EXCLUSIVELY FOR DESIGNERS AND DESIGN MANAGERS IN ELECTRONICS

EDN

There's more to consider than price when selecting solenoids

Users want more details-less specsmanship on DPM data sheets

Complete one-board LSI minicomputer breaks the $1000 barrier minicomputer

A CAHNERS PUBLICATION

MAY 5, 1973

Good design doesn't change.

Ten years ago, Acopian came out with a line of plug-in D.C. power supplies, which were conservatively designed and built to last. It's the same basic line of power modules which electronic engineers specify today in their product designs.

This stability is a rarity in the electronics industry, where the life expectancy of a product design seldom goes beyond three years. Where, during the past decade, other companies, styles, and trends have come and gone.

Today, as in 1963, the Acopian plug-in power supply design continues to be valid. No change just for the sake of change. Only to improve the product. No sacrifices just to achieve arbitrary size reduction or a contemporary appearance. Or to stretch their operating environment.

These concepts are confirmed by the reliability and consistent performance of Acopian plug-in power modules proven by their field use during the past decade.

Additionally, Acopian plug-in power supplies offer many inherent advantages.

Consider how they could simplify your product design. With thousands of models available to precisely fit your requirements. Single and dual output. Regulated and unregulated (for economically driving lights and relays). Special high-isolation types for powering strain gauges and other transducers. A range of power ratings from 1 to 200 volts . . . from 100 ma. to 5.0 amps. A choice of performance levels. Models tested to military specifications.

Consider further how our octal base power modules could reduce your assembly costs. With the input and output connections simply pre-wired to an octal socket on the chassis, installation and removal of the power supply become one second operations. There's no need for a wire harness. No need for brackets or special connectors. No need in most applications even for mounting screws.

Send or phone for a current catalog of Acopian power modules and accessories. They're backed by a firm five-year warranty, which includes the cost of **both** parts and labor. And by a promise which we have never failed to keep: manufacture and shipping in three days after your order is received. Acopian Corp., Easton, Pa. 18042. Phone (215) 258-5441. TWX (510) 651-4919. Telex 847-493.

CHECK NO. 3

Acopian

MAY 5, 1973
VOLUME 18, NUMBER 9

EDN with EEE

EXCLUSIVELY FOR DESIGNERS AND DESIGN MANAGERS IN ELECTRONICS

COVER

Now that a complete 4k minicomputer is available for less than $1000 from Computer Automation, other minicomputer manufacturers will have to take a hard look at their approach to the OEM market. This mini also rivals the micro-processors-on-a-chip in price, yet outperforms them. Shown on the cover is the discrete component breadboard used to prove out the single-board LSI concept. For more details see pg. 78.

DESIGN NEWS

New, single-module, programmable computer has 2k memory. . .Magnetic-levitation train relies on cryogenics for high-speed transport. . .Canadian digital-data communications system offers users dramatic savings. . .High-storage-density holographic memory system that is said to provide high-quality images.

DESIGN FEATURES

PROGRESS IN PRODUCTS

DESIGN PRODUCTS

DESIGN DEPARTMENTS

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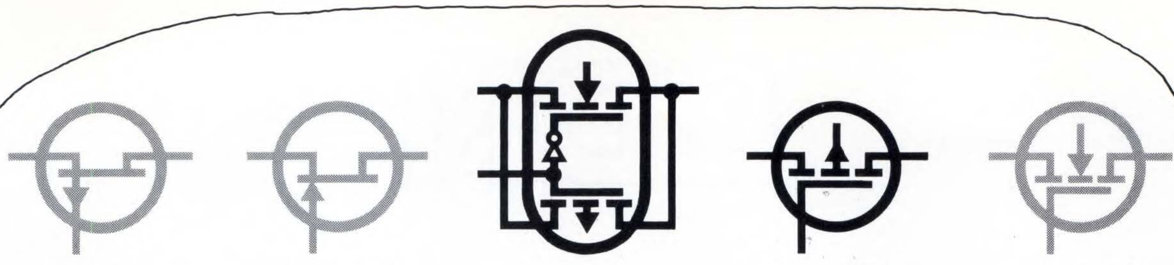
BPA ABP



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

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

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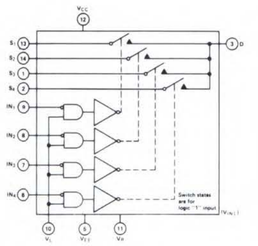
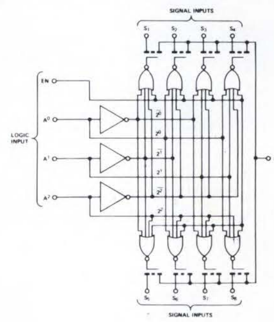
Now available: analog switches specially selected for industrial control service, at per-channel prices as low as 80c (DG501CJ) and 90c (DG172CJ) in 1000-unit quantities.



DG172CJ



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- PMOS/bipolar—DG172, 4 channels, 20 V peak-to-peak signal capability, PMOS FETs and bipolars on a single chip

All of these FET switch/driver combinations are *off-the-shelf* and at your nearest Siliconix distributor *right now*. They're priced to compete with reed relays and other electromechanical devices—and they switch 1000 times faster, last far longer, require less drive power and associated hardware, and operate directly from industrial computer logic.

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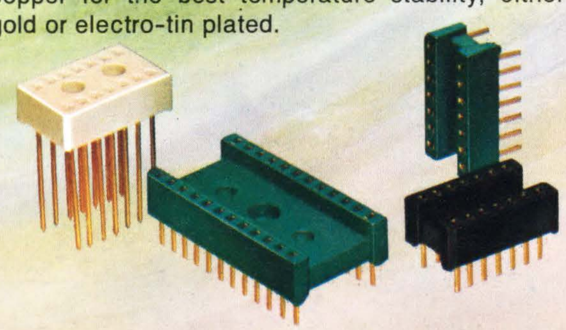
Cinch sockets have a unique bowed pin contact that provides high contact forces but permits easy insertion and removal of the DIP. Broad contact surfaces give you maximum wiping action on two sides of the DIP terminal, be it flat, round or square.

You can choose from high performance diallyl phthalate or economical GP black phenolic monoblock insulators. The contacts are of beryllium copper for the best temperature stability, either gold or electro-tin plated.



Sockets with Wire Wrap* terminals and closed entry, one-piece insulators are also available in a variety of insulations and terminal materials . . . in addition to our DIP sockets with dip solder terminals.

Many styles are available off-the-shelf from Cinch distributors nationwide.

You can find out all about these sockets from your Cinch Distributor, Cinch Sales Office or by writing to Cinch Connectors, an Electronic Components Division of TRW Inc., 1501 Morse Avenue, Elk Grove Village, Illinois 60007, (312) 439-8800.

**Trade name Gardner-Denver* CM-7303

TRW® CINCH CONNECTORS

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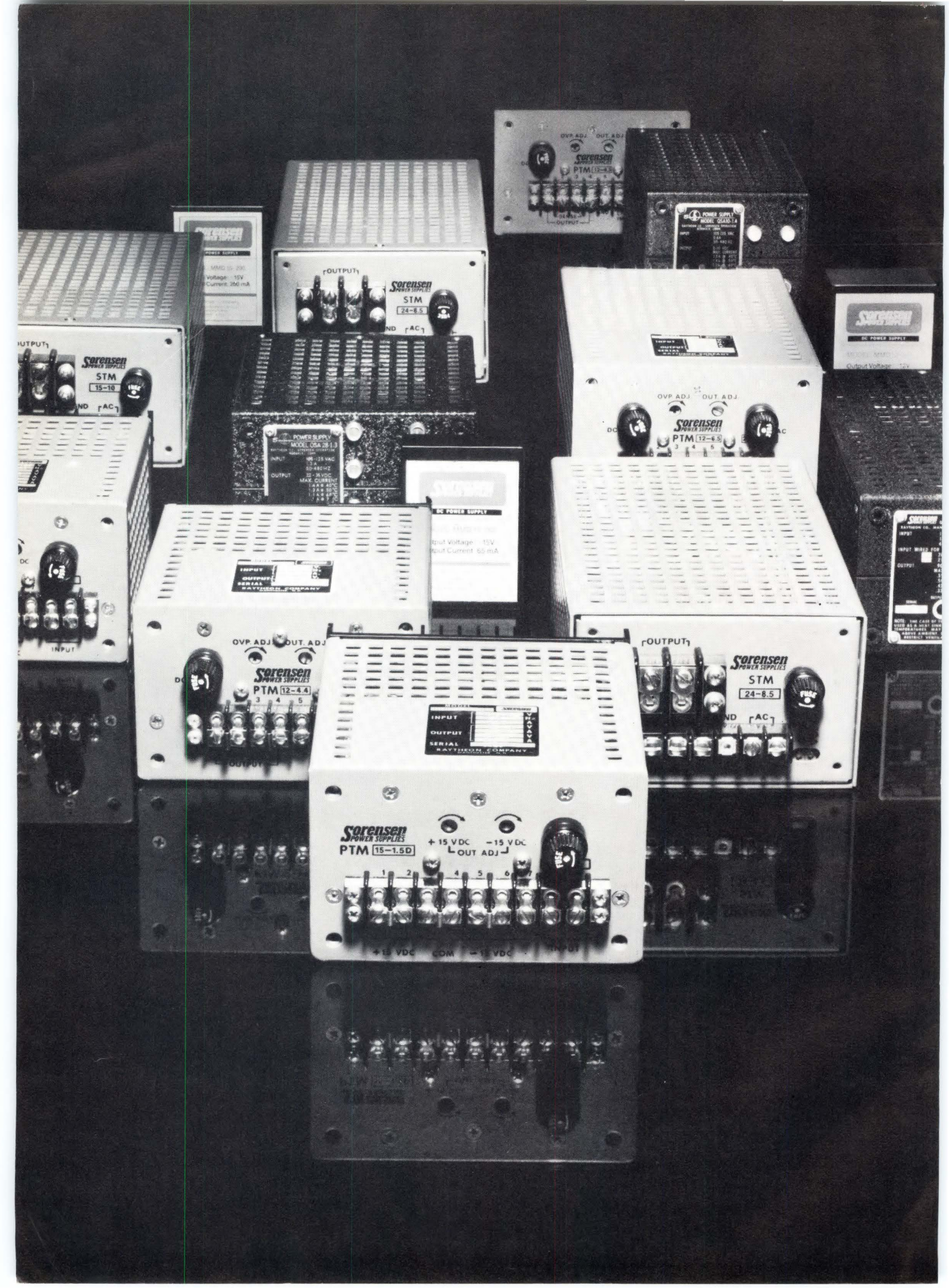
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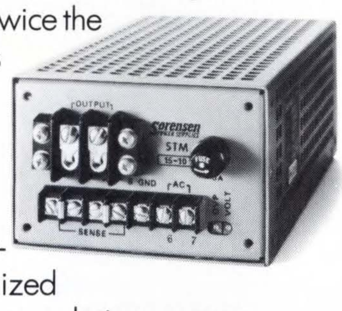
STM Series — 40 models. Switching-transistor modulars that provide twice the efficiency of series-pass competitors in half the space — and eliminate need for external cooling. STMs feature built-in overvoltage protection; computer-optimized filtering; 0.05% voltage regulation; output voltages range from 3.0 (min.) to 56 (max.) Vdc.



PTM Series — 12 models. All solid-state series-pass modulars that achieve state-of-the-art power density; deliver more power per cubic inch than comparable competitive units, at lower cost per watt. Features include built-in overvoltage protection; highest quality components; adjustable automatic current limiting; 0.05% + 5mV voltage regulation; low ripple and noise; six voltage levels to 100 watts.

Dual Output

PTM DUALS Series — 9 models. Dual output versions of PTM series, with the same advanced design and construction. Compact, solid-state series-pass modulars with built-in overvoltage protection; feature tracking accuracy to 0.2%; voltage regulation — .02%; transient response — 50 μsec. Series includes +5, −12 volt model for CMOS applications.

Miniature

MM Series — MMS (single) MMD (dual) MMT (triple) — 15 models, 4 package sizes. Designed for maximum reliability in microminiature electronic applications. All MM encapsulated modulars feature built-in overvoltage protection; excellent voltage regulation; single outputs from 5 to 28 Vdc; dual outputs of ±12 or ±15 Vdc.

Other dependable Sorensen power supplies

QSA Series — 29 models. Modular, wide range, convection-cooled power supplies feature excellent operating specifications plus a wide range of accessories. Models provide outputs from 3-330 volts and up to 300 watts. Top choice for multi-output systems.

Lab/Systems Power Supplies

SRL Series — 14 models. Low voltage, regulated, solid-state DC power supplies. Rack-mount style featuring excellent stability, fast response time over the full load range, built-in overvoltage protection. Power ranges from 0-60 Vdc and 100 Amps.

DCR Series — 37 models. High performance, all-solid-state power supplies featuring the lowest cost per watt on the market. 10 voltage ranges from 20 Vdc to 30,000 Vdc; 7 power levels from 400 to 20,000 watts. Ideal combination of economy, reliability and performance.

SORENSEN CATALOG/73 provides fully detailed specifications for all models of Sorensen modular and lab/systems power supplies. Write for your copy. Sorensen Company, a unit of the Raytheon Company, 676 Island Pond Road, Manchester, N.H. 03103. Tel. (603) 668-4500. Or TWX 710-220-1339.

Sorensen POWER SUPPLIES

See us at Booth #2010 at the 1973 National Computer Conference.

Circle No. 9

EDITORIAL

Business is good . . . but

In just about every segment of the electronics business today, it's a seller's market. Not only can companies sell everything they produce, but many are under severe pressure from both customers and potential customers to increase their output and shorten delivery times. As a result, capital expenditures for production equipment have soared, plant additions are occuring at a brisk rate and work forces are approaching the highs of the late 1960s.

When you combine these things with the end of the war in Vietnam, which should mean more funding for military and aerospace electronics programs, as well as the expected penetration of electronics into mass markets like watches and automobiles, the outlook for our industry is rosy indeed.

Lest we get carried away with optimism, though, it should be noted that when it comes to business and the economy, nothing is ever certain. Even now conditions and situations exist that could upset the economic applecart as far as electronics is concerned.

Ecology is far from a dead issue. And power and energy problems are just beginning to be felt. How these will effect the electronics industry can only be speculated on now. But affect it they will.

Of even greater impact could be skilled labor shortages, particularly in production areas, and a reduction in product quality and support—an all too frequent occurrence in a boom market. Stiffer foreign competition, in spite of the recent dollar devaluations, and a still barely sufficient level of R&D funding are other factors to be contended with.

We raise these points not as a prophet of doom or a negative thinker, but more as a devil's advocate. People have a way in times of prosperity of developing peripheral vision concerning the economic facts of life. They forget the traditional up and down cycles of business, or the fact that good times for the industry do not necessarily mean good times for their particular company.

What can individual engineers do, though? They can't spend their time speculating on and worrying about the future state of the economy. And as individuals they have little control over its course. But they can continually evaluate their own company and their position in it. Their future is tied to how well their own company is equipped to face the ever shifting and changing market.

Does it have the foresight, the drive, the structure and the people needed not just to survive, but to prosper? Determining these things is not easy, and requires careful, objective evaluation. Should the evaluation turn out negative, the men begin being separated from the boys.

Frank Egan

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Honeywell announces the end.

Our new Honeywell Model Ninety-Six isn't just another high-performance magnetic tape recording system. As far as state-of-the-art will reach...it's **the end**—the ultimate—an instrumentation system that incorporates every feature you have been asking for in a laboratory system.

For example, like previous Honeywell recorders, our Model Ninety-Six has a vacuum-buffered, low-tension tape drive for gentle tape handling, minimum head and tape wear. But unlike all other tape recorders, it will handle 16" reels, through nine tape speeds from 15/16 to 240 ips, and incorporates six other important improvements that together spell **the end** in tape recording:

The end of head wear worries. All of the new Honeywell solid ferrite heads are warranted for 3,000 hours. This alone should help solve one of your biggest headaches.

The end of spectral pollution. Two Honeywell features, FM flutter compensation, and an all new wideband phase lock servo system combine to give you the cleanest reproduce spectrum in tape recording. You'll be happy to know, too, that this servo system offers flutter attenuation at a band-width we believe you simply cannot buy anywhere else.

The end of configuration problems. Tired of trying to match your available electronics to a new task? The 28-channel Model Ninety-Six has omniband electronics. This means you can configure the recorder—at minimum expense—to match your needs as your needs change. Which also means...

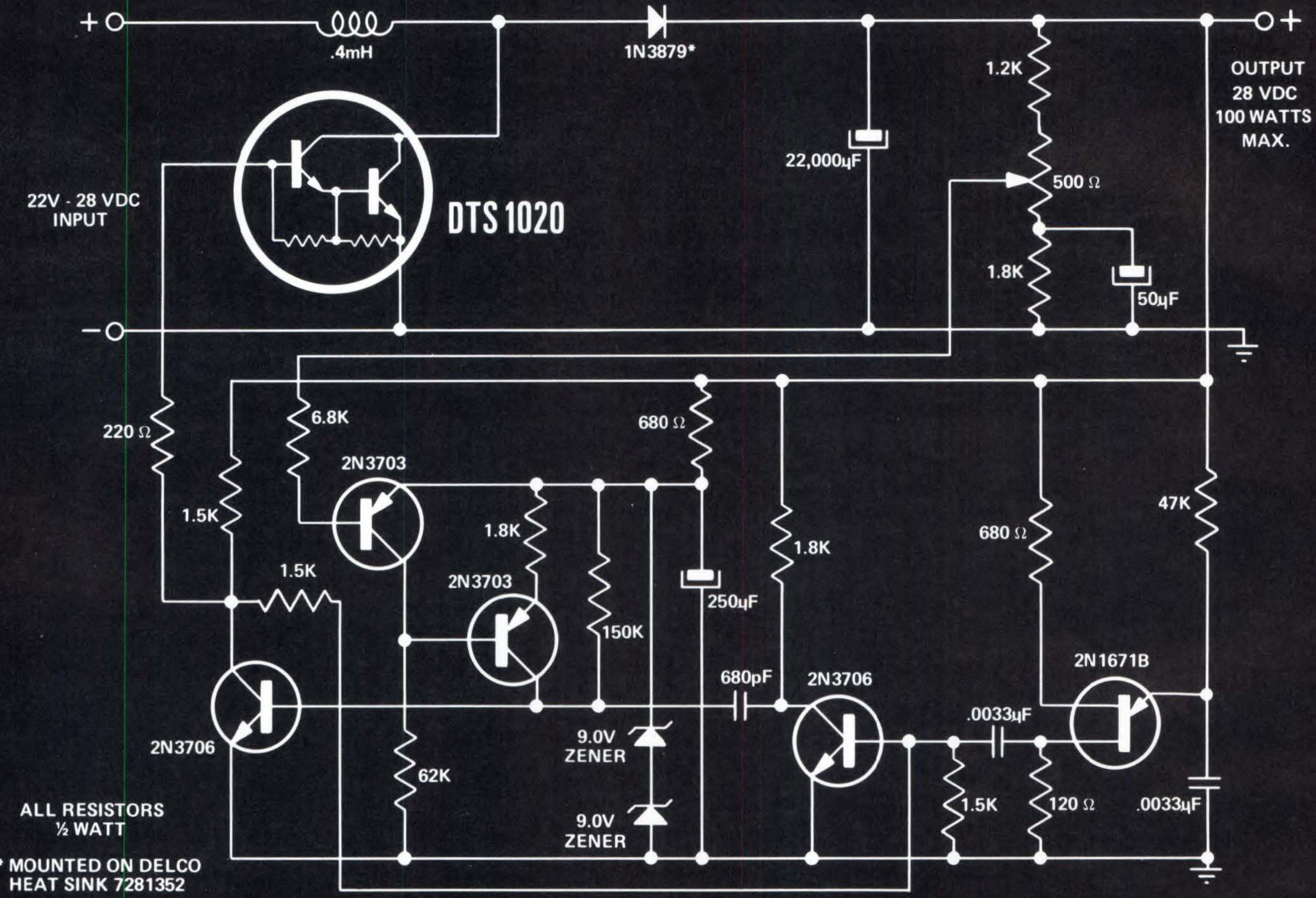
The end of support concerns. Omniband signal electronics require only six basic plug-in assemblies to accommodate **all** record and reproduce functions, including bias oscillator, head drivers and preamps.

The end of maintenance hang-ups. Our new Model Ninety-Six is probably the most thoroughly tested tape system ever offered. We've spent thousands of hours wringing the bugs out...to make sure you don't have to. What's more, the testing, front panel access and built-in transport calibration system all were designed to be simple and reliable...to minimize service requirements.

For full details on the new Honeywell Model Ninety-Six, call or write: Charles O. Miller, MS211, Honeywell, Inc., Test Instruments Division, P.O. Box 5227, Denver, Colorado 80217, (303) 771-4700.

Honeywell
The Automation Company

Circle No. 25

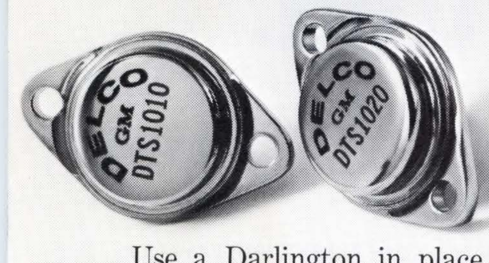


SWITCHING REGULATOR

	V_{CEO} @ 0.1 mA	V_{EBO} @ 50 mA	$V_{CE(SUS)}$ @ 500mA	h_{fe} @ 1 MHz (V_{CE}=10V, I_C=200 mA)	h_{FE} (V_{CE}=5V, I_C=10A)	$V_{CE(SAT)}$ @ 5.0 A	I_C	P_T @ 75°C
DTS-1010	120V	7V	80V	12	200	1.8V	10A	100W*
DTS-1020	120V	7V	80V	12	500	1.5V	10A	100W*

*100 percent tested at 2.5A, 40V.

The Kokomoans now give you Darlington Switching Power.



Use a Darlington in place of an ordinary transistor, and you'll realize an additional magnitude of gain plus increased switching power. Use a Delco silicon power Darlington (DTS-1010 or DTS-1020) and you'll also realize a gain in dependability.

Delco's Darlingtons are triple diffused mesa units housed in copper TO204MA cases and built for ruggedness. The design gives them high energy capability—the ability to handle surges of current and voltage simultaneously. They are ideal for switching inductive loads in circuits subject to transients or fault conditions.

Design a switching regulator circuit around a Delco Darlington or use it in any 60-100 volt application to reduce circuit size, weight, and cost. In addition, the Darlington space saving feature allows you more design flexibility. Unlike an ordinary transistor, it's only energy-limited, not beta-limited. You can exploit its full energy capability in your circuit.

Call your nearest Delco distributor. He has them in stock and he's got the data on high energy switching for small spaces.

For details on the switching regulator circuit, ask for Application Note 49.

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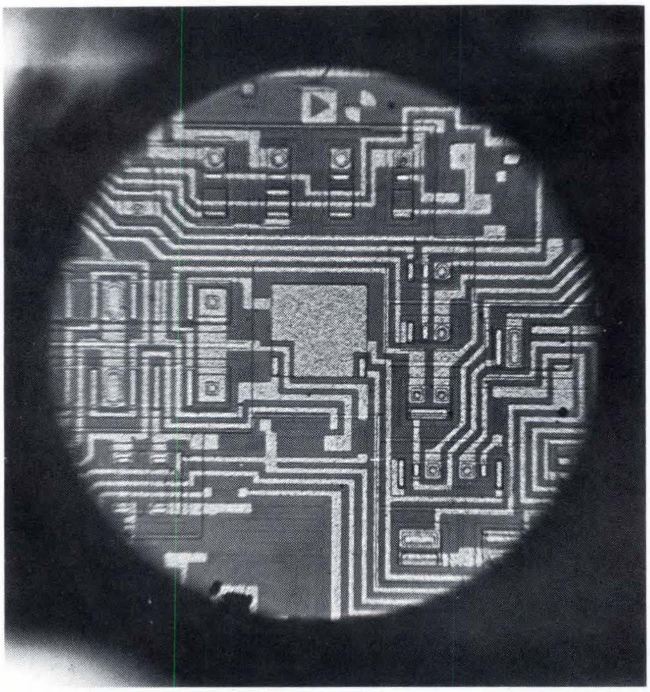


AD532. Internally laser-trimmed by us. No problems for you. $16 in 100's.

The AD532 is the first totally self-contained monolithic multiplier/divider. Thin-film resistors are deposited directly on the chip and trimmed during production with a computer-monitored laser.

The results?

First of all, you don't have to mess around with the trimming yourself, which saves you time and money.

Plus, you can take advantage of the inherently greater reliability of a monolithic IC. We've eliminated off-the-chip trim adjustments, so there are fewer connections and less possibility that something will go wrong.

The PSRR is improved, too, because variations in the power supply have a minimal effect on trim.

In addition, you get differential X and Y inputs, because the -X and -Y inputs are no longer needed for off-the-chip trimming. This gives you two instrumentation amplifier-like inputs with 70dB of CMR.

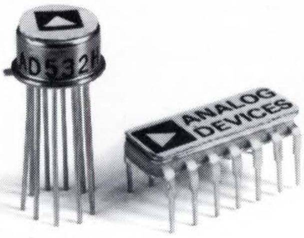
The AD532 is a plug-in replacement for our AD530, which has been, until now, the industry standard for small size, low cost, high performance multipliers.

Other features include a maximum error of less than 1.0% and an output swing of $\pm$10V. An output null terminal permits independent setting of the output offset. The AD532 multiplies in four quadrants with a transfer function of $(X_1\text{-}X_2)(Y_1\text{-}Y_2)/10$, divides in two quadrants with a $10Z/(X_1\text{-}X_2)$ transfer function, and square roots in one quadrant with a transfer function of $\pm\sqrt{10Z}$.

All that for only $16 in 100's. And if you'd like to see for yourself, we'll sell you five evaluation samples at the 100's price. Just give us a call.

We still make our high-accuracy AD530 multiplier, and you may also be interested in the AD531, the first programmable IC XY/Z multiplier. They're two more of the unique IC solutions we can offer to your design problems. Ask for complete specs.

Analog Devices, Inc., Norwood, Massachusetts 02062.



ANALOG DEVICES

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for everything you need to know about multipliers.

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Circle No. 16

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it's part of the TY-RAP® System

Now tie quicker than ever before...

Our new high speed tool does it all . . . feeds a TY-RAP tie around bundle, cinches to a preset tension, locks securely and trims evenly . . . all in 8/10 of a second. There is no tool adjustment needed regardless of bundle diameter from 1/32" to 5/8".

The off-the-board harnessing method allows the tool optimum use. This technique utilizes our new harness board and harnessing aids. The board is reusable and reversible. It's modular too . . . snaps together for larger work areas. It's constructed of polyethene foam sandwiched between two metal screens — nails are pushed in by hand. It's all part of the TY-RAP System to lower your costs of harness fabrication.

Write for new catalog, The Thomas & Betts Company, Elizabeth, New Jersey 07207 (201) 345-4321. In Canada, Thomas & Betts Ltd., P. Q.

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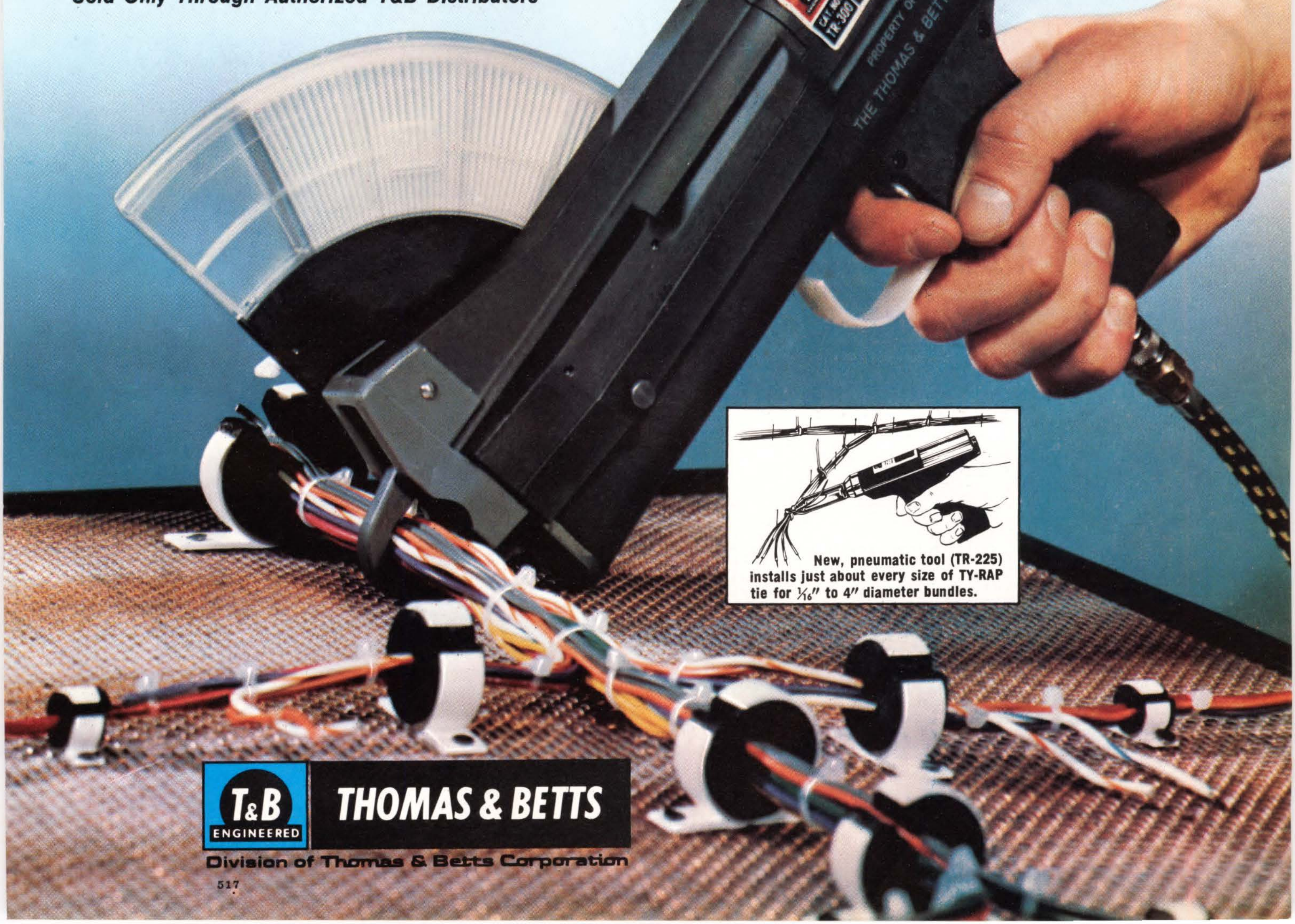

New, pneumatic tool (TR-225) installs just about every size of TY-RAP tie for 1/16" to 4" diameter bundles.

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093/41

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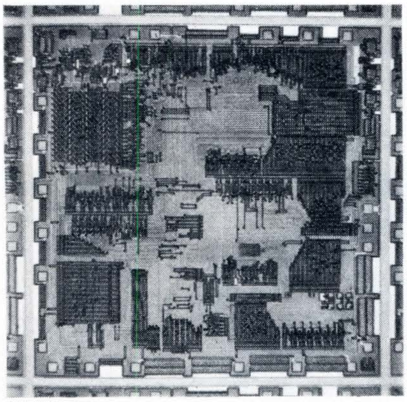
LSI in consumer applications, Round 2: clocks on a chip

Large-scale integration became a common word around most American offices with the advent of the one-chip calculator. By the end of this year MOS/LSI will have made major inroads into another market with so much more potential that it boggles the imagination—clocks!

To get a rough idea of the magnitude of the clock market we took a quick survey of several offices in our Boston based publishing company. The question was "how many wristwatches (another area where LSI will eventually dominate), clocks and calculators do you have in the office and at home?" The proportions were : 1 calculator to 9 wristwatches to 24 clocks (numbers rounded off). There is little doubt that calculators are presently the most desirable of the three commodities, and had the question been phrased as "which do you plan to buy next?", the results would have been far different. But the point is that whether you *want* a calculator or not, you *buy* clocks, and lots of them. Small wonder then, that many MOS suppliers are designing and marketing LSI devices that can drive digital-readout clocks. One of the newest of these devices is a clock/calendar circuit, the CT7001, recently introduced by Cal-Tex Semiconductor. Packaged in a single 28-pin DIP, the CT 7001 will drive 4- or 6-digit, 7-segment displays.



PROGRAMMABLE CLOCK CHIP, the MK5017P, from Mostek is available in three standard versions or can be custom programmed.

The chip contains all counting, decoding, and multiplexing functions. It uses the 60-Hz power-line frequency as its time base, and the OEM may also connect the circuit for 50-Hz lines. Other wiring options built in are for 12-hour clocks with AM and PM indications or 24-hour use; hours, minutes and seconds display or hours/ minutes only. It may be wired to show time for 8 seconds and date for 2 seconds or the time can be displayed continuously until a date switch commands the date to be displayed.

As part of a clock-radio, the CT7001 offers positive output for alarm, snooze alarm (14 minute snooze period), auxiliary appliance timer and presettable clock-radio timer.

The circuit also generates a 1-Hz square wave for flashing second pulses or other applications. It has an on-chip display oscillator and a back-up 50/60-Hz oscillator—also on-chip—which requires no external components.

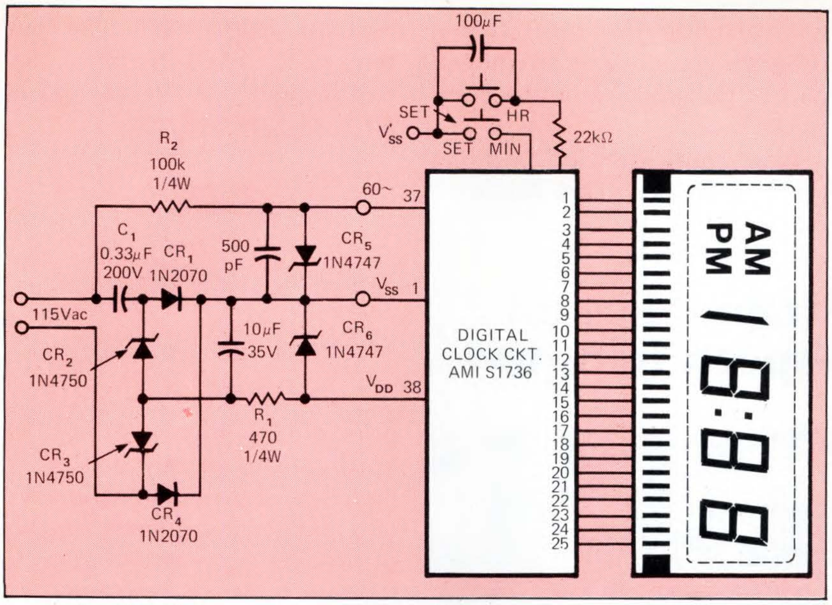
Designed to be used with battery back-up (to keep it running even during power loss), it signals low battery power by displaying all 8's.

The CT7001 is processed by p-channel depletion-mode MOS with ion-implantation at Cal-Tex's Santa Clara plant.

Circuits from other manufacturers differ in details; some don't have internal standby clocks, some have longer or shorter snooze-alarm cycles and most can be wire-OR tied to share a display with calculator chips.

The S1736 clock chip from American Micro-Systems is designed for direct driving of liquid-crystal readouts and can drive either 12-hour displays with AM/PM indication or 24-hour displays by merely changing three connections at the display. In fact, a designer can arrange the pinouts of his display so that 12-hour and 24-hour clocks can be produced, intermixed, on the same assembly line. Or the clocks can be modified from one type to the other by merely replacing the readout module.

One of the first clock chips was the Mostek MK5017, now available in three standard versions. Between the three of them you can have any or all of the features discussed here. In addition, Mostek's MK5009 P is available to provide a 50-Hz



A mere handful of discrete components is all you need to put together a wall clock using American Micro-System's clock circuit.

signal from a 1-MHz crystal for portable applications or where the line frequency doesn't have sufficient accuracy for timekeeping.

If you still don't believe the market for clock chips is real, take a look at National Semiconductor's product offering. They have already introduced five standard clock circuits in their MM4311/5311 series. RCA has also produced a custom CMOS circuit now being used in Chrysler Corp.'s digital automotive clock. And the applications for clock chips include a lot more than clocks.

Other applications already being investigated include: a computer-system time base; stopwatches; sequential controllers; darkroom timers and industrial timers. As prices begin to dip even lower, these ICs will bring precise timing to hundreds of consumer areas where it was previously uneconomic. — *BF*

Want more information?

American Micro-Systems, Inc.
3800 Homestead Rd.
Santa Clara, CA 95051
Phone(408)246-0330 or
circle **145**

Antex Industries
1059 E. Meadow Circle
Palo Alto, CA 94303
Phone(415)326-2441 or
circle **146**

Cal-Tex Semiconductor, Inc.
3090 Alfred St.
Santa Clara, CA 95050
Phone(408)247-7660 or
circle **147**

Mostek Corp.
1215 West Crosby Rd.
Carrollton, TX 75006
Phone(214)242-0444 or
circle **148**

(National Semiconductor Corp. will respond only to letterhead, phone or TWX inquiries)

New, single-module, programmable computer has 2k memory

A lightweight, versatile, programmable digital computer, designed for automotive, process control, petroleum and other industries has been announced as a first of its kind by Teledyne Systems Co.

A throw-away, palm sized computer? That may be a reality if the marketing and price projections for this 16-bit machine come true.

It permits long life and reliable performance for any number of new industrial and commercial applications.

Each computer is contained within a 2.5-in. diameter, 0.10-in. high, hermetically sealed package. Contained within the package is all the functional capability and memory capacity of a micro-computer: a 47-instruction repertoire, 10-μsec ADD-instruction execution speed and 2048 words of memory at 16 bits per word. The package weighs approximately 25 grams, and dissipates 7W of power.

The computer may be considered as disposable in that no calibration, adjustment, maintenance or service equipment is required. If a malfunction should occur the package is merely replaced by a spare.

This unique computer utilizes packaging technology originally developed for its aerospace programs.

It will be marketed mainly on a "private label" O.E.M. basis. The unit can be used as a front-end preprocessor, a central processor or in groups, as distributed processors.

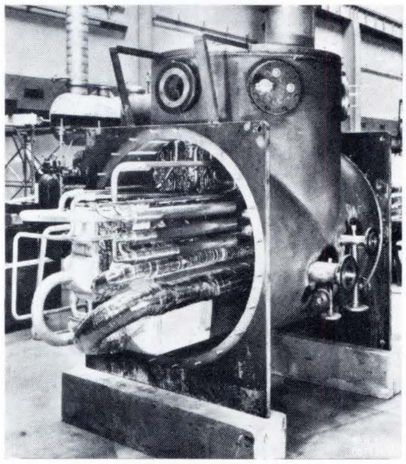
A comprehensive set of programming software support is also available. Teledyne Systems will provide the operational program complete as an integral part of the single-modular computer.

Want more detailed information? Contact, The Advance Systems Dept., Teledyne Systems Co., 19601 Nordhoff St., Northridge, CA 91324. Phone (213)886-2211 ext. 2203. — *BF* □

Magnetic-levitation train relies on cryogenics for high-speed transport

The magnetic-levitation train is an advanced high-speed ground transport facility that is sure to make a substantial contribution to the solution of transport problems. As a facility of tomorrow, the magnetic-levitation train will be designed for average speeds of 300 - 450 km/h (186-280 MPH) and a maximum speed of 550 km/h (343 MPH), thus offering greater speed than present-day short-haul airliners.

Japanese engineers are at present working on the project of a magnetic-levitation train with Sulzer (Switzerland) participating in the program. Engineering preliminaries are scheduled to be completed by the end of 1975. The novel transport facility is due to start operation in 1980 at the earliest.



Laboratory model of the cold box for a helium liquifier that will be supplied for use in the preliminary research work in conjunction with a Japanese magnetic-field supported train project.

Having considered all the major factors involved, such as capacity, safety, geographical conditions, noise, environmental pollution, the Japanese experts have finally decided in favor of the superconducting magnetic-levitation system. This principle is highly suited for application in an advanced high-speed ground transport system and is consequently capable of providing a major solution to modern transport problems.

The system consists of a linear motor drive with the primary on the ground, superconducting magnetic suspension installed on the vehicle and loops or sheets of normal conductor on the track. One of the main prerequisites attached to this is, however, the further development of more advanced superconductor magnets and cryogenic apparatus. Sulzer is participating in this development project by supplying a low-temperature plant. Cryogenic technology and superconductors should consequently make a substantial contribution to the solution of modern transport problems—*RF* □

Canadian digital-data communications system offers users dramatic savings

By using a backbone of microwave links and sophisticated multiplexing equipment, the Trans-Canada Telephone System has been able to reduce user costs by as much as 90%.

Service began this April in eleven major Canadian cities, with more to be added by the end of the year. Called Dataroute, the new service is said to be the world's first nationwide digital-data system operating on a commercial basis.

Much of the equipment and networking expertise needed for the Dataroute operation has been provided by Computer Transmission Corp. (TRAN), of Los Angeles, CA, through its wholly owned Canadian subsidiary, TRAN Communications, Ltd. TRAN is the only American company involved in the Canadian operation and has been involved in virtually all aspects of the planning and implementation of Dataroute.

