and recommended practices and periodicals. Instrument Society of America, Pittsburgh, Pa.

CIRCLE NO. 608

Semi replacement guide

A comprehensive revision of Sprague's 64-page Semiconductor Manual and Replacement Guide lists over 38,000 domestic and foreign OEM semiconductor parts numbers and their recommended replacement. All listings are alphanumerical to make the manual easy to use. Sprague, North Adams, Mass.

CIRCLE NO. 609

Industrial thermocouples

A 16-page catalog covers thermocouple elements, protecting tubes, assemblies, accessories and insulators. Selection and use data and temperature recommendations are presented in an easy-to-read style. Marlin Manufacturing, Cleveland, Ohio.

CIRCLE NO. 610

Process-control systems

A brochure describes the building blocks—computers, operating systems, high-level programming languages and specific hardware—that make up process-control systems built around small computers. A typical process-control system using a back-up computer is diagrammed and explained. Data General, Southboro, Mass.

CIRCLE NO. 611

Acoustic couplers

An acoustic coupler for message communications and time-sharing applications on an international level is described in a brochure. The literature shows how a unit manufactured to CCITT standards can be used for domestic to overseas communication as well as applications to international telephone systems where permitted. Omnitec, Phoenix, Ariz.

CIRCLE NO. 612

Multiplying DAC

Model 869 four-quadrant multiplying digital-to-analog converter is covered in a six-page catalog. Block and functional diagrams, an illustration of the four-quadrant multiplier mode, plus tabulations of performance specifications and environmental characteristics clarify product capabilities and applications. Beckman Instruments, Helipot Div., Fullerton, Calif.

CIRCLE NO. 613

quick ads

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Thin-Trim variable capacitors provide a reliable means of adjusting capacitance without abrasive trimming or interchange of fixed capacitors. Series 9401 has high Q's and a range of capacitance values from 0.2-0.6 pf to 3.0-12.0 pf and 250 WVDC working voltage. Johanson Manufacturing Corporation, Boonton, New Jersey (201) 334-2676.

INFORMATION RETRIEVAL NUMBER 181

3 things make a great tape core: The proper materials . . . correct engineering . . . Magnetics. Magnetics has been a leading supplier of high permeability tape wound cores and magnetic components since 1949. Our tape cores helped put men on the moon; are used exclusively for Viking Mars Lander. Magnetics, Butler, Pa. 16001.

INFORMATION RETRIEVAL NUMBER 184

AMP Capitron data entry products. High performance. Outstanding reliability. Includes card reader/scanner and matrix badge reader. Plus tab, credit, and magnetic card readers. All are available as individual components, with choice of interface on reader/scanner. AMP Incorporated, Capitron Division, Elizabethtown Pa. 17022. (717) 367-1105.

INFORMATION RETRIEVAL NUMBER 187

Complete minicomputer mag tape systems for the PDP-8, PDP-11, and NOVA feature IBM compatibility with low price. Three reel sizes to choose from, and all standard densities, including 1600 bpi phase encoded. These systems incorporate the best-designed transports built today. Digi-Data, 8580 Dorsey Run Rd., Jessup, MD 20794, (301) 498-0200.

INFORMATION RETRIEVAL NUMBER 182

Free catalog of 34,500 power supplies from the worlds largest manufacturer of quality Power Supplies. New '74 catalog covers over 34,500 D.C. Power Supplies for every application. All units are UL approved, and meet most military and commercial specs for industrial and computer uses. Power Mate Corp. (201) 343-6294.

INFORMATION RETRIEVAL NUMBER 185

A collector's item . . . 20th anniversary issue of Electronic Design (11/23/72) salutes 25th anniversary of the transistor, features milestones in design over past quarter century. Rare nostalgic view of industry. Fascinating reading. $2 per copy prepaid. Checks, money orders: Electronic Design, Promotion Mgr., 50 Essex St., Rochelle Park, N.J. 07662.

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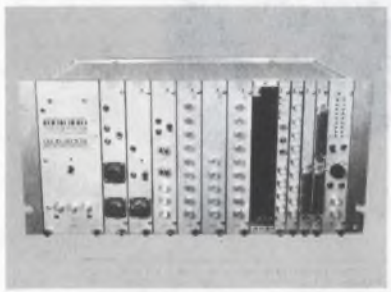

MIDAS is a universal system for controlling and monitoring scientific experiments. It operates with a teletype or interfaces with a computer to command instruments or test stands and print their responses. MIDAS is keyboard programmed by the experimenter. Starts at $2325. TRI-COM, Inc., 12216 Parklawn Drive, Rockville, MD., 301-770-5585.

