EXCLUSIVELY FOR DESIGNERS AND DESIGN MANAGERS IN ELECTRONICS

EDN

Modular power supplies: answer to many problems

Binary multiplication: higher speed from fewer components

Minicomputer selection criteria

A CAHNERS PUBLICATION

MAY 1, 1972

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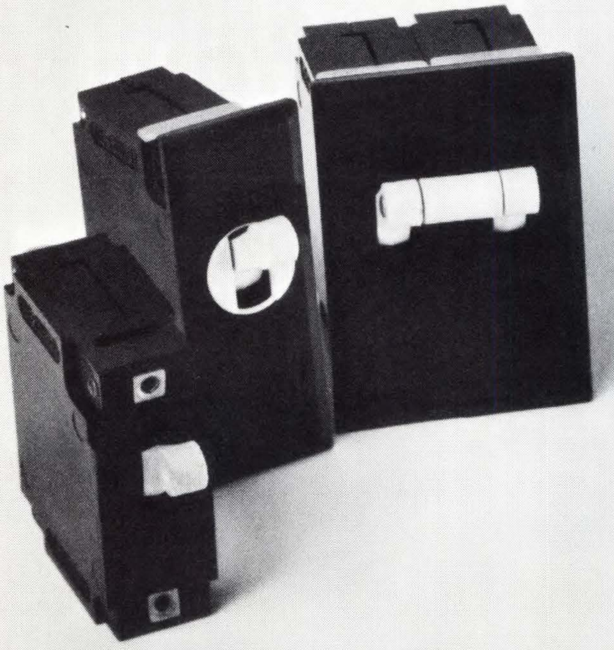
In fact, whenever you need DC power for op amps, think of Acopian. We offer a wide range of supplies designed specifically for operational amplifiers and rated up to 5.0 amps. Try them . . . you'll like them.

And incidentally . . . if your wife ever asks you why you dream of Acopian, tell her that we really deliver. To prove it, send your order to Acopian Corp., Easton, Pa. 18042, or call (215) 258-5441. Your op amp power supply will be shipped bearing this tag . . .

CIRCLE NO. 1



Toggle handles in white. Rocker handles in white, gray, black, or custom colors. Rectangular pushbuttons, lighted green for ON, white for OFF. Cylindrical pushbuttons, not lighted at all. An environment-protected model with a sealed bat handle. A model for fast snap-in mounting.

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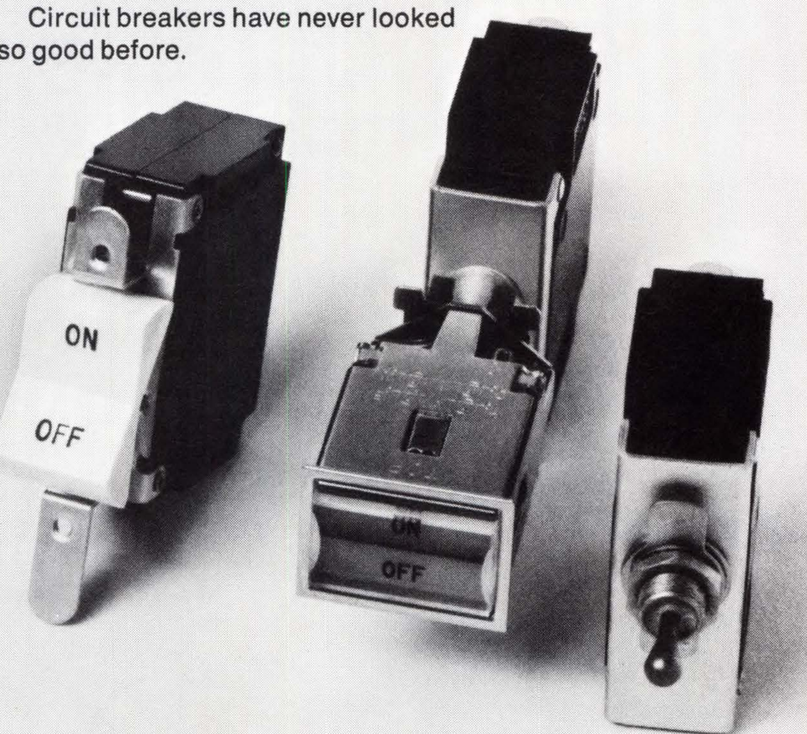
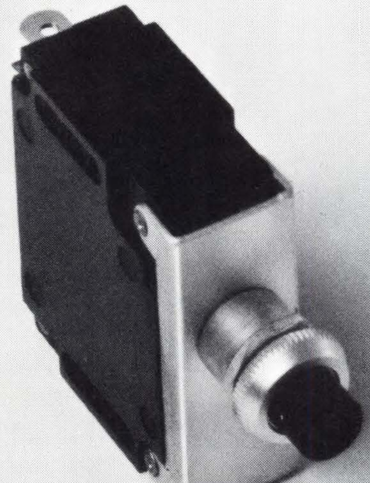
Circuit breakers have never looked so good before.