A major element of the Trans-Canada network is the master-clocking scheme which is essential to all synchronous, digital-communications systems. Called Synchtran, this proprietary master-clock synchronizer and alarm system allows the network's management center to monitor the entire nationwide network, and to continuously keep track of every channel of data. Functioning as a diagnostic alarm, Synchtran automatically alarms the center when any network component or transmission line fails—frequently before the user is aware of the fact that a problem exists.

Synchtran's principle role is to provide the synchronous clocking hierarchy which assures that the Dataroute will always have a national clock.

Using TRAN hardware, Dataroute provides two means of entry to the user's premises and equipment. TRAN's Directran devices interface with sites operating at low and medium asynchronous speeds, up to 2400 bps. Directran employs local loops (unloaded, unswitched telephone company circuits) to communicate between customer installations and Trans-Canada Telephone System central offices.

For medium- and high-speed synchronous terminals, the network incorporates TRAN's Intertran packages. These are similar to data sets and are used for synchronous transmissions up to 50 kbps.

At TCTS central offices, TRAN's Multitran, a time division multiplexing/switching device, multiplexes signals into 50 kbps packages that are then transmitted over the network "spine," a series of high-speed microwave links.

In discussing the user benefits of the new Dataroute service, J.C. Carlile, president of Trans-Canada Telephone System, explained: "The Dataroute will provide dramatic improvements in computer communications. There's much more to Dataroute than lower customer charges. There's improved accuracy, from the very nature of digital technology. There's greater flexibility because the equipment is modular and can be easily procured and installed as the demand grows. And there's greater reliability."

The improved accuracy is partly attributable to the inherent advantages of digital transmission, as opposed to analog techniques. In an all-digital system, the original signal is regenerated during transmission, rather than being amplified with the interference at each repeater point as in an analog system. As a consequence, there is less distortion.

Reliability is stressed in all stages of the network. For example, a proprietary pulse-mode modulation technique enhances the quality of local data distribution, where most of the error rate problems occur in analog systems.

The new service rates made possible by Dataroute are less dependent upon distance, making the longhaul communications typical of Canadian geography more economically feasible. The speed at which the data is transmitted and the time period of transmission are prime factors in determining the rates. However, because of the nature of the new system, lower-speed, small-volume users are getting the best break. For example, using analog transmission, a single 300-bps line leased from Montreal to Vancouver previously cost $3515 per month. Now with the new digital technique, Dataroute offers the same service for $375 per month.

The time-division multiplexing/switching technology used enables the system to achieve more efficient throughput, thus making highly effective use of the bandwidth of the links comprising the network.

The Trans-Canada Telephone System customer is offered Dataroute service covering a complete range of speeds—from 101 bps up to 50,000 bps. Multitran can accommodate any intermix of any data rates—low, medium and high speeds—which makes the scope of this offering possible.

One of the big advantages to

the customer is that he now has fully end-to-end service. That is, the entire communications function is handled as one integrated system. He need only select his speed, his point-to-point locations and whether he wants day, night or 24-hour service. He does not have to concern himself with data communications equipments such as modems, nor does the data-processing manager have to be an expert in the field of communications.—*AS* □

High-density holographic memory system provides high-quality images

For high-speed and high-density storage and processing of image information, holographic memory systems with Fourier-transforming lenses are said to be tops. But they do suffer from one very important drawback: they contain low-quality image information and low diffraction efficiencies due to the self-interference of the laser waves used to carry the information.

Now, thanks to a newly developed technique called random phase sampling **(Fig. 1)**, Hitachi Ltd., of Japan has developed a high-speed, high-density holographic system without any of these deficiencies. The new system is reported to yield good-to-excellent quality images and can be used for analog, digital and hybrid information systems.

This memory system **(Fig. 2)** has high access speeds ranging from 1 msec up to 1 μsec, can store approximately 10^6 bits of data per mm^2, is random accessible and is not affected by scratches and dust. The simplified mechanism used for the readout is self reconstructing.

The system is expected to find uses in high-density document files, image files, and information-retrieval devices, and in computer output units. Its storage density is some ten times higher than that of microfiche systems.

Image information is divided into a large number of sampled portions (by a mesh patterned

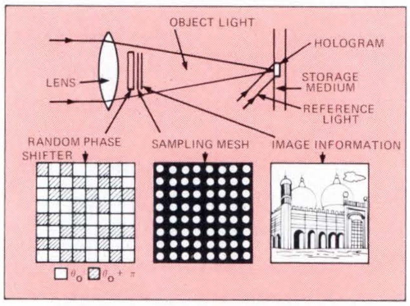


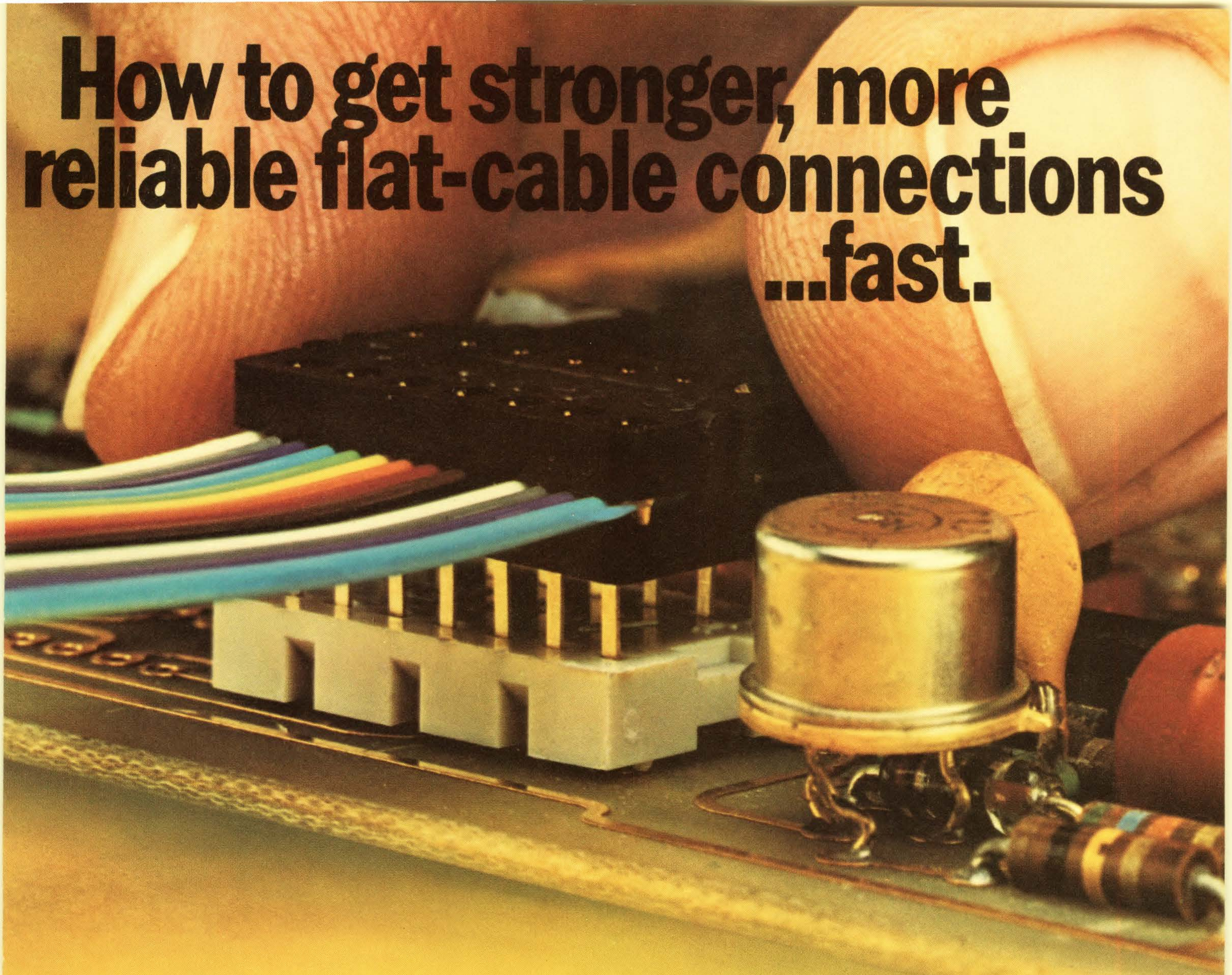
Fig. 1—Basic concept of the random-phase sampling method used in the new holographic memory system for high-density, high-speed image recording. The concept is said to increase image quality.

device, for example) so that large amounts of low-frequency components are spread over an area corresponding to the diameter of the sampling hole.

When the sampling holes are arranged and spaced evenly, keen spectra of the light energy from the laser appear on the hologram plane, depending upon correlations among the different beams filtering through the holes. The random phase-shifter method has proven to be quite successful in resolving these light spectra.

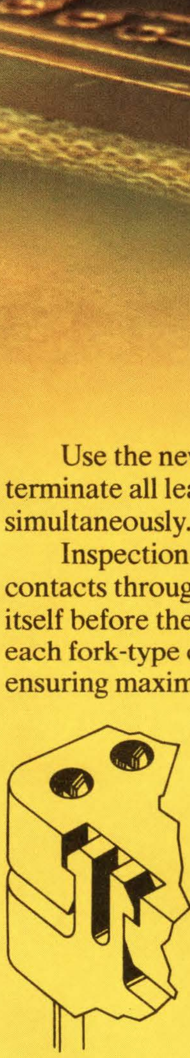
During development, it was found that pitch size of each sampling hole had to be less than the resolvable limit of the human eye, or about 130 μm. It was then determined that the pitch size of the mesh and the random phase shifter was 100 μm in an image information of a 50 X 50-mm frame. The hologram diameter was 1.8 mm and diffraction efficiency was 15%. —*RA* □

How to get stronger, more reliable flat-cable connections ...fast.

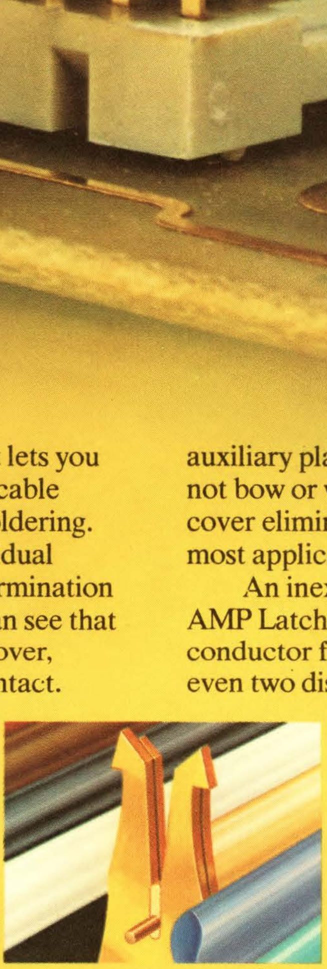


Use the new AMP Latch connector. It lets you terminate all leads on multiconductor flat cable simultaneously. Without prestripping or soldering.

Inspection is simple, whether of individual contacts through special ports, or of the termination itself before the cover is applied. So you can see that each fork-type contact is locked into the cover, ensuring maximum pressure at point of contact.



These foldover forks make contact with conductors at four points—not just two—to provide true redundancy. The cover also locks to both sides of the connector housing with auxiliary plastic latches. AMP Latch connectors will not bow or warp. And, a strain-relief detent in the cover eliminates the need for accessory hardware in most applications.



Dual camming and latching ears on AMP contacts provide 4-point contact and grip for each conductor.

An inexpensive hand press lets you terminate AMP Latch connectors in seconds—to round-conductor flat cable, ribbon cable, woven cable... even two discrete wires. You can interconnect to pc board spring sockets, DIP headers, or directly to the board itself... wherever you want to interface on high-density, .100-inch centers.

See it for yourself.

Try it for yourself. Ask your AMP representative for an in-plant demonstration. Or write for Latch connector literature to AMP Industrial Division, Harrisburg, Pa. 17105.

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Guidelines for selecting linear solenoids

Cost can be a prime factor when selecting a solenoid. Do you know which things effect cost and performance other than voltage and pull force?

L. Richardson, OAK Industries, Inc., Switch Div.

Solenoids come in all sizes, shapes and voltages. They have pull forces from a few grams to hundreds of pounds and some deliver a linear motion while others deliver a rotary motion. Yet they all have one thing in common—they are electromagnetic devices, and therefore, must conform to the physical laws of electromagnetics.

Some solenoids convert the solenoid's normal motion into rotary motion and thus become rotary solenoids. Others are wound on a bobbin such that the plunger travels in a curved motion like an arc. Solenoids of this type are found quite frequently in displays for retail sales stores. They are also found in some electronic organs and in the older automobile clocks that were electrically wound.

Catalog data can be misleading

Most users of solenoids have one primary concern and that is to select a solenoid to do a certain amount of work for the least amount of money. In looking over the catalogs of the various manufacturers, we find many interesting things. First, there are no standards for solenoids and thus each manufacturer states his data in the manner he thinks best. One will specify pull-force curves at 149°F, another at room temperature, and another at 110°C. One specifies an 85°C heat rise while others don't specify any particular heat rise.

Solenoids come in many sizes, shapes and push/pull forces. They even provide rotary motion if needed.

For seemingly identical solenoids from different manufacturers we find the pull force for a given stroke varying from a few ounces to several ounces. We know that there are various ways of improving the pull force, but not in the order of magnitude that their catalogs state. Are they kidding then? No! It is all in the manner in which they test their solenoids and present their data.

Let the spring do the work

Let us go back to the user—the engineer or designer who must select the solenoid. Remember, he wants this solenoid at the lowest possible cost. He should have the solenoid in mind at the earliest possible stage of conception and literally design everything as a package. The solenoid must do some work. But how will it do this work?

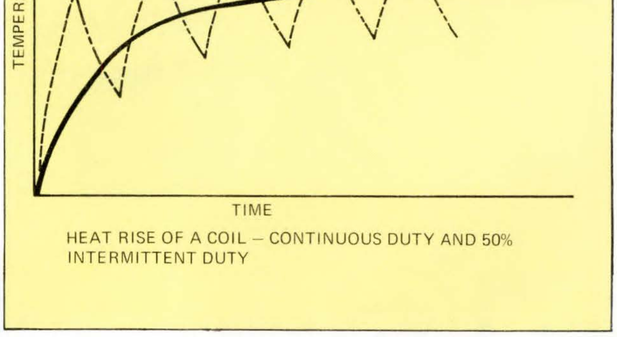
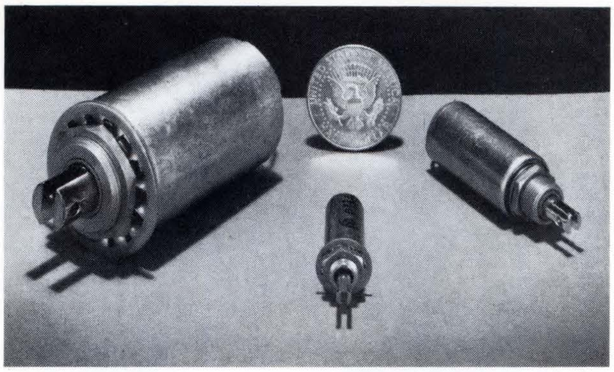


Fig. 1—Typical heat rise vs time for a continuous-ON solenoid. The dotted line shows when the same solenoid has twice the heat input, but is run on a 50% duty cycle.

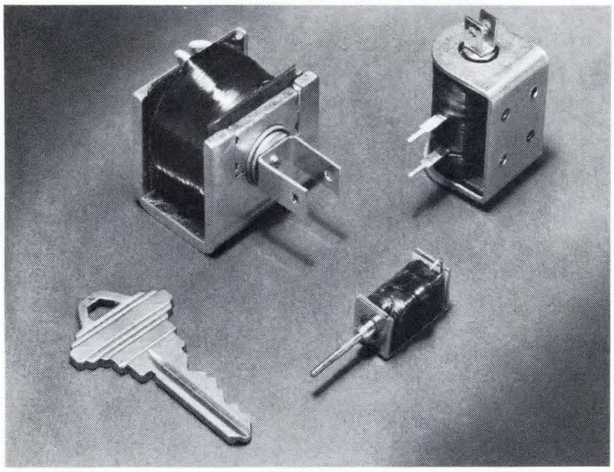


Typical tubular solenoids—sometimes called cylindrical solenoids. Because their coils are completely enclosed in steel, these units have the highest relative efficiency for dc operation. Relative cost—32.

Will it be a push or pull solenoid? A push solenoid will usually cost a little more money and be a little less efficient for a given package size.

Will it be spring return or will the plunger be returned to rest position by the mechanism of the load? Sure the spring costs money, but you're going to be using a spring anyway so what is the difference who furnishes it? If the solenoid manufacturer designs the spring, he will match it to the force of the plunger. This will usually be a conical spring that has an increasing spring rate as it is compressed. Why not take advantage of this characteristic and let the spring do the actual work? We energize the solenoid, compress the spring, and when the solenoid is de-energized, the spring returns the plunger and moves the load. This is done rather often on ratchet mechanisms. Thus, the only work the solenoid does is to compress the spring.

The spring obviously is weakest at the same time the solenoid has its weakest pull (plunger out) and is strongest when the solenoid is strongest. This concept can be advantageous if the spring drives the load. When the load is static, it will have its greatest coefficient of friction, but the spring, when compressed, will at the same time, have its greatest force—a perfect work combination. A second bonus for this type of operation is that the load on the solenoid will be nearly constant over a period of years.



C-frame solenoid—sometimes called U frame or open frame. The name is derived from the shape of the magnetic-steel frame enclosing the coil. These are the lowest-cost units of the solenoid family. Relative cost—10.

There is one last plus for this type of operation. If there is a malfunction in the driven mechanism in applications where the solenoid drives it, rather than the spring, an ac operated solenoid draws three or four times normal current and consequently, the coil heats up. If the malfunction remains, the solenoid burns up due to the higher current drawn when the plunger is in the out position. This is not the case with dc operated solenoids.

Coupling method costs too

There are many applications where the solenoid plunger must be coupled directly to a linkage mechanism and the spring concept cannot be used. For these applications, the end of the plunger is usually slotted with a cross hole for a pin. This is a rather expensive process as the slot and cross holes are usually two secondary operations and both create rather large burrs, which are also expensive to remove.

A less expensive method is to have a tapped hole in the end of the plunger, or to have a groove cut near the end and a stamped part with ears that fits into the recess.

The various means of coupling the plunger to the load is almost infinite, and the designer must give serious thought to this problem to keep the overall cost of the project down. One other concern with the plunger is to maintain the coupling in the same plane as the motion of the plunger. A little misalignment here can limit the solenoid's mechanical life.

Consider the mounting cost

Almost all solenoids use a steel frame to support the coil, and also to provide a means of mounting the solenoid. The usual means of mounting is to provide tapped holes in the solenoid frame. The designer must be careful here to prevent a blind-assembly situation where the solenoid is on one side of a panel and the assembler on the other, trying to line up the mounting holes an arm's length away.

A better method would be to provide ears on the solenoid with the mounting screws on the same side as the solenoid. This is a natural for the "C" frame or open-frame solenoid. Here too, there is a bonus—if the solenoid is mounted on a steel plate, there will be about a 10% improvement in the pull force as the plate now actually becomes part of the magnetic circuit.

Use of self-tapping or self-threading screws would be another savings that would appear in the overall project. One particular large volume user of solenoids uses a single-point mounting with only one screw. The elimination of one screw, plus the operation of tightening that screw, results in a fantastic savings over a year's time (possibly $25,000).

Select metal materials carefully

Another savings that is a little more deeply hidden is in the material used in the plunger, stop and frame. One of the least expensive materials used for these parts is cold rolled steel for the frame and A1S1 C1215 screw stock for the plunger and stop. Another popular material is ingot iron or electromagnetic iron (commonly referred to as EMI). Any of these materials, to give maximum magnetic properties, must be given a heat-treating anneal which costs anywhere from $0.19 to $0.41 a pound. (Both cold rolled steel and EMI require heat treatment for maximum pull and low residual magnetism. There are other higher-permeability materials available, but machinability and costs usually negate their use. Only in extremely unusual applications would these be used.)

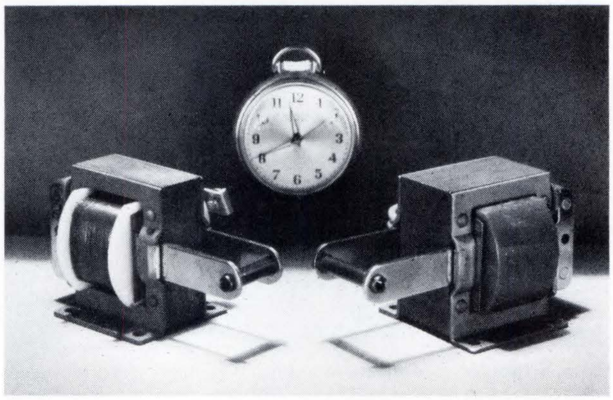
By using a little larger solenoid it is possible that the heat treating can be eliminated at a substantial savings. Be careful at this point, though, as the steel may have an aging effect, and consequently lose some of its pull force over a period of years. Also, the residual magnetism in the nonheat treated steel will be higher; thus, a larger return spring is required to break this residual magnetism. The net result would be, in effect, a lower pull-in force. It is best to consult with various manufacturers early in the design stage and get their recommendations.

Molded coil bobbin saves $$

The coil itself is a large part of the total cost of a solenoid—perhaps as high as 50%. Why? Because of the relatively large amount of expensive copper-magnet wire used, the number of hand operations necessary for fastening lead wires, etc., and the cost of the bobbin on which the coil is wound.

It is true that there are coil-winding machines on the market today that wind, tape the start lead, solder, finish wrap, etc., all automatically. These machines are expensive and are used primarily on large-volume orders; so if you only use a few thousand solenoids a year, chances are they will be wound in the same manner and method that your grandfather knew, especially so if you ask for wire leads.

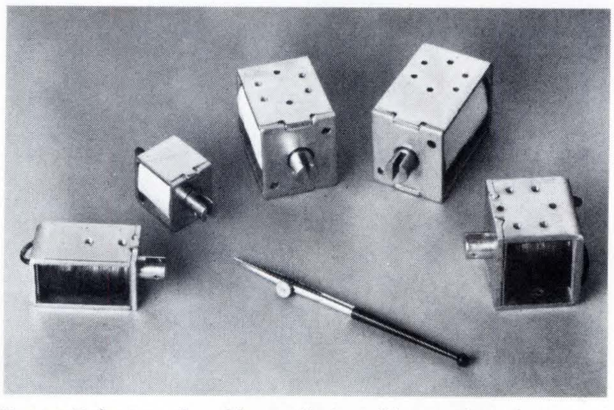
If a buyer goes to a distributor, he will be able



Laminated solenoids are designed primarily for ac operation because their laminated frame and plunger reduce eddy currents and thus increases efficiency. Relative cost—23.

to find the solenoid he needs that day. If he goes to the factory, he must wait to get scheduled for production. For a few thousand coils, most manufacturers will not set up an automatic coil-winding machine. The buyer should check with the distributor first and see what he can get in performance, and if what's available will meet his needs. If there is something a buyer cannot get from the distributor, then he can come to the factory and it will be scheduled through normal production. A simple change in the plunger such as adding a mounting hole in the frame will make the solenoid a "special." It's practical for "specials" when ordering 100,000 units or more, but the buyer ends up paying more for a small special order.

The least expensive coil would use a plastic molded bobbin—nylon (glass filled or plain), delrin, or some of the newer plastics like "Celanex." These are less expensive because they can incorporate a start-lead slot (the start lead is the start of the winding which must run up the flange of the bobbin to permit the attachment of the lead wire for electrical continuity) integral with the flange, and they also allow terminals of various designs to be inserted.



Box or D-frame solenoids are designed for medium force and medium stroke. Because the steel frame encloses the coil on two sides, a better flux path is formed making these units more efficient than open-frame solenoids. Relative cost—14.

These terminals allow for faster winding and finishing of the coils, and also result in a neat, smooth coil. The terminals eliminate a large percentage of hand operations and thus remove the human element for a higher quality coil. These terminals can be solder terminals as well as quick-disconnect type. If you must have lead wires, it is well to look at soldering the leads directly to the terminals rather than have them embedded in the coil.

Excessive heat-rise spells derating

How high a solenoid's heat rises depends upon several factors: wattage or heat input, the amount of copper and iron in the solenoid, the thermal conductivity between the copper and iron, the ambient temperature, the size of the heat sink on which the solenoid is mounted, etc. The formula for determining heat rise by change of resistance is:

$$R_t = R_{20}\,[1 + A_{20}(T-20)]$$

Where, R_t = Resistance at any temperature
R_{20} = Resistance at 20°C
A_{20} = Temperature coefficient of copper at 20°C
T = Any temperature in degrees centigrade

Almost all manufacturers list this formula or one related to it in their catalogs, so there is little need to dwell on it. However, for convenience, **Table 1** is given to facilitate the heat rise calculation. Usually hot resistance and room-temperature resistance is known. By dividing hot resistance by room-temperature resistance and entering the resulting number on the chart, a temperature is found. When room temperature is subtracted from it, we obtain the heat rise.

Example: Assume hot resistance is 131.44Ω as measured by a wheatstone bridge. The resistance at 20°C (room temperature) is 100Ω.

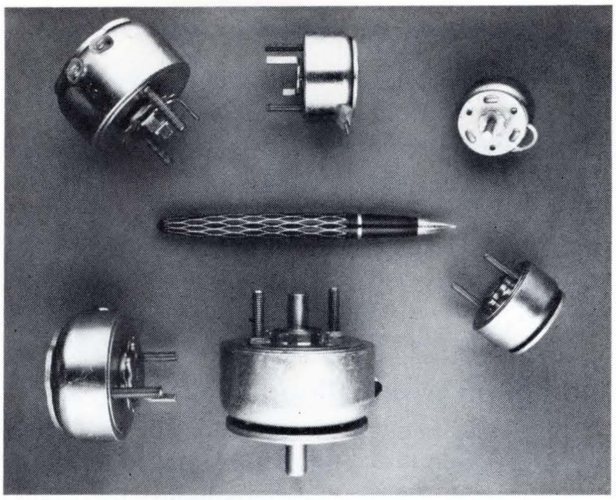
$$\frac{131.44}{100} = 1.3144$$

Enter the table and find this number—to the left read 100°C.

$$100°C - 20°C = 80°C$$

Therefore, this coil had an 80°C rise. Since the size of the heat sink on which the solenoid is mounted affects its heat rise, the only practical way to test the solenoid is to mount it and test it exactly as it will be used. Any other way will give erroneous results.

When first selecting your solenoid from the various catalogs, check the size of the heat sink on which the data was collected. Also check the expected heat rise on that heat sink. If the heat sink is large in comparison to the one that you

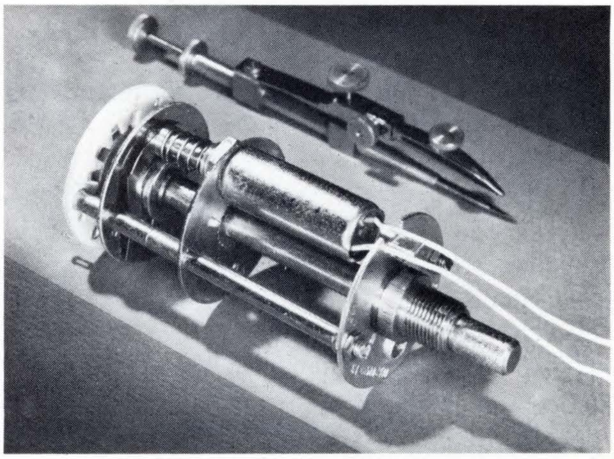


Rotary and flat-pack solenoids. Like the tubular solenoids, these have their coils totally enclosed in steel and thus are highly efficient. Their relatively short length and large diameter provide a large-diameter core or plunger, thereby providing more force than tubular solenoids, but over a much shorter stroke. The ball races, which convert linear motion to rotary, are shown at the upper right. Flat-pack solenoids are the same as rotary solenoids except that they don't have the ball races and therefore provide linear motion only. Relative cost—48.

have in actual practice, you had better derate the catalog pull-force curve.

If the catalog states an expected heat rise of 85°C and you are operating in a 60°C ambient, you've got problems. Any 85°C rise plus a 60°C ambient is equal to 145°C. (U.L. 508 allows a 105°C rise for a 130°C system.) Again, we would have to derate the pull-force curve. But how much? Since the coil is wound to a certain depth and this depth affects the heat rise, we don't want to change that dimension.

Now if we change the wire size one size smaller, keeping the coil to the same degree of fullness, we will change the resistance by 1.6 times (for an explanation of this see "Rotors - Electro Magnetic Devices," John Wiley and Sons).



Typical application for a tubular solenoid. When energized, the solenoid releases the rotary-switch detent mechanism to allow the rotor to return to the neutral position.

Watts $= \frac{E^2}{R}$, and if we keep the voltage constant, a 1.6 change in resistance changes the wattage by 40%. Now this 40% change in wattage will affect the pull by approximately $\sqrt{.40}$ or 63%. Thus, we will either decrease the stroke by 63% for the same pull, or decrease the force for the same stroke by 63%. This is not a true derating, but will give ballpark figures for comparison purposes. Just remember, "When in doubt you better find out—call the manufacturer."

Aluminum wire balloons coil

There has been a lot of literature published recently exploiting aluminum wire. Pound for pound aluminum is considerably less expensive than copper, so why not use aluminum-magnet wire. True, it is less expensive—for larger-size wires (about #28AWG), and if you have a low-voltage source of around 12V, you may be able to affect a savings by using aluminum wire. Of course, you would have to use more of it (because of the difference in conductivity between copper and aluminum to get the same pull characteristics), and thus the solenoid would be larger. But the possibility of using aluminum where a smaller size wire is needed is practically nil, because the cost goes up at a fantastic rate.

As a rule of thumb, with aluminum wire you would have to use three wires sizes larger than copper to get the same conductivity as copper.

Don't mix duty cycles

Catalog data from the various manufacturers on intermittent-duty solenoids is probably more confusing than any other single aspect. It is pretty well agreed that the duty cycle of a solenoid is equal to the ON-time divided by the ON-time + OFF-time. This gives a fractional number which, when multiplied by 100, gives the result in percentage.

$$\text{Duty Cycle} = \frac{\text{ON-time}}{\text{ON-time} + \text{OFF-time}} \times 100$$

Example: For a solenoid energized for one minute and de-energized for three minutes,

$$\text{Duty Cycle } \frac{1}{1+3} = \frac{1}{4} \text{ or } (0.25 \times 100 = 25\%)$$

Thus, for this example the duty cycle is 1/4, or 25%, depending on the manufacturer, which seems simple enough. But let's examine this a little closer. To understand the whole concept of duty cycle, we must know something about the heat rise and the cooling rate of the coil as well as the type of insulation on the magnet wire.

The magnet-wire insulation is rated according to its ability to withstand temperature and is set into classes. These classes are:

Class	90	(also called class D)	90°C
Class	105	(" " " A)	105°C
Class	130	(" " " B)	130°C
Class	155	(" " " F)	155°C
Class	180	(" " " H)	180°C
Class	200	( )	200°C
Class	220	(" " " C)	220°C

The life of the wire is usually rated at 20,000 hours at a temperature within the class stated above.

There are other factors which can affect the life of the insulation, such as abrasion received when winding the coil, thickness of the coating, concentricity of the coating relative to the wire diameter, porosity of the coating, etc. We are not concerned with the actual life at this time, only the relative life; therefore, we will disregard these other factors.

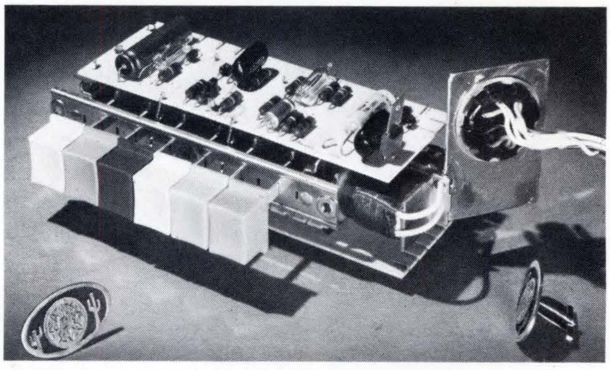
The ASTM spec states that "many film insulations deteriorate in a manner such that the following equation applies":

$$L = Ae^{b/K}$$

Where, L = insulation life
K = absolute temperature, K°
A, b = constants for each insulation
e = base of natural logarithms

From this equation we can show that for every 10°C increase in temperature, the life of the insulation is decreased by approximately 50%. Therefore, if we take a coil that uses a wire rated at 130°C and energize it with a current so that the total temperature (ambient plus coil rise) will stabilize at 130°C, and this coil remains energized, we can expect it to have a life of X number of years. It matters not at the present time if this life is 20,000 hours or 10,000 hours.

If we take this same coil and energize it only 50% of the time, we have essentially doubled its life. This coil is now a 50% duty-cycle coil if we energize and de-energize it at regular intervals. Since this coil has twice the life at a 50% duty cycle as at continuous duty, we could double that



An open-frame solenoid is selected for this application because of its low cost and short length. It provides an electrically operated pushbutton-switch release.

TABLE 1

Factors by which the resistance at 20°C must be multiplied to get resistance at any temperature (based on the factor .003929 and rounded off to 4 decimals).

Temp., °C	Resistance Factor	Temp., °C	Resistance Factor	Temp., °C	Resistance Factor	Temp., °C	Resistance Factor	Temp., °C	Resistance Factor	Temp., °C	Resistance Factor
1	0.9253	26	1.0236	51	1.1218	76	1.2200	101	1.3183	126	1.4165
2	0.9293	27	1.0275	52	1.1257	77	1.2240	102	1.3222	127	1.4204
3	0.9332	28	1.0314	53	1.1297	78	1.2279	103	1.3261	128	1.4243
4	0.9371	29	1.0354	54	1.1336	79	1.2318	104	1.3300	129	1.4283
5	0.9411	30	1.0393	55	1.1375	80	1.2357	105	1.3340	130	1.4322
6	0.9450	31	1.0432	56	1.1414	81	1.2397	106	1.3379	131	1.4361
7	0.9489	32	1.0471	57	1.1454	82	1.2436	107	1.3418	132	1.4400
8	0.9529	33	1.0512	58	1.1493	83	1.2475	108	1.3458	133	1.4440
9	0.9568	34	1.0550	59	1.1532	84	1.2515	109	1.3497	134	1.4479
10	0.9607	35	1.0589	60	1.1572	85	1.2554	110	1.3536	135	1.4518
11	0.9646	36	1.0629	61	1.1611	86	1.2593	111	1.3575	136	1.4558
12	0.9686	37	1.0668	62	1.1650	87	1.2632	112	1.3615	137	1.4597
13	0.9725	38	1.0707	63	1.1689	88	1.2672	113	1.3654	138	1.4636
14	0.9764	39	1.0747	64	1.1729	89	1.2711	114	1.3693	139	1.4676
15	0.9804	40	1.0786	65	1.1768	90	1.2750	115	1.3733	140	1.4715
16	0.9843	41	1.0825	66	1.1807	91	1.2790	116	1.3772	141	1.4754
17	0.9882	42	1.0864	67	1.1847	92	1.2829	117	1.3811	142	1.4793
18	0.9921	43	1.0904	68	1.1886	93	1.2868	118	1.3850	143	1.4833
19	0.9961	44	1.0943	69	1.1925	94	1.2907	119	1.3890	144	1.4872
20	1.0000	45	1.0982	70	1.1965	95	1.2947	120	1.3929	145	1.4911
21	1.0039	46	1.1022	71	1.2004	96	1.2986	121	1.3968	146	1.4951
22	1.0079	47	1.1061	72	1.2043	97	1.3025	122	1.4008	147	1.4990
23	1.0118	48	1.1001	73	1.2082	98	1.3065	123	1.4047	148	1.5029
24	1.0157	49	1.1139	74	1.2122	99	1.3104	124	1.4086	149	1.5068
25	1.0196	50	1.1179	75	1.2161	100	1.3143	125	1.4125	150	1.5108

Given: Hot Resistance and Resistance at 20°C: Hot Resistance Divided by Cold Resistance = Factor

Directly opposite factor is temperature °. This is total temperature subtract 20 to get temperature rise of coil.

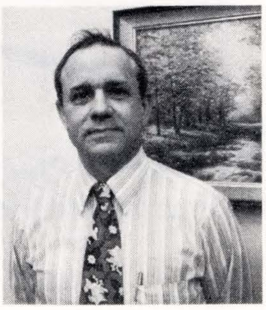
heat input and reduce its life back to the continuous duty level. But, if the temperature is higher than 130°C, we must therefore limit the time the coil can be energized.

Fig. 1 shows a typical heat rise vs time for a solenoid coil ON continuously. The dotted line shows the same coil with twice the wattage and thus twice the heat input, but the ON time equal to 6 minutes. It can be seen that the coil was de-energized at a time equal to what the heat rise was for continuous duty. However, the cooling rate is essentially the same, and thus does not come down to the point from which the coil originally started. On the next energization period, the temperature went still higher. After several cycles the temperature stabilizes with peak points and valleys that average the same as the continuous-duty temperature. It is the peak temperature in which we are interested since the peak temperature determines the thermal life of the coil.

To determine the actual time the coil can be energized, the frequency of operation must be determined. The frequency must not be confused with duty cycle. The duty cycle really specifies the wattage input. If we double the wattage, then we double the heat input. Consequently, we will have the same life as a continuous-duty coil if energized 1/2 the time. By frequency of operation we mean how many times this duty cycle is called upon to operate.

If the coil is energized only a few times a day, thermal life should be no problem. Hence, we can have the peak temperature approach the thermoplastic flow of the insulation. (For Nysol 130°C insulation made by REA Wire Co., this is 240°C for #38 wire, heavy build.) If we allow a safety factor of 25%, or 60°C, to allow for hot spots in a coil and other contingencies, we could actually allow the peak heat to reach 180°C. The rated life of the coil at this temperature would only be 312 hours, but since it is energized for short periods (let us assume five minutes) and only a few times a day (assume 4 times a day), the actual life of the coil would be 936 days or 22,464 hours. (Rated life expressed in hours (312) times 60 = 18,720 minutes; 18,720 minutes (actual ON-time) divided by 20 minutes/day = 936 days. To convert back to hours, then, we have 936 times 24 = 22,464 hours.) This is approximately the same life as if we had limited the total temperature to 130° for 20,000 hours. However, if the coil is to be energized cyclic for long periods, it is suggested that the peak temperature not exceed 10°C over the rating of the magnet wire. □

Author's biography



Lonnie J. Richardson has been employed as a design engineer for solenoid and relay products at OAK Industries, Inc., Switch Div., Crystal Lake, IL, for 8 years. Lonnie graduated from Elgin Community College and has had 4 patents issued to him.

The smallest 5 amp general purpose relay

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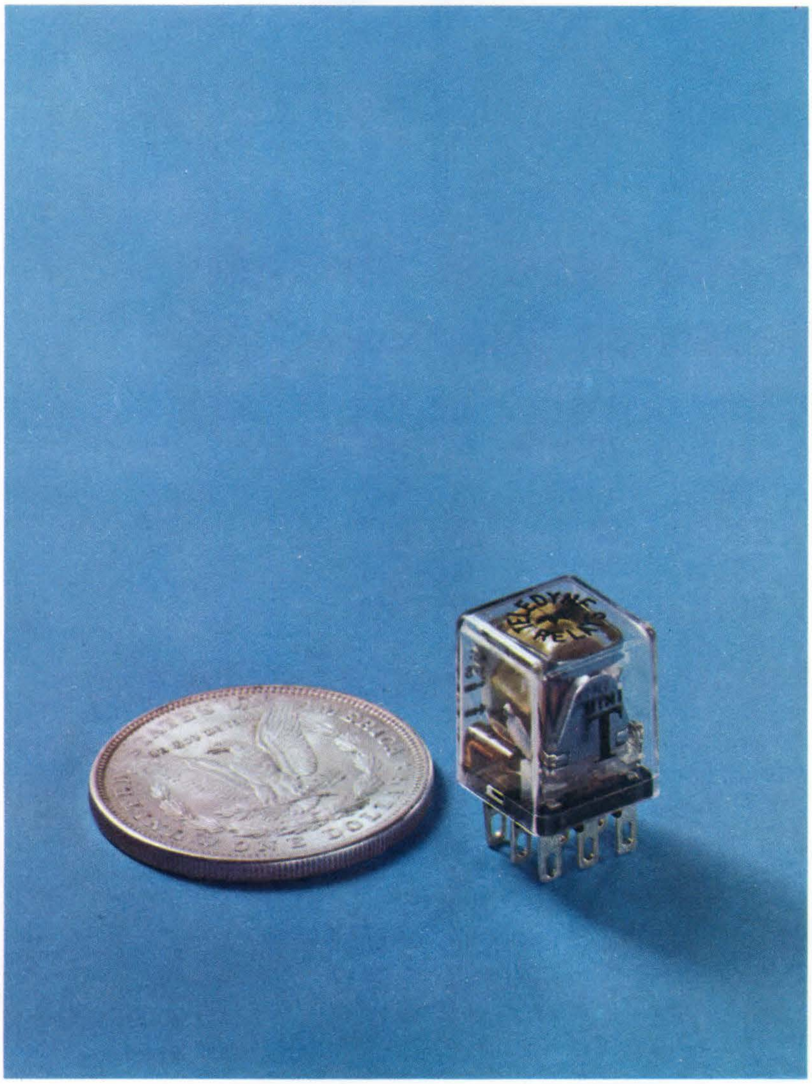

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Designers Guide to: Instrumentation amplifiers

The old adage that instrumentation-amplifier systems shall have only one ground point is no longer valid when using modern differential amplifiers.