INFORMATION RETRIEVAL NUMBER 183

Thick Film Technology—Fundamentals and Applications in Microelectronics, by Jeremy Agnew. From design to finished product, this book details each processing phase, describing what to do and what pitfalls to avoid. 176 pp., 6 x 9, illus., cloth, $8.50. Circle number for 15-day examination copy. Hayden Book Company, Rochelle Park, N.J. 07662.

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The Pulsecom Model 461-6 Automatic Message Numbering Device electronically inserts station identification and message numbers. This device saves operator time, and prevents mistakes. The 461-6 operates at 45-1200 Baud with most terminals. Pulsecom Div of Harvey Hubbell Inc., 5714 Columbia Pike, Falls Church, Va. 22014. 703-820-0652.

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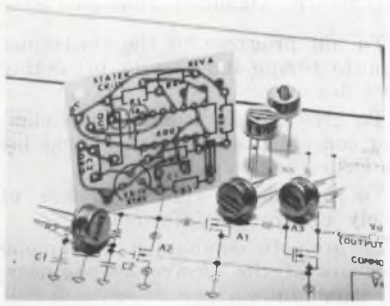

Quartz Crystal Oscillator Kits for $27. Make bipolar series or CMOS parallel resonant oscillators. Kits include 5 or 6 SX-1 crystals (10 kHz to 240 kHz), in low profile TO-5 cans, a PC board (1.3" × 1.6") and design note. Statek Corp., 1233 Alvarez Ave., Orange, Calif. 92668. (714) 639-7810.

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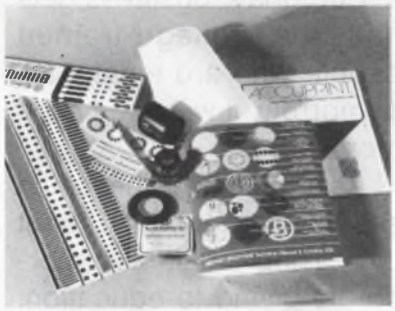

Free 84-page Printed Circuit Drafting Aids Technical Manual & Catalog contains hundreds of time & money-saving tips, plus details on over 15,000 component symbols & tapes, film, vellum, grids. Bishop Graphics, Inc., 7300 Radford Ave., North Hollywood, CA 91605, (213) 982-2000.

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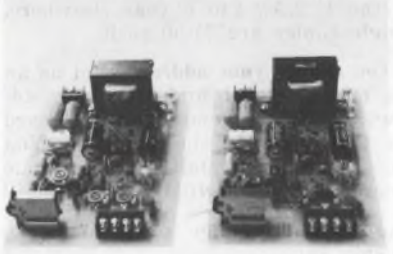

AC-line data transceiver modules wire directly to 120V AC, transmit & receive FM data via carrier-current signals on power line. Can be used with 45Ω speaker for high-quality voice communication or in telemetry applications. Stock to 4 wks., $109/pr (1-100). Electronics Research Group, Arlington, Mass. (617) 646-9760.

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The new Computer Labs RDA Series D/A's eliminate harmonic distortion and produce clean "glitchless" pictures for reconstructed TV or other video signals. Input word rate for all models is 15 MHz with accuracies to ±0.05%. Min. settling time to either 8-bit or 10-bit accuracies. Computer Labs, 1109 S. Chapman St., Greensboro, N.C. 27403.

INFORMATION RETRIEVAL NUMBER 192

Materials for Semiconductor Functions, by E. G. Bylander. Practical handbook for selecting materials for diodes and transistors for applications in amplifiers, generators, and multi-junction devices. 220 pp., 6 x 9, illus., cloth, $13.50. Circle number below for 15-day examination copy. Hayden Book Company, Rochelle Park, N.J. 07662.