You don't have to settle for homely circuit breakers anymore.



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All are available for operation on any of the commonly used DC or AC voltages (60Hz or 400Hz). In any current rating from 0.020 to 30 amp.

All are reasonably priced. Even in modest OEM quantities.

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HEINEMANN

CIRCLE NO. 3

5292

If our capacitors weren't worth a lot more, we couldn't charge a little more for them

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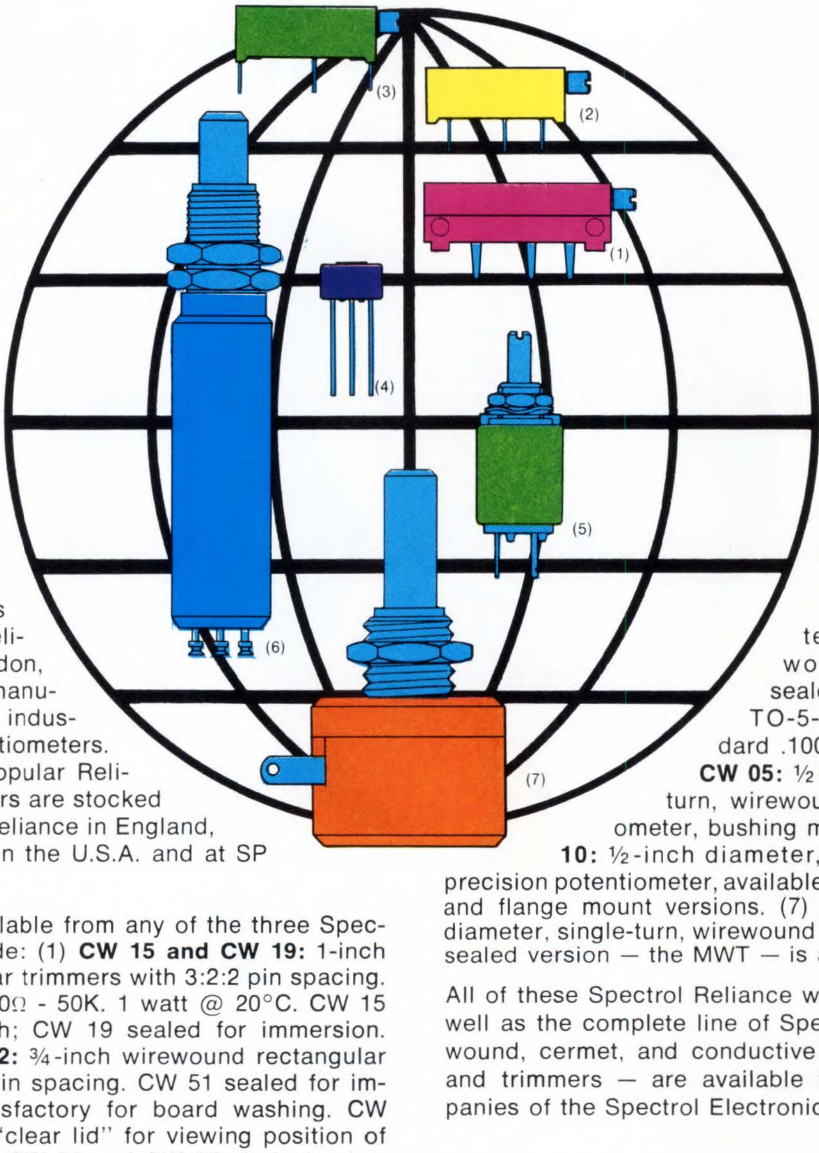
CIRCLE NO. 4

Now available worldwide... a line of low-cost wirewound pots and trimmers from Spectrol Reliance Ltd.



The most recent company to join the Spectrol Electronics Group is Spectrol Reliance Limited of Swindon, England, a leading manufacturer of low-cost industrial wirewound potentiometers. And now the most popular Reliance pots and trimmers are stocked in depth not only at Reliance in England, but also at Spectrol in the U.S.A. and at SP Elettronica in Italy.

Reliance models available from any of the three Spectrol companies include: (1) **CW 15 and CW 19:** 1-inch wirewound rectangular trimmers with 3:2:2 pin spacing. Standard RT range 10Ω - 50K. 1 watt @ 20°C. CW 15 sealed for boardwash; CW 19 sealed for immersion. (2) **CW 51 and CW 52:** ¾-inch wirewound rectangular trimmers with 3:2:1 pin spacing. CW 51 sealed for immersion; CW 52 satisfactory for board washing. CW 52CL available with "clear lid" for viewing position of wiper on element. (3) **CW 54 and CW 55:** ¾-inch wirewound rectangular trimmers with RT12Y (4:3:1) pin spacing. CW 54 sealed for immersion; CW 55 meets board washing requirements. (4) **CW 40:** 0.326-inch diameter, single-turn, wirewound trimmer, fully sealed for immersion in a TO-5-type can, with standard .100-inch pin spacing. (5) **CW 05:** ½-inch diameter, single-turn, wirewound, precision potentiometer, bushing mount only. (6) **HEL 05-10:** ½-inch diameter, 10-turn, wirewound, precision potentiometer, available in both bushing mount and flange mount versions. (7) **MW:** Low-cost, 1-inch diameter, single-turn, wirewound pot. Military approved, sealed version — the MWT — is also available.