John W. Jaquay, Ectron Corp.

Most engineers and technicians have at one time or another connected various combinations of equipment and found that the output contained excessive 60-Hz interference. In these instances, the solution has normally been to remove all grounds in the system except one and install an independent ground wire from each piece of equipment to this point. This sometimes required the use of separate isolation transformers for equipment that had excessive coupling to the ac line.

The use of a single ground in many situations is absolutely proper and was the concept employed in low-level dc signal-conditioning systems for many years. This was before the advent of differential amplifiers when only single ended units were available.

Now that differential amplifiers are used almost exclusively in low-level systems, a new set of conditions exist requiring both the input- and the output-signal systems to be grounded at some point. If this is not done, it is actually possible to obtain worse results with a differential amplifier than with a single ended unit.

Single ended amplifiers reviewed

To make this point clear, we will first review the use of a single ended amplifier system that has a common line between the signal source, the amplifier, the output device and ground. A simplified diagram of a typical single ended system is shown in **Fig. 1**.

In analyzing **Fig. 1**, it is not important that the common-mode source (CMV) and leakage impedance (Z_L) are in practice a complex network of fields, stray capacitances, etc. The important point is that all of these factors combine to produce a current through loop B-C-D-E-F-B. The resulting IR drop from point B to C appears as an input to the amplifier which responds to the sum of the potentials between terminals A and C.

To reduce the IR drop from B to C, designers employed two techniques. The first was to reduce the resistance between B and C by employing heavy-gauge drain wires or even large buss bars. This resulted in some improvement, but unfortunately, with magnetically induced CMV, the current increased as resistance dropped.

The second technique was to lower the current by raising the impedance of Z_L. This was accomplished by isolating all input lines from ground and by the extensive use of shields. In strain-gage applications this technique led to the development of strain-gage excitation supplies which had a high degree of isolation between their outputs, chassis ground and the power line. Internally these devices employed elaborate shields and power transformers which normally had triple box shielding. Such supplies were costly but necessary for reasonable system performance.

Before discussing differential techniques, several factors should be reviewed in the single ended system:

1. An IR drop from B to C of only a few millivolts (**Fig. 1**) could be disastrous. For example, if the system full-scale input signal was 10 mV, a drop of only 3 mV represented 30% of full scale.
2. Even in low-accuracy systems, the magnitude of the IR drop could not be allowed to become too high or the system would be totally ineffective.
3. All points in the system ultimately have a fairly low-impedance path to ground; therefore, it is not possible to develop large potentials due to electrostatic coupling. This is the most important point to bear in mind when changing from a single ended to a differential system.

To illustrate this point, **Fig. 2** shows another simplified single ended system with a strain-gage excitation supply connected in the input system.

The capacitive leakage in **Fig. 2** has intentionally been made large to prove a point. At 27 pF, its reactance at 60 Hz is 100 MΩ. Even though this capacitance is coupled to the 115V ac line, it cannot introduce a large voltage in the ground lines because their impedance cannot be more than a few ohms plus the strain-gage resistance.

Now let us replace the single ended amplifier with a differential amplifier which has a common-mode impedance between its input lines and ground of 100 MΩ (**Fig. 3**). Since this is the only impedance path to ground, it means that the input lines would attempt to assume a common-mode potential equal to 1/2 the line voltage. No differential amplifier is perfect, thus a significant part of this common-mode potential will appear at the output terminals. In addition, the differential amplifier might not be capable of handling that much common-mode voltage.

The actual effect in this example is impossible

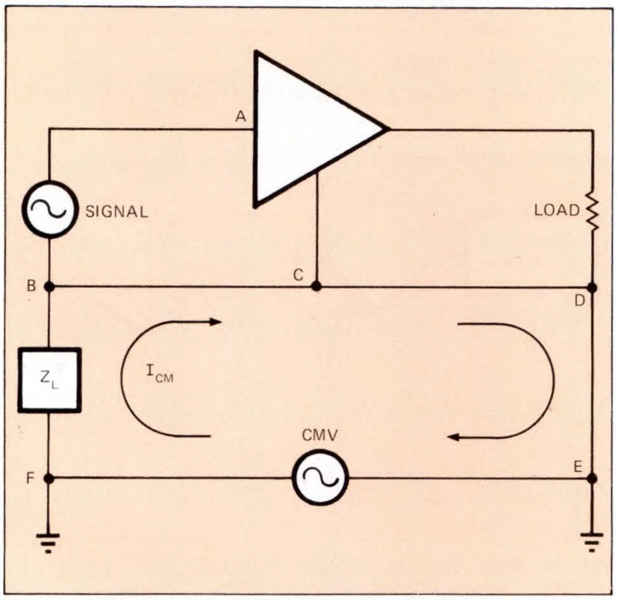


Fig. 1—Current in loop B-C-D-E-F-B results in an IR drop from B to C that adds to the input signal.

to predict without specific knowledge of the differential amplifier involved. But at the very best, some common-mode rectification is bound to occur and the resulting output error will be partially determined by the internal impedances and the energy content of the common-mode source.

The substitution of a differential amplifier effectively broke the input ground return and left the system vulnerable to electrostatic interference. In **Fig. 3**, the common-mode source impedance and the common-mode impedance of the amplifier were approximately equal resulting in a common-mode voltage equal to 1/2 the line voltage.

It is interesting to note that if a better differential amplifier is substituted, it will have a higher common-mode impedance and superior common-mode rejection, but its higher impedance is somewhat self-defeating because it causes the induced common-mode potential to rise. For example, if the common-mode impedance of the amplifier were 100 MΩ, the common-mode potential would be approximately 90% of the line voltage. This assumes that the amplifier is capable of operating normally with this common-mode voltage level.

Proper grounding is essential

The ironic part of the previous example is that it is totally unnecessary to operate with these high common-mode potentials. Even a modest impedance to ground would relieve the electrostatic problem, and a good solid ground would be even better. This is normally accomplished by simply grounding the strain-gage excitation supply. When this is done, there is no longer a need for an excitation supply having superior isolation. Whether the supply is purchased or designed by the user, it no longer requires elaborate guarding

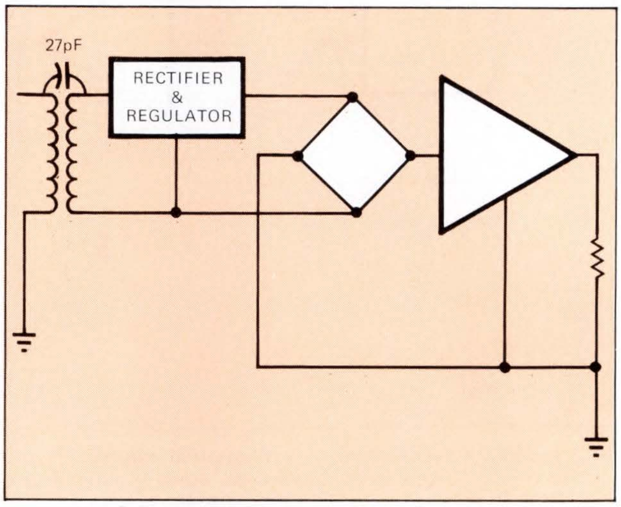


Fig. 2—In a single ended system, low impedance to ground prevents high common-mode voltages from appearing at the input.

or a very expensive power transformer with triple box shields.

Due to the hangover from single ended days, the user may be frightened by having both an input and output ground in his system. After all, there is almost certain to be a slight difference of potential between these two points.

These individuals simply do not have faith in their differential amplifier. In a single ended system, if a ground loop existed which caused a 3 mV potential in the input portion of the common line, the amplifier was incapable of seeing a difference between this potential and the desired signal. If the amplifier had a gain of 1000, it would simply produce an output error signal of 3V.

In a differential system, a 3 mV common-mode signal will cause virtually no effect. For example, if the amplifier's common-mode rejection is 120 dB, the equivalent input effect would be only 3 nV and the output error signal would only be 3 μV. In real systems, grounding of the input and output will typically produce common-mode potentials considerably greater than 3 mV, but with proper guarding and a quality differential amplifier, excellent results can be obtained. Even if some error potential exists, the results are considerably better than with a system left unguarded and vulnerable to electrostatic pickup.

If you attempt to make a mathematical analysis of the electrostatic problem, you may conclude that it is not as severe as inferred here. If so, this could be because you are considering only the fundamental power-line frequency. This is an invalid assumption.

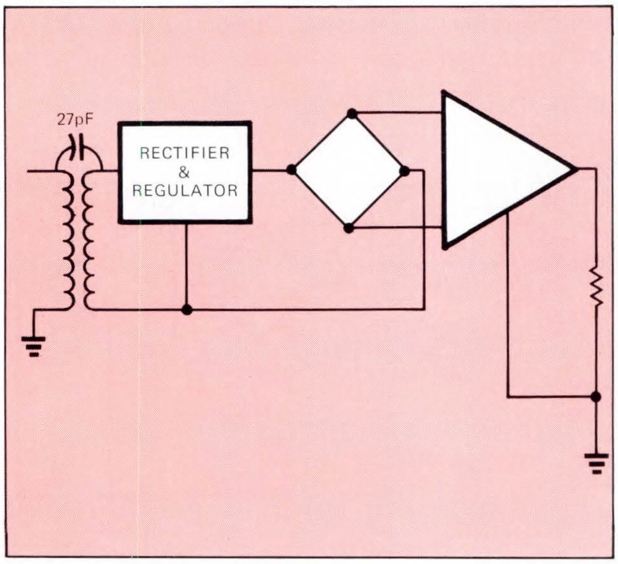


Fig. 3—Simple substitution of a differential amplifier in the circuit of **Fig. 2** effectively breaks the input ground return leaving the system vulnerable to electrostatic interference.

If electrostatic problems do exist in a system, it will first be observed by spikes and other miscellaneous hash. These will have a 60-Hz repetition rate, but their primary energy content will be in a much higher frequency spectrum. These spikes and hash are generated by such items as fluorescent lights, SCR control devices, brush motors, etc.

The fact that the signals have high-frequency components is significant for two reasons. First, it requires far less capacitance to couple significant energy into the input lines, and second, the common-mode rejection of an amplifier typically deteriorates at higher frequencies.

Floating inputs are still practical

There are always exceptions to the rule of grounding at both the input and output of a differential-amplifier system. It is possible that applications exist where the input system must be floated. Even though this is a more difficult problem, adequate results may be achieved by careful analysis of the overall system. **Fig. 4** shows a differential system operating with the input essentially floating. In this system, the guard is connected to the common-mode source and is bypassed to ground at the amplifer.

If the value of this bypass capacitor is not too large, it can provide electrostatic relief for the system without seriously degrading common-mode rejection. The actual value that provides best results may be determined empirically in a particular system by simply adjusting the value until minimum interference is observed at the amplifier's output.

This capacitance already exists in some instrumentation amplifiers. In others, it may not exist and operational difficulties may be encountered when it is added. This can occur with certain types of amplifiers that have active guard circuits. If it does, you may be able to break the guard connection close to the amplifier and insert the capacitance on the source side of the break. When this is done, it may also be necessary to insert a resistor across the broken guard connection if the amplifier in question depends on a guard connection to return its pump-out current from the input terminals to ground.

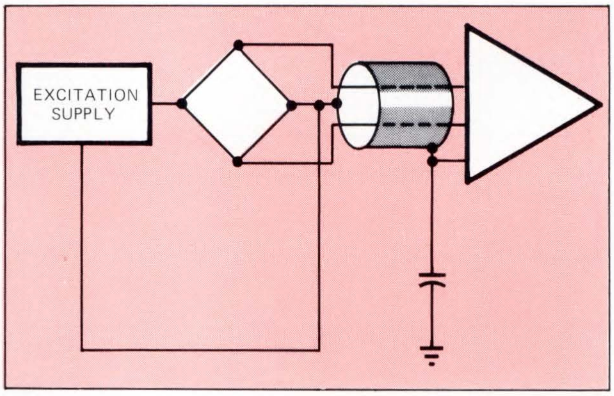


Fig. 4—When the input must be floated, adequate results might be obtained by inserting capacitance between the guard and ground.

RF filtering may be necessary

If the preceding has been accomplished and results are still unsatisfactory because of high-frequency common-mode signals, it may be necessary to include RF filtering in the input lines. Before attempting to do this, you should be aware of a fundamental conflict.

To have good common-mode rejection, an

amplifier must have extremely low capacitance between the input lines and output ground. However, RF filters consist of a series impedance and bypass capacitors to ground which means there is a direct conflict. It is still possible to achieve substantial RF filtering without seriously degrading common-mode rejection at power-line frequencies as shown in **Fig. 5**.

In this filter, the RF bypass capacitors are not returned to ground, but to the input guard. The guard is, in turn, capacitively coupled to ground. In this configuration the capacitance between guard and ground must be sufficiently low so that the guard will not draw excessive current. If it does, the quality of the guard gradually deteriorates as it approaches the amplifier and common-mode rejection suffers. As indicated previously, this value can be determined empirically

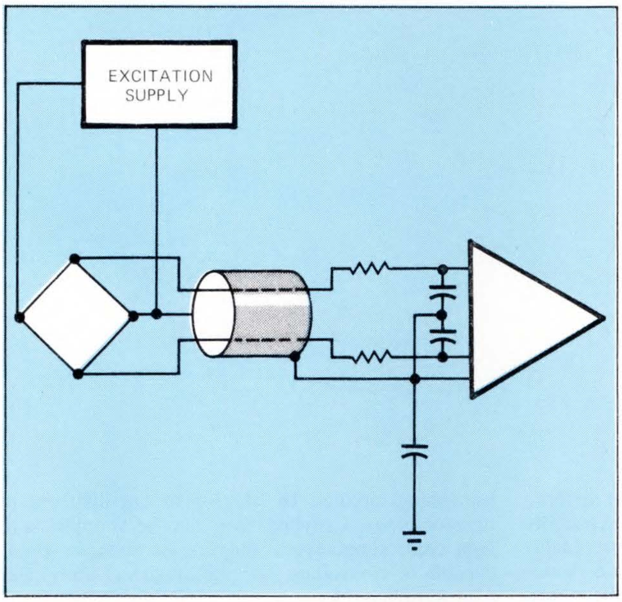


Fig. 5—RF filtering of the input lines requires special consideration. Connecting RF bypass capacitors to the input guard, which is capacitively coupled to ground, will prevent significant degradation of CMR.

before the bypass capacitors are installed.

The value of the filter capacitors should be kept as small as possible, since their return point does not represent the common-mode potential with perfect accuracy. In addition, the bandwidth of the system to normal-mode signals could be impaired if they are too large. In this respect, the series impedance must also be considered. This should be kept low to avoid several undesirable consequences, e.g., a high impedance will degrade the noise and zero stability of the amplifier.

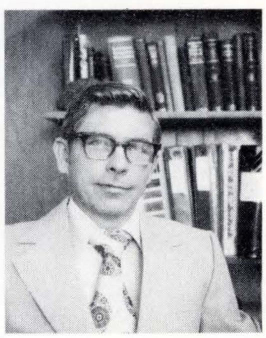
The suggestions for RF filtering primarily apply to the use of very low-cost and/or modular amplifiers. A well designed general-purpose instrumentation amplifier will normally have an input common-mode filter incorporating the preceding techniques and possibly more effective filters involving bi-filer or tri-filer chokes. However, since these amplifiers are designed for the best general-purpose situations, they may not necessarily be optimum for a specific application. In these instances, it is best to contact the manufacturer rather than attempt modification or the use of external filters.

Many engineers discount the damage that high-frequency common-mode signals can cause. A typical example is where there is only interest in data from dc to 10 Hz. If RF is present, it would seem that a passive filter between the amplifier and the output device could solve the problem. This may be true if the common-mode potentials are small, but there is a greater possibility that the high-frequency signals are being rectified within the amplifier and a dc error signal is produced which varies as a function of the level of common-mode potentials.

This occurs directly at the input stage when the common-mode potential is high. It also occurs, to a lesser degree, with potentials that are within the dynamic range of the amplifier. All amplifiers have a limit in their ability to follow rapidly changing signals. This is referred to as the amplifier's maximum slewing rate. A given amplifier will amost invariably be able to slew faster in one direction than the other. When this happens, the effect is partial rectification with a resultant dc error component.

This discussion of some of the application problems of instrumentation amplifiers is, of course, an over simplification of any but the most elementary system. However, modern high-performance differential-instrumentation amplifiers can generally produce precise data signals in spite of high common-mode voltage levels and even RF interference. These amplifiers usually permit the use of grounded bridge-excitation supplies and, in fact, can generally perform better with a ground point in the input signal system. □

Author's biography



John W. JaQuay is Vice President of marketing for Ectron Corp. where he has worked for over 3 years. His professional experience includes work in field service, technical writing and applications engineering. John is a member of IEEE and is the author of 2 previous technical articles.

Data-sheet dialogue

Reader's responses to DPM data sheets: More details—less specsmanship!

When EDN asked for its readers' opinions on the "typical" DPM data sheet that appeared in the January 20, 1973 issue, it didn't expect such a lopsided indictment of specsmanship. All of EDN's readers were unanimously critical in their comments over the lack of information contained in the data sheet.

While a handful thought that this representative data sheet was thoughtfully laid out and easy to read, (some felt the listing of features was easier to follow than the description), they were equally vehement in their objections to "incomplete specs" and "meaningless data" as they put it. Here is a sampling of their comments: (italicized statements are the opinions of EDN's editors).

No pricing is all too common

That in a nutshell was the sentiment expressed by every single reader. The "low cost of under $100 (for xx quantities)" stated in the data sheet was simply not clear enough for the readers. "What is the exact cost in quantity?", "What is the single-unit cost?", "What is the cost for additional options?" were some of the comments heard. One reader felt that pricing should be included for sample quantities as a very minimum.

"It is better to include all prices for all quantities or none at all. Since prices vary faster than technical specs, I prefer a separately dated price and availability sheet with the name of a nearby distributor who will have them in stock for low-quantity and/or quick-availability purchases" was the way another reader put it.

In defense of the manufacturers, it should be pointed out that prices do indeed vary faster than technical specs, particularly in the highly competitive DPM field, and as a result, some manufacturers put out regularly revised and dated pricing sheets. But not all do. A separate price sheet is of no use to a designer who is holding only a nondated data sheet pulled out of a catalog or advertisement, so perhaps some provision should be made for including complete and up-to-date pricing information in every data sheet.

Dimensions are lacking

Readers were quick to spot the missing dimensional data for the DPM's case. As for the number of square inches given for the DPM's panel space, several felt that this was meaningless, as there was no way of knowing what the specific panel width and height dimensions were. "Square inches mean nothing" was one adamant reader's opinion. "What is the behind-the-panel depth?", "I have no way of knowing what the size of my

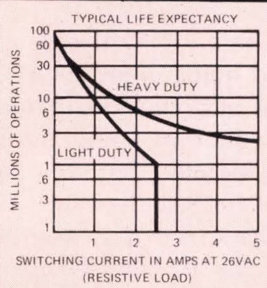
"Data-Sheet Dialogues" are a series of reports on what's wrong (or right) with data sheets as seen through the eyes of those who use them: the design engineers. Representative data sheets will be chosen from specific product fields, and collective readers' opinions will be given in the next installment of **"Data-Sheet Dialogue",** when a different data sheet will also appear. So let us hear from you, the reader. Send your comments on the latest data sheet at the end of this section to:

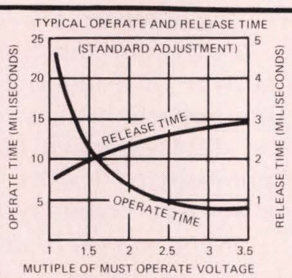
EDN Data-Sheet Dialogue Editor
221 Columbus Avenue, Boston, MA 02116

"Anonymous Relays, Inc."

MINIATURE GENERAL–PURPOSE RELAYS UP TO 6 PDT CONTACTS SERIES XY 747

General purpose miniature relays in plastic dust cover–Interchangeable with other cradle type relays–Combination solder and plug-in terminals. UL-version listed under UL Recognition Fil 43203.





Notes: 1. Coils not arc suppressed
2. Switched battery voltage source

FEATURES

- International Standard type
- Combination plug in/wire or PC terminals
- Low level bifurcated, 2 amp or 5 amp contacts
- Life expectancy more than 100 million operations
- Form A, B, C and D contacts are available
- Molded cradle eliminates phenolic dust inside the relay
- Balanced, spring-held armature allows dependable operation in any position
- Round core and larger coil volume provides more pull force, eliminating expensive, sensitive version.
- Slim profile mounting with right-angle socket
- Sockets are of unbreakable fiberglass-filled base and have unique knife-type connectors for dependable contact
- Available from stock.

GENERAL DESCRIPTION

The XY miniature general-purpose, comb-actuated relay can be used in a wide variety of applications such as computer systems, control and alarm systems, business machines and data processing equipment, etc.

The field-proved, long life characteristics of the relay, along with its unique plug-in design and integral dust cover, allow it to be used in transistorized systems where space requirements and operational longevity are of prime consideration. The relay requires less than one cubic inch of space. When installed with the XY right-angle socket, its overall height is only ¾".

XY miniature relays are available in all contact configurations through 6PDT. The contacts are capable of carrying loads up to 5 amps, as well as low-level signals. For low-level, high reliability switching, bifurcated contacts are available.

All parts of the magnetic circuit are made from armco magnetic ingot iron and aged in the most modern hydrogen annealing equipment; a process which assures optimal stability of operating data during the life of the relay. All relays are insulated with the highest quality pre-aged phenolic obtainable.

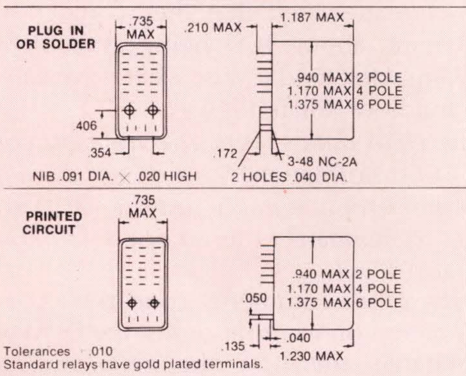
The XY relays described in this brochure are all of the round-core type. This design feature provides a higher number of turns at the same coil resistance, resulting in greater mechanical force with less coil power. Only one adjustment is needed for any application. Standard and sensitive versions are thereby eliminated.

The unique armature retention spring dissipates kinetic energy of the armature resulting in minimum bounce. The molded low-friction cradle results in further reduction of bounce and eliminates the problem of phenolic dust inside of the relay.

Additional features of the XY747 include a new base and socket design made of unbreakable fiberglass-filled polyurethane, with an insulation resistance of 10^{10} ohms. A unique knife-type connector provides a more secure connection and eliminates flux contamination of contact surfaces during machine soldering.

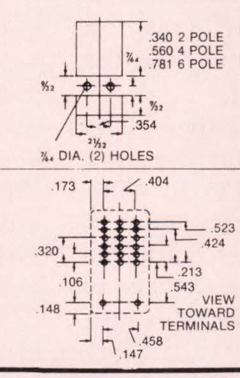
MECHANICAL SPECIFICATIONS

DIMENSIONS (inches)

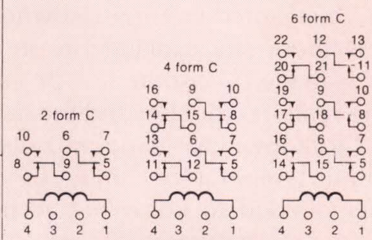


Tolerances ± .010
Standard relays have gold plated terminals.

SUGG. PANEL LAYOUT OR P/C BOARD



WIRING DIAGRAM



Terminals 2 · 3 for dual coil version, on single coil not inserted.

ELECTRICAL SPECIFICATIONS

Contact Rating — Noninductive load
Light Duty (Code L): Fine silver goldplated — low level to 2 amps @ 26 VDC or 1 amp @ 115 VAC
Heavy Duty (Code H): Silver cadmium oxide — 5 amp @ 26 VDC or 3 amp @ 115 VAC
Other contact material available

Life Expectancy — Mechanical Operations: 10^3
Operation at Rated Load: 10^4

Contact Resistance — 50 milliohms max. initially
200 milliohms at end of life

Operate Time — At two times "must operate" voltage or current: ⩽8ms

Release Time — At two times "must operate" voltage or current. ⩽3ms

Weight — 23 to 35 grams (approx. 1 oz.)

Dielectric Strength — 1000 V rms; 500 V rms across contact gap

Insulation Resistance — 10,000 megohms minimum @ 25°C, 100 VDC, 50% RH

Coil Temperature — Max 105°C (220°F)

Ambient Temperature—
Operating: −55°C (−72°F) to 80°C (175°F) @ nominal operating voltage
Storage: — 55°C (−72°F) to 105°C (220°F)

Vibration — Operating: .062 DA @ 5-55 Hz; 10g @ 55-110 Hz
Non-Operating: 10 g @ 5-500 Hz

Shock — Operating: 20 g @ 11ms Non-Operating: 30 g @ 11ms

Contact Bounce — At 10 ma contact current:
2 ms max. at operate, N.O. contacts
3 ms max. at release, N.C. contacts

panel cutout should be", and "We need to know the dimensions of the display used" were comments heard over and over.

The "so-many square inches of panel space" approach is often used by manufacturers in competitive advertising for claiming the world's smallest panel-space dimensions. Unfortunately, manufacturers tend to overemphasize the wrong things. They forget that their engineer customers are professional designers who live by facts and figures.

On the subject of dimensions, it may not be a bad idea if manufacturers attempted to put in both English and metric dimensions, as the latter system of measurement gains in worldwide popularity.

Numbers tell the whole story

"It goes without saying, descriptions such as great noise rejection or flutter-free readout are as good as worthless when no specific numbers are given" was the feeling of one reader. Others asked for more clarification of given specs.

"What does overrange of 25% mean?", "What's the DPM's slew rate?", "What are the time and temperature conditions under which accuracy is specified?" many readers asked.

Several readers spotted the confusing specs of 10 readings/sec and a response time of 1 sec in the DPM data sheet. They felt that such confusion is typical with many other types of parameters and should at least be clarified.

One reader pointed out an obvious lack of clarification. "Is the voltage range available in ac or dc?" he wanted to know. Nowhere in the data sheet is there any explanation on this, and the reader is made to assume it is dc volts.

Some readers went beyond the data sheet. One wanted to know what happens outside the given operating temperature limits of 5°C to 45°C. Another needed to know the accuracy limits of the operating-temperature extremes, and the maximum inputs permitted without damage to the meter. "Can input polarity reversal cause damage?" he asked.

The practice of making product descriptions such as "top-value, high-grade components used" and "high-speed, noise-free readings" without supporting statistical data is as old as electronics itself. So it is better for a manufacturer to supply actual MTBF (mean-time between failure) figures (and what they are based upon) that substantiate "high-reliability" claims than to merely ask an engineer to take his word for it. He just might be more believable in future dealings.

What type of readout?

Next to the lack of pricing information, readers complained of the absence of a description of the type of readout used in the DPM. Comments heard include, "We need some indication of the future maintenance requirements for the type of display used," "By knowing the type of readout used, we can determine its lifetime, intensity and color; factors that are important when considering the purchase of a DPM."

Readers also indicated that their knowledge of the type of readout used helps them determine the proportional amount of power dissipated in the display section (gas-discharge and fluorescent-display devices generally require more power than liquid-crystal and LED types).

On the subject of displays, nearly all manufacturers do not give specific brightness figures, although they might say something like "a bright and clear Nixie display" or "the LED readout we use can be seen easily from a distance of so many feet." And it is no wonder why they don't when one realizes the many terms being used for measuring luminous intensity. Hardly any standardization exists on measurement units to use.

The connector can be a problem

That's what two readers related. One complained about having to wait months for a commonly available connector due to the lack of sufficient data-sheet information, compared against the short delivery time for the DPM of only a few weeks. He suggested that data be given on the type of connector used with the original manufacturer's nomenclature.

Most readers felt that they could not accept statements about BCD being available without knowing what kind it was, what drive capability it had and how isolated it was.

Few DPM data sheets give detailed connector and BCD information. Most do not even mention the connector and might just say "BCD available" either as standard or as an option without going into any detail.

Many other comments concerned the lack of information on whether or not the DPM was field calibratable and how the zero and full-scale calibrations could be accomplished, if at all. There were a few comments on the need to know what kind of case was being used (for noisy environments), be it plastic, metal, or metal lined packages.

"Equipment containing TTL or MOS LSI is important to know and should be spelled out in the data sheet. This is to keep the DPM circuitry consistent with current logic designs. A high-quantity TTL designer would prefer a TTL DPM vs an MOS one to maintain the field-service capability using TTL oriented personnel and equipment" said a reader. □

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BT2222A	NPN General Purpose Amp
BT2369A	NPN Hi-speed Switch
BT2483	NPN Low-level Amp
BT2484	NPN Low-level Amp
BT2604	PNP Low-level Amp
BT2605	PNP Low-level Amp
BT2906A	PNP General Purpose Amp
BT2907A	PNP General Purpose Amp
BT2946	PNP Chopper
BT3906	PNP Hi-gain Amp
BT4856	N-channel FET*
BT4857	N-channel FET*
BT4858	N-channel FET*
BT5109	NPN UHF Power Amp

*Available in second half of 1973.

Diodes

BD914	2 Anode, 2 Cathode Leads
B2D914	1 Anode & Cathode, 2 Open Leads
BD3600	2 Anode, 2 Cathode Leads
B2D3600	1 Anode & Cathode, 2 Open Leads
BZ752	5.6V Zener
BZ758	10V Zener
BZ821T	6.2V Temp Comp Zener
BZ969	22V Zener

Linears

RM101ABL	Op Amp
RM104BL	Negative Voltage Regulator
RM105BL	Positive Voltage Regulator
RM106BL	Voltage Comparator
RM709BL	Hi-gain Op Amp
RM710BL	Hi-speed Differential Voltage Comparator
RM711BL	Dual Differential Voltage Comparator
RM741BL	Op Amp
RM1741BL	Op Amp
RF9601BL	Monostable Multivibrator
RF8601BL	Monostable Multivibrator
RC4131BL	Hi-gain Op Amp
RM4132BL	Micropower Op Amp

TTL

RF50BL	J-K Flip-flop (AND Inputs)
RF60BL	J-K Flip-flop (NOR Inputs)
RF100BL	Dual J-K Flip-flop (Separate Clocks)
RF110BL	Dual J-K Flip-flop (Common Clock)
RF200BL	J-K Flip-flop (AND Inputs)
RF210BL	J-K Flip-flop (OR Inputs)
RG40BL	Dual 4-input NAND Gate
RG50BL	AND-OR Inverter Quad 2-input Gate
RG80BL	Dual Pulse Shaper AND Gate
RG130BL	Dual 4-input Line Driver
RG140BL	Quad 2-input NAND Gate
RG200BL	Expandable Single 8 NAND Gate
RG220BL	Quad 2-input NAND Gate
RG231BL	Quad 2-input A01 Gate
RG240BL	Dual 4-input NAND Gate
RG250BL	Expandable Quad 2 A01 Gate
RG310BL	Expandable Dual Output 2-input A01 Gate
RG320BL	Triple 3-input NAND Gate
RG380BL	Hex Inverter
RL10BL	Fast Full Adder
RL20BL	Dependent Carry Fast Adder
RL30BL	Independent Carry Fast Adder
RL60BL	4-bit Storage Register
RL70BL	4-bit Storage Register
RG3380BL	Hex Inverter
RG3390BL	Dual 4-input AND Gate (Split Outputs)
RG3410BL	Quad 2-input NOR Gate
RR5102BL	64-bit Bipolar RAM

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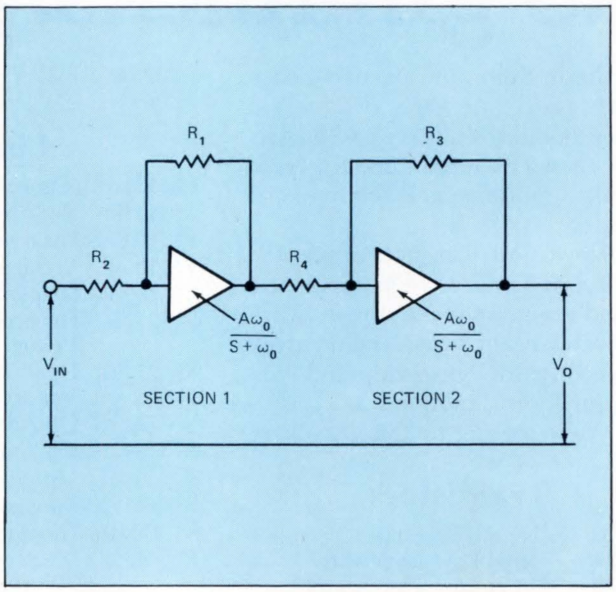
Are you getting the most bandwidth from your design?

Don't arbitrarily set individual gain in tandem connections. Proper adjustment of each closed-loop gain results in optimum bandwidth.

Ronald Saracco, Norden Div., United Aircraft Corp.

Gain-bandwidth has always been a troublesome problem in the design of analog-processing circuits. The designs that result usually maintain gain but sacrifice bandwidth. Although not much can be done to extend the gain-bandwidth product of one amplifier, it is possible with two or more amplifiers in tandem to optimize both gain and bandwidth.

Consider an example that frequently occurs in analog-data processing. Data is to be sent and received from one circuit module to another using two amplifiers (**Fig. 1**). Amplifiers must be selected that will meet the end-to-end gain and 3-dB bandwidth specifications. The designer is then faced with the problem of selecting from the infinite number of possible combinations that will satisfy gain the one combination that will also optimize bandwidth. By using the technique for gain-bandwidth optimization described in this article, such amplifier selection can be made easily.



Optimization of gain-bandwidth product of multiple-amplifier circuits is possible through proper adjustment of each amplifier's closed-loop gain.

Developing the technique

Many of the approaches to optimization are subject to a gain constraint. However, that of Lagrange appears to be the most straightforward. To develop this technique, it will be assumed that the open-loop frequency characteristics of A_1 and A_2 (**Fig. 1**) are identical. The closed-loop transfer functions and optimum bandwidth expressions can then be derived as follows:

In the circuit of **Fig. 1**,

A = open-loop gain
ω_0 = first dominant pole
R_1 = feedback resistor
R_2 = input resistor
R_3 = feedback resistor
R_4 = input resistor
$R_1/R_2 = \mu_1$
$R_3/R_4 = \mu_2$
λ = Lagrange's multiplier

The voltage transfer function for section 1 and 2 are:

$$G_1(\omega) = \frac{\dfrac{A\omega_0\,\mu_1}{1+\mu_1}}{j\omega + \dfrac{\omega_0(A+1+\mu_1)}{1+\mu_1}} \quad \textbf{(1)}$$

$$G_2(\omega) = \frac{\dfrac{A\omega_0\,\mu_2}{1+\mu_2}}{j\omega + \dfrac{\omega_0(A+1+\mu_2)}{1+\mu_2}} \quad \textbf{(2)}$$

and the end-to-end gain is the product of 1 and 2, or

$$\frac{V_0}{V_{IN}}(\omega) = G_1(\omega)\,G_2(\omega) \quad \textbf{(3)}$$

The dc (zero frequency) gain of sections 1 and 2 are:

A practical example

Using two LM101 operational amplifiers connected as shown in **Fig. 1**, determine the closed-loop gain, the poles for optimum bandwidth and the ratios μ_1 and μ_2.

Given:

1. Dc end-to-end gain, K = 16
2. $A_1 = A_2 = 10^5$
3. $\omega_0 = 60$ radians/sec
4. $R_2 = R_4 = 10^4\ \Omega$

First, determine μ_1 and μ_2 from **Eq. 12** & **13**.

$$\mu_1 = \frac{10^5 + 1}{\frac{10^5}{4} - 1} = 4.0002 \cong 4$$

$$\mu_2 = \frac{10^5 + 1}{\frac{10^5}{4} - 1} = 4.0002 \cong 4$$

Second, determine P_1 and P_2 from **Eq. 16** & **17**.

$$P_1 = \frac{60(10^5 + 1)}{5} = 1.2 \times 10^6 \text{ radian/sec}$$

$$P_2 = \frac{60(10^5 + 1)}{5} = 1.2 \times 10^6 \text{ radians/sec}$$

The overall combined 3-dB bandwidth is therefore,

$$\omega_{3\ dB} = 0.64P_1 = 7.68 \times 10^5 \text{ radians/sec}$$

$$G_1(0) = \frac{A\mu_1}{A + \mu_1 + 1} \quad \textbf{(4)}$$

$$G_2(0) = \frac{A\mu_2}{A + \mu_2 + 1} \quad \textbf{(5)}$$

The poles of 1 and 2 are:

$$P_1 = \frac{\omega_0(A + 1 + \mu_1)}{1 + \mu_1} \quad \textbf{(6)}$$

$$P_2 = \frac{\omega_0(A + 1 + \mu_2)}{1 + \mu_2} \quad \textbf{(7)}$$

And the end-to-end dc gain is noted by K

$$K = \frac{A^2\mu_1\mu_2}{(A + 1 + \mu_1)(A + 1 + \mu_2)} \quad \textbf{(8)}$$

Using **Eq. 6, 7** and **8** in Lagrange's form, the function F is

$$F = \left[\frac{\omega_0(A + 1 + \mu_1)}{1 + \mu_1}\right]\left[\frac{\omega_0(A + 1 + \mu_2)}{1 + \mu_2}\right] + \lambda \frac{A^2\mu_1\mu_2}{(A + 1 + \mu_1)(A + 1 + \mu_2)} \quad \textbf{(9)}$$

Then, using the calculus, the poles of **Eq. 9** will be optimized subject to the constraint K. The partial derivatives of F with respect to μ_1 and μ_2 are:

$$\frac{\partial F}{\partial \mu_1} = \frac{-\omega_0^2A(A + 1 + \mu_2)}{(1 + \mu_1)^2\ (1 + \mu_2)} + \frac{\lambda\ A^2\mu_2(A + 1)}{(A + 1 + \mu_2)(A + 1 + \mu_1)^2} \quad \textbf{(10)}$$

$$\frac{\partial F}{\partial \mu_2} = \frac{-\omega_0^2A(A + 1 + \mu_1)}{(1 + \mu_2)^2\ (1 + \mu_1)} + \frac{\lambda\ A^2\mu_1\ (A + 1)}{(A + 1 + \mu_1)(A + 1 + \mu_2)^2} \quad \textbf{(11)}$$

A considerable amount of manipulation is involved in the simultaneous solutions for μ_1 and μ_2, and for brevity, will not be shown here. However, the procedure for those who wish to work through the solution is as follows: First, set **Eq. 10** and **11** to zero. Multiply **Eq. 10** by $\frac{A + 1 + \mu_1}{A + 1}$ and **Eq. 11** by $\frac{A + 1 + \mu_2}{A + 1}$. After multiplying, add both equations and solve for λ. Substitute the solution for λ back into **Eq. 10** and **11** and simultaneously solve for μ_1 and μ_2. The results for μ_1 and μ_2 are:

$$\mu_1 = \frac{A + 1}{\frac{A}{\sqrt{K}} - 1} \quad \textbf{(12)}$$

$$\mu_2 = \frac{A + 1}{\frac{A}{\sqrt{K}} - 1} \quad \textbf{(13)}$$

Substituting **Eq. 12** and **13** into **Eq. 4** and **5**, respectively, gives the dc gain in terms of K.

$$G_1(0) = \sqrt{K} \quad \textbf{(14)}$$

$$G_2(0) = \sqrt{K} \quad \textbf{(15)}$$

And the poles for maximum bandwidth are:

$$P_1 = \frac{\omega_0(A+1)}{1+\sqrt{K}} \quad (16)$$

$$P_2 = \frac{\omega_0(A+1)}{1+\sqrt{K}} \quad (17)$$

These results indicate that the closed-loop gain and bandwidth of sections 1 and 2 are equal for optimum bandwidth.

In the above analysis it was assumed that each amplifier had one pole. However, all amplifiers have more than a single pole, which usually occurs after crossover, and often the phase contribution of additional poles give rise to overshoot in the step response. Although the proof is not shown here, the result of **Eq. 12** and **13** are equally applicable for a number of poles.

The transfer function of sections 1 or 2 (1 is shown) in terms of K is:

$$G_1(\omega) = \frac{\omega_0\sqrt{K}(A+1)}{j\omega + \dfrac{\omega_0(A+1)}{1+\sqrt{K}}} \quad (18)$$

And the perfectly general result for N amplifiers in tandem is:

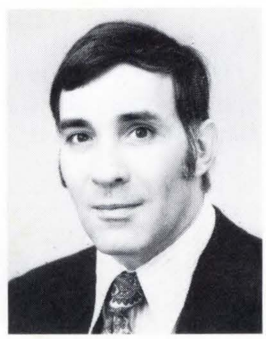
$$\mu_i = \frac{A+1}{\dfrac{A}{(K)^{1/N}} - 1} \quad (19)$$

$$P_i = \frac{\omega_0(A+1)}{(K)^{1/N}+1} \quad (20)$$

The example in the accompanying box shows how **Eq. 12** through **17** is used in an actual application. □

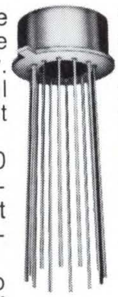
Reference:
Taylor, Angus E., *Advanced Calculus*, Ginn and Company, pp. 198, 199.