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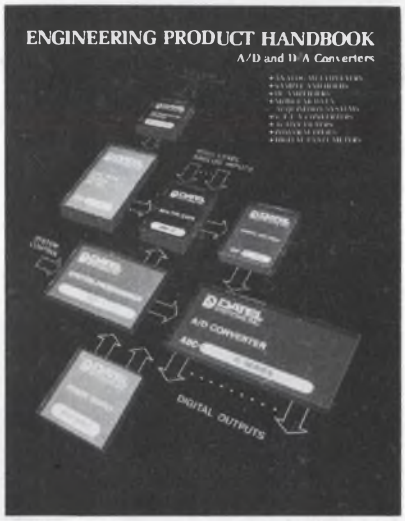

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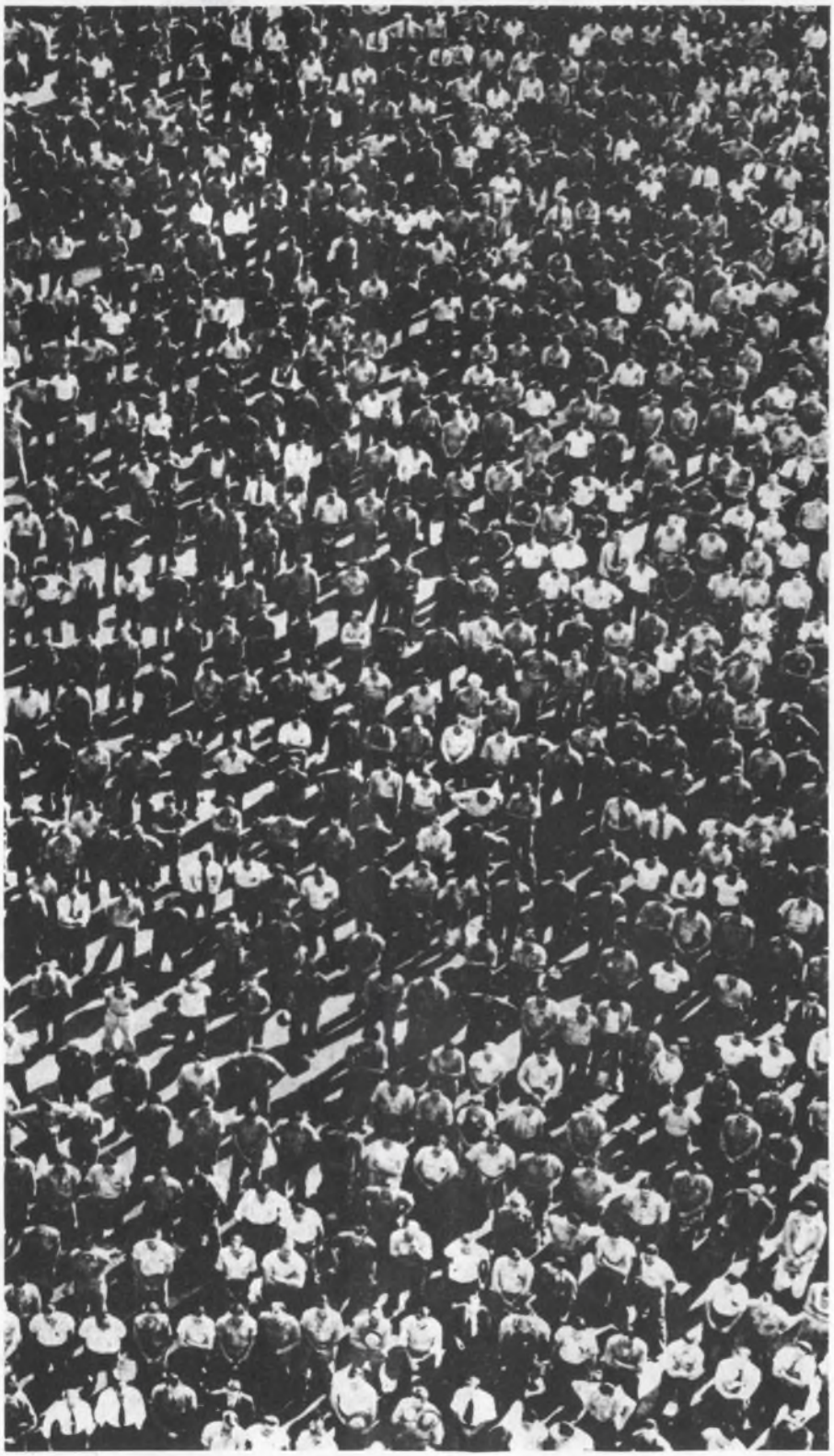

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