Author's biography



Ronald Saracco is a senior development engineer at the Norden Div. of United Aircraft Corp., where he has been employed for 14 years. He is presently involved in circuit design analysis in the Data Processing Dept. Mr. Saracco attended Columbia Univ.

RCA's new amplifier may turn you off!



Actually, it may turn your system off. Or turn it on. Because the new CA3094 linear amplifier is also a very effective Power Switch that can operate off a single power supply. That's right!...a programmable Power Switch/Amplifier all in one TO-5 package. And this makes it one of the most flexible devices available to you today.

For example, the CA3094 has high power capability (10 watts peak or 3 watts average), ideal for controlling thyristors, relays, lamps, etc. Yet it can be programmed to idle at microwatt power levels, a real plus in low duty cycle applications.

And its programmable input impedance allows you to design economical timer circuits with delays in excess of four hours.

Add to this, programmable strobing, gating, squelching and AGC capabilities and an excellent THD (@ 0.6 W in class A operation of 1.4% typ), and you can see why applications for the CA3094 are almost endless.

And variety of applications is where this device really shines. Whether you're designing error signal detector systems (temperature, motor speed controls), alarm systems, analog timers, long time ramp generators, high power single-ended class A amplifiers, automotive or process control systems or even household appliances, the CA3094 should be your top choice.

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*Type	Voltage Single Supply	Gain	Voltage Dual Supply	Output Current Peak	Output Current Average
CA3094T	24V	100dB typ.	±12	300 ma	100 ma
CA3094AT	36V	100dB typ.	±18	300 ma	100 ma
CA3094BT	44V	100dB typ.	±22	300 ma	100 ma

*These three types are also available in formed-lead TO-5 for dual-in-line socket configuration, as CA3094S, CA3094AS, and CA3094BS.

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A technique called intermediate coding exploits the fact that column patterns tend to become highly redundant as matrix size increases.

Dale Mrazek, National Semiconductor Corp.

Conventionally, the number of bits in a digital character generator's read-only memory is proportional to the number of dots in the character matrix. That is, the ROM array ordinarily doubles and redoubles in size as one scales up the resolution or changes from an upper-case only to an upper-case/lower-case font.

Fortunately, such progressions are not always required. Reorganizing the ROMs to suit the specific application can often save thousands of bits and allow the designer to use smaller, faster and more economical monolithic ROMs. As a simple example, if you expand the array in 32-character subsets rather than the more conventional 64-character subsets, you will enhance performance and save up to 25% of ROM capacity in typical upper-case/lower-case (UC/LC) applications.

Savings much greater than 25% are possible when the matrix size reaches the point where several monolithic ROMs are needed to store the font. In cases like these, a 2-stage, column-generation approach called "intermediate coding" has been found to be much more efficient than straightforward dot-matrix generation. Intermediate coding exploits the probability that column patterns will become highly redundant as the matrix size increases.

One version of this new technique automatically proportions character widths, as in letterpress print-

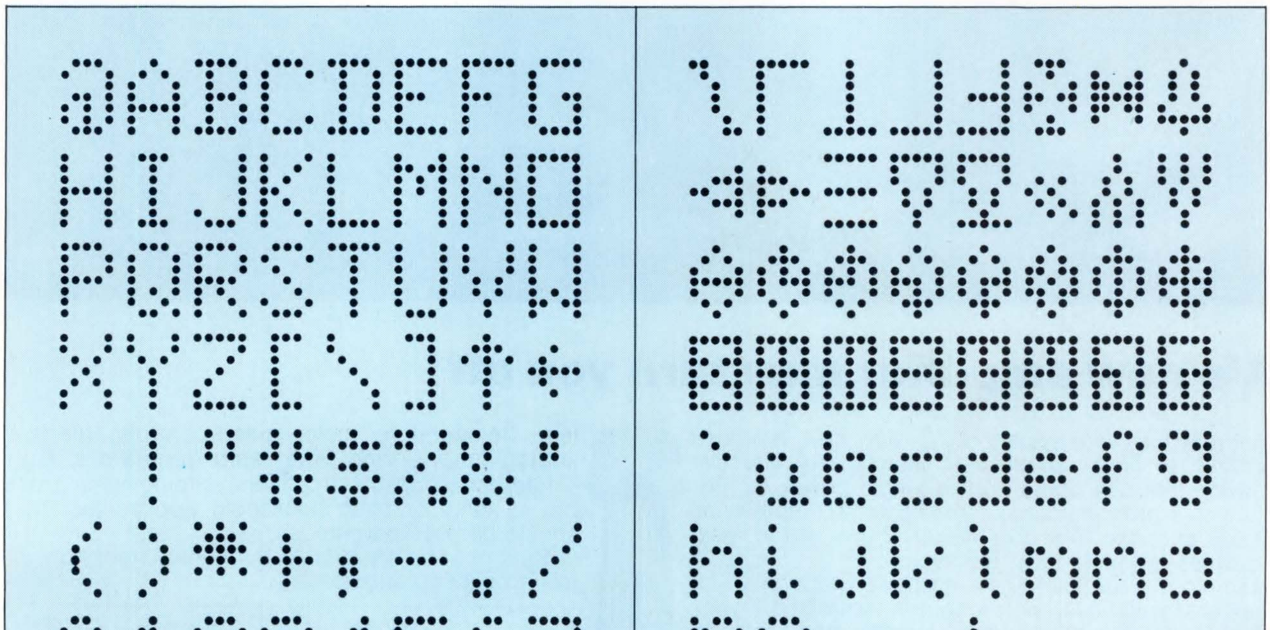

Fig. 1 — The ASCII full set font consists of 154 5 × 7 characters and control symbols.

ing. This gives each character a more natural shape and eliminates the irregular spacings usually seen around "I" and other narrow characters. Yet, the control logic is simple, and the ROM savings approach 40% for typical font sizes. Such advantages are available immediately, without development of special ROMs. The designs can be implemented with standard MOS or bipolar ROMs currently in production. In fact, intermediate coding broadens cost/performance options by allowing a combination of MOS and bipolar ROMs to be used.

Dot-character fonts come in many sizes

Dot-character styles ranging in complexity from 5 × 7 to 12 × 24 or more dots per character have been developed to meet the human-engineering standards of various industries using digital displays and printers. Popular sizes are listed in **Table 1.**

The 5 × 7 fonts (**Fig. 1**) are most widely used due to their cost attractiveness for low-cost data interface terminals (although some terminal manufacturers are going to larger sizes in response to complaints that 5 × 7 presentations cause eyestrain). In other applications, a standard is often set by older printing techniques. To cite a few examples: business-machine users are accustomed to typewriting; advertisers want characters with "sales appeal" on their billboard displays; traffic-control signs must be read easily at a distance; and electronic printing systems

TABLE I – TYPICAL DOT-MATRIX CHARACTER FONTS

Size and scanning	Dots per character	Theoretical character ROM	Design effectiveness	Practical designs
5 X 7 Horizontal	35	64 X 7 X 5 = 2500	1.00	Fig. 3
7 X 5 Vertical	35	64 X 5 X 7 = 2560	1.00	Fig. 3
7 X 9 Horizontal	63	64 X 9 X 7 = 4032	0.67	Fig. 6 & 7
9 X 7 Vertical	63	64 X 7 X 9 = 4032	1.00	Fig. 5 & 8
7 X 12 & 8 X 12 Horizontal	96	64 X 12 X 8 = 6144	1.00	Fig. 6 & 7
12 X 7 & 12 X 8 Vertical	96	64 X 8 X 12 = 6144	1.00	Fig. 8
12 X 16 Horizontal	192	64 X 16 X 12 = 12,288	1.50 for Fig. 9a	Fig. 8
16 X 12 Vertical	192	64 X 12 X 16 = 12,288	1.50 for Fig. 9a	Fig. 6 & 7 Fig. 9
24 X 12 Vertical	288	64 X 12 X 24 = 18,432	2.00 For Fig. 9b	Fig. 6 & 7 Fig. 9
64 X 13 X 10 to 64 X 13 X 16 Variable font width	208	64 X 13 X 16 = 13,312	3.06 for Fig. 10	Fig. 10

may have to simulate several metal-type fonts.

The matrix size is also frequently enlarged to improve lower-case character definition in upper-case/lower-case applications. A 5 × 7 font typically grows to 7 × 9 for UC and 7 × 12 for LC, as in **Fig. 2**. Likewise, 7 × 9 is expanded to 8 × 12 and 12 × 16 to 12 × 24 for LC.

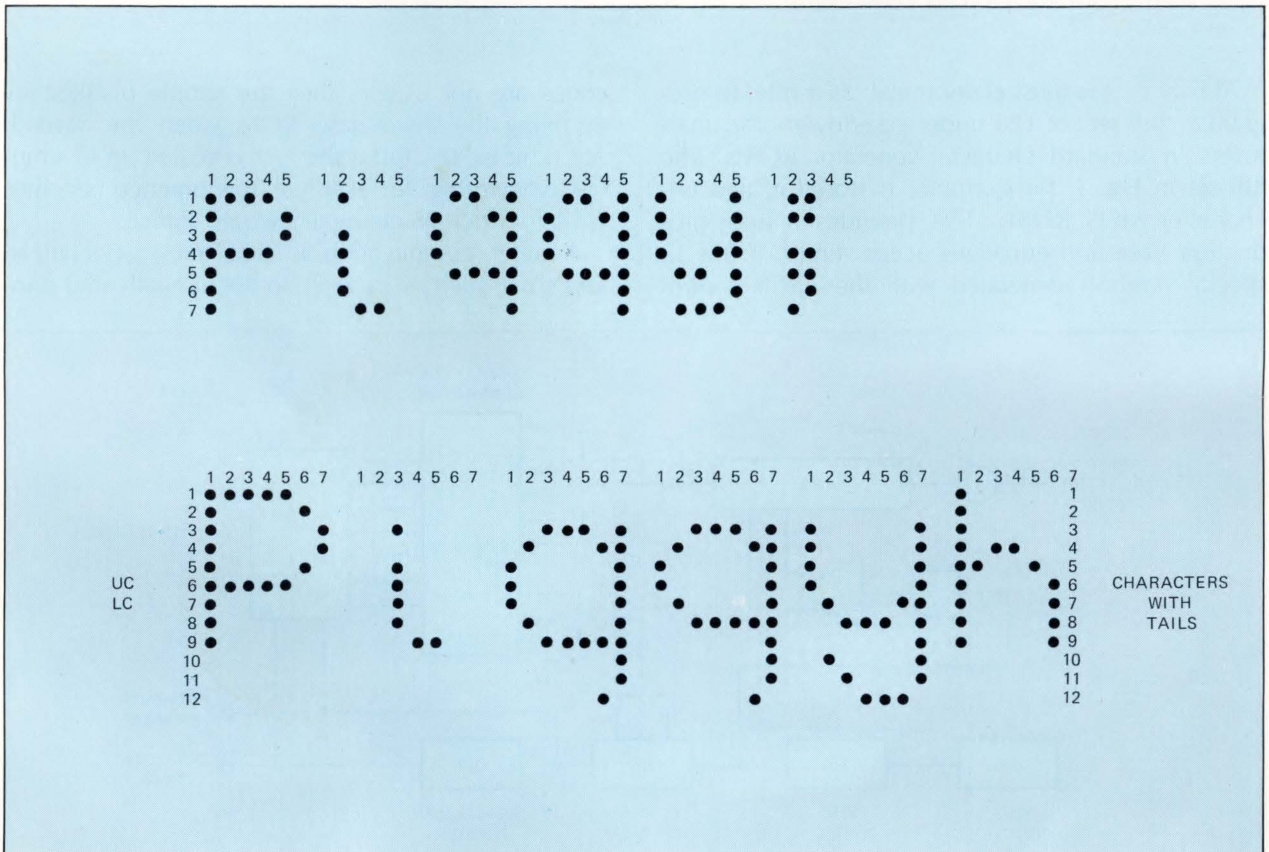

Fig. 2 – Lower-case character definition is often improved by an increase in the dot matrix size.

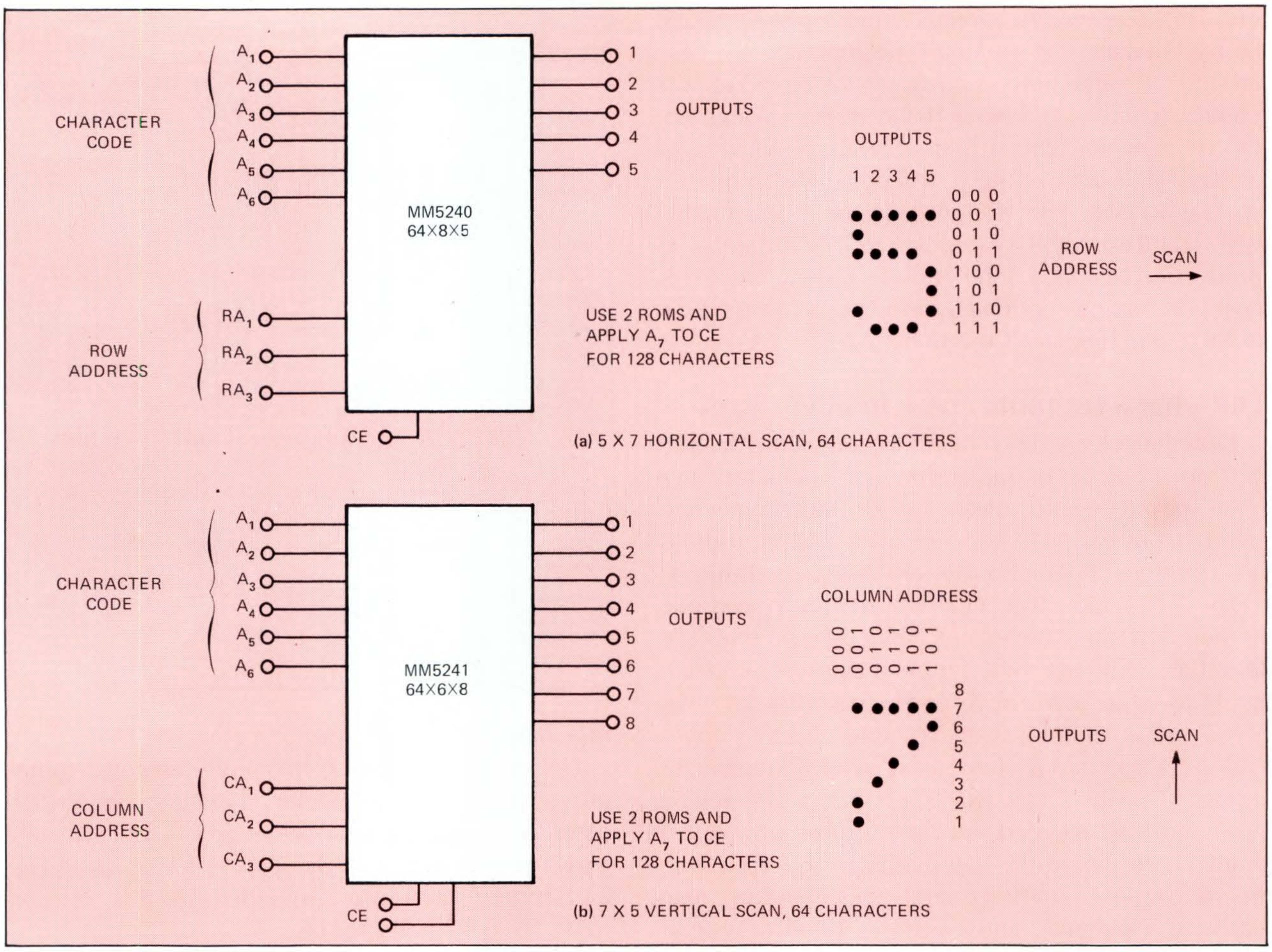

Fig. 3—Standard character-generator ROMs such as these can be adapted to a variety of font sizes.

At 5 × 7, it is most economical, as a rule, to program a "full set" of 128 upper-case/lower-case characters in standard character-generator ROMs. The full set in **Fig. 1**, for example, is stored in two 64-character MOS ROMs. This provides a mass-production base and equalizes access times. If the 32 special symbols generated with the ASCII control codes are not usable, they are simple blanked by disabling the lower-case ROM when the seventh ASCII bit is "0". But if the font is scaled up to simulate typewriting, for example, this practice becomes wasteful since 96 characters would suffice.

Another complication is that many specialized font sizes, such as 11 × 9, do not fit neatly into stan-

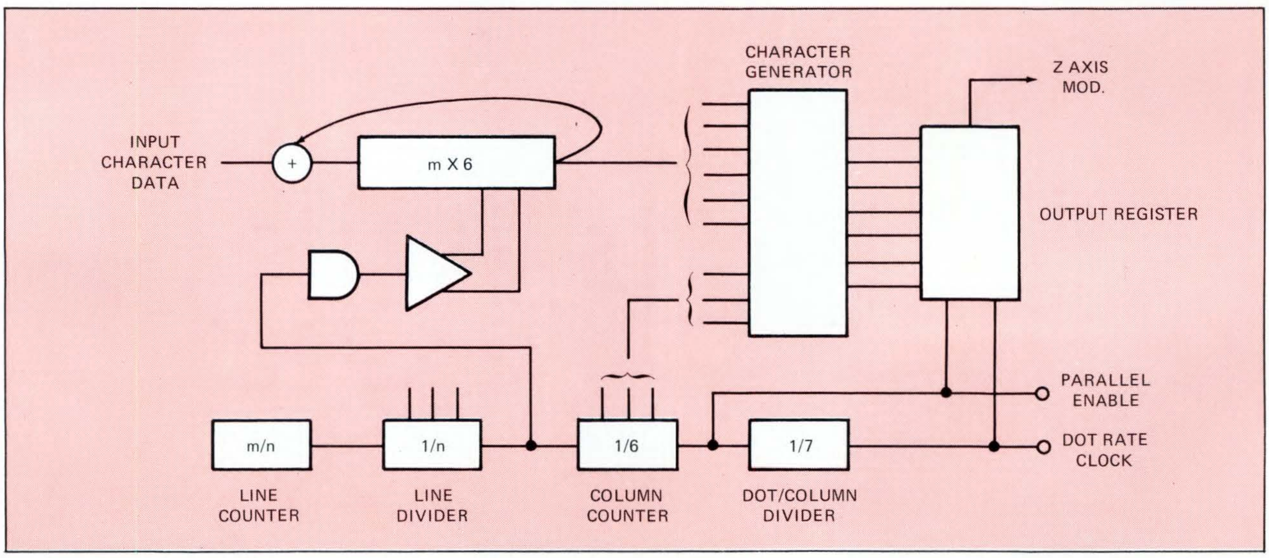

Fig. 4—Typical 7 × 5 vertical-scan character generator requires support logic for its operation.

dard ROMs made in building block sizes. In other words, one cannot store the font in a minimum sized array without paying the extra costs of custom ROM development or specialized low-volume ROMS.

Consequently, character-generator ROMs have been developed that adapt to a variety of font sizes. They may not exactly fit the minimum matrix array at odd sizes, but that is easily offset by the economy of parts standardization. Two such MOS ROMs are outlined in **Fig. 3** together with their addressing for 5 × 7 horizontal scanning and 7 × 5 vertical scanning. The vertical-scan subsystem in **Fig. 4** shows the amount of support logic typically required in that type of display.

The MM5240 of **Fig. 3a** expands in a straightforward manner in 64-character increments to larger fonts, such as the 9 × 7 or 10 × 8 arrays shown in **Fig. 5**. An expansion, such as **Fig. 5**, would be used to provide a full set upper-case/lower-case font. These expansions keep the character rate the same as at 5 × 7, whereas doubling the size of each monolithic ROM would not.

A similar expansion of the MM5241 of **Fig. 3b**, as in **Fig. 6**, would provide 7 × 9 to 8 × 12 horizontal

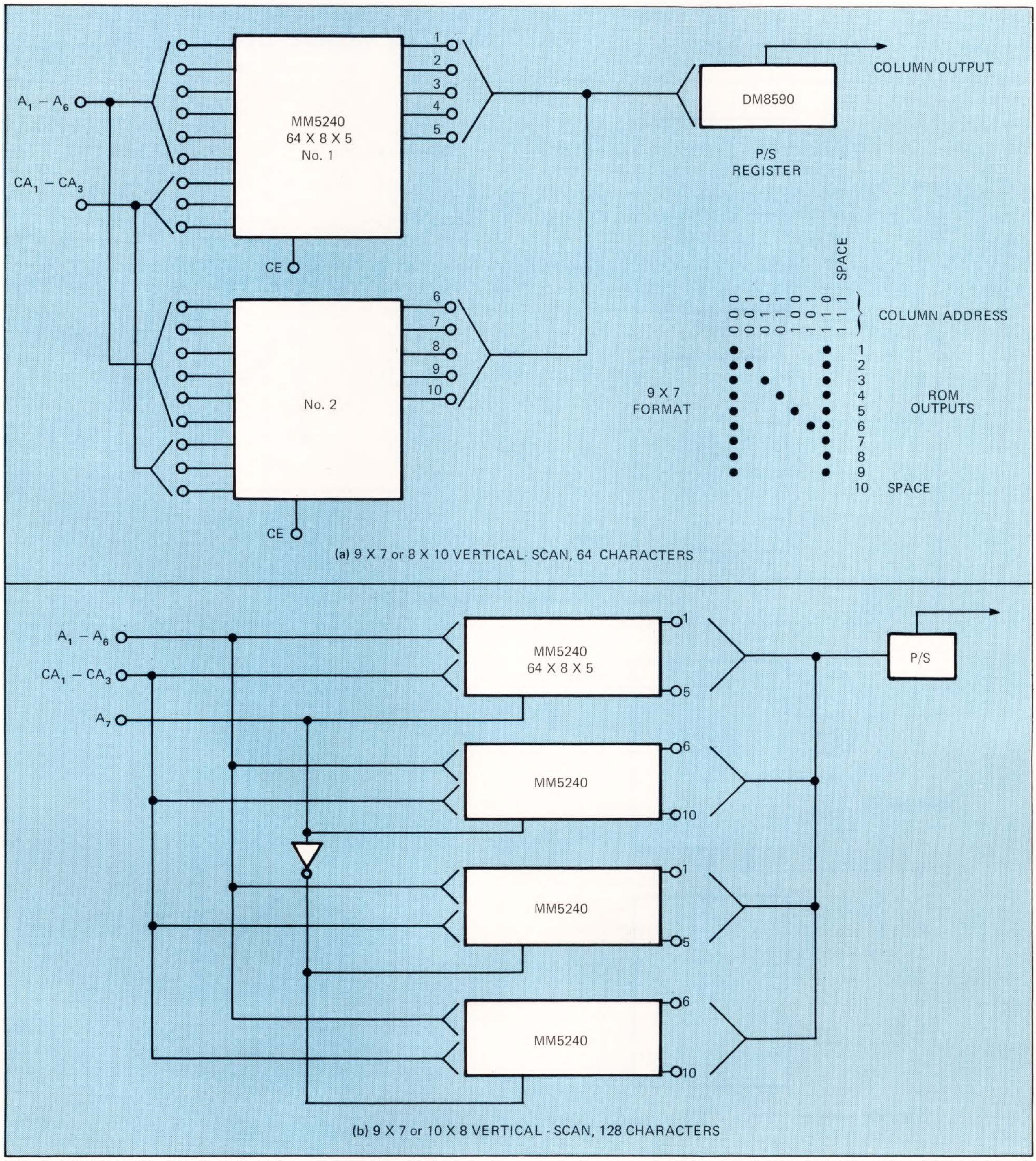

Fig. 5 — Larger fonts such as these are possible by expanding the 5 × 7 MM5240 of **Fig. 3a.**

scan fonts. However, the direct 64-character expansion places a ROM-enabling operation in the middle of the character. Such operations are common in large-font generator designs.

A simple solution to this problem is to "steal" a character-address input, use it as a row-address input, and then use a chip-enable input as a character input (**Fig. 6**). This provides a 32-character or 64-character block enabled during the between-characters spacing interval. A 32-character block would be the only ROM required in a system using only numbers and symbols. However, the chief attraction of this conversion is in upper-case/lower-case applications. **Fig. 7** shows how to use three ROMs to generate 96 7 × 9 to 8 × 12 horizontal-scan characters—a 25% savings compared with a "full-set" expansion. The chip-enable inputs are programmed to sense the sixth and seventh character-address bits. External decoders aren't needed.

If each ROM in **Fig. 7** is replaced with a parallel assembly of three ROMs (24 outputs), the result is a 24 × 12, 96-character vertical-scan generator having the same character rate as at 8 × 12. In other words, the 32-character approach maintains the benefits of parts standardization and performance up to a very high resolution.

Other ROMs can be used in this fashion. In **Fig. 8**, the MM5227 Tri-State and MM5228 256 × 12 ROMs are shown in expansions that complement those of the MM5241. These ROMs provide access

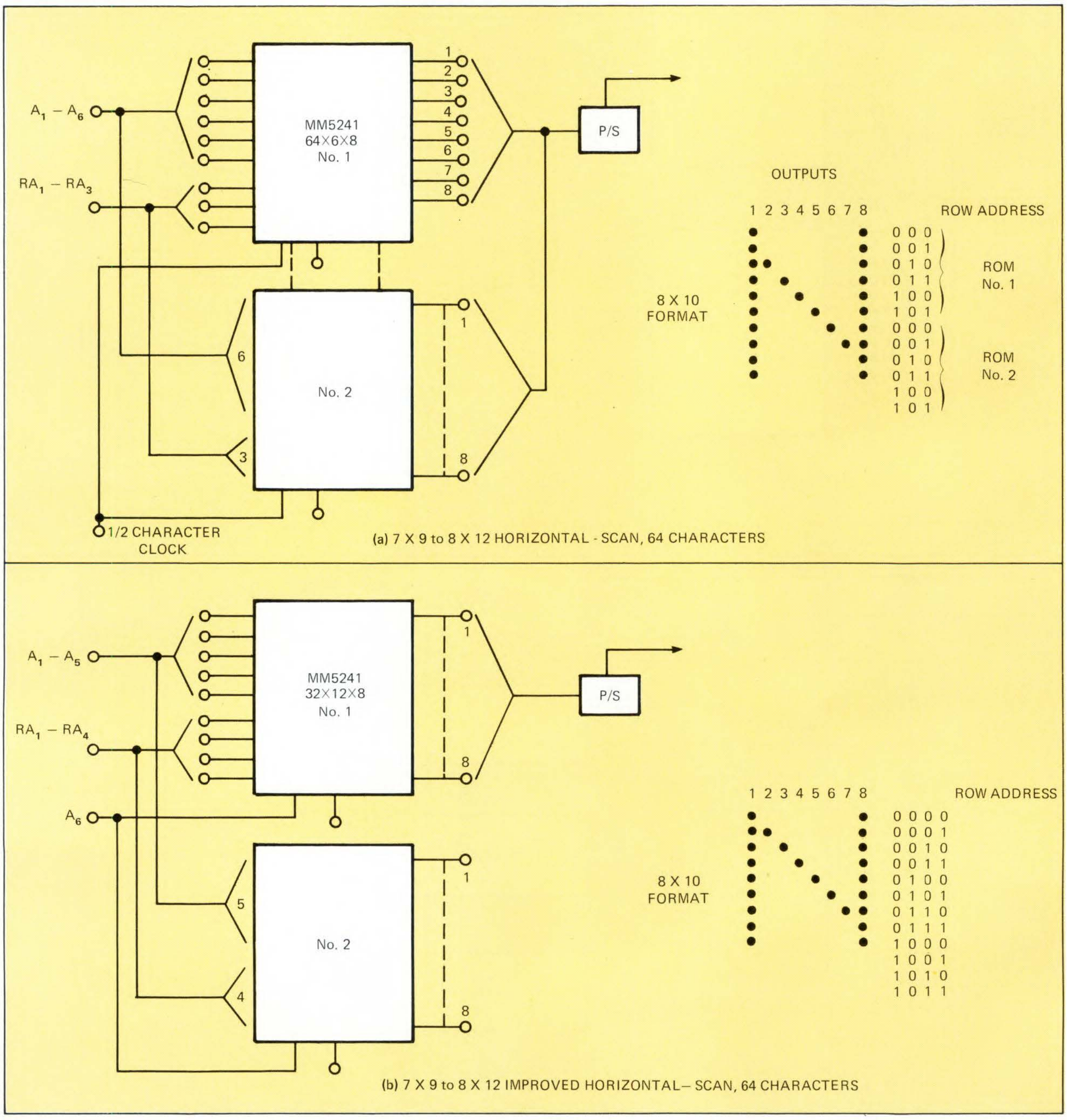

Fig. 6—Conventional and improved expansions of the 7 × 5 MM5241 of **Fig. 3b** are possible.

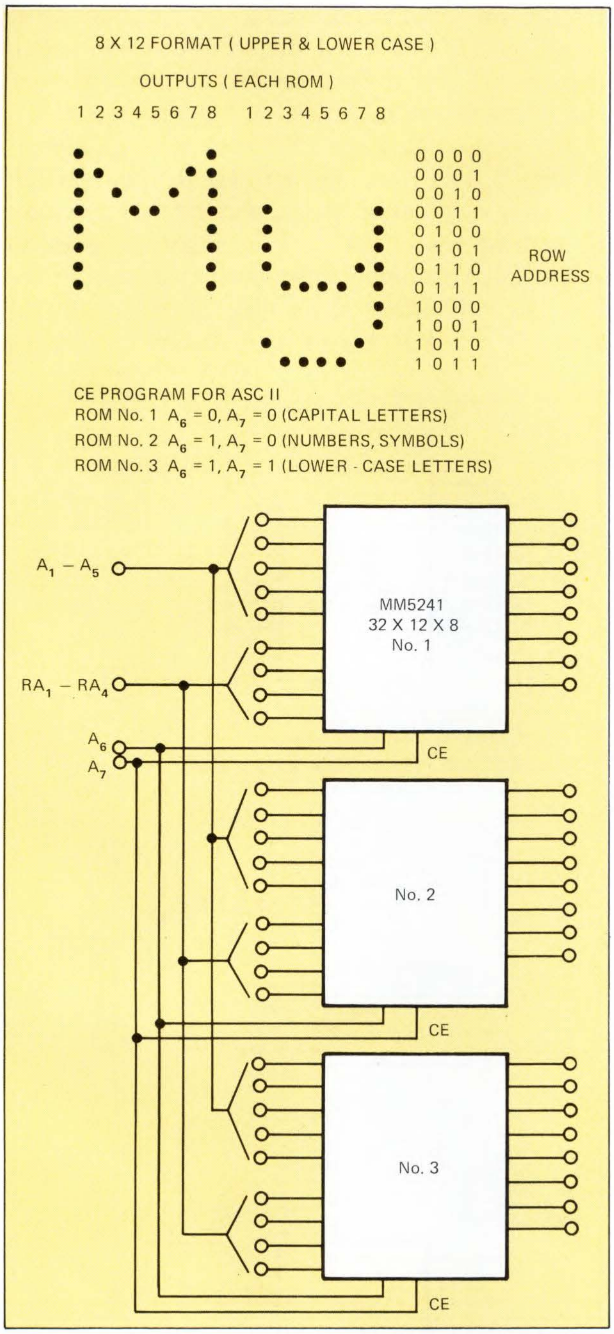

Fig. 7 — Three 32-character ROMs can be expanded to produce a 7 × 12 or 8 × 12 96-character generator.

times well under a microsecond. For rates in the nanosecond range, general-purpose bipolar ROMs having four or eight outputs, such as the DM8597 256 × 4 and DM8575 512 × 8 can be worked into similar organizations.

Intermediate coding saves bits

Designs proportioned to the matrix size are not the most efficient at larger font sizes. It pays to analyze the actual character patterns to determine whether other organizations can be used. For example, the full-dot columns in such vertical-scan characters as b, B, d, D, H, T, etc., are usually identical. An upper-case font typically contains only 60 unique column patterns at 7 × 5, 110 at 9 × 7, 120 at 11 × 9 and 122 at 16 × 12. Theoretically, they could all have been unique, since there is a possible pattern variation ranging from 128 to 65,536 (2^7 to 2^{16}). Upper-case/lower-case and horizontal-scan fonts are more variable than upper-case vertical-scan fonts, but they are still far from worst-case.

The preceding analysis of full-dot columns led to the organization of **Fig. 9**. Instead of doubling the 64 × 12 × 8 organization to produce fonts up to 16 × 12, it adds only a 2k ROM. Up to 128 unique column patterns are stored in 8-bit, half-column segments in the MM5231 256 × 8 ROM. These are accessed with 7-bit intermediate codes selected with the input array and a half-column clock at a submul-

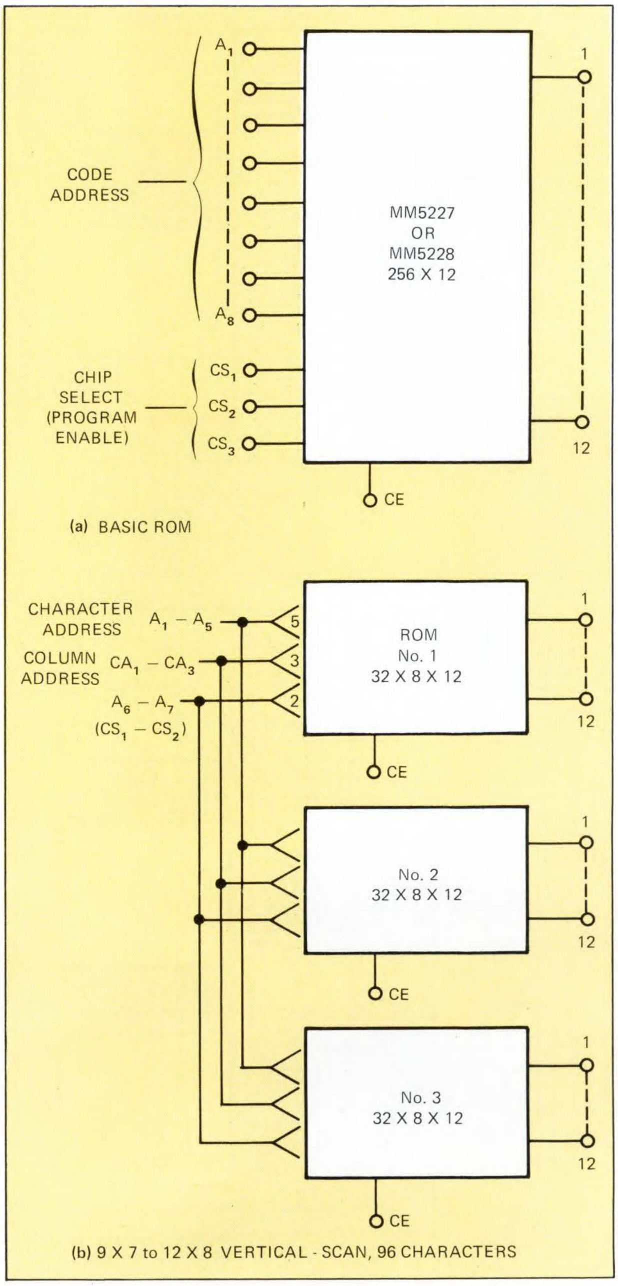

Fig. 8 — Other general-purpose ROMs can be expanded to very high resolutions.

tiple of the dot rate. The intermediate codes necessary to form each character are simply listed in character-generator fashion in the input code converters. At 16 × 12, the reduced requirements for an upper-case font are from 12k to 8k, or a reduction of 4 kilobits (33%).

Since the 8-bit outputs of the 256 × 8-bit ROMs actually allow 128 unique columns to be selected, the savings could grow rapidly through several expansion levels, even without further rearranging. If more than 128 unique column codes are required, the second ROM in the string can be changed to possibly a 512 × 8 ROM, thereby giving 256 unique columns which can be generated for the larger fonts and character group sets (96 or 128 characters).

Assuming a 16 × 12, 96-character requirement, the 256 × 8 ROMs added as in **Fig. 9** would provide 192 unique column patterns, and the savings would be at least 18k − 12k = 6k. It might be necessary at the 24 × 12 upper-case/lower-case size to use two 256 × 12 ROMs in parallel, but this would still save 27k − 15k = 12k (or perhaps 36k − 18k in a

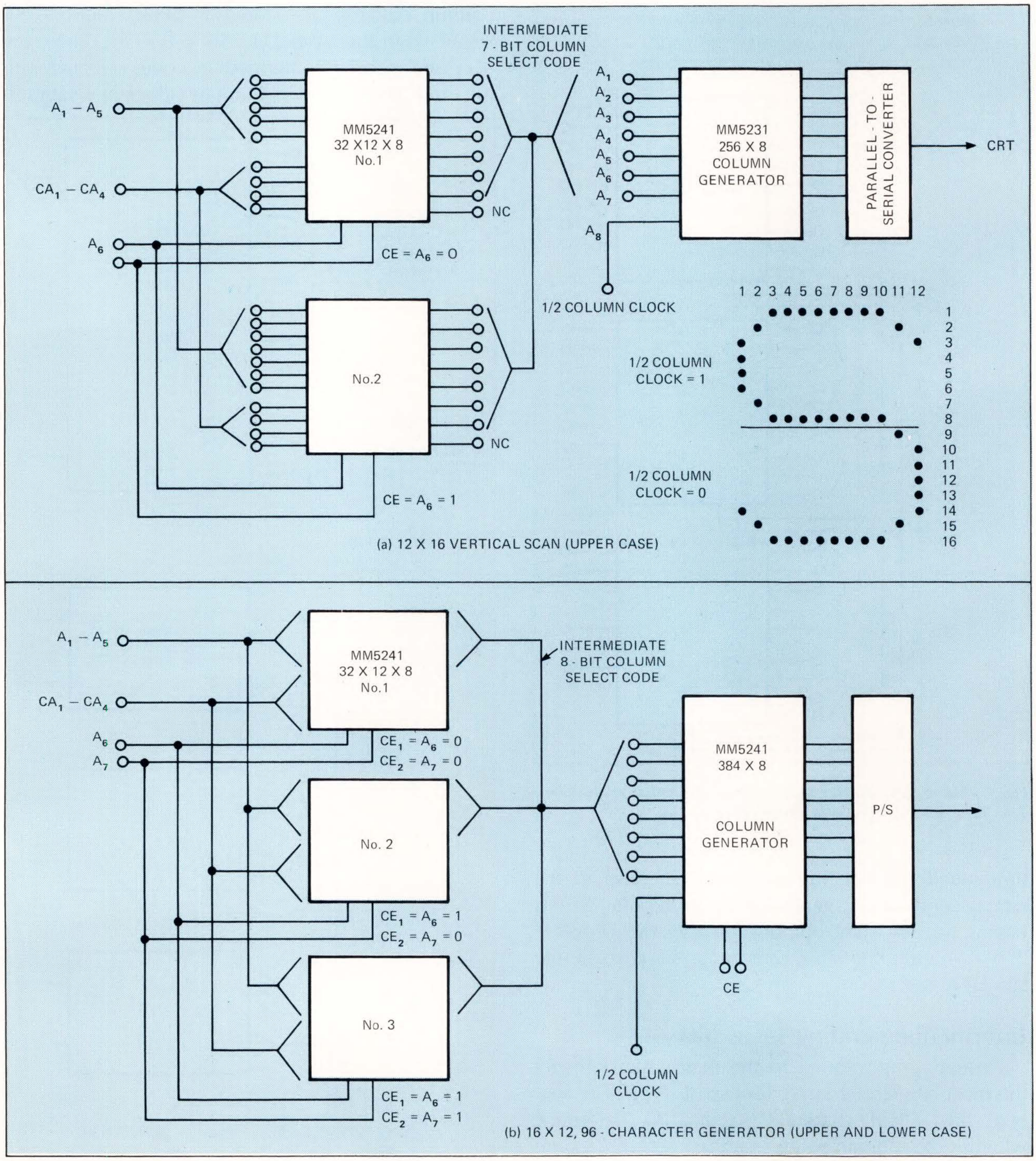

Fig. 9—Intermediate coding schemes such as these are devised by analyzing the actual character patterns to be generated. They require considerably less ROM capacity than would conventional ROM expansion.

128-character application, using four input and two output ROMs). The efficiency grows with font size because the column patterns become redundant.

At first glance, the organization appears to double the access time because there are two stages to be accessed in sequence. But since there is no feedback, the stages can operate in a ripple mode. Thus, an 8-bit bipolar register can be inserted between the stages to temporarily store each intermediate code. This restores the overall access time to that of the slowest ROM in the series (e.g., less than a microsecond for MOS ROMs), and the character rate is essentially the same as that achieved with conventional ROM techniques.

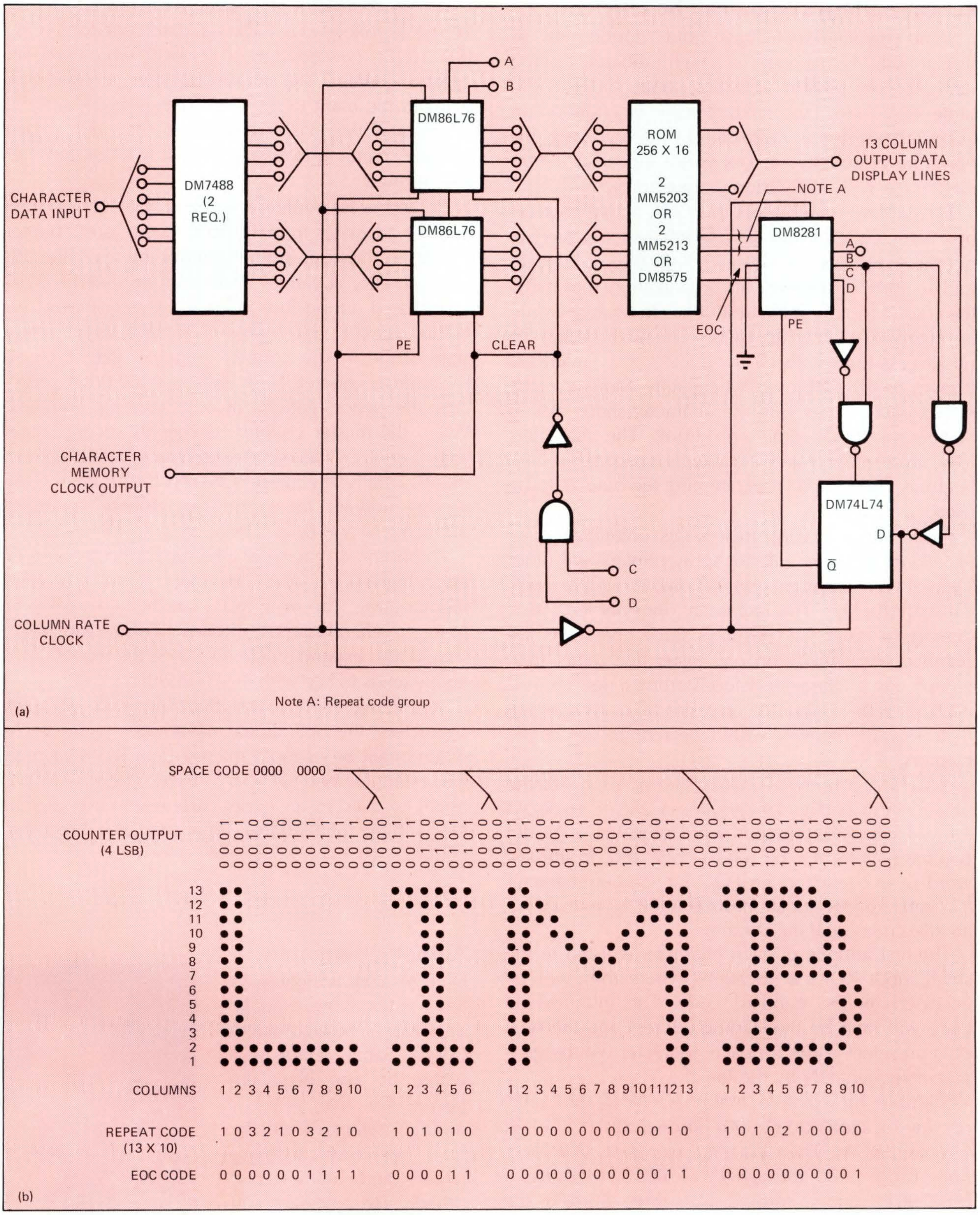

Fig. 10—Repeat-pattern vertical-scan generator (a) holds the vertical column output static until it has to change. The design produces a variable-width matrix, which results in a very pleasing character appearance (b).

Alternatively, the output ROM, the input ROM, or both may be bipolar to increase the rate. The DM8575 512 × 8 ROM fits most large-font geometries quite well and costs less than subassemblies of 1k bipolar ROMs. Again, an intermediate register will maximize the rate.

Repeat-pattern coding can be efficient

Some character styles have bold "double dot" or similar patterns that result in a high probability of the same column pattern repeating sequentially in the same character. This characteristic is common in ticker-tape systems, large-panel and billboard displays, news bulletins broadcast to appear as a running line across a television picture and so forth.

Typical fonts exhibit less than 256 actual changes of column patterns through a 64-character sequence, not the worst-case of 320 at 7 × 5, 640 at 10 × 8, and so forth. Therefore, an organization that holds the column output static until it has to change would be highly efficient. **Fig. 10** is a practical design for upper-case fonts with 10 × 10 to 13 × 10 matrices. It saves nearly 40% of ROM capacity. Moreover, the matrix width varies with the character shape as can be seen in the example word LIMB. The characters look more natural and are evenly spaced. Column height is changed by programming the outputs to be used.

Proportional spacing makes this organization an excellent choice for ink-dot spray printers and other "line-of-type" printing applications, as well as vertical-scan displays. This technique does not lend itself directly to raster-scan displays since characters are scanned sequentially on one raster line rather than completing a character before starting a new character. To use this technique on raster scan, an intermediate storage memory would be required as a line memory.

Assuming a nominal matrix size of 13 × 10, the organization of **Fig. 10** requires a 256 × 16 ROM array. Each 16-bit output word contains a 13-dot column pattern, a 2-bit repeat code and, in the last word of a character, an EOC bit (end-of-character "1" bit). Address location 0000 0000 is reserved for an all-zeroing spacing column.

The first address of each character is listed in the small input ROM at locations where they will be accessed by the standard code. The intermediate code will then be the starting address and the next column-select codes for each character will be generated sequentially by the logic.

Suppose, for example, that character @ through K occupy locations 0000 0001 through 0010 1111 in the main ROM. Then L's three words occupy locations 0011 0000 through 0011 0010, M starts at 0011 0011, and so forth. L takes three words at the 13 × 10 size since the 2-dot bar pattern can be repeated only four times with a 2-bit repeat code. If the columns were programmed 12 or less dots high, a 3-bit repeat code could be used. L would be generated with two words, and single-pattern characters like "dash" with one word. This solution uses only 2 × 16 = 32 bits of storage for the character L, compared with the present technique of 10 × 12 = 120 bits.

The procedure for generating the word LIMB (**Fig. 10b**) is as follows: First, the standard code for L (e.g., 001 100) is converted to 0011 0000, which sets the address counter. The address counter accesses that word in the main ROM, and the repeat code in the output sets the master counter to time out in two column scanning intervals. L's first two columns are thus formed.

At the master counter's terminal state, the address counter advances to 0011 0001, the master counter is reset to time out in four column intervals, the address counter advances again and word 0011 0010 is accessed during four intervals. This last word includes an EOC bit. When EOC and the time-out state of the master counter coincide, gate 1 clears the address counter. Now address 0000 0000 generates the space pattern in two spacing columns. When the master counter reaches its second state, gate 2 enables the address counter's parallel preset inputs. Finally, the input ROM sets the counter to the starting address for I and the process continues through I, M and B.

Proportional spacing is inherent in this technique. So is high-speed, since the input ROM is a small bipolar array. The main ROM can be either MOS or bipolar general-purpose ROMs. This organization should also expand efficiently, since the repeat probability tends to rise with matrix width.

In printing applications involving more complex characters, the operational advantages of the technique might be of more interest than ROM savings. For example, two 64 × 6 × 8 or 512 × 8 ROMs might be used as an upper-case/lower-case generator, with the ninth address input used as a direct shift control. ▭

Author's biography

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Choose the right analog multiplier by understanding its limitations

A knowledge of performance limitations of major parameters can be helpful in assuring the proper choice of a monolithic-IC multiplier.

Gilbert Marosi, Intech Inc.

Analog multipliers, particularly the IC-transconductance types, have provided designers with a new dimension in versatility, much like the IC op amp of yesterday. They can be used to multiply, divide, square and take the square root of a wide range of signals. When combined with IC op amps, a large variety of functional-circuit applications can result.

Getting the most usefulness out of analog multipliers, however, requires a thorough understanding of how they work. Like many other ICs, the monolithic-analog multiplier can catch a designer off guard if he relies on the data sheet alone. Limitations and unfortunate surprises not presented in the specs can be foreseen by a study of the circuit itself.

This article will demonstrate how a transconductance multiplier works and shows its intrinsic limitations on accuracy, feedthrough, linearity and frequency response. Other surprises observed empirically, such as the long-term drift phenomenon, will be discussed and the results of successful solutions revealed. External circuits, effective in improving performance of some major parameters, will also be covered in detail. This should give the engineer a better handle on effecting a better total-system design.

Parameters of primary concern for improving IC-multiplier performance are:

- **Dc accuracy** which is specified with reference to the output-voltage swing, generally ±10V.
- **Feedthrough,** which takes on added importance when the multiplier is used in agc applications.
- **Linearity,** a parameter essential for low-distortion applications.
- **Frequency response.** The higher the response, the more application a multiplier has in wideband-analog functions.

The basic multiplier circuit

The transconductance multiplier **(Fig. 1)** is made up of four basic circuit components: two voltage-to-current converters which transform the two input voltages E_x and E_y into currents; a logarithmic-diode circuit which accepts one of these currents; an anti-logarithmic circuit whose output current is a function of the product and sign of the two inputs E_x and E_y; and a turnaround circuit that acts as a buffer and level shifter to make the output "usable" for general-purpose applications.

The voltage-to-current converter **(Fig. 2)** is made up of 7 transistors. Transistors Q_6 and Q_7 are constant-current sources which supply equal biasing to the 4 voltage-to-current converter transistors Q_1, Q_2, Q_3 and Q_4. Summing voltage drops around Q_1, Q_2, Q_3 and Q_4 results in:

$$I_y \approx \frac{E_y - V_{be1} - V_{be2} + V_{be3} + V_{be4}}{R_y + r_{e2} + r_{e3}}; \quad (1)$$

given $V_{be1} = V_{be2} = V_{be3} = V_{be4}$ and $r_{e1} = r_{e2}$ for the E_x voltage-to-current converter,

$$I_y = \frac{E_y}{R_y + 2r_{ey}}; \quad I_x = \frac{E_x}{R_x + 2r_{ex}}$$

The above equation holds true for $I_y < 51$ and $I_x < 51$. Transistors Q_2 and Q_3 are operating in small-signal conditons where r_{e2} and r_{e3} are the small-sig-

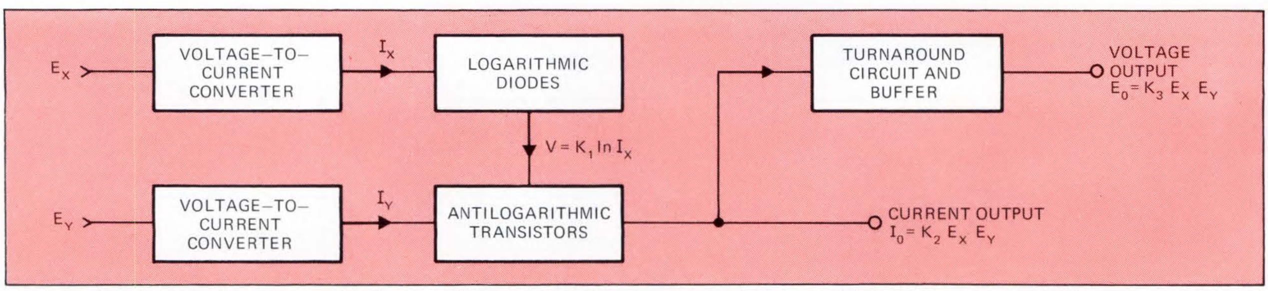


Fig. 1—The transconductance multiplier can be conveniently broken up into four major circuit segments: a pair of voltage-to-current converters, a logarithmic-diode circuit which accepts one of the two currents, an antilogarithmic circuit whose output current is a function of the product and sign of the two inputs E_x and E_y, and a turnaround circuit that acts as a buffer and level shifter to make the output useable for general-purpose applications.

nal incremental-emitter resistances of Q_2 and Q_3.

The frequency response and slew rate of the multiplier is inherently dependent on the size of the voltage-to-current converter's resistors R_y and R_x as shown in **Fig. 3.** Each side of the resistors is shunted by the collector-to-substrate capacitances of constant-current transistors Q_{14}, Q_{15}, Q_{16} and Q_{17}, as well as the intrinsic capacitances of those same transistors.

The output of the multiplier is a differential current out of the collectors of Q_3, Q_4, Q_5 and Q_6. The collectors must be set at no less than +13V for proper operation at $E_y = +10V$. A turnaround circuit (**Fig. 4**) is necessary to convert the differential-current output of the multiplier into a single ended current suitable for conversion into a voltage output by an op amp. The impedance level of this turnaround circuit must be low enough to maintain high-frequency response.

Improving drift

The various drifts encountered in the multiplier are zero-offset drift, feedthrough drift and gain drift. The zero drift is caused by offset-voltage drift in all transistor-pair amplifiers within the multiplier. This is due to beta mismatch between the pairs. Since this beta mismatch in monolithic devices is small, (1 mV/°C at the output is typical) it is not too significant.

Feedthrough drift is caused mostly by offset-voltage drift in the voltage-to-current converter transistors and the six logarithmic and antilogarithmic transistors. This drift causes a finite output for either E_x or E_y equal to zero.

Gain drift is caused primarily by variations of current from biasing the voltage-to-current converter of the multiplier. Gain is inversely proportional to the current. The V_b drift of Q_{18} accounts for a good portion of the gain change with temperature since it is in series with the resistor which sets I_3.

The worst drift in a modified circuit is a negative scale-factor temperature coefficient of 0.05%/°C. The gain goes up as the temperature goes down and vice versa. The solution to the drift problem is to select the gain-determining resistors R_x, R_y and R_3 in the voltage-to-current converter with a temperature coefficient which nullifies the inherent negative temperature coefficient of the scale factor.

It was found that 1/8W glass-composition resistors could be selected with either positive or negative temperature coefficients such that temperature compensation was achieved with a resulting scale-factor temperature coefficient of 0.01%/°C.

Logarithmic and antilogarithmic circuits

The function of Q_1 and Q_2 in **Fig. 5a** is to take the logarithm of both currents $(I + I_y)$ and $(I - I_y)$, and apply the resulting logarithmic voltage to the antilogarithmic circuits Q_3, Q_4 and Q_5, Q_6 whose output is the product of both E_x and E_y.

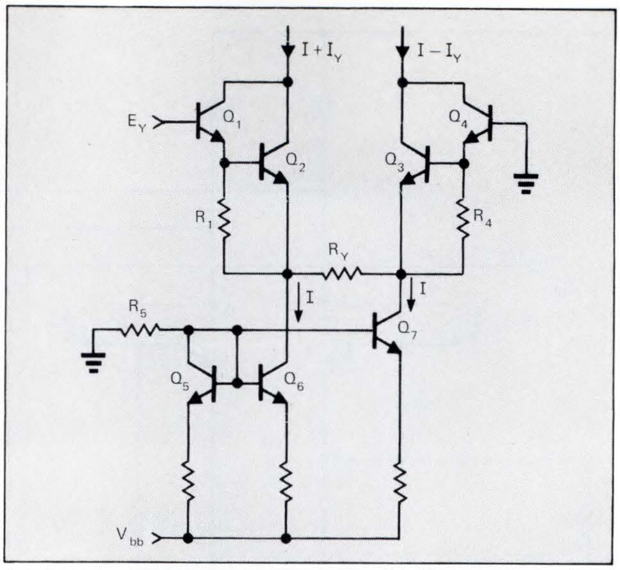


Fig. 2—A voltage-to-current converter circuit contains a pair of transistor constant-current sources (Q_6 and Q_7) which supply equal biasing currents to transistors Q_1 through Q_4.

To analyze the circuit of **Fig. 5a,** break it down into a simpler circuit as in **Fig. 5b.**

Summing voltage drops around Q_1, Q_2, Q_3 and Q_4 results in the following equations:

$$-\frac{KT}{Q}\ln\frac{I_3}{I_S} - \frac{KT}{Q}\ln\frac{I_1}{I_S} + \frac{KT}{Q}\ln\frac{I_2}{I_S} + \frac{KT}{Q}\ln\frac{I_4}{I_S} = 0 \qquad (2)$$

I_S is the reverse-saturation current of the emitter diodes. The above equation reduces to:

$$-\ln\frac{I_3}{I_4} - \ln\frac{I_1}{I_2} = 0;\ \text{and}\ \frac{I_4}{I_3} = \frac{I_1}{I_2}.$$

Since $I_1 + I_2 = I$, then

$$\frac{I_4}{I_3} = \frac{I_1}{I - I_1}\ \text{and solving for}\ I_1\ \text{and}\ I_2$$

$$I_1 = \frac{I}{\frac{I_3}{I_4} + 1}\ \text{and} \qquad (3)$$

$$I_2 = \frac{I}{\frac{I_4}{I_3} + 1} \qquad (4)$$

If both of these currents are added into equal resistors, the differential voltage is

$$V = \frac{I_K I + I_x I_y}{I} - \frac{I_K I - I_x I_y}{I} V = \frac{2 I_x I_y}{I} R \qquad (5)$$

Substituting **Eq. 1** into **Eq. 5,**

$$V = \left(\frac{2\,E_x}{R_x + 2r_{ex}}\right)\left(\frac{E_y}{R_y + 2r_{ey}}\right)\left(\frac{R}{I}\right); \qquad (6)$$

where E_x and E_y may be of either polarity.

Eq. 6 shows that the gain of the multiplier is inversely proportional to the biasing current of the E_y voltage-to-current converter.

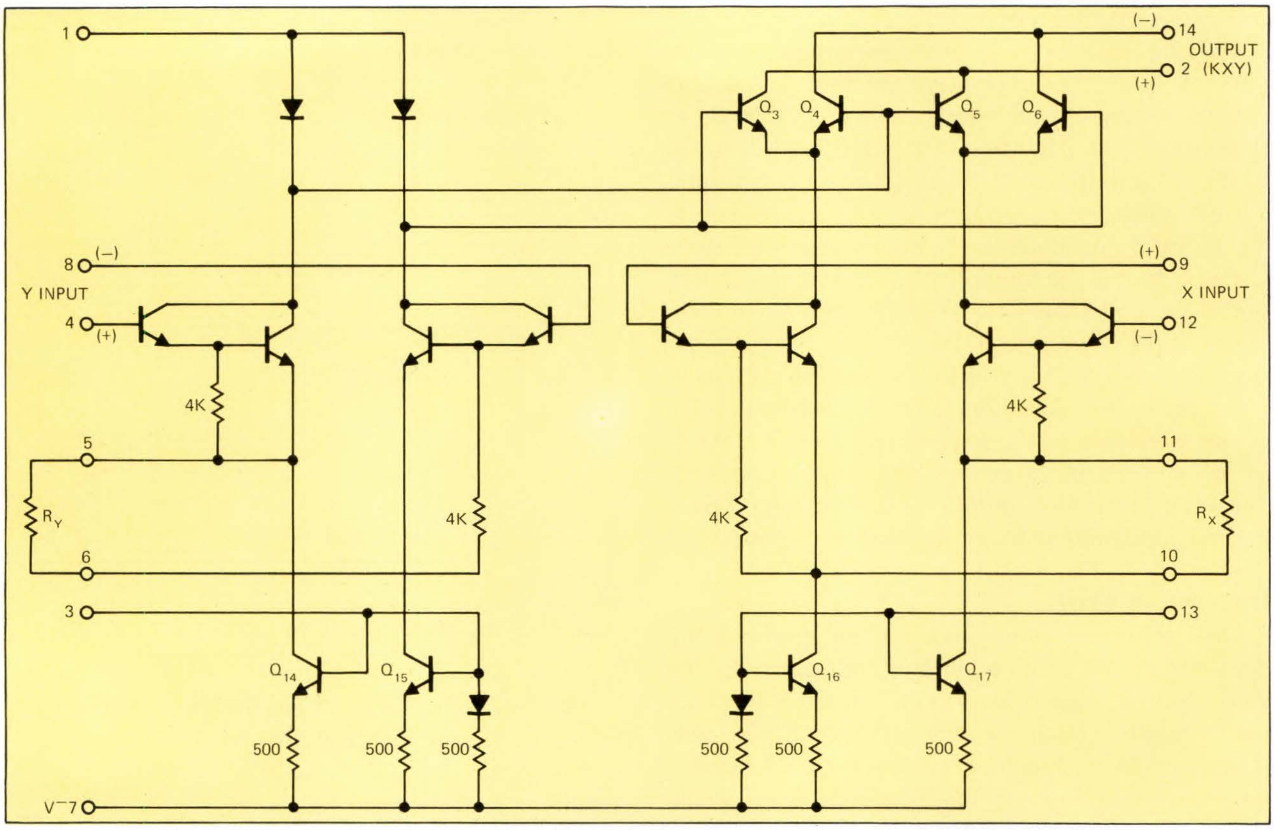


Fig. 3—A typical IC-multiplier circuit. Resistors R_x and R_y, shunted by the collector-to-substrate capacitances of constant-current transistors Q_{14} through Q_{17} as well as their intrinsic capacitances, control the multiplier's frequency response and slew rate.

Improving accuracy

Nonlinearities in the output of the multiplier arise because of ohmic-resistance components and offset mismatch in the 6 transistors of the logarithmic and antilogarithmic circuit of **Fig. 5a.** The major nonlinearity of IC multipliers is offset mismatch in all 6 transistors. To analyze the resulting nonlinearity in the 4-semiconductor circuit of **Fig. 5b,**

$$-\frac{KT}{Q}\ln\frac{I_3}{I_{S3}} - \frac{KT}{Q}\ln\frac{I_1}{I_{S1}} + \frac{KT}{Q}\ln\frac{I_2}{I_{S2}} + \frac{KT}{Q}\ln\frac{I_4}{I_{S4}} = 0 \quad (7)$$

I_{S1} through I_{S4} are the reverse-saturation currents of the base-emitter diodes of Q_1 through Q_4, which are now assumed to be different. **Eq. 7** reduces to:

$$-\frac{KT}{Q}\ln\frac{I_3}{I_4}\frac{I_{S4}}{I_{S3}} - \frac{KT}{Q}\ln\frac{I_1}{I_2}\frac{I_{S2}}{I_{S1}} = 0. \quad \textbf{(8)}$$

The above equation may be rewritten as:

$$-\frac{KT}{Q}\ln\frac{I_3}{I_4} - \frac{KT}{Q}\ln\frac{I_1}{I_2} - \frac{KT}{Q}\ln\frac{I_{S4}}{I_{S3}}\frac{I_{S2}}{I_{S1}} \quad \textbf{(9)}$$

to show that different reverse-saturation currents cause an offset voltage of;

$$V_0 = \frac{KT}{Q}\ln\frac{I_{S4}}{I_{S3}}\frac{I_{S2}}{I_{S1}}$$

Offset mismatch occurs because the areas of the base-emitter junctions are not exactly equal. Their reverse-saturation currents are different causing an offset voltage of ρ.

Eq. 8 reduces to:

$$\rho\frac{I_4}{I_3} = \frac{I_1}{I_2}$$

$$\text{Where } \rho = \frac{I_{S3}}{I_{S4}}\frac{I_{S1}}{I_{S2}} \quad \textbf{(10)}$$

$$I_2 = \frac{I}{\frac{\rho I_3}{I_4} + 1} \quad \textbf{(11)}$$

$$I_1 = \frac{I}{\frac{I_4}{\rho I_3} + 1} \quad \textbf{(12)}$$

The above equations determine the nonlinearities due to offset voltages in the input current of any of the antilogarithmic transistors. Referring back to **Fig. 5a,** I_3 and its corresponding nonlinearity can be determined. **Eq. 10** and **Eq. 11** show that

$$I_4 = \frac{I_E}{\frac{\rho(I - I_y)}{(I + I_y)} + 1} \quad \textbf{(13)}$$

where $I_E = I_k + I_x$ and $\rho = \frac{I_{S2}}{I_{S1}}\frac{I_{S3}}{I_{S4}}$ and

$$\frac{I_4}{I_E} = \frac{(I + I_y)}{I(1 + \rho) + I_y(1 - \rho)} \quad \textbf{(14)}$$

where $I_E = I_k + I_x$

The previous equation may be written as follows for $\rho \approx 1$.

$$\frac{I_4}{I_E} = \frac{I}{2I + I_y(1-\rho)} + \frac{I_y}{2I + I_y(1-\rho)} \quad \textbf{(15)}$$

$$\frac{I_4}{I_E} \approx \frac{1}{2} + \frac{I_y}{2I} - \frac{I_y}{4I}(1-\rho)$$

$$\approx \frac{1}{2} + \frac{I_y}{2I} - (1-\rho)\frac{I_y}{4I}\left(1 + \frac{I_y}{I}\right)$$

The above equation may be written as

$$\frac{I_4}{I_E} \approx \frac{1}{2} + \frac{I_y}{2I} - D_A$$

which shows the linear and the nonlinear terms where

$$D_A = \left(1 + \frac{I_y}{I}\right)(1-\rho)\frac{I_y}{4I} \quad \textbf{(16)}$$

D_A is the distortion introduced by the offset voltage and is defined as the deviation from linearity referenced to maximum output.

D_A is a parabolic function of $\frac{I_y}{I}$ with a peak value of 0.25 $(1 - \rho)$. The percentage distortion (**D**) with respect to the full-scale current $\frac{I_y}{2Y}$ is

$$D = \frac{D_A}{\frac{I_y}{2I}} = \left(1 + \frac{I_y}{I}\right)(1-\rho)\frac{1}{2} \quad \textbf{(17)}$$

Eq. 17 shows nonlinearity as a function of the ratio of the signal current to the biasing current. The linearity improves if this ratio is made as small as possible and still maintains a high-frequency response and stable operation with temperature.

Accuracy can be improved from an inherent 1.5% to better than 1% by reducing logarithmic and antilogarithmic transistor-bias currents from 1 mA to less than 0.8 mA and reducing the signal currents by 40%. The effect is to operate in a more linear region. Out of four major multiplier manufacturers whose devices were selected, only one met all the specifications necessary to produce a 1% multiplier.

Improving speed

To improve the bandwidth of the multiplier, use a turnaround circuit to convert the differential current out of the multiplier into a single ended current, grounded and suitable for driving an op amp. Such a circuit is shown in **Fig. 4.** The turnaround circuit is made up of two matched pairs of transistors Q_1 and Q_2 (matched betas within 10% and V_{be} within 5 mV). Q_{1a} and Q_{1b} are a pair of common-base transistors whose emitter currents are made up of a standby of 1.6 mA less the quiescent-multiplier current of 1 mA plus or minus the signal current which is approximately 0.2 mA. Resulting current of ±0.4 mA flows out of the collectors of Q_{1a} and Q_{1b}. The collector current of Q_{1a} is turned around on a one-to-one basis by the pair of transistors Q_{2a} and Q_{2b}.

The turnaround output is a current composed of the XY signal currents only. The standby currents from the common-base transistors Q_{1a} and Q_2 and the quiescent current of the multiplier cancel each other out. Since Q_1 and Q_2 are both parts of matched and encapsulated transistors, their contribution to either scale factor or offset drift is minimal.

The choice of the output-buffer amplifier is determined by the frequency response and slew rate required for the multiplier. For multipliers with a smal-signal output frequency of 5 MHz and a full-power response of 1.4 MHz, the corresponding op amp should have a unity gain bandwidth of at least 5 MHz, and a slew rate of at least 100 V/μsec.

Long-term drift

A peculiarity of IC multipliers was observed after a run of 25 units was adjusted for minimum feedthrough and best accuracy, then tested at various temperatures starting at ambient room temperature. Between 10 and 20% of the multipliers were out of specification. The problem was traced to the lack of burning-in of each IC multiplier.

A 48-hour burn-in at + 150°C of all IC multipliers reduced this drift to a 2% rejection margin. Those unstabilized units were found to be contaminated, and thus useless. This problem of processing has yet to be solved completely in manufacturing IC multipliers with 1% accuracy.

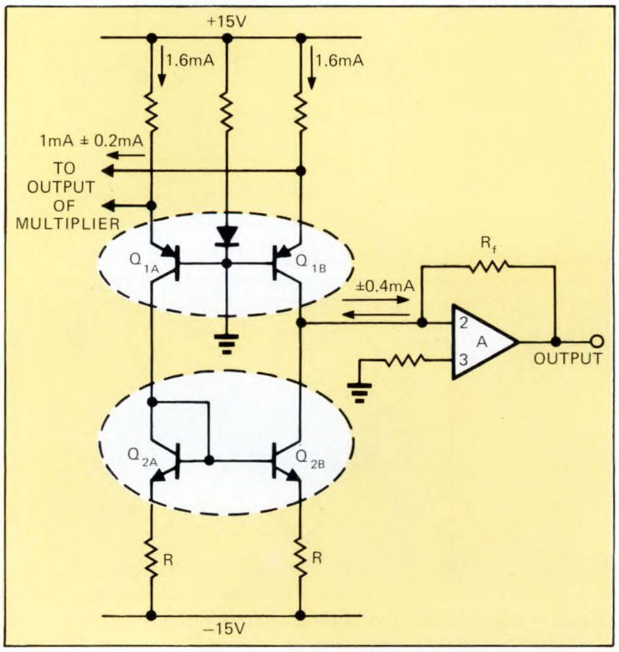


Fig. 4—To convert the multiplier's differential-output current to a usable voltage, this turnaround circuit is employed. It produces a single ended current suitable for conversion into a voltage output by an op amp.

Fig. 4 shows the basic IC multiplier circuit. **Fig. 6** shows the added circuitry necessary to improve the device's operating characteristics. The physical choice of these additional components is a major factor in multiplier performance improvement.

Bringing it all together

To summarize, each of the following parameters can be improved by the following sections of the total circuit.

1. Dc Accuracy: logarithmic and antilogarithmic circuitry. Reduce bias-current level for optimum accuracy. This improves the inherent 1.5% accuracy to less than 1%.

2. Feedthrough: the voltage-to-current converter is the key to feedthrough drift. This is improved by external temperature-sensitive resistors. The feedthrough-linearity error is caused by the logarithmic/antilogarithmic circuitry. An IC must be preselected to achieve true 1% accuracy. Typically, these errors will limit overall accuracy to 2%.

3. Linearity: gain drift is caused by the inherent negative temperature coefficient of the scale factor. An external resistor can be selected with a temperature coefficient that nullifies this effect. Dynamic nonlinearity is usually caused by mismatched transistors in the logarithmic and antilogarithmic circuits. The nonlinear function is parabolic in nature whose second-harmonic distortion is usually the common nonlinear term. This effect is minimized by reducing

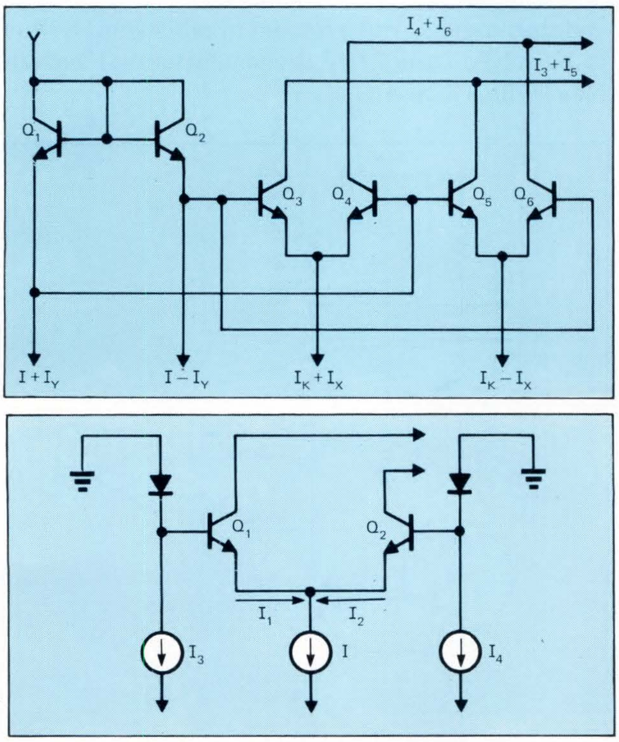


Fig. 5—**Logarithmic and antilogarithmic circuits (a).** Transistors Q_1 and Q_2 take the logarithm of currents $(I+I_y)$ and $(I-I_y)$ and apply the resulting voltage to the antilogarithmic circuit of transistors Q_3 through Q_6 whose output is the product of the multiplier's E_x and E_y inputs. The simplified logarithmic/antilogarithmic circuit of **(b)** allows for simpler circuit analysis.

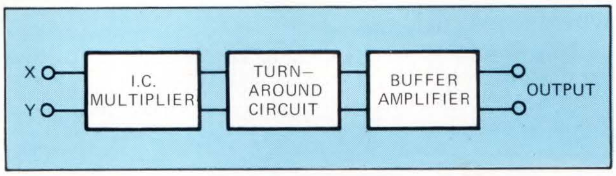


Fig. 6—The improved IC multiplier. Additional circuit components include a turnaround circuit and a buffer amplifier. The physical choice of these added-on components can be a major factor in performance improvement.

the ratio of internal signal current to biasing current. The trade-off is stable temperature operation and frequency response.

4. Frequency response: small-signal response is limited by the IC circuit. It is usually in the 1 to 10-MHz region, depending on optimization of other parameters.

Full-power response is mainly limited by the choice of the turnaround circuit and the output-buffer amplifier. Slew rate is the key parameter for choosing the output-buffer amplifier.

When a multiplier is designed into a system, an engineer has three general choices:

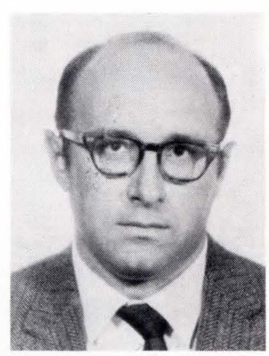
1. He can use existing ICs and design in the external circuit at a components cost in the range of $15 for a 2 to 5%-accurate multiplier. Vendors of such devices include Motorola, Fairchild, Signetics and Silicon General.

2. He can use existing modules obtained from the major op-amp companies such as Intech, Burr-Brown, Analog Devices and Teledyne Philbrick. These save the cost of engineering time and add the advantage of special chip selection, when necessary, due to the volume of business in this field.

The device cost however will range from $30 to $200, depending on accuracy (0.1% to 2%) and speed (10 kHz to 2 MHz for full-power response and 100 kHz to 10 MHz for small-signal response).

3. Or he can design a multiplier circuit using discrete devices. This approach is quite costly both in engineering time and effort and should only be undertaken where performance is required beyond the state-of-the-art. Other overall system approaches should be reconsidered before taking on this task. □

Author's biography



Gilbert Marosi is a senior project engineer with Intech Inc., where he has been responsible for the design and development of high-speed A/D, D/A and nonlinear function modules. A year ago, Mr. Marosi was employed by the Philco Ford Corp. He holds a BSEE degree from the Lawrence Institute of Technology and a MSEE degree from Santa Clara Univ.

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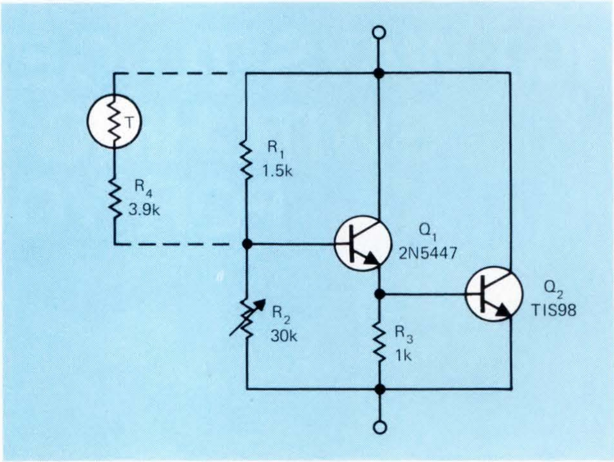
Compensated adjustable zener

Ralph Tenny
Texas Instruments Inc., Dallas, TX

This circuit, when constructed with low-cost plastic transistors, has 1Ω or less dynamic impedance from about 1 mA to the maximum allowable dissipation of Q_2. Substitution of different TIS98s for Q_2 has negligible effect on the output, and random substitution of 2N5447s for Q_1 causes only a ±2% change in the output. All these features demonstrate the circuit's suitability in regulator service for battery powered MOS instruments, except for the circuit's linear -0.4%/°C temperature coefficient (20% change 0 - 50°C).

By adding a thermistor (Gulton 35TF1) and R_4, the circuit is compensated to a maximum deviation of ±0.5% over the 0 - 50°C range. Circuit values shown yield this compensation over the output range of 3.5 to 15.5V, with only R_2 changing to set output voltage. Dynamic temperature compensation depends upon low thermal impedance between the thermistor and Q_1, otherwise the time constant of the compensation is equal to that of the thermistor. ▭



2-transistor adjustable zener has only a 1Ω dynamic impedance. Thermistor compensating network replaces R_1 for ±0.5% stability from 0 - 50°C.

To Vote For This Circuit
Check 150

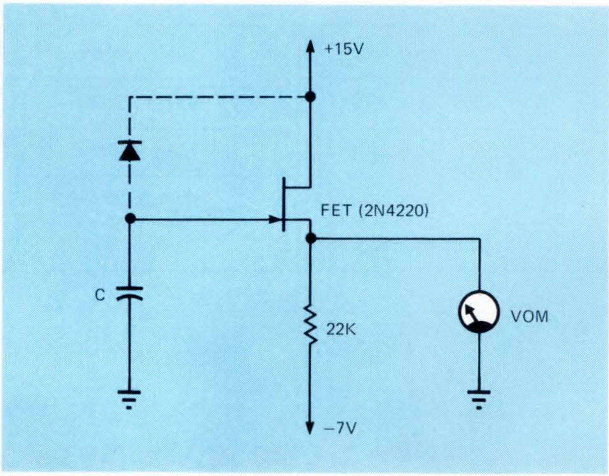
Leakage testing of diode and JFETs

David Dilatush
National Camera, Englewood, CO

A very sensitive circuit for testing diodes and FETs for leakage can be made using an FET, a capacitor and a resistor.

The FET to be tested for leakage and a 22 kΩ resistor are connected as a source-follower, with a capacitor across the input from the gate to ground. The leakage of the FET charges the capacitor at a rate which is directly proportional to leakage and inversely proportional to the capacitance. The quantities are related mathematically as follows:

$$\text{I (in amperes)} = \frac{\text{Q (in coulombs)}}{\text{T (in seconds)}},\ \text{and}$$



JFET leakage can be checked with a voltmeter and a stopwatch or timer in this simple test setup.

$$V \text{ (in volts)} = \frac{Q \text{ (in coulombs)}}{C \text{ (in farads)}}$$

A suitable value of C is 0.01 μF. With this capacitance, each volt of potential change across C indicates a stored charge of 10^{-8} coulomb. This can be interpreted as current if the time for the voltage on the capacitor to rise 1V is known.

$$\text{Example: } C = 10^{-8} \text{ F}, \frac{dv}{dt} = \frac{1V}{38.7 \text{ sec}}$$

$$I = \frac{dQ}{dt} = \frac{10^{-8} \text{ coul.}}{38.7 \text{ sec.}} = 2.58 \times 10^{-10} \text{ A} = 0.258 \text{ nA.}$$

Diodes are tested in the same way, except that a "good" FET is used as a follower and the diode provides almost all of the charging current. □

To Vote For This Circuit
Circle 151

IC timer makes adjustable Schmitt trigger

Don Hoven
Ford Industries, Portland, OR

The MC1455 lends itself for use as a low-cost versatile Schmitt trigger. Both thresholds are adjustable by choosing resistors as shown with accompanying diagrams. The device will drive up to 6 TTL loads. $T_r + T_f \cong 100$ nsec. Referring to the block diagram of the MC1455 shown in **Fig. 1,** it is evident that if pins 2 & 6 are connected and a gradually increasing voltage is applied to these pins, switching will occur (the output will go LOW) when the comparator input voltage just exceeds the reference voltage at pin 5 ($2/3\ V_{cc}$). Conversely, when the voltage gradually goes negative at pin 2, reversion of the output to the high state will occur at $1/3\ V_{cc}$.

The hysteresis between these two points is adjustable by varying R_1 and R_2. More specifically, the hysteresis can be reduced to 1/2V. (With pin 2 connected to pin 6, the unit trips at $2/3\ V_{cc}$ and resets at $1/3\ V_{cc}$ for a hysteresis of 1.6V at $V_{cc} = 5V$.)

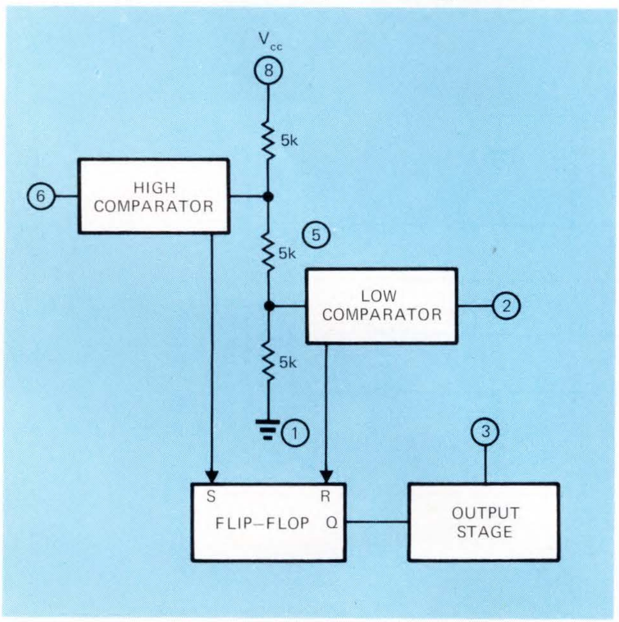


Fig. 1—Monolithic timers can be converted to Schmitt-trigger operation with this simple 3-resistor network.

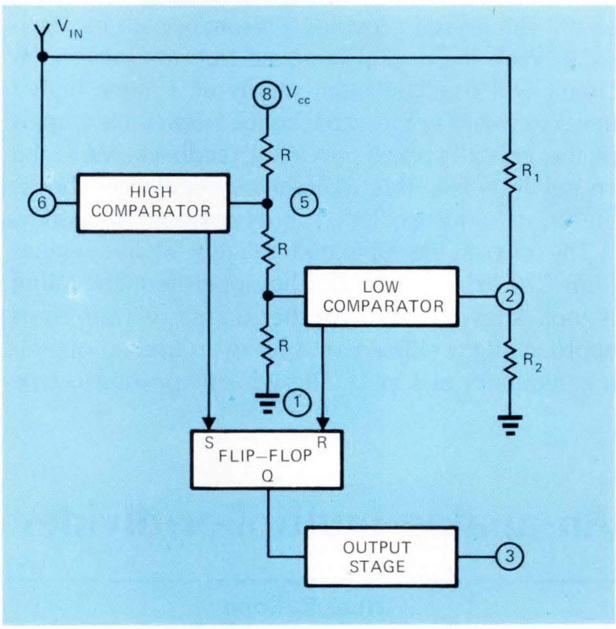


Fig. 2—The addition of R_1 and R_2 permits adjustment of hysteresis between the trip points down to 0.5V.

The lower trip point in **Fig. 2** occurs when $V_{in}\left(\frac{R_2}{R_1 + R_2}\right) = 1/3\ V_{cc}$. To allow for V_{be} variations, V_{in} should never be below $1/3\ V_{cc} + 0.2V$. The upper trip point will occur at $2/3\ V_{cc}$.

A further modification can be made to the hysteresis by lowering the voltage at pin 5 by placing a resistor to ground.

The upper trip point is then whatever the voltage is at pin 5. The lower trip point occurs when

$$V_{in}\left(\frac{R_2}{R_1 + R_2}\right) = V \text{ pin } 5 + 0.2V. \quad □$$

To Vote For This Circuit
Circle 152

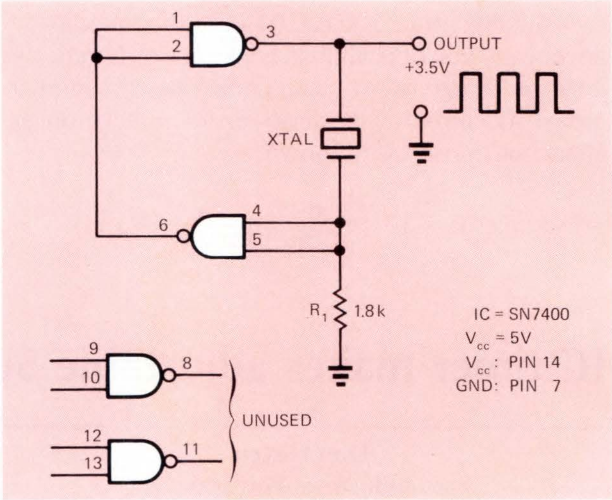
2 gates make quartz oscillator

Edward G. Olson
Naval Air Development Center, Warminster, PA

A type SN7400 IC quad-2 input NAND gate, a quartz crystal of the desired frequency, and a resistor may be arranged as shown to provide a square-wave output of approximately 3.5V. One of the two remaining gates may be used to gate the generator output.

Resistor R_1 biases the emitters of this NAND such that the output terminal (lead 6) is approximately halfway between V_{cc} and ground which in turn, biases the emitters of the upper NAND at a suitable point. The crystal provides a resonant path for feedback. With the crystal removed from its socket, the circuit will oscillate momentarily at a much higher frequency due to the capacitance between terminals of the crystal socket providing feedback. With the crystal installed, this momentary oscillation shocks the crystal into oscillation at its resonant frequency.

The circuit has operated reliably at frequencies from 120 kHz to 4 MHz. The upper-frequency limit is not known although the output waveform is approaching a clipped sine wave around an operating frequency of 4 MHz. This waveshape triggers type SN7490 decade counters reliably. The output terminal (3) is capable of normal fan out. □



Half a TTL package and a quartz crystal combine to make stable clock sources up to 4 MHz.

To Vote For This Circuit
Circle 153

An analog multiplier/divider circuit

Arthur R. Kopp
Optical Scanning Corp., Newtown, PA

A video signal from a photodiode array had to be controlled in amplitude over a 2 to 1 range. An inexpensive analog divider was thus required with a

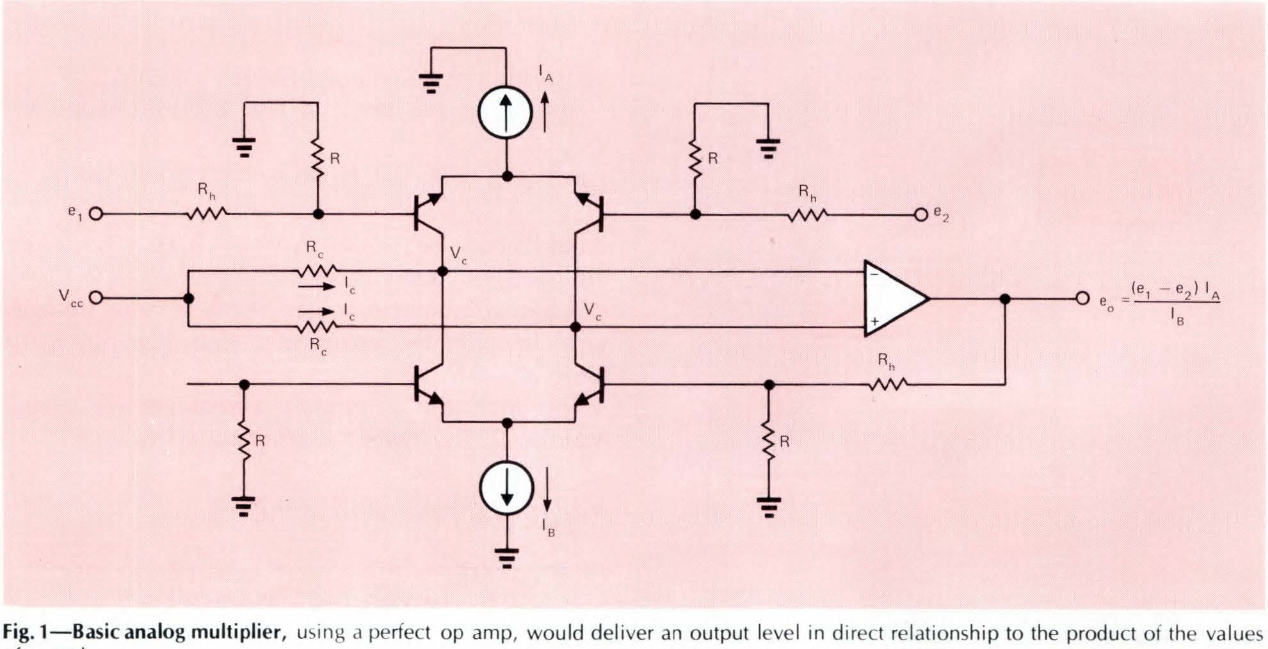


Fig. 1—Basic analog multiplier, using a perfect op amp, would deliver an output level in direct relationship to the product of the values of e_1 and e_2.

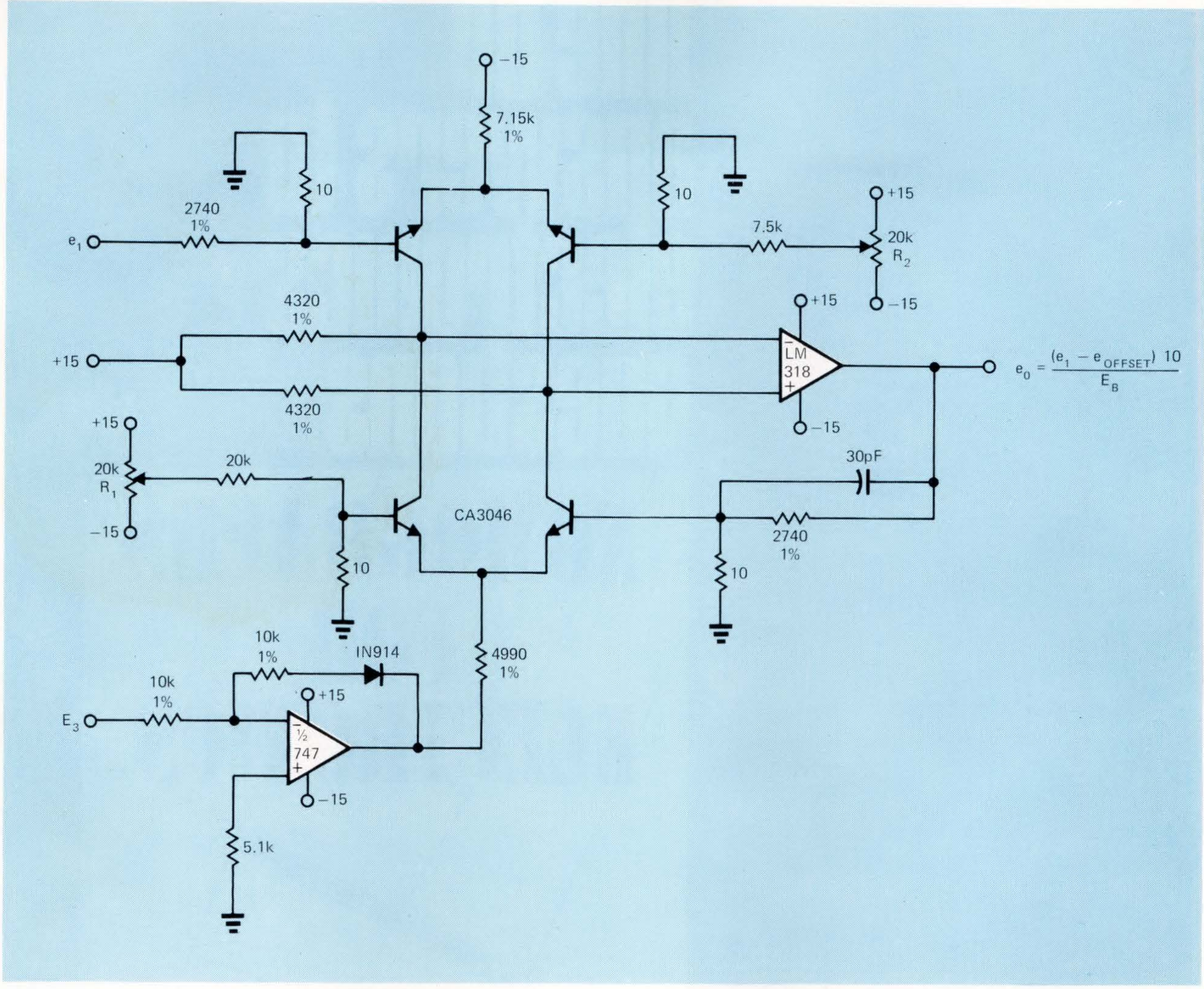


Fig. 2—Analog divider with 2-MHz bandwidth gives 2% accuracy and can be employed as a (XY) ÷ Z element.

numerator bandwidth of 2 MHz minimum, 2% accuracy over the range and provisions for bias referencing the output.

The excellent V_{be} matching and gain-bandwidth of a CA3046 array is combined with an LM318 operational amplifier to provide the solution. As a bonus, the basic circuit derived may be employed as a full (XY) ÷ Z multiply-divide element with differential bipolar signals on one numerator input.

Fig. 1 illustrates the basic circuit, which may be analyzed to yield the output shown to a first approximation. Starting assumptions include identical transistors with large h_{fe}. An ideal op amp with matched resistors causes equal currents through each R_c with zero-offset voltage. The h_{ib} of the transistors is assumed proportional to the reciprocal of collector current. This puts the negative feedback network of the op amp under control of I_A and I_B.

Fig. 2 shows the circuit employed as a divider to meet my requirements. The 30-pF capacitor stabilizes the circuit and gives a 3-dB bandwidth of 3 MHz. Step response is free of overshoot with a risetime of 100 nsec.

One half of a 747 op amp is used to create the I_B current source. The diode compensates for the base-emitter characteristics of the transistors making I_B proportionate as E_B.

Potentiometer R_1 is set for a constant output as E_B is varied. R_2 is set so that the output is zero when $e_1 = -1V$ in this application. This provides the desired level shift of the input signal, and the output swing is positive from zero.

Collector currents must be kept below about 1 mA with the CA3046 or accuracy deteriorates noticeably. 1 to 2% accuracy can be achieved, this is limited mainly by resistor matching tolerances. Bandwidth suffers at very low values of E_B because of the transistors' F_t at low collector currents.

The other half of the 747 could be used identically on I_A for another unipolar numerator input. Bandwidth would be limited to 1 MHz or less by the 747. □

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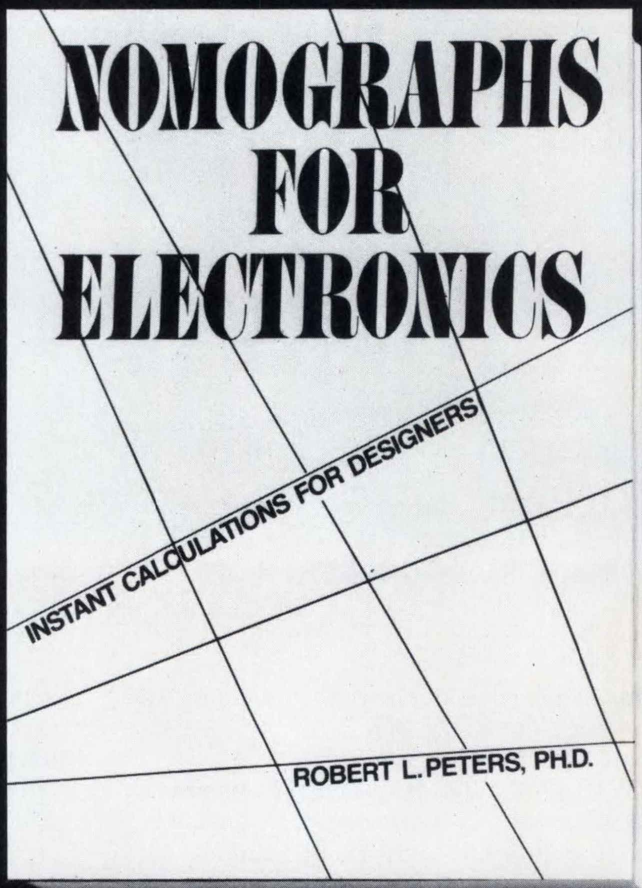

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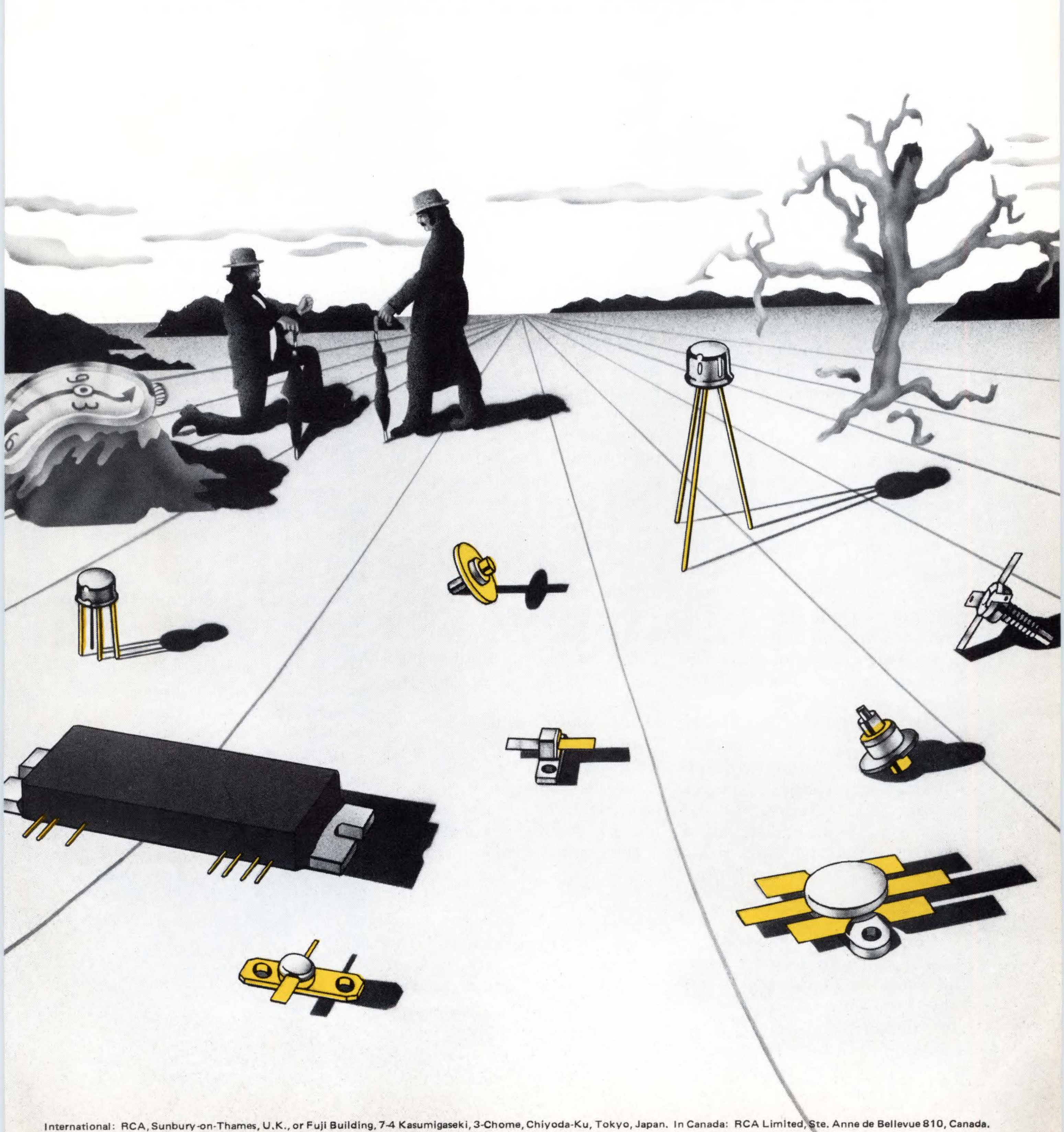

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Circle No. 33

16-bit LSI minicomputer could open up new application areas

PROGRESS IN COMPUTERS

Original equipment manufacturers who use minicomputers or even microcomputers in their end products will be interested in a new full-scale 16-bit LSI minicomputer priced under $1000.

Using MOS/LSI technology, Computer Automation has succeeded in putting the whole computer on a single card (**Fig. 1**) that includes a 7-chip processor, 4k of memory and direct memory access (DMA). Of equal importance to the cost and size reductions is the fact that the computer provides performance comparable to other 16-bit minis costing twice as much.

Called the Naked Mini/LSI, the computer is fully upward compatible with all previous Computer Automation mini hardware and software, with full arithmetic and byte processing power. In OEM quantities of 200, it sells for $990.

The Alpha/LSI, also being introduced, is a Naked Mini/LSI plugged into a fully encased chassis that includes a power supply and a control console with a hexidecimal-data input keyboard and LED binary displays (**Fig. 2**). Price of the Alpha/LSI in single quantity is $1990.

The 15 x 16-in. pc board—which is common to both machines—contains the 7 LSI chips, memory-control logic, TTL I/O bus interface, a clock generator to furnish the 4-phase processor clock and 4k of memory. In addition, the single-board configuration will accommodate up to 8k of memory and accept a small "piggyback" option board that can contain any or all the following three options: real-time clock; teletype or CRT interface; or auto-loader. Board options include a power-failure detector and auto restart.

P-channel saves space

To achieve the low cost and small size, the mini uses 7 P-channel silicon-gate devices that were designed by Computer Automation. The only apparent performance tradeoff made by taking this approach is in speed, with a processor cycle time of 1.6 μsec.

Two basic types of chips form the 7-chip CPU. Each of four identical processor chips is a 4-bit slice of the 16-bit arithmetic logic unit and register file.

The three control-unit chips are identical except for the masked contents of their internal control memories. Here, Computer Automation departed from conventional design and went to a programmed logic array (PLA), or associative ROM to implement the instruction set.

The reason for this approach is twofold—speed and cost. Because MOS is a relatively slow-speed technique, very slow operation would result if the processor—working with a large instruction set—had to examine a large number of bits in the instruction word before deciding what processing is specified by the instruction. In addition, it would require either a very large ROM, which is expensive, or a great deal of random logic ahead of the ROM to partially decode the instruction prior to execution by the microprogram.

The PLA is a regular logic form that does not waste space by storing "don't-care" bits. Only needed product terms are built into the matrix. The result is that the PLA increases instruction speed by eliminating many instruction microcycles to jump to and return from microprogram subroutines.

The disadvantage of this approach is that the user is not offered writable-control store. However, because this is a MOS machine with a processor-cycle time roughly equivalent to memory-cycle time, this will not be a particular disadvantage. This mini is not intended to be a user microprogrammable computer, according to Computer Automation. It has a set of 162 instructions, not counting all possible addressing variations, implemented by the PLA.

The combination of a powerful instruction set and low cost may allow the computer to be used in applications previously handled by hard wiring or

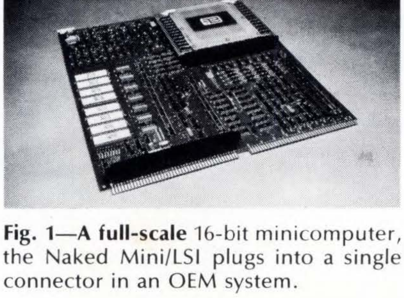

Fig. 1—A full-scale 16-bit minicomputer, the Naked Mini/LSI plugs into a single connector in an OEM system.

microcomputers, in addition to those requiring large full-performance minicomputers.

TTL logic is used to generate the 4-phase clocks, and to interface between the MOS voltage levels within the processor and the TTL/DTL levels used on the external bus.

The standard "maxibus" (**Fig. 3**) has five I/O systems. These systems provide 58 parallel lines for data, command, device-address and status-control information. They include DMA (previously an option), high-speed block I/O and conditional I/O tests and transfers.

Unique bussing scheme

Of importance to the user is the fact that all memory modules and controllers look the same to the I/O bus. A proprietary arrangement makes the memory self-organizing so that memory modules of different sizes and types (core, MOS, RAMs, ROMs and others) can be mixed or rearranged on the bus. The computer will automatically assign addresses without any reference to software.

Software packages available with the new minis are the same as those offered with the Naked Mini 16 and Alpha 16 including Operating Systems, Real Time Executive, Conversational Assembler, BASIC and FORTRAN.

Fig. 2—Add a power supply, a control console with a hexidecimal keyboard and a cabinet to the Naked Mini/LSI and you have an Alpha/LSI.

MOS memory available

The standard memory offered with the Naked Mini/LSI is 4k of core which is expandable to 8k on the single board. In addition, MOS memories are offered in 1k, 2k and 4k modules for users with smaller requirements.

Extended memory capability of the Alpha version includes 40k with four additional memory modules and another 40k with an optional control card and an expansion chassis.

Using a banking structure, up to 32 8k/16-bit modules can be accommodated providing 256k 16-bit words. This structure creates an overlay memory that is said to be especially efficient in most multi-user or multi-task environments.

Direct memory access, which is a standard feature on both minis, operates essentially independent of the CPU and transfers on a cycle-stealing basis. Using a single memory bank, the transfer rate is 625,000 words/sec. If two banks are used alternately within each memory cycle, the rate can be doubled.

Delivery of OEM quantities is being quoted in Dec. 1973.

Computer Automation, Inc., 18651 Von Karman, Irvine, CA 92664. Phone (714) 833-8830. **140**

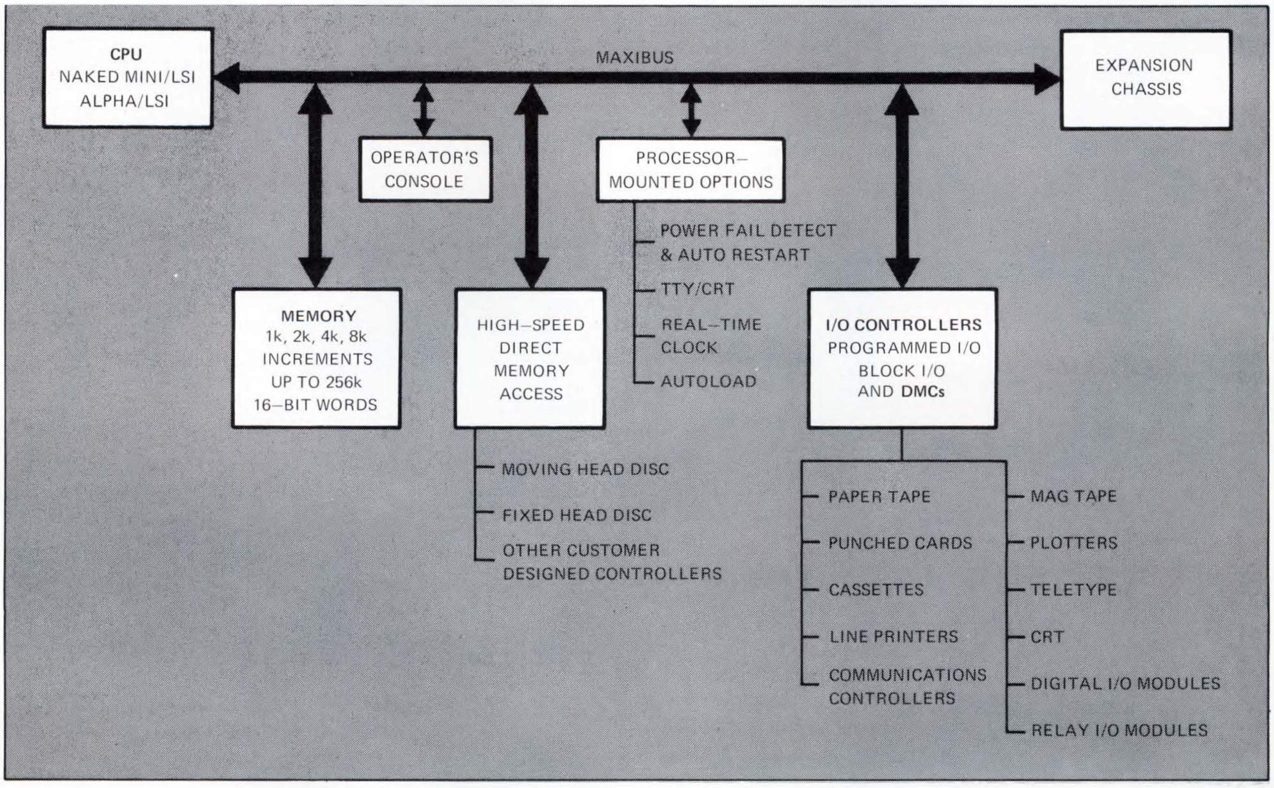

Fig. 3—System architecture is similar to other microprogrammed minicomputers; however, a Programmed Logic Array is used instead of ROMs for microprogramming. New I/O bussing structure simplifies memory expansion and allows I/O controllers to communicate with each other as well as memory independent of the CPU.

Dialight sees a need:

(**Need:** The right switch for the right price.)

See Dialight.

For the switch buyer, choice of function and esthetics, reliability, ease of mounting, and low cost are his prime concerns. He may need a pushbutton switch for panel, sub-panel or snap-in mounting. He may need a choice of bezels with or without barriers in black, gray, dark gray or white. He may need a legend that's positive, negative, or hidden until energized . . . one that's white when "off" and red, green, amber, blue or light yellow when "on" . . . or colored both "on" and "off." He may need a highly reliable switch proven in thousands of installations . . . available in momentary or alternate action . . . N.O., N.C. or two circuit (one N.O., one N.C.) or for low level, low voltage and current applications . . . that accommodates a T-1¾ bulb with midget flanged base, incandescent, in voltages from 6 to 28 V. Matching indicators with same front-of-panel appearance are also available. These are some custom needs he may face, and these switches are some off-the-shelf answers from Dialight.

Digital processing interface ties the scope to the computer

PROGRESS IN INSTRUMENTATION

Many parameters that once required indirect measurements followed by complex and time-consuming calculations can now be displayed in seconds with the push of a few buttons on a scope, thanks to a new processor and operating-software plug-in for Tektronix's 7704A scope.

The processor, which digitizes incoming analog waveforms, interfaces the scope to the PDP-11 minicomputer, stores digital data and converts it to analog information for the scope's display, allows the 7704A scope to differentiate waveforms, extracts signals buried deep in noise by signal averaging, displays time as well as frequency spectra of signals by Fourier and inverse-Fourier transformations, and shows the convolution, deconvolution and correlation functions of the input signals.

As an example of the versatility the new digital processor plug-in provides, an engineer can instantly determine the instantaneous power dissipation in a transistor circuit by having the scope multiply the collector current by the collector-emitter voltage. In fact, the product of any two waveforms can be displayed at once, where alternate means of using mental arithmetic calculations can take much longer.

The new system uses BASIC language for the software and can be adapted to the Data General Nova minicomputer; however no software support will be provided here by Tektronix.

Assuming that an engineer already has a 7704A scope and a PDP-11 minicomputer, the interface will cost $5200 plus $650 or $900 for either one of two BASIC software packages, and $1000 for a software interface.

When one adds to this the cost of a decent terminal such as a Teletype or a CRT terminal, the

Linking the scope to the minicomputer, a new digital processor plug-in interface for Tektronix's 7704A scope allows it to extract signals buried deep within noise by signal averaging, take the Fourier and inverse-Fourier transforms, convolutions, deconvolutions and correlation functions, and automatically scale the displayed waveform to a convenient form. The plug-in interfaces to a PDP-11 minicomputer.

system can cost upwards of $11,000. For those who don't have either the scope or the minicomputer, an additional $2400 is needed for the 7704A scope, and either $7795 (8k memory) or $12,130 (16k memory) for the PDP-11.

Tektronix, Inc., Box 500A, Beaverton, OR 97005. Phone (503) 644-0161. **141**

Careful there . . . you're likely to start something.

Just a "flutter" of pressure . . . and SNAP!

Less than 2 grams of force actuates this Cherry snap-action miniature switch. Outside, the external aluminum actuator is purposely 2⅜″ long to provide this unusually low operating force. Inside, an extra internal actuator further reduces operating force while maintaining solid contact mating pressure for reliable performance.

The "flutter force" switch is only one of Cherry's E22 series of unique miniatures. All are rated 3 amps, 125 VAC. All are also available in gold "crosspoint" configuration for low energy solid state circuits.

A switch in your hand is worth two in the tree, so . . . SNAP UP A FREE SNAP-ACTION SAMPLE.

Just TWX 910-235-1572 . . . or PHONE 312/689-7704 and ask Frank to give you facts on miniature switches . . . or circle appropriate reader service number.

E22-75HX
5 grams LIGHT FORCE actuation
Circle No. 35 for Free Sample

E22-55HX
3.5 grams LIGHTER FORCE actuation
Circle No. 84 for Free Sample

E22-85HX
Less than 2 grams "FLUTTER FORCE" actuation
Circle No. 85 for Free Sample

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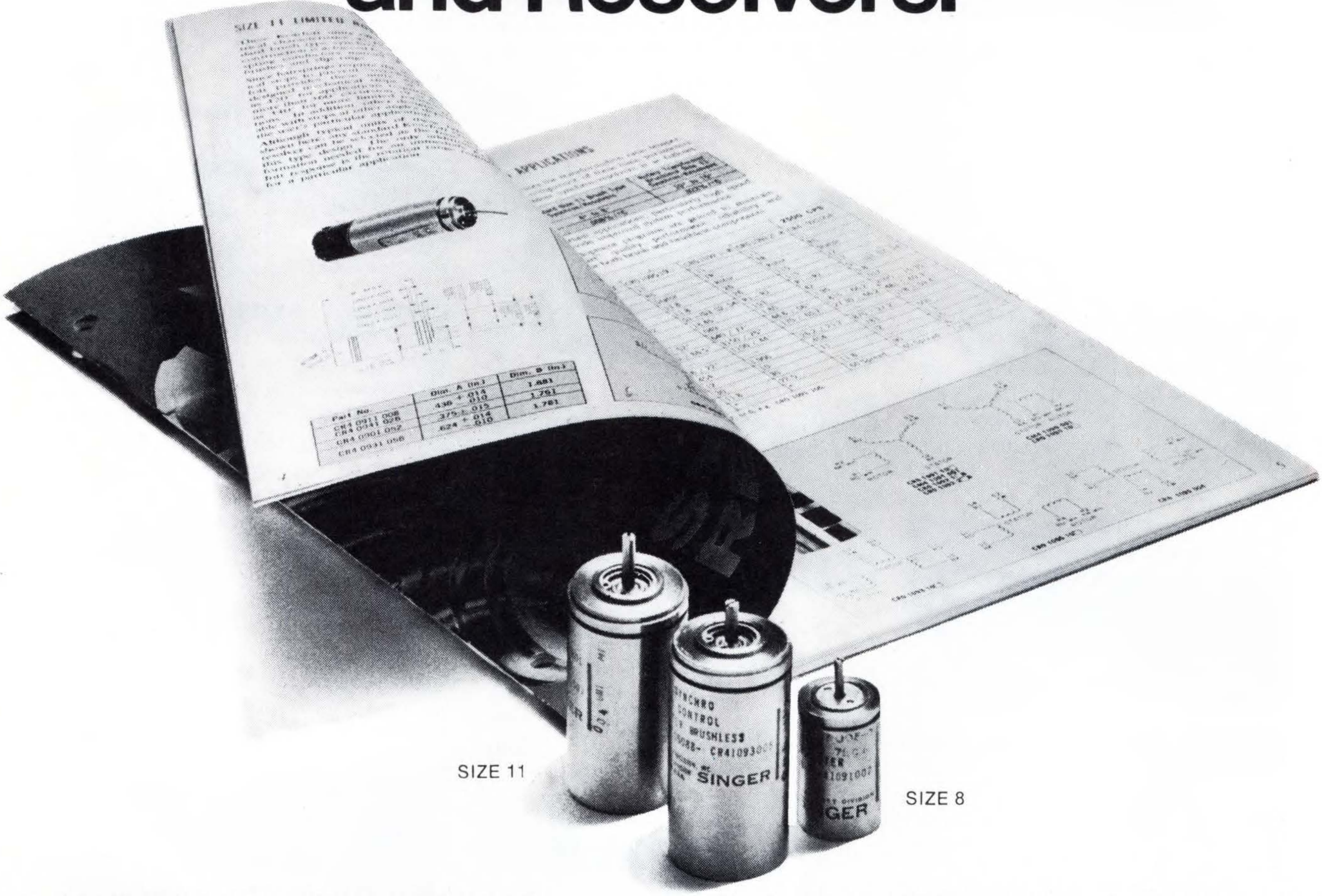
Send for our brushup course on Brushless Synchros and Resolvers.



SIZE 11

SIZE 8

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.

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☐ I have an application for Brushless Synchros. Have a company representative call.

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Title__________

Company__________

Address__________

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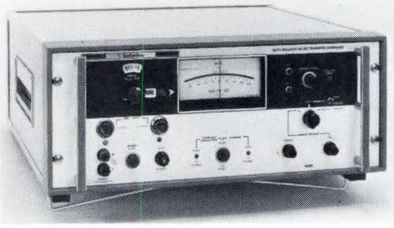
Circle No. 75



Ac/dc TRANSFER STANDARD IS FULLY AUTOMATIC. Model 1600A requires no manual balancing or calibrations for standards traceable to NBS references. The direct-reading instrument offers manual balancing if needed. It automatically compares the heating effect of an internally servoed dc voltage with that of the ac input, and at balance, generates a dc voltage with the same heating value as that of the ac input. Dc frequency range is 5 Hz to 30 MHz (up to 1 GHz with external converters). Twelve dc voltage ranges span 0.25 to 1000V. Crest factor is 1.75:1 (full range) and 3.5:1 (bottom range). $3950. Ballantine Laboratories, Inc., Box 97, Boonton, NJ 07005. Phone (201)335-0900. **203**

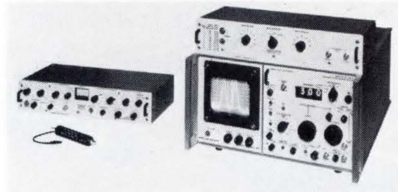
4-3/4-DIGIT MULTIMETER HAS 300% OVERRANGING. The 3400 offers measurements up to a maximum display of 39999. It contains 25 ranges: 5 dc voltage ranges with 10-μV resolution to 1500V full scale and accuracy of $\pm$0.01% of reading $\pm$1 count; 5 ac voltage ranges with 10-μV resolution to 1000V full scale and accuracy of $\pm$0.2% of reading, $\pm$0.1% of full scale (bandwidth of 30 Hz to 50 kHz); 5 ac and dc current ranges with 10-nA resolution each to 2A full scale and accuracies of $\pm$0.03% and $\pm$0.1% of reading, respectively, $\pm$1 count; and 6 resistance ranges with 10-mΩ resolution to 20-MΩ full scale and accuracy of $\pm$0.05% of reading $\pm$2 counts. $595. Hickok Electrical Instrument Co., 10514 Dupont Ave., Cleveland, OH 44108. Phone (216)541-8060. **204**

DMM PAIR FEATURES INCREASED RESOLUTION AND HIGH SPEED. The 4-digit Model DMM-40 offers 1-μV resolution on signals up to 240 mV. The $695 autoranging unit has 20 ranges: ac and dc voltage from 0.1 to 1000V full scale, ac and dc current from 0.1 to 2A and resistance from 0.1 kΩ to 24 MΩ. The $1195 5-digit Model DMM-50 provides 20 readings/sec at 60 dB NMR. It has 20 ranges: 5 for dc and 4 for ac voltage from 0.1 to 1000V (from 1V for ac) full scale, 6 for resistance from 0.1Ω to 12,000 kΩ, and 5 for external dc-dc references from 0.1:1 to 1000:1 full scale. Cimron Instruments, 714 N. Brookhurst St., Anaheim, CA 92803. Phone (714)774-1010. **205**

550-MHz FREQUENCY COUNTER HAS 10-mV rms SENSITIVITY. The 9-digit 5108 uhf counter features an attenuator dynamic range of 35 dB with auto-attenuation and automatic noise suppression and an additional 20 dB with a manually switched attenuator. The temperature controlled crystal oscillator's aging rate is 5 × 10^{-8}/day. Four decades of resolution are provided, from 1 kHz at 16 msec gate time to 1 Hz at 16 sec gate time. Service and parts are available throughout the USA from Honeywell. $950. Miida, 2 Hammarskjold Plaza, New York, NY 10017. Phone (212)973-7152. **206**

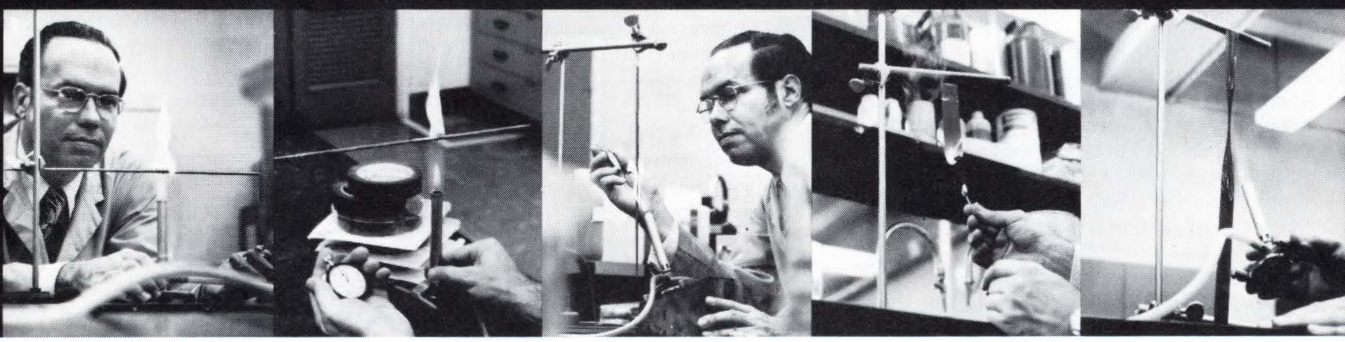
16-CHANNEL ANALOG FILTER IS FULLY PROGRAMMABLE. System 816 provides individual filter channels, each mounted on a plug-in board. Cutoff frequencies from 10 Hz to 150 kHz with 48-dB/octave rolloff may be programmed remotely or locally by front-panel switches. A standard Butterworth low-pass configuration may be altered to high-pass, and thus by combining 2 channels, band-pass and band-reject filters may also be produced. Stability of cutoff frequency is $\pm$200 ppm/°C and noise level is 80 dB down. Remote programming is with TTL levels. $750 for the basic cabinet plus $650 per filter card. Rockland Systems Corp., 230 W. Nyack Rd., W. Nyack, NY 10994. Phone (914)623-6666. **207**

3-CHANNEL RECORDER MEASURES 3-5/8 × 9 × 8 IN. Model 301 features an Astro-Tip heated inkless stylus that can be replaced, when necessary, in less than 10 sec by untrained personnel. The recorder's galvanometer provides accurate performance at frequencies beyond 125 Hz and sensitivity of 10 mV/mm ($\pm$1/4V full scale), with a 1 MΩ input impedance. Model 301 features a channel width of 50 mm and automatic chart threading for quick loading in less than 5 sec. Astro-Med, Div. of Atlan-Tol Industries, Inc., Atlan-Tol Industrial Park, W. Warwick, RI 02893. Phone (401)828-7010. **208**

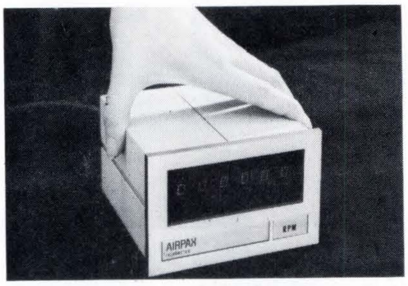


SPECTRUM-ANALYZER RANGE EXTENDER ACCOMMODATES 400 MHz. Model RE-7292 is a modular accessory to the Nelson-Ross Model CSA-290 system to provide 10-Hz resolution. It provides direct-reading quantitative signal analysis from 10 Hz to 400 MHz at an accuracy of $\pm$0.1% with its internal digital-frequency counter. Incremental fine-tuning accuracy is $\pm$10 Hz using the counter as a ΔF control. Features include intermodulation-distortion dynamic range to 70 dB, preset scans with automatic optimum resolution and self-checking for frequency, absolute level and frequency-scan calibrations. $2000. Nelson-Ross Electronics, 5 Delaware Dr., Lake Success, NY 11040. Phone (516)328-1100. **209**

DIGITIZER SYSTEM USES PROGRAMMABLE CALCULATOR. The Gradicon/HP9800 is designed for production drawings, maps, x-rays, photographs and other graphic material. In operation, the calculator keyboard and display provides a means of entering numerical data to be merged with coordinate data from the digitizer section for operations such as on-line coordinate transformation, area and volume calculations with 2- or 3-axes coordinates. The data entered from the keyboard is verified in the calculator display before transmission to the output-data recorder. Digitizing and calculating functions can be operated independently without disconnecting or modifying the system which frees the Hewlett-Packard 9800 calculator for handling other mathematical programs. Instronics, Inc., Suite 204, Bridge Plaza, Ogdensburg, NY 13669. Phone (315)393-7550. **210**

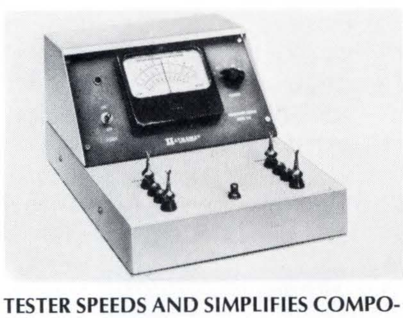


EQUIPMENT



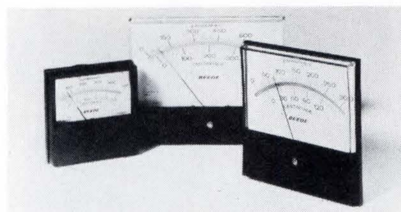
DIGITAL TACHOMETER/COUNTERS ARE COMPACT IN DESIGN. Series 77 units are offered in miniaturized (5-3/16 × 3-3/8 × 5-9/16 in.) cases with nonblinking LED displays for "event-per-unit-time" (tachometer) or "accumulation" (counter) applications. They operate from signals produced by magnetic analog or digital transducers located in proximity to shaft mounted gears, or from other signal sources such as proximity closures and switches, photo cells and flow meters. Tachometer input signals are normalized to produce readouts in significant units such as rpm, fpm and gpm. Input sensitivity is 50 mV rms max. Price for 4-digit models is $275. Airpax Electronics/Controls Div., 6801 W. Sunrise Blvd., Ft. Lauderdale, FL 33313. Phone (305)587-1100. **211**

FAULT LOCATOR SPOTS EARLY STAGE FAILURES. The K2007 is a device that recognizes early stage contact-resistance variations in switches, solder joints and pc boards. It operates over a 3-kHz to 10-MHz range to check telecommunications and components and can be used on production lines, in test rooms, and for bay and station wiring. It detects and reports via metered and audible measurements, developing breaks, corrosion and weakening of contact pressures. Sudden variations in resistance which alter the propagation constant by as little as 0.1% can be readily recognized. $2000. Siemens Corp., 186 Wood Ave. S., Iselin, NJ 08830. Phone (201)494-1000. **212**



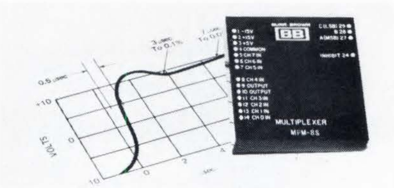
TESTER SPEEDS AND SIMPLIFIES COMPONENTS CHECKING. Used for measuring, matching and rejecting such components as resistors, capacitors and inductors, the E-2 comparison bridge allows even unskilled operators to average about 0.1% accuracy checks. Component testing can take place at a rate of up to 1000 components an hour. The E-2 is easily calibrated and has a sensitivity of 1 part in 10,000. Test limits are: resistance, 1Ω to 5 MΩ; capacitance, 500 pF to 2000 μF; and inductance, 3 mH to 10,000H. Hathaway Industries, Box 45381, Southeast Station, Tulsa, OK 74145. Phone (918)663-0110. **213**

POWER-SYSTEM PACKAGE INCLUDES DUAL TRANSDUCERS for voltage and current monitoring. Each dual transducer consists of 2 separate measuring circuits housed in a single 2 × 5-1/2 × 6-1/4-in. standard case. Two voltage, 2 current, or a voltage and current circuit may be ordered in a single case. The field accuracy per circuit is 0.5%. Current inputs are 1, 2, 5 and 10A. Voltage inputs are 100, 110, 120 and 150V. All R-2000 transducers are available for 50-, 60- or 400-Hz operation. Outputs are 1 mA dc into 0 to 10 kΩ, 50 mV dc across 10 kΩ and 10V dc across 1 MΩ. F. W. Bell, Inc., 4949 Freeway Dr. E., Columbus, OH 43229. Phone (614)888-7501. **214**



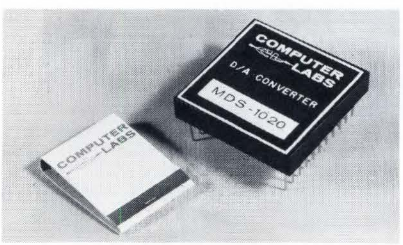
TEMPERATURE-INDICATING INSTRUMENT LINE covers up to 2500°F. Available in 6 standard ranges from 0-300°F to 0-2500°F, these panel-meter pyrometers feature basic sensitivity of 10Ω/mV and a dc input accuracy of ±1% at room temperature. They incorporate Beede's Shielded-Bar taut-band movement in Certak panel meters with factory certified tracking accuracy. Cold-junction and copper-error compensation are provided. Pyrometers are available in 5 case styles and sizes, including both front and behind-the-panel mounting. The standard design also includes an external adjustment for thermocouple lead resistance from 0 to 10Ω, and mirror scales indicating °F and °C. Beede Electrical Instrument Co., Inc., Penacook, NH 03301. Phone (603)753-6362. **215**

POWER SYSTEMS PROVIDE UNINTERRUPTIBLE OUTPUTS. These high-efficiency power supplies are available with batteries, inverters and automatic-switching circuits. They come in sizes from 500 VA to 10 kVA. Each system includes a battery charger and a choice of a relay or solid-state switch with actuation time of as little as 4 msec. Operation is from power lines of 95 to 130V ac. Systems up to 2000 VA contain sealed, maintenance-free batteries. Prices of the systems range from $1825 to $11,300. Topaz Electronics, 3855 Ruffin Rd., San Diego, CA 92123. Phone (714)279-0111. **216**



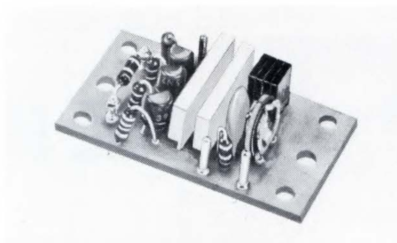
0.01% 8-CHANNEL ANALOG MULTIPLEXER HAS INTERNAL ADDRESS DECODER. Model MPM-8S is capable of expansion to 256 channels in multi-tiered matrix configurations. It accepts ±10V analog signals and binary coded TTL-compatible channel-address information and provides a time multiplied output signal suitable for input to A/D converters, S/H amplifiers and v/f converters. Throughput speeds of up to 250 kHz are possible. The MPM-8S settles to 0.1% in 3 μsec and to 0.01% in 7 μsec, with a 1000Ω source impedance. Crosstalk is −115 dB with a 1000-Hz full scale sinewave on all OFF channels. ON resistance is 200Ω and drift is only 1%/°C from 0°C to +70°C. The unit operates over −25°C to +85°C. $125. Burr-Brown Research Corp., International Airport Industrial Park, Tucson, AZ 85706. Phone (602)294-1431. **249**

DE-GLITCHED 13-BIT D/A CONVERTER HAS 50-nSEC SETTLING TIME. Model DDAC thick-film hybrid unit features low glitch of 150 mV-nsec at a 5-MHz word rate. The converter is available as a set of 3 DIPs (from $485) or a complete pc-card assembly (from $550). It has programmable ±2.5V, ±5V or ±10V voltage outputs with 100-mA, 50Ω coax drive, internal or external references, MIL-STD-883 processing and short-circuit protected outputs. The 3 basic parts are a 13-bit D/A converter in a 24-pin DIP, a track-and-hold deglitcher in a 24-pin DIP and a coax driver amplifier in a TO-3 case. ILC Data Device Corp., 100 Tec St., Hicksville, NY 11801. Phone (516)433-5330. **250**



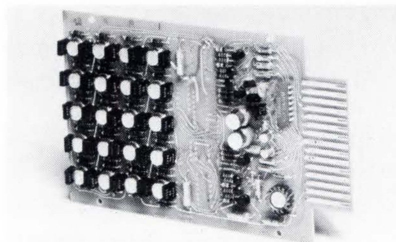
ULTRA-FAST D/A CONVERTERS SUPPLY HIGH OUTPUTS. The MDS/MDP Series of 8 and 10-bit modular D/A units feature settling times as low as 15 nsec for 8-bit accuracy and 20 nsec for 10-bit units. High output current on the converters assures good drive capability even on low-impedance loads, without sacrificing settling time. In the unipolar mode, the units will supply outputs of 15 mA or 1.5V; in the bipolar mode, they can supply ±7.5 mA at ±1.1V. MDS 8-bit units range in price from $89 to $109 and 10-bit units from $109 to $129. MDP 8-bit units range from $109 to $129 and 10-bit units from $129 to $149. Computer Labs, 1109 S. Chapman St., Greensboro, NC 27403. Phone (919)292-6427. **251**

LED NUMERIC DISPLAY ASSEMBLIES FEATURE 0.8-IN.-HIGH CHARACTERS. The SLB-3 Series is presently available with red numerics in standard 3 to 8-digit assemblies as well as customer design. Green and yellow versions are to be available shortly. All extend only 0.6 in. behind the panel and are mounted on 0.8-in. centers. Design advantages include an easy push-on clip for bezel mounting and plug-in use of OPCOA's standard red SLA-3 and SLA-4 0.8-in.-high numeric displays. OPCOA, Inc., 330 Talmadge Rd., Edison, NJ 08817. Phone (201)287-0355. **252**

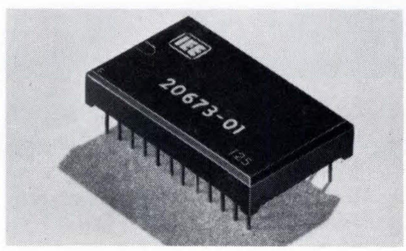


PULSE TONE ENCODER COMES IN A THICK-FILM NETWORK. This exceptionally small tone encoder is for use in telemetry, remote control systems and radio communications. The AE-50 will produce a burst of tone on any frequency between 20 and 3000 Hz. The burst or pulse duration can be varied from 100 msec to 15 sec, or can be strapped for a continuous encode. The miniature size of 1-1/4-in. long × 15/16-in. wide × 1/2-in. high makes the unit especially useful where space is at a premium. Temperature range is from −40°C to +100°C and power requirements are 4 mA at 12V dc. Frequency stability is ±0.5%. Alpha Electronic Services, Inc., 8431 Monroe Ave., Staton, CA 90680. Phone (714)821-4400. **253**

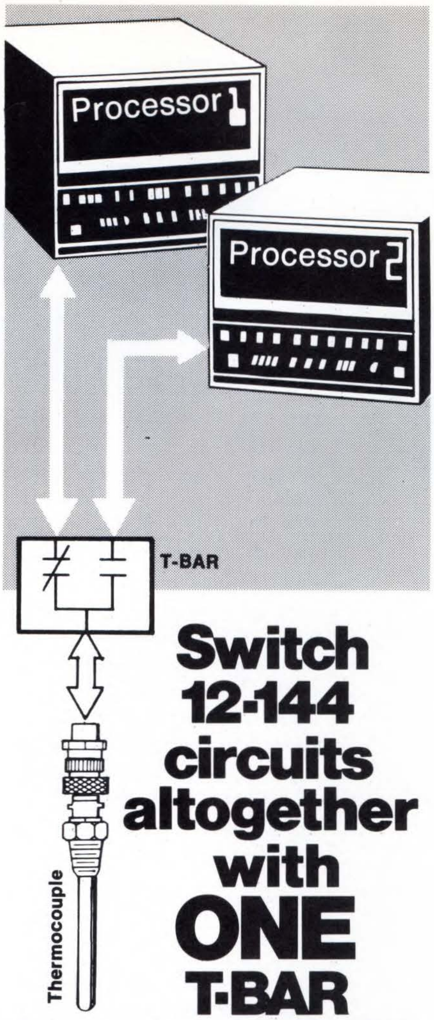
TONE ENCODER/DECODER MOUNTS ON PLUG-IN CARD. Used in a wide variety of control and signaling applications, the unit operates from a nominal 12V dc supply and has an encoder tone ±25 Hz from the nominal specified frequency. Once set, it will remain in frequency with a stability of ±5 Hz over a temperature range of 0°C to ±50°C. The encoder is keyed OFF and ON by a ground connection capable of drawing 10 mA. The encoder is designated FL2605-2 and the decoder is designated FL2605-3. The latter responds to the encoder signal by closing a relay with two Form C contacts. Ferritronics, Ltd., 222 Newkirk Rd., Richmond Hill, Ontario, Canada. Phone (415)889-7313. **254**



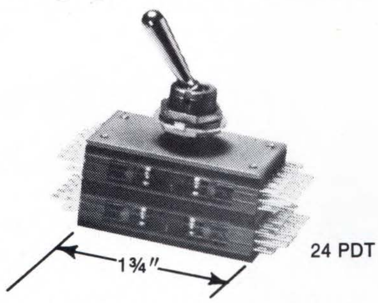
MOS DELAY LINE MEMORY HAS 20k BITS AT 0.5¢/BIT. Model 2269 is used to replace magneto-strictive delay lines and in CRT terminals, buffer memories, drum memories, sequential-access memories, line storage and line printers. Delay length and storage capacity can be tailored to exact customer requirements. The card is 4-1/2 × 6 in. and is suitable for either edge-finger or connector mounting. It accepts standard TTL inputs and generates standard TTL outputs. Data and clock rates range from 500 Hz to 4 MHz. Melcor Electronics Corp., 1750 New Highway, Farmingdale, NY 11735. Phone (516)694-5570. **255**



HYBRID DECODER/DRIVER COSTS $17. Series 20673 24-pin DIP measures only 0.762 × 1.277 in. It has drive capability of 300 mA at 30V and operates from 5V lines. The unit is designed to decode standard 8421 BCD to 12 outputs or, if only 10 decoded outputs are required, the two remaining may be connected as lamp buffers. The 20673 is DTL/TTL compatible, available with or without memory, and features lamp blanking as standard. Industrial Electronic Engineers, Inc., 7720 Lemona Ave., Van Nuys, CA 91405. Phone (213)787-0311. **256**



Switch 12-144 circuits altogether with ONE T-BAR Toggle Switch!



T-Bar Toggle Switches are designed specifically for manually switching many parallel lines. 8 - 144 pole T-Bar Toggle Switches are available in Form A and C contacts. For low level switching, specify Series 902 T-Bars with bifurcated contacts for high reliability.

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TX S	(713) 461-4487
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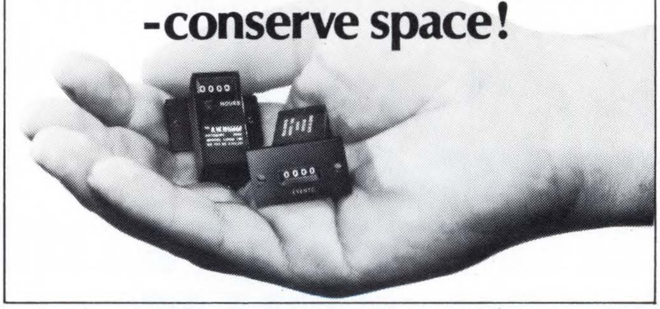
Circle No. 41

Monitor events-track time -conserve space!



Mini events or time indicators for important billing or maintenance functions.

Although they measure only 37/64" square x 1¼" long, these precision indicators have a clearly visible 4-digit readout. They're easy to see, yet occupy only a minimum of space. They're non-resettable and tamper-proof — the perfect way to monitor elapsed time or events in peripherals, business machines, production machinery or similar electrical/electronic equipment.

The Elapsed Time Indicator is furnished with either front or side readout, for surface or through-panel mounting. Available for 50 or 60 Hz operation.

The Events Counter comes with the flange-type mount only. Count rate is 1200 cpm. It can be supplied for DC or 50, 60 or 400 Hz operation at various voltages. Power consumption is 2.5 watts nominal.

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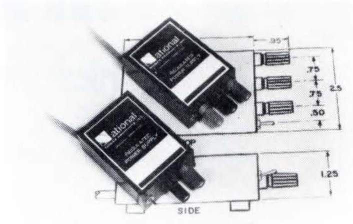
Circle No. 42

CIRCUITS

DIGITAL-IC POWER SUPPLIES DELIVER UP TO 35A. The UPM-5 family of five modular power supplies features output current ratings of 5.7A ($119), 10A ($149), 17A ($199), 25A ($299) and 35A ($359) at +5V dc. All supplies deliver full output at +40°C, with derating to +70°C. Line and load regulation is 0.1% or 5 mV, whichever is greater. Ripple and noise is 2 mV rms and 20 mV p-p and temperature coefficient is 0.02%/°C max. over 0 to +71°C. Load transients over the range of full to half load show a recovery to within regulation limits within 50 μsec. Standard supplies are rated for 105 to 125V ac, 47 to 63 Hz operation. Datel Systems, Inc., 1020 Turnpike St., Canton, MA 02021. Phone (617)828-6395. **257**

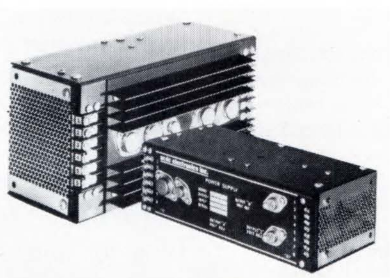
50-CONTACT CARD PROGRAMMABLE SWITCH COSTS $75. Model 50B can be used to program a display, open a door or set up a machine. The card is 1-1/2 × 3-3/4 in. and its material is either Mylar or Vinyl. It contains a 5 × 10-hole matrix on 1/4-in. centers. With this matrix, the switch can be programmed by punching the card with a simple hand punch. The switch will read cards 0.007 to 0.030-in. thick. The Model 50B will perform more than 25,000 operations when switching 115V before contact cleaning is necessary. Hickok Electrical Instrument Co., 10514 Dupont Ave., Cleveland, OH 44108. Phone(216)541-8060. **258**

INDUSTRIAL-CONTROL LOGIC MODULES ADD VERSATILITY. A Series of Controlpac II solid-state plug-in logic modules consists of 30 modules grouped in nine families to be formally introduced over the next several months. The plug-in cards enable Controlpac II users to increase the system's capabilities without altering its basic wiring. Four connector kits for use with modules when upgrading a system are also available. The nine functional families are: basic-logic, input buffer, output buffer, load driver, timer/counter, programming, memory, power supply and miscellaneous. Eagle Signal Industrial Control Div., 736 Federal St., Davenport, IA 52803. Phone (319)326-8111. **259**



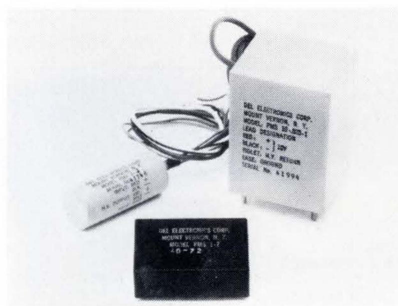
TINY LAB SUPPLIES MEASURE 2.5 × 3.5 × 1.25 IN. A line of pocket-size lab supplies come complete with five-way binding posts, on-off switches and five-foot three-conductor line cords. There are 6 standard models in the "L" Series, which provide voltages of 5, ±12 or ±15V dc at 500 or 1000 mA (5V dc) and 100 or 200 mA (±12 or ±15V dc). Line regulation (105-125V ac input) is 0.05% max. and load regulation (0-100% load) is 0.1% max. TC is 0.015%/°C, ripple and noise is 0.5 mV rms max. (±15V) and 1 mV rms max. (5V). Output-voltage tolerance is factory set at ±1%. Dual outputs track to within 0.025%. $49 and $69. National Products, Inc., Box 292, Haverhill, MA 01830. Phone (617)374-0777. **260**

A/D CONVERTER LINE SPANS 8 TO 14 BITS. Utilizing successive approximation, they feature conversion times from 80 μsec for 14 bits to 8 μsec for 8 bits with accuracy to 0.01% of full scale range, and an overall temperature coefficient of 12 ppm over 0 to +70°C. Accuracy and temperature-coefficient specifications in the new 400 Series include errors due to the analog switches, internal reference voltage generator, comparator offset, gain error, non-linearity, calibration resolution, resistor network tracking, quantizing error and power-supply variations within ±5% tolerance. Single-unit prices are $175 (8 bits); $215 (10 bits); $260 (12 bits); $310 (13 bits); $345 (14 bits). Phoenix Data, Inc., 3384 W. Osborne Rd., Phoenix, AZ 85017. Phone (602)278-8528. **261**

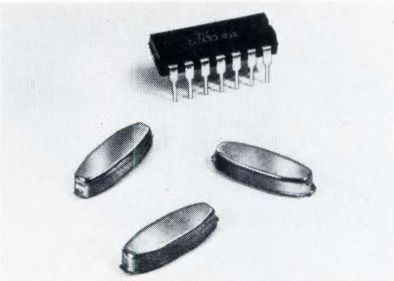


OEM SUPPLIES DRIVE OP AMPS AND ICs. The TR series supplies provide a single voltage output for driving IC logic and a dual-voltage output for driving op amps and A/D converters. By combining these functions into a single compact package, the OEM can realize a savings in cost, along with reduced size and weight. The supplies are available with voltage outputs of 5V/±12V and 5V/±15V. Current ratings are 5A or 10A on the single output and 1A on the dual (tracking) output. Overvoltage protection is built into the single output and is optional on the dual output. Regulation is 0.1%. $109 for 5A models and $129 for 10A models. ACDC Electronics, Inc., Oceanside Industrial Center, Oceanside, CA 92054. Phone (714)757-1880. **262**

PRESELECTOR FILTERS COVER "C" BAND. The new line of tunable-cavity units employ a micrometer head for calibrated tuning over a 500-MHz frequency range in C band. The micrometer tuning adjustment can be locked at any desired frequency. The bandwidth is controlled to within 20 and 30 MHz and the insertion loss is 0.5 dB. VSWR is 1.2:1. These preselector filters measure 1-1/2 × 1-1/2 × 5 in., including tuner, and weigh 8 oz. SMA connectors are standard. Price is $125 ($75 each in large quantities). Texscan Corp., 2446 N. Shadeland Ave., Indianapolis, IN 46219. Phone (317)357-8781. **263**

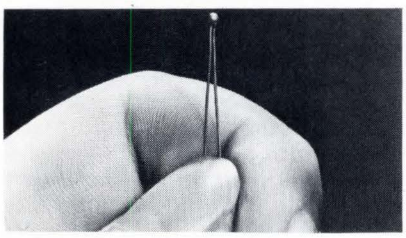


POWER SUPPLIES FOR PHOTOMULTIPLIERS FEATURE COMPACTNESS. The new PMS Series of photomultiplier-tube power supplies represent a family of extremely compact dc-to-dc proportional converters. These devices cover various output voltage ranges from 300 to 10,000V. They are reported to have low output ripple, reverse polarity and momentary flashover protection. Some models are also available for battery power or ac-line input operation. Most units are available from stock or on a short-delivery basis. Price on some models is under $30 in quantity. Del Electronics Corp., 250 E. Sandford Blvd., Mt. Vernon, NY 10550. Phone(914)OW9-2000. **264**

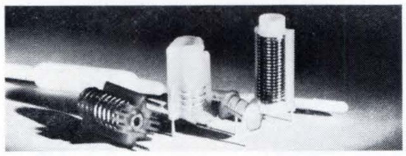


SHOCK-RESISTANT MINIATURE CRYSTALS PROVIDE HIGH Q FACTOR. Used in micropower-electronic circuits, the quartz crystal typically requires only about 100 nW of drive power. The crystals are 15 mm long × 5 mm wide × 3 mm high. The metal enclosed quartz crystals were originally developed to meet the stringent packaging and performance requirements of precision quartz-crystal watches. They are available at 32.0 kHz. $9.75 each in quantities of 100. Frequency & Time Systems, Inc., 182 Conant St., Danvers, MA 01923. Phone(617)777-1255. **170**

HIGH-VOLTAGE CAPACITORS HAVE 20-40% LESS VOLUME. The line of tubular high-voltage capacitors range from 1-200 kV dc. Among the principle features of the PHV Series are rigid phenolic housing, oil impregnated and oil filled capacitors which are hermetically sealed and operate at 85°C without derating. The units are completely insulated by the housing and sealing material. They are also wax free and feature a lower power factor that will not exceed .75%. $2.37 each in quantities of 100. The Elmag Corp., 54 Clark St., Newark, NJ 07104. Phone(201)481-1600. **171**

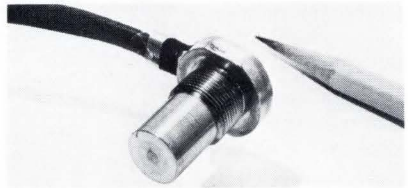


BARE-WIRE THERMOCOUPLES ALLOW FAST AND ACCURATE MEASUREMENTS. These unsheathed, fine-gage thermocouples are available in chromel-alumel, iron-constantan, chromel-constantan, copper-constantan, platinum-platinum/rhodium and tungsten-rhenium alloy combinations. Fine thermocouple wire diameters enable temperatures to be measured without disturbing the base temperature of the body in which the installation is made. They are available in wire diameters ranging from 0.0005 to 0.032 in. Thermocouples are of the beaded-junction type with the bead diameter about 3 times the wire diameter. Omega Engineering, Inc., Box 4047, Springdale Station, Stamford, CT 06907. Phone(203)359-1660. **172**

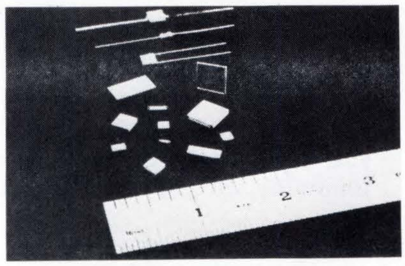


VHF COILS COVER 10- TO 450-MHz FREQUENCY RANGES) The coils are designed for use in mobile communications equipment, color TV and FM receivers, and provide high resistance to shock and vibration. Series 48A adjustable coils with inductance values from 0.046 to 3.51 μH cover the frequency range from 30 to 250 MHz. Series 49A adjustable coils with inductance values from 0.06 to 1.53 μH cover the frequency range from 10 to 250 MHz. Series 75F fixed coils with inductance values from 0.023 to 0.59 μH cover the frequency range from 50 to 450 MHz. Bell Industries, J. W. Miller Div., 19070 Reyes Ave., Compton, CA 90224. Phone(213)537-5200. **173**

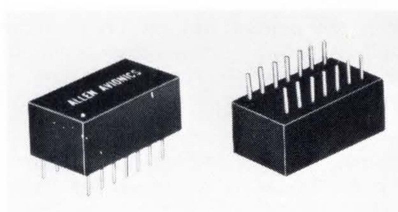
SEE-THROUGH SWITCH MATRIX EMBEDDED IN PLASTIC. The "CUE-SWITCH" products are based on an ingenious switch element consisting of matrixed conductors embedded in transparent-plastic membranes. Without mechanical linkages, springs or buttons, the switch elements are sealed from dirt and moisture. They offer exceptionally low mass and profile to designers. By their transparent nature, the switch elements can be placed over any surface and retain readability of printed, silk screened or projected data e.g., CRT faces, calculator keyboards, rear projected graphics, etc. Industrial Electronic Engineers, Inc., 7720 Lemona Ave., Van Nuys, CA 91405. Phone(213)787-0311. **174**



MINIATURE TRANSDUCERS SENSE MOTION WITHOUT CONTACT. The PT Series of miniature proximity transducers are suitable for noncontacting measurement of both lateral and radial motion, whether static or dynamic. These variable-reluctance units are precision electromagnetic devices that respond to the proximate presence of ferromagnetic objects and give electrical output approx. inversely proportional to the distance between a ferromagnetic surface and the sensitive face of the transducer without physical contact. Schaevitz Engineering, Rt. 130 & Union Ave., Pennsauken, NJ 08110. Phone(609)662-8000. **175**



MICROMINIATURE CERAMIC CAPACITOR LINE EXPANDED. The Unicerams provide a minimum Q of 5000 at 1 MHz. Typical Q values are better than 10,000. VSWR and insertion loss are extremely low. The ratio of capacitance to unit volume is very high. Unicerams utilize fine silver threads bonded to the capacitor by an unusual solderless process resulting in ultra-low loss RF conductivity. Ceramic-dielectric layers are fused into a solid monolithic structure and then encapsulated in glass to insure total protection from surface contamination, moisture and other environmental hazards. Capacitance ranges from 0.5 to 3000 pF. Under $1 in quantities of 1000. JFD Electronics Corp., 1462 62nd St., Brooklyn, NY 11219. Phone(212)331-1000. **176**

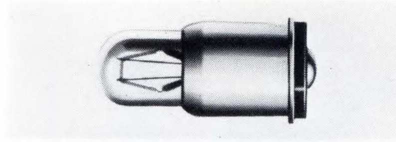


DIP DELAY AVAILABLE UP TO 1000 NSEC. The unit incorporates 10 equal delay taps, which along with dual-in-line packaging and low silhouette, make it compatible with semiconductor and other assemblies where circuit board height is restricted. Units are available with time delay to rise time ratios of 5:1 and working voltage of 50V dc. $20.00. Allen Avionics, Inc., 224 E. 2nd St., Mineola, NY 11501. Phone(516)248-8080. **177**

MINIATURE LOAD CELL COMBINES ACCURACY WITH LOW COST. The standard miniature load cell features guaranteed specifications of ±0.03% linearity, ±0.02% hysteresis and ±0.01% nonrepeatability. Until now, the least expensive load cells of comparable performance were OEM priced between $200 and $300. The Minibeam load cell is designed for controlled environment electronic-weighing applications and force measurements. Rated output of the Minibeam is 3 mV/V. Full scale deflection is just 0.005 in. Available in standard ranges of 0 to ±50, 0 to ±75, 0 to ±100 and 0 to ±150 lbs, the unit is ideal for lever type or fully electronic scales. $99. Interface, Inc., 7210 E. Acoma Dr., Scottsdale, AZ 85254. Phone(602)948-5555. **178**

ANALOG COUNTERS HANDLE HIGH-SPEED FUNCTIONS. These analog counters are rugged, small, low-cost devices which occupy less than 1/10 of a cu. in., weigh only 1 gram and have no moving parts. The counters are activated directly by any type of digital-logic signal or similar pulse. They require no independent power supply and consume only a few mW of power. No EMI shielding is necessary. Maximum counting rates are over 100,000/sec. They have storage capacities of 30,000 counts and up, with infinite memory. Curtis Instruments, Inc., 200 Kisco Ave., Mt. Kisco, NY 10549. Phone(914)666-2971. **179**

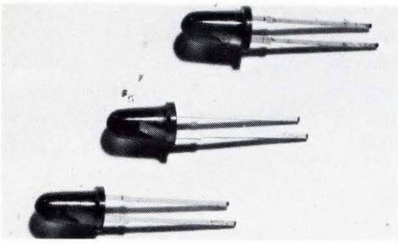
ROTARY SWITCH PLUGS INTO pc BOARDS. The Series JMP 36 sub-microminiature rotary switch is dimensionally compatible with discrete components normally used on pc boards. The switch pin terminals are set to fit a standard TO-100 grid pattern. It measures only 0.3-in. in diameter and 0.5-in. overall in length and weighs only 1-1/2 grams. Its 36° angle of throw (10 positions), 1 or 2 poles in addition to bridging functions, is in a single-deck design. A screwdriver slotted shaft actuates the unit and the "positive-action" detent mechanism prevents accidental switch settings. Voltage breakdown is 500V ac minimum between mutually insulated parts. Electrical rating is 2A continuous. Janco Corp., 2111 Winona Ave., Burbank, CA 91504. Phone(213)845-7473. **180**



LOW-CURRENT LAMP IS IC COMPATIBLE. The incandescent subminiature lamp draws only 40 mA at 5V to make it suitable for direct drive by many TTL buffer gates. Type H 540 has an industry standard T1-3/4 submidget flange-base configuration and is available in all popular socket-base styles (wire terminal, bi-pin, midget grooved, midget screw). 1k piece price is .25¢. Industrial Electronic Engineers, Inc., 7720 Lemona Ave., Van Nuys, CA 91405. Phone(213)787-0311. **181**

RELAYS PROVIDE SOLID-STATE SWITCHING. A family of solid-state relays featuring zero-voltage switching and optical isolation take an input of 4 to 30V while providing an output of up to 10A at 140V. Besides having 1500V rms optoelectronic isolation, both models also feature input to TTL and 30V dc compatibility. Model GSR10AU5 is rated at 5A, 120V or 700W output with a suggested resale price of $11.70 in lots of 100. Model GSR10A10 is rated at 10A, 120V or 1400W output with a suggested resale price of $13 in lots of 100. GE Semiconductor Products Dept., Bldg. 7, Mail Drop 49, Electronics Pk., Syracuse, NY 13201. Phone(315)456-2021. **182**

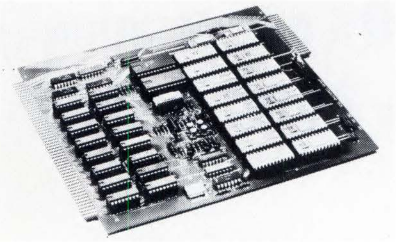
IC SOCKETS HAVE LOW PROFILE. These 28-and 40-pin low-profile dip-solder sockets for high-density packaging of LSI devices feature a 0.150-in. overall height, plastic barriers to eliminate solder-wicking and a closed-entry insulator for easy device insertion. Contacts are heat treated beryllium copper, gold plated and housed in a glass filled nylon base. The 28-pin sockets (CSA3201-28) sell for $1.07 each in quantities of 100 and the 40-pin sockets (CSA3201-40) cost $1.51 each in the same quantities. Stanford Applied Engineering, 340 Martin Ave., Santa Clara, CA 95050. Phone(408)243-9200. **183**



GaP LEDs OFFER 3 TO 5 TIMES EFFICIENCY OF GaAsP. The XC524 has typical brightness of 5 millicandela at I_f = 10 mA. GaAsP equivalents offer 1.5 millicandela at I_f = 20 mA as typical values for similar lens configurations. The higher efficiency can be used to reduce the power consumption by up to 80%. The devices offer direct-drive compatibility with single gate TTL and MOS. $1.12; 1-99 quantities. 78¢, 100-999. 69¢, 1000. Xciton Corp., 5 Hemlock, Latham, NY 12110. Phone(518)783-7726. **184**

1-IN. MINIATURE CRT HAS HIGH RESOLUTION. Operating over a 5 to 10 kV range at a minimum of 850 lines, the CRT is capable of 350 ft-lmbts (P-1 at 7 kV) output from a useful area of 6 × 6 in. All P- phosphors are available. Magnetic deflection enables high-resolution applications and spot sizes to 0.6 mils. All leads, including the anode lead, exit from the base for streamlined design. The tube weighs only 38 grams and is 5.5-in. long. The flat face permits simplification of associated optical systems. Hi-g shock resistant guns are employed. Sub screen, black screen and fiber-optic screens are available. Video Products Inc., 7550 San Fernando Rd., Sun Valley, CA 91352. Phone(213)767-0748. **185**

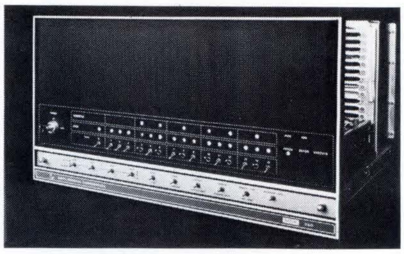
HEAT PIPE REPLACES ELECTRONIC HEAT SINKS. Primary applications of the Model 1333 H are for cooling semiconductors, ICs, transformers and electron tubes. The heat pipe, a more efficient thermal conductor than metals such as copper, consists of a sealed container, a wick and working fluid. In operation, heat vaporizes the working fluid in the evaporator region; the vapor then moves to the condenser region where it gives up thermal energy as heat of condensation, and the condensed fluid then returns through the wick by means of capillary action. It has a maximum load capability of 15W and a usable temperature range of −60°C to +100°C. Hughes Electron Dynamics Div., 3100 W. Lomita Blvd., Torrance, CA 90509. Phone(213)534-2121. **186**



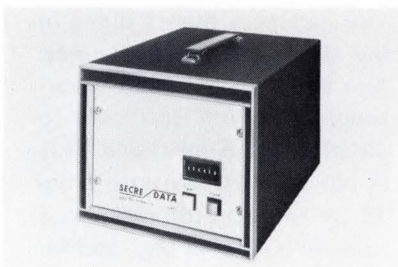
SINGLE pc BOARD MICROCOMPUTER SELLS FOR $695. This parallel 4-bit general-purpose self contained microcomputer features a stable crystal clock that cannot be false triggered by noise. The microcomputer is a complete operating system with cycle times of 11.8 μsec. It consists of 5 basic functional elements: a CPU, a ROM for assembled program storage, a RAM for data storage, an expandable universal I/O bus and a computer clock. Important options include: RAM data storage expansion in increments of 80-word RAM IC chips to a maximum of 1280 words, ROM assembled program storage expansion in increments of 512-word preprogrammed ROM IC to a maximum of 8192 words. Applied Computing Technology, Inc., 17815 G Sky Park Circle, Irvine, CA 92707. Phone(714)549-3123. **217**

PORTABLE TELETERM DESIGNED FOR "MULTICS" TIME-SHARING SYSTEM. The 1030/MULTICS TELETERM weighs only 22 lbs and fits under an airline seat. Connection to the MULTICS time-sharing system is via built-in acoustic coupler; data is transmitted and received over voice-grade telephone lines at up to 30 cps. Its thermal printer makes it nearly silent. An added standard feature is the ACK/NAK keyboard inhibit capability, similar to the TTY-37 terminal. Because of this similarity, the 1030/MULTICS simplifies operator training, making possible fast, error-free computer use for anyone using MULTICS. $3350 purchase or $97 per month. Computer Devices, Inc., 9 Ray Ave., Burlington, MA 01803. Phone(617)273-1550. **218**

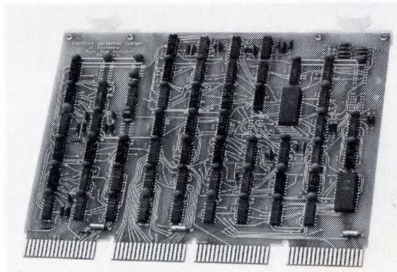
RJE SYSTEM OPERATES WITH DIGITAL PLOTTER. This remote job entry system operates with a high-speed flatbed digital plotter for automatic drafting. It uses a DATA 100 terminal which includes a punched-card reader, a high-speed line printer, an operator's keyboard console and a modem for connection to a phone line. A magnetic-tape unit for mass storage is optional. The system operates over standard voice-grade telephone lines at a 2000 baud transmission rate. After processing, output data is received by the DATA 100 and directed to the plotting system. Telephone use charges are minimized by the data compacting and high-speed data transmitting and receiving capabilities of the DATA 100 unit. Xynetics, Inc., 6710 Variel Ave., Canoga Park, CA 91303. Phone(213)887-1022. **219**



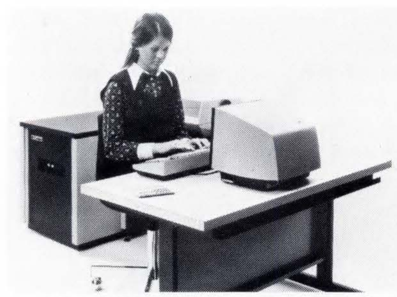
MINICOMPUTER IS DEDICATED TO COMMUNICATIONS. The Nova 840 is a compatible, expanded version of the Nova 800 computer series. The computer has a built-in memory management and protection unit that allows expansion of main memory to 128k 16-bit words, provides memory mapping in 1k word blocks, incorporates I/O device protection and write and validity protection for main memories. Typical applications include handling front end, data concentrator, or message switching in the foreground, and supplemental data-processing jobs in the background, or supporting store-and-forward systems. Basic unit, $16,530. Average system prices, $40,000 to $70,000. Data General Corp., Southboro, MA 01722. Phone(617)485-9100. **266**



DATA SCRAMBLERS FOIL DATA THIEVES. To meet the growing concern about stolen data, the Series 102 SECRE/DATA scramblers provide a high level of security to all data users. Included in the series is a synchronous version requiring no external timing. All models contain the unique feature of automatic-cipher synchronization. There are over 200,000,000 code settings available for scrambling the data. The synchronous models can operate up to 1M bps with external timing and up to 9600 boud if no external timing is available. The asynchronous models can operate for any of the standard code formats and speeds. Com/Tech Systems, Inc., 15 Williams St., New York, NY 10005. Phone(212)245-0733. **267**



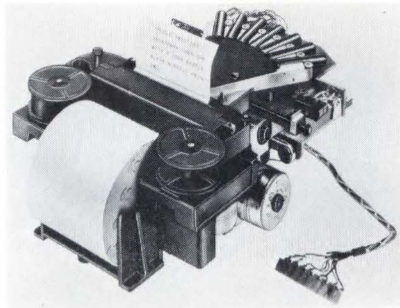
BOARDS INTERFACE READER TO COMPUTER. Interface boards extend direct plug-in installation of any EECO photoelectric punched-tape reader or punch to PDP-8 and -11 series minicomputers. EECO computer interface boards are both hardware and software compatible to the computers. Cables are provided for direct connection between computer and reader or punch and a diagnostic software package is furnished. Passive filtering and anti-ambiguity logic are incorporated to guard against fiberous tape, pin holes, tape jitter or cable noise. Electronic Engineering Co. of California, 1441 E. Chestnut Ave., Santa Ana, CA 92701. Phone(714)547-5651. **268**



REMOTE-INTELLIGENT TERMINAL SYSTEM. Packaged in a 26-in. high pedestal, the System IV/40 features a 72k byte LSI processor with an integrated discette or cartridge disc drive and an integrated communications controller. The system can accommodate 2 to 16 video terminals and 16 printers. System IV-40 is communications compatible with IBM computers and with Four-Phase's larger System IV/70. When operated with the DATA IV/70 source data entry program provided, System IV-40 combines the functions of key entry, verification and validation with the communications and output capabilities of a remote-batch terminal. Four-Phase Systems, Inc., 10420 N. Tantau Ave., Cupertino, CA 95014. Phone(408)255-0900. **269**

DIGITAL CASSETTE SYSTEMS USED FOR DATA COMMUNICATION. The STR-LINK Series digital cassette systems provides an inexpensive, reliable method of data communications through the use of digital cassette recorders. The STR-LINK units incorporate both a standard RS-232 interface and a 20 mA current-loop interface; on some models, an 8-bit parallel interface is also available. STR-LINK units that record data in blocks using the nonincremental STR-200 drive can receive data at 1200 baud. $890 for single units. Dual drives, $1700 each. Electronic Processors, Inc., 5050 S. Federal Blvd., Englewood, CO 80110. Phone(303)798-9305. **270**

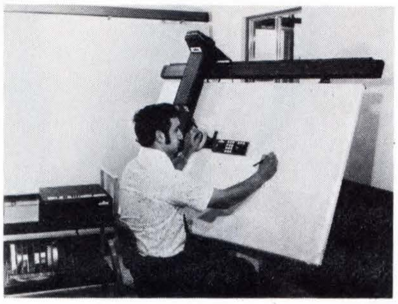
COMPUTER PRODUCTS



5 × 7 DOT-MATRIX PRINTER PRINTS AT 50 cps. Designed for OEM use and capable of printing any character or symbol that can be created by a 5 × 7 dot matrix, the printer uses either conventional paper and ribbon or "direct action" paper for which no ribbon is required. Two "carbonless" copies may be produced along with the original. The printer uses electronic control to drive the needles which produce the 5 × 7 dot matrix. This method of printing provides a simple, versatile system which can be changed electronically rather than mechanically. Model 60SA/60HZ price is $216.75 in lots of 100. Model 60SR/60HZ is priced at $255. Amperex Electronic Corp., Hicksville Div., Hicksville, NY 11802. Phone(516)931-6200. **271**

ROUND PLUNGER SWITCHES OFFER LOW PROFILE. The Phase 2 Bi-Pac-SC, a series of round plunger keyboard switches, consist of 2-piece solvent resistant/glass filled nylon housings, 2-shot round keys and dual conical-spring contacts mounted 1 inside the other. Switches mount on 3/4-in. centers with maximum length of 3.050 in. for the 4 unit module. Over-all height is 0.80. in. The simple 4-part switches offer light touch (2.5 oz) and short 0.150-in. stroke (including 0.075-in. overtravel). Life expectancy is over 10 million cycles at 10V dc and 0.050A max. Initial contact bounce is 2 msec with resistance less than 0.250Ω. Temperature range is 0° to +65°C. Price: 21¢ per position for 1 million pc. quantity. Controls Research Corp., 2100 S. Fairview, Santa Ana, CA 92704. Phone(714)557-7161. **272**

TDM INTERFACE OFFERED FOR MOST MINIS. A parallel interface for the ADS-670 data-distribution system, a time-division multiplexer, has resulted in a lower-cost communications interface compatible with most minicomputers. The parallel interface eliminates normal character timing software by providing all I/O character interrupt timing. It allows data transfers to be made only when control changes or data requests are detected, eliminating continuous frame-scan software, and it provides a 16-bit bidirectional bus interface. American Data Systems, 8851 Mason Ave., Canoga Park, CA 91306. Phone(213)882-0020. **273**



DIGITIZER PUNCHES COORDINATE DATA ON TAPE. The orthograph digitizing unit links a basic drafting machine to computers, numerically controlled machine tools and plotters. It is compatible with any basic orthograph drafting machine equipped with a coordinate measuring unit. It converts graphic and pictorial drafting information to digital data on punched tape. By proper positioning of the digitizing head and operation of the keyboard, the draftsman can automatically punch necessary coordinate data and instructions. The data is recorded on the punched tape in USASCII output format. EIA format may be added as an option. Dietzgen Corp., 2425 N. Sheffield Ave., Chicago, IL 60614. Phone(312) 549-3300. **274**

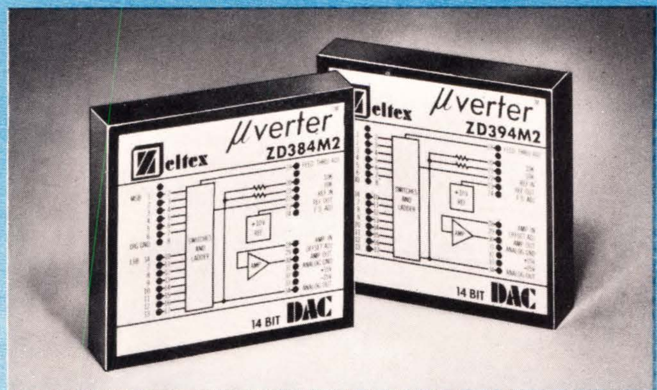
CODE CONVERTER INTERFACES BAUDOT AND ASCII SYSTEMS. The Model CC 1040/1005 code converter provides direct 2-way interface between serial 5-level Baudot systems and serial 8-level ASCII systems. Unique I/O circuitry provides either constant-current or switch output. Speed difference when converting from ASCII to Baudot is handled by means of a standard EIA control line. The CC 1040/1005 is mounted in a 19-in. rack-mount cabinet. Nationwide Electronic Systems, Inc., 7N662 Rt. 53, Itasca, IL 60143. Phone(312)773-0370. **275**

CALCULATOR KIT OFFERS 1/2-IN. 8-DIGIT DISPLAY. The IC-2108 is a complete 4-function desk-top calculator with both floating and fixed decimal. A constant key permits chain calculations and a clear entry allows removal of an entry from the display window without disturbing prior calculations. Negative-answer, entry and result-overflow indicators are automatically displayed. The color coded keyboard eliminates confusion. The keyboard slopes to the desk for comfortable arm positioning. $79.95. Heath Co., Benton Harbor, MI 49022. Phone(616)983-3961. **276**

NEW!

from ZELTEX...

14-Bit DAC's from $85



LOW COST 14-BIT DAC's–The new ZD300 Series include ten new models that offer excellent linearity, fast settling, current and voltage outputs, bipolar and unipolar coding, slaveable reference, and two quadrant multiplication. Prices range from $85 to $179 in single quantities.

FAST SETTLING TIMES (1 us)–Settling times as fast as 1 us for current output models and 2 us for voltage output DAC's makes the ZD300 Series useful in a variety of data conversion applications.

UNIPOLAR, BIPOLAR OUTPUTS–Unipolar and bipolar operation is specified at 0 to ±10V, and ±10V, respectively. Current output models are rated at 0-2 mA. Voltage output models also feature current output capability as well as two-quadrant multiplication-up to 100 kHz.

LINEARITY 0.005%–High performance units feature linearity error of only 0.005% of full scale. Moreover, the extremely low linearity temperature coefficient of only 0.0005%/°C ensures high resolution accuracy.

SMALLEST 14-BIT DAC's–The ZD300 Series modular DAC's measure only 1.96 x 1.76 x 0.40 inches high–less than 1.4 cubic inches in volume. Low profile, DIP pinning compatibility and interchangeability of models make the series highly desirable for OEM usage.

APPLICATIONS–The versatility of the ZD300 Series makes them an excellent choice for use in process-control systems, automated test equipment, servo/synchro/resolver systems, and biomedical instrumentation.

Multiplying capabilities further enhance their use for CRT character generation, digital modulation, and polar-to-rectangular coordinate conversion.

Zeltex INC. LEADERS IN DATA CONVERSION TECHNOLOGY

CALL or WRITE TODAY for detailed data on these and other ZELTEX Conversion and Linear products.

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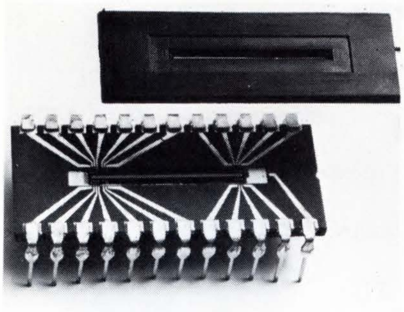
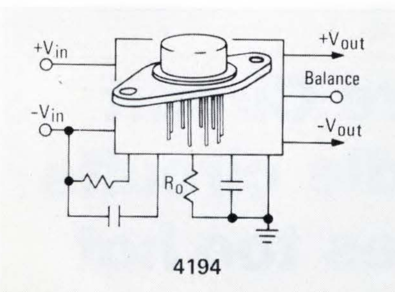
Circle No. 81

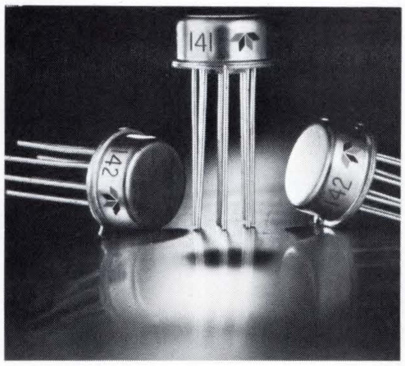


FIRST CCD IMAGE-SENSOR ARRAY HITS MARKET. The device has a typical dynamic range of 1000 to 1, and combines this capability with high sensitivity, which is rated at 15μ footcandle seconds. The monolithic n-channel device includes a 500-element photosensing strip sealed under an anti-reflective glass window, 2 charge-transfer gates, 2,250-element CCD analog-shift registers, a 2-element CCD selection register and an on-chip NMOS output device. Fairchild Semiconductor Components Group, 464 Ellis St., Mt. View, CA 94040. Phone (415)962-3816. **187**

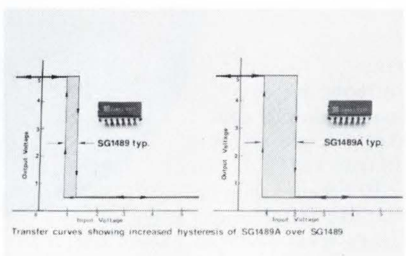


VARIABLE DUAL-TRACKING REGULATOR EASES DESIGN PROBLEMS. A variable voltage regulator, designated RM/RC4194, offers a 45V input and an output range of ±50 mV to ±42V. Only 1 external resistor to ground is required to set the desired output voltage. With 0.2% load regulation, the 4194 provides 200 mA at both outputs simultaneously; with external pass transistors it can supply up to 10A or greater. The regulator also provides thermal-shutdown protection when temperatures approach 175°C. Prices for 100-lot quantities begin at less than $2. Raytheon Semiconductor, 350 Ellis St., Mt. View, CA 94040. Phone (415)968-9211. **188**

LINEAR ICS FOR CONSUMER APPLICATIONS. The CA2111AE and the CA2111AQ contain FM-IF amplifier-limiters driving a quadrature-type FM detector. Their principle use is as an FM-IF/detector in radios and as sound IFs in TV receivers. The CA312OF is a TV signal processor incorporating a sync separator, noise inverter, AGC comparator and RF AGC delay amplifier for use in TV receivers. The CA312OF represents RCA's first expedition into TV "jungle circuits"—a term used by TV engineers to describe a circuit which is a "jungle" of miscellaneous circuit functions. RCA Solid State Div., Box 3200, Somerville, NJ 08876. Phone (201)722-3200. **189**



SAMPLE OP AMPS OFFERED TO DESIGNERS. The LM 141/142 fills the performance gap between the 741- and 108-type op amps. Improved characteristics of the series include slew rate of 2V/μ sec, input bias current of 30 mA max and 5 mA input-offset current max. The LM 141 series is fully compensated and is compatible with existing designs utilizing the 741, 107 and 1556. The uncompensated LM 142 series is a replacement for 101A, 748 and 777 applications and approaches the input performance of the 108 series. Teledyne Semiconductors will provide a free sample to qualified engineers who respond on company letterhead with information on intended application. Teledyne Semiconductor, 1300 Terra Bella Ave., Mt. View, CA 94040. Phone (415)968-9241. **190**



Transfer curves showing increased hysteresis of SG1489A over SG1489

QUAD LINE RECEIVERS OFFER INCREASED HYSTERESIS. SG1489J and SG1489AJ offer built-in threshold hysteresis. A greater margin of hysteresis, more than double that of the SG1489J, is provided by the A version. Both types offer logic-threshold shifting and input-noise filtering capability. Input resistance is 3.0 to 7.0 kΩ and input signal range is ±30V. The primary application for these devices is in interfacing data terminals with data communications equipment meeting EIA Standard RS-232C. Package style is 14-pin cerdip. Price: (100 pcs) SG1489J: $4; SG1489AJ: $4.50. Silicon General Inc., 7382 Bolsa Ave., Westminster, CA 92683. Phone (714)892-5531. **191**

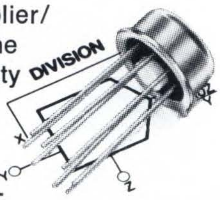
MSI, SSI LOGIC FUNCTIONS BUILD ECL 10,000 SELECTION. The MECL 10,000 devices are: the MC1014, quad AND gate; MC10114, triple-line receiver; MC10173, quad 2-input multiplexer/latch; and the MC10175, a quint latch. Like other standard MECL 10,000 logic devices, these circuits offer efficient high-speed logic operation; 2.0 nsec typical propagation delay/gate (shorter for MSI gates) with only 25-mW dissipation/basic gate (less for gates in MSI circuits). All parts are specified for operation over the broad industrial temperature range: −30°C to ±85°C. Motorola Inc., Semiconductor Products Div., P.O. Box 20924. Phoenix, AZ 85036. Phone (602)244-3466. **192**

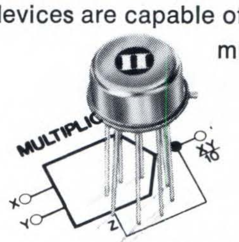
LOW-POWER SUCCESSIVE-APPROXIMATION REGISTERS. These monolithic devices can be used in successive approximation A/D converters replacing the 8- to 10-gate and flip-flop packages normally required to perform this function. The devices dissipate 110 mW (12-bit version, 150 mW), and operate at typical speeds of 5 MHz. The units are capable of making a comparison in 9 clock periods (the 12-bit version requires 13); have synchronous start capability and the capability for truncation. Advanced Micro Devices Inc., 901 Thompson Pl., Sunnyvale, CA 94086. Phone (408) 732-2400. **193**

Intronics multiplies your design flexibility

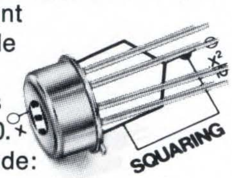
with low-cost, high accuracy M530 IC multiplier/dividers

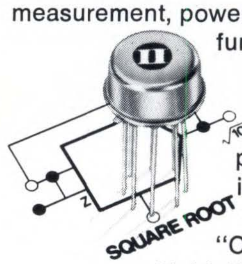
Intronics IC multiplier/dividers provide the packaging flexibility you need when space is at a premuim. These low-cost, fully self-contained, four-quadrant monolithic devices are capable of





multiplication $\frac{XY}{10}$, division $\frac{10Z}{Y}$, squaring $\frac{X^2}{10}$, and square rooting $\sqrt{10Z}$, and feature high accuracy to 0.5% with excellent stability and a wide bandwidth of one megahertz. Prices start as low as $20. Applications include: modulation and demodulation, phase detection and measurement, ratio measurement, power measurement, function generation and frequency discrimination. Write for complete applications information in our designer's guide, "Optimizing Analog Multiplier Performance."





When you're in a tight spot specify Intronics M530 IC multiplier/dividers.

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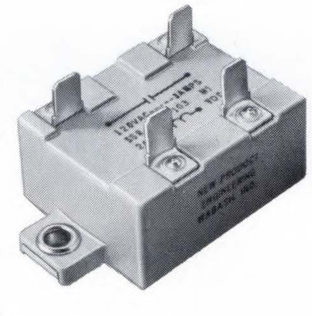
Circle No. 61

For price, delivery, quality
look to wabash

For SSR modules
look to wabash



930 series semi-solid state on-off relay in low profile package. Provides complete isolation between low control power input, high power load. Exceptional switching reliability. TTL logic-compatible. Use to switch inductive, capacitive, tungsten or resistive loads in wide range of equipment. For fast delivery, call today.

SPECIFICATIONS

		Load Current (maximum)	10 amps A.C.
Control Voltage (nominal)	5-48v D.C.	**Life**	up to 500 × 10⁶ Operation
Load Voltage (maximum)	200 or 400v (peak)	**Size**	2.63" L × 1.52" W × .850" H

For all relay types
look to wabash

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a subsidiary of Wabash Magnetics, Inc.
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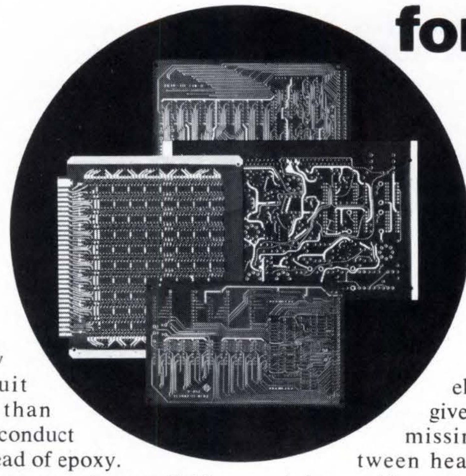
■ RF SWITCHING & MERCURY WETTED RELAYS ■ SUBMINIATURE REED SWITCHES
■ DIP REED RELAYS ■ SSR MODULES ■ STANDARD & MINIATURE REED RELAYS

Circle No. 62

Metal Core Circuit Boards handle circuits 4 to 13 times too hot for G-10



You can load a lot more hot components on our new Metal Core Circuit Boards (MCCB) than G-10 because they conduct heat like metal instead of epoxy. Here's what you can expect over G-10:

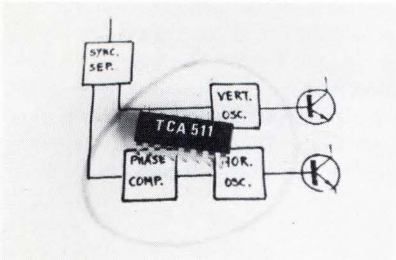
Environment	Power Density Increase
Still air	Four times
Forced air	Eight times
Thermally grounded system	Thirteen times

MCCB's spread the heat around for efficient convection, eliminate hot spots and give you the heretofore missing thermal link between heat producing device and the outside world. If your circuits are too hot to handle, write to IERC, a subsidiary of Dynamics Corporation of America, 135 West Magnolia Boulevard, Burbank, California 91502.

IERC DCA **Heat Sinks**

Circle No. 63

SEMICONDUCTORS

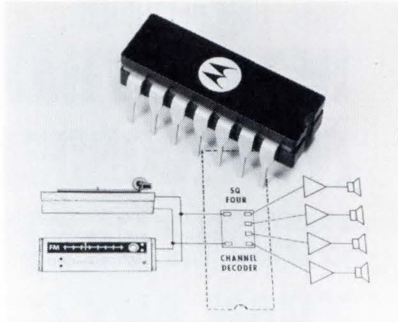


HORIZONTAL AND VERTICAL PROCESSOR FOR TELEVISION RECEIVERS. This silicon monolithic circuit combines 6 TV receiver functions and requires only half the number of external components needed in discrete design. Operating without coils or transformers, the TCA511 incorporates the following functions: horizontal oscillator, horizontal APC and AFC circuits, pull-in range and noise-bandwidth switch, vertical oscillator and sawtooth generator. Features include the elimination of horizontal-hold control, the ability to drive different types of output stages, and ease of alignment. $4.50 for 1-99 and $3 for 100-999. SGS-ATES Semiconductor Corp., 435 Newtonville Ave., Newtonville, MA 02160. Phone (617)969-1610. **194**

COMPENSATED OP AMP FEATURES HIGH SLEW RATE, fast settling time and low cost. Settling to 0.1% in 0.7 μsec slew rates are achieved in the mono OP-01 through use of an internal feed-forward frequency compensation network; no external capacitors are required for stable, high-speed performance. 250kHz power bandwidth and 2.5MHz small-signal bandwidth are attained despite very low bias currents of 20 nA and power consumption of 50 mW. The mono OP-01 is completely protected at both input and output, is pin-compatible with standard 741 sockets and is easily offset nulled with a single 10 kΩ pot. Precision Monolithics Inc., 1500 Space Park Dr., Santa Clara, CA 95050. Phone (408)246-9225. **195**

10 TO 250 KHz CRYSTAL-CLOCK OSCILLATORS ARE LOW COST. A series of multipurpose crystal controlled low-frequency clock oscillators, featuring bipolar design with buffered output, designated the SQXO-2, include the crystal oscillator and all related oscillator circuit components housed in a TO-5 package. The quartz crystal, which is photolithographically produced in a tuning-fork configuration, is then laser tuned to the precise selected frequency. Power requirements are 0.2 to 2 mA at 5V, depending on frequency. Statek Corp., 1233 Alvarez Ave., Orange, CA 92668. Phone(714)639-7810. **196**

SEMICONDUCTORS



IC DECODES "SQ" 4-CHANNEL SOUND. The MC1312 is intended for home-entertainment equipment and the MC1313 for automotive applications. Both feature channel balance and voltage gain of ±1.0 dB. The MC1312 version can handle signals up to 2V (rms) and features a signal-to-noise ratio of 80 dB and total harmonic distortion (THD) of 0.1% at a signal level of 0.5V (rms). For high-performance "component-type" systems, logic separation enhancement may be added to the MC1313. The MC1312 sells for $2.15 while the MC1313 lists for $2.40, 100-up quantities. Motorola Inc., Semiconductor Div., P.O. Box 20912, Phoeniz, AZ 85036. Phone(602)244-3466. **197**

MOS/LSI 9 × 64 DIGITAL FIFO STORAGE BUFFER. This buffer is used as a link between 2 digital systems operating at different data rates. Data is fed into the storage buffer at a certain rate and is made available upon demand at the output. The input and output data rates are completely independent. The major components of the device are a 9 × 64 dynamic RAM, 3 counters, and comparison and control logic. The TMS4024 is offered in either a 28-pin plastic (NC suffix) or ceramic (JC suffix) DIP. In 100-999-piece quantities, price for the TMS4024NC is $13.80 and $17.25 for the TM4024JC. Texas Instruments Inc., P.O. Box 5012, Dallas, TX 75222. Phone(214)238-3741. **198**

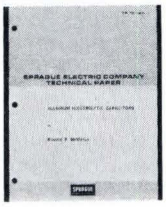
IC TRANSIENT SUPPRESSOR PROVIDES ZENER-TYPE PROTECTION for TTL, ECL, DTL, MOS ICs operating on either 5 or 15V power supplies. It permits safe, continued operation of circuits when voltage transients occur, and has also proven effective in suppressing transients developed by lightning. Rated for a peak pulse power of 1200W for 1 msec at 25°C, the unit responds to rising transients in less than 5 nsec. It clamps the line to a specified voltage while absorbing the energy of the transient. Available in 2 models, the clamp point of the VZ6 is 6.5V dc, and the VZ16 is 16.5V dc, ±5% tolerance. Peak pulse current for 1 msec is 20A. Transtector Systems, Div. of Konic International Corp., 532 Monterey Pass Rd., Monterey Pk., CA 91754. Phone(213)283-9278. **199**

ANALOG MULTIPLIER PRICES CUT IN HALF. The 8013CC monolithic 4-quadrant multiplier, with ±2% overall accuracy, now is selling for $7.50 (100-999 pieces) and the 8013BC ±1% multiplier is now priced at $11.25 (100-999 pieces). Both operate at 0° to +70°C and are packaged in TO-99 cans. The 8013 contains almost all circuitry essential to its operation, including thin-film resistors and level-shifting op amp. It handles +1V input and output signal, has a slew rate of 45 V/μ sec typical and is available in versions accurate to ±0.5%. Intersil, 10900 N. Tantau Ave., Cupertino, CA 95014. Phone(408)257-5450. **200**

TTL/MSI CIRCUIT DECODES AND DRIVES LED DISPLAYS. The 9368 includes a high-speed 4-bit latch for storing input data, a 1-of-16 decoder, a 7-segment encoder and output components that source 19 mA of current at 1.6V. Input loading is 10 μA except when the latches are enabled. Decoding format is hexadecimal, binary or BCD numbers 0 through 9 are displayed as numerals, while numbers from 10 through 15 are displayed as alphabetic characters A through F. The 9368 is supplied in a 16-pin ceramic DIP. Price in 100-999 quantities is $2.90. Fairchild Semiconductor Components Group, 464 Ellis St., Mt. View, CA 94040. Phone(415)962-3816. **201**

ZERO-CROSSING SWITCH IS LED COUPLED. The SYNCHRO-DIP is a SPST ac solid-state relay mounted in a modified TO-116, 4-lead DIP plastic package. It provides direct load drive and is designed to operate directly off an ac line. Input control terminals are LED coupled (photo isolated) from the output load terminals. Output is zero-voltage switching (integral number of half cycles) up to 240V ac. The LED coupled input is rated for 2.0 to 32V dc and the output is 400V ac at 500 mA. Grigsby-Barton, Inc., 3800 Industrial Dr., Rolling Meadows, IL 60008. Phone(312)392-5900. **202**

LITERATURE



ALUMINUM ELECTROLYTIC CAPACITORS. The 24-pg. technical paper, No. TP-72-2A, describes the manufacture of aluminum electrolytic capacitors and explains their areas of application. The paper was originally developed for use by Sprague application engineers and discusses the merits of aluminum electrolytic capacitors in circuit design. Technical Literature Service, Sprague Electric Co., Marshall St., N. Adams, MA 01247. **277**

WIRE AND CABLE. This is a comprehensive compilation of wire and cable information. The 112-pg. technical manual and catalog contains 5 sections of valuable information. It includes a comprehensive catalog, a glossary of wire and cable terminology and complete information on coaxial cable as well as comparison charts, general wire tables, charts and conversion factors. Standard Wire and Cable Co., 3400 Overland Ave., Los Angles, CA 90034. **278**

COMPUTER USER APPLICATION TOOLS. The hardware and software tools needed by computer users to match almost any requirement in measurement, control, communications and FORTRAN computing applications are detailed in this 4-book series. The series consists of a 12-pg. family brochure, a systems-design handbook, a 12-pg. communications brochure and a 90-pg. communications handbook. Modular Computer Systems, 1650 W. McNab Rd., Ft. Lauderdale, FL 33309. **279**

LASER INTERFEROMETER Model 5900-R from Perkin-Elmer is described in an 8-pg. brochure. The instrument is ideally suited for applications in metalworking, computer industries and in standards laboratories, and incorporates a remote interferometer as an integral part of its design. Since it is removable from the laser head, the remote interferometer isolates the heat of the laser from the measurement area and permits measurements to be made in confined spaces. Perkin-Elmer Corp., Main Ave., Norwalk, CT 06856. **280**

ELECTRONIC PACKAGING HARDWARE. A short-form 8-pg. catalog which briefly describes Scanbe's total product line covers new socket cards, kit cards, socket panels, card files, sockets and strips, IC-packaging drawers and wiring. Scanbe Mfg. Corp., 3445 Fletcher Ave., El Monte, CA 91731. **281**

ILLUMINATED-PUSHBUTTON SWITCHES. This 8-pg. catalog, S104, provides complete mechanical and electrical specifications and ordering data (both military and commercial) for 8 Marco-Oak Presslite™ illuminated-pushbutton switches recently qualified under MIL-S-22885 and listed on QPL 22885. The catalog tabulates both government designations and Marco-Oak part numbers. Marco Oak Inc., 207 S. Helena St., Anaheim, CA 92803. **282**

MODEM BROCHURE. The 24-pg. brochure describes a complete line of all-digital-modem packs for switched-voice networks and leased line applications. Featuring a performance range from 300 through 2400 bps, modem packs are all GSA and UL listed and compatible with FTS networks. Specifications are listed for each Sanders modem series along with charts depicting the probability of error vs signal to noise ratio for each modem. Sanders Associates, Inc., Mail Stop NCA 5-2146, Nashua, NH 03060. **283**

IF YOU UNDERSTAND TIME-INTERVAL AVERAGING, you can, when measuring repetitive events, improve the resolution of time-interval measurements a thousand times, achieving resolution as fine as 100 psec, and even measure intervals as short as 150 psec. That's what a new application note shows you how to do. It resolves all mysteries surrounding the time-interval averaging process, gives a rigorous analysis of possible errors and explains how to avoid them. Hewlett-Packard Co., 1501 Page Mill Rd., Palo Alto, CA 94304. **284**

MULTIPOINT MEASURING INDICATORS. Sixteen different multipoint measuring indicator panels are described in this catalog. For each panel configuration, the catalog contains outline drawings, the number of points monitored, the type of switching (pushbutton or toggle) employed, mounting, point-identification marking and over-all dimensions. A listing of available thermocouple ranges and resolution, and calibrated and over-all accuracy is also included. Howell Instruments, Inc., 3479 W. Vickery Blvd., Fort Worth, TX 76107. **285**

CONNECTOR DESIGN GUIDE. This 28-pg. design-guide catalog describes plate-connector and molded-connector products. It contains detailed information about design, custom-plate connector systems as well as describing the design and construction of components for wire wrapped plate systems. It illustrates a wide variety of plate-connector and pc components. National Connector, 5901 S. County Rd. 18, Minneapolis, MN 55436. **286**

ELECTRIC-MOTOR NOMOGRAPH. With it, one can visually determine unknown values of motor torque, speed, frequency, horsepower and stator poles. Part of the January/February issue of the Bodine Electric Co.'s Motorgram (Vol. 53, No. 1), the nomograph is accompanied by examples for finding motor speed when the frequency and number of stator poles are known, and for finding the correct torque value when the known factors are horsepower and speed. Bodine Electric Co., 2500 W. Bradley Pl., Chicago, IL 60618. **241**

MAGNETIC RECORDING HEADS. The 2nd edition of "Design Digest for Digital Magnetic Recording Heads" contains over 40 pp. of technical and applications information. Magnetic heads discussed are for applications using 1/2-in., IBM-compatible tape formats. The digest includes technical and applications information, test procedures and descriptions of Nortronics' Lifetime Ceramic Coating, No Flux gate heads and 19 pp. of data on Nortronics heads for digital applications. Nortronics Co., Inc., 8101 Tenth Ave. N., Minneapolis, MN 55427. **242**

LITERATURE

NEON LAMPS FOR APPLIANCE PILOT LIGHTS. A 4-pg. illustrated data sheet describes the use of neon lamps as pilot lights in a wide variety of appliances and portable tools. The data sheet is keyed around functional and visual design suggestions for indicating several electrical conditions: when the appliance is carrying electricity, when the battery is charging, when a pre-set temperature has been reached, or when the appliance or tool is plugged in. Specific circuit diagrams are given to illustrate how the devices may be wired into the appliance or tool circuitry. Signalite, Inc., 1933 Heck Ave., Neptune, NJ 07753. **243**

SLIDE POTS CONTROL MOTOR SPEED. Linear slide actuated potentiometers, initially developed for the recording industry, are rapidly being applied to industrial controls. The key advantages of quick, accurate adjustment and instant visual observation of settings have encouraged the use of these devices in electronic speed controls for all sizes of universal electronic motors. Details are contained in Series 220 and 300 brochures available from Duncan Electronics, Inc., 2865 Fairview Rd., Costa Mesa, CA 92626. **244**

MICROWAVE COMPONENTS and calorimetric systems are illustrated in a 12-pg. guide. The publication gives detailed specifications for calorimetric measurement systems, waveguide and coaxial waterloads and power controls. Raytheon Co., Microwave and Power Tube Div., 190 Willow St., Waltham, MA 02154. **245**

LINEAR IC PRODUCT GUIDE provides quick-reference information on ICs for control, communications, instrumentation and computer applications. This catalog, designated CDL-820E, includes an easy-to-read format permitting ready access to schematics and block diagrams, quick-reference charts, general applications, features and comparison between types. The CDL-820E supersedes the CDL-820D and features: special contents pages, quick-selection applications charts, data charts, schematics, block diagrams, industry cross-reference guide, app notes and technical papers, dimensional outlines, IC chips, beam lead ICs, high-reliability ICs and MOSFETs. RCA/Solid State Div., Rt. 202, Somerville, NJ 08876. **246**

TTL IC DATA BOOK AVAILABLE. Called *The TTL Data Book for Design Engineers,* this 640-pg. hardback book provides comprehensive specifications on TI's 5 families of 54/74 TTL ICs. Parameters are given for the standard Series 54/74, the high-speed Series 54H/74H, the low-power Series 54L/74L, the Schottky clamped Series 54S/74S and low-power Schottky Series 54LS/74LS. Also included are radiation hardened and beam-lead circuits and TTL high-performance RAMs, as well as Series 29000 and Series 29300/39300. The TTL Data Book is priced at $3.95 per copy inside the US, F.O.B. destination, book rate. Texas Instruments, Inc., Box 5012, Dallas, TX 75222.

2000VA ac-LINE REGULATOR, Varax C474, from Tele-Dynamics', Wanlass Div. is described in a 2-pg. data sheet. The regulator uses a variable inductor as a series regulating element in a patented circuit with inherent short-circuit, overvoltage and over-current protection. It is specifically designed to cope with industrial plant-line voltage variations caused by heavy load switching such as motor starting. The C474 operates from a 105 to 130V ac, single-phase, 60-Hz source. Tele-Dynamics/Wanless, Div. of AMBAC Industries, Inc., 525 Virginia Dr., Fort Washington, PA 19034. **247**

SOLID-STATE STANDARD CELLS. A 12-pg. application bulletin compares the accuracy and precision of Codi Semiconductor's Certa-Cell (solid-state standard cell) vs unsaturated standard cells of the mercury-cadmium type. The comparison report explains the significant improvements obtainable by using a solid-state standard cell and clearly illustrates that the solid-state standard cell is far superior to the electro-chemical cell when conditions encountered in normal laboratory use, such as temperature changes (recovery time and hysteresis effects), mechanical shock and vibration, and coulombic transfer (charge and discharge) are considered. Codi Semiconductor, Pollitt Dr. S., Fair Lawn, NJ 07410. **248**

signals and noise

Brickbats and bouquets...

Our Jan. 20th editorial by associate editor Bill Furlow caused so much response that we decided to devote this page to the reprinting of some of those letters. Overall response was more than 2:1 in support of Bill's position on electronics in automotive safety.

Your "sleeping giant" editorial takes a real swipe at automotive electronics but your reasoning is as solid as a puff of smoke.

I share your frustration with buzzing seat belt alarms, but I react by fastening the seatbelt, even for very short trips.

The coming auto-electronics markets are huge, could very well dominate the semiconductor markets, and that's nice for almost all of us cats in the electronics game.

Raymond Daniel Speer
President
Speer Marketing Services Corp.
New York, NY

Particularly thought-provoking was Bill Furlow's editorial. His words were exceptionally well selected and his pithy comments were the most direct, courageous and agreeable (to me) of any I've seen on the subject. Furlow has penetrated the politics and ballyhoo of auto-safety engineering and emerged with a view of reality that no other writer has yet grasped.

What really galls me, whenever I muse on the subject, is that the same federal government that is pushing for airbags and unbelted grocery-box buzzers, is also compelling children to ride long distances on school buses that have no seat belts. You'd think the guys who have time to dictate electronics subsystems to Detroit would examine the unsafe conditions inside the buses their kids ride to school.

Richard L. Molay
Manager, Marketing Services
Teledyne Semiconductor
Mt. View, CA

Amen to your editorial of January 20th, 1973!

The semiconductor industry in particular, has taken leave of their senses, by seeking out large customers to justify a production line for a new device, thereby putting all their eggs in one basket.

We look forward to 1973 being *the* year of vendor problems!

P. Charles Caringella
President
Caringella Electronics, Inc.
Upland, CA

Atten: Bill Furlow
Congratulations on your editorial of January 20, 1973. I agree with you that there is too much engineering time wasted on silly gadgetry in the automotive industry as well as in many other industries.

Alex Gawron
Skil Corp.

Dear Sir:
Re: Your editorial of 20 January, 1973. BULL!
Re: The magazine. The finest published.

J. Wendell Harris

Excellent editorial re: "Should we wake the Sleeping Giant".

Thomas F. Edwards
FAA
Atlantic City, NJ

Did not like editorial—"Idiot airbag + technical language".

Karl Steiner, P.E.
Consulting Engineer
Hammond, IN

Yea for the editorial.

Victor Shiff
C/M Labs
Norwalk, CT

Bill Furlow's editorial in this issue was excellent and to the point. Good!

Charles Primm
Texas Instruments, Inc.
Dallas, TX

Timely and well done intro to CCD's, a valuable service here, on the other hand your editorial is worthless—stick to producing good articles.

Donald K. Georgi
Graco Inc.
Minneapolis, MN

Keep up good awareness in editorial as well as technical policy!

N.H. Hixon
Comsay
Clarksburg, MO

January editorial complete hogwash.

Don Mennie
Anatron Systems
Belleville, NJ

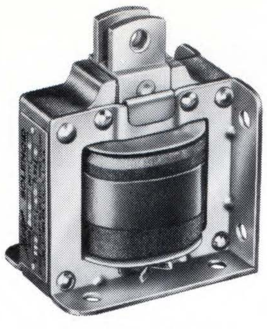
Editorial should have been on the front cover—Push harder to tieup the "Sleeping Giant".

R.C. McKenzie
Litton Industries
San Carlos, CA

Bully for Furlow.

R.V. Snyder
NASA
Wallops Is., VA

AND THIS YEAR OUR SEATBELT CONTROLS ARE 35 NANOSECONDS FASTER.



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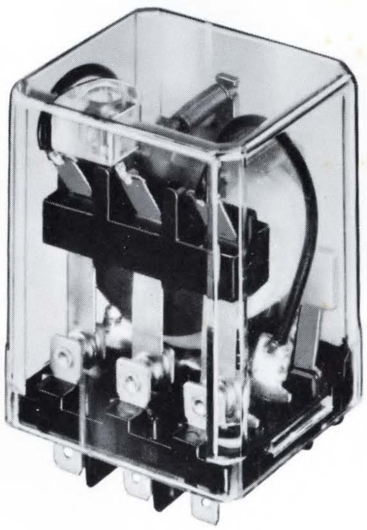

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