All of these Spectrol Reliance wirewound models — as well as the complete line of Spectrol Electronics wirewound, cermet, and conductive plastic precision pots and trimmers — are available from any of the companies of the Spectrol Electronics Group.

For more information, contact your nearest local source below.

Spectrol

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Swindon, Wiltshire, England
Swindon 21351 • TELEX: 44692

UNITED STATES
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CIRCLE NO. 5

MAY 1, 1972
VOLUME 17, NUMBER 9

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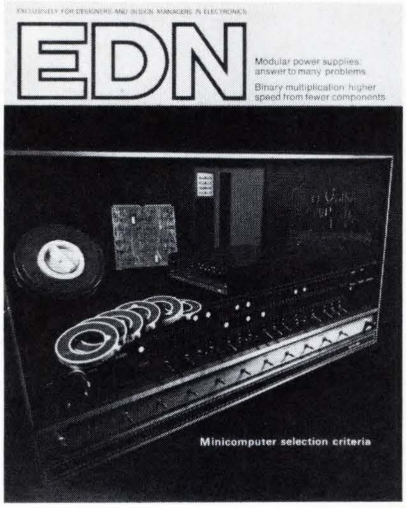

COVER

Buying a minicomputer isn't like buying a radio or other appliance. Some of the things to be considered are illustrated in the photo supplied by Data General Corporation, Southboro, MA and discussed in the article, "Buying a Minicomputer?—" starting on page 20.

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She's learning to test semiconductors ... *FASTER!*

With the 172 Programmable Test Fixture for the TEKTRONIX 576 Curve Tracer, you program up to eleven sequential tests on FETs, transistors and diodes. This new fixture saves measurement time in applications such as incoming inspection where you make a series of tests on a number of devices.

Programming is straightforward. Inserting pins in holes in programming cards sets individual test conditions. Omit the pin from a particular test hole and the 172 skips that test.

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Programmed testing frees your technically trained personnel to concentrate on more creative processes, speeds incoming inspection, saves training time, reduces errors and decreases measurement time.

Do you have a TEKTRONIX 7000-Series or 5100-Series Oscilloscope? Planning to get one? If so, you'll want to know about our new plug-in curve tracers too. For complete information, call your local TEKTRONIX Field Office and ask for the new Semiconductor Curve Tracer Booklet. Or write Tektronix, Inc., P. O. Box 500, Beaverton, Oregon 97005. We will send you complete information—immediately.

172 Programmable Test Fixture $1400

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CIRCLE NO. 7

Editorial

We've made some changes

Anyone who is at all observant will have noticed that there are two significant changes in this issue of EDN. The first of these is our new cover style, which we hope will be as attractive and appealing to all readers as it is to us. We feel that the cover fully satisfies our basic criteria—namely, that it be clean, functional, distinctive and attractive.

A considerable amount of time, effort and talent are involved in the birth of a new cover design, and once the final choice is made, all we editors can do is sit back and wait to see the readers' reactions. If you have any strong ones, either positive or negative, we'd like to hear them.

The second change is the shortening of our name from EDN/EEE to just EDN. This is the result of the overwhelming feedback we've gotten from readers concerning the awkwardness of the name EDN/EEE. We'd be less than honest if we didn't admit that the name has caused us problems, too, because of its unwieldly nature.

It should be emphasized that the cutting of the name to a more manageable size will have no effect on our editorial content and philosophy. What we have been doing under the EDN/EEE banner, we will continue to do as EDN. After all, it's not what we call ourselves that really counts, but what others, namely our readers, think of us. Lest we be accused of immodesty, we won't relate the situation to Shakespeare's oft-quoted "A rose by any other name . . .".

While we're on the subject of change, we should also announce that EDN has a new West Coast Field Editor. His name is Jerry Moseley, and he comes to us from Rydax, Inc., where he had been designing circuits for telemetry and data processing equipment for 2-1/2 years.

Jerry graduated from Cornell University and then become one of those Easterners who headed west to California.

Should you happen to bump into Jerry, either in your own plant during one of his visits, or maybe at a technical conference, don't be shy. Tell him what you do like and what you don't like about what we're doing. Even better, tell him what you've been doing in the design area. It may be the basis for a story or a technical article. This is really what Jerry's job is all about.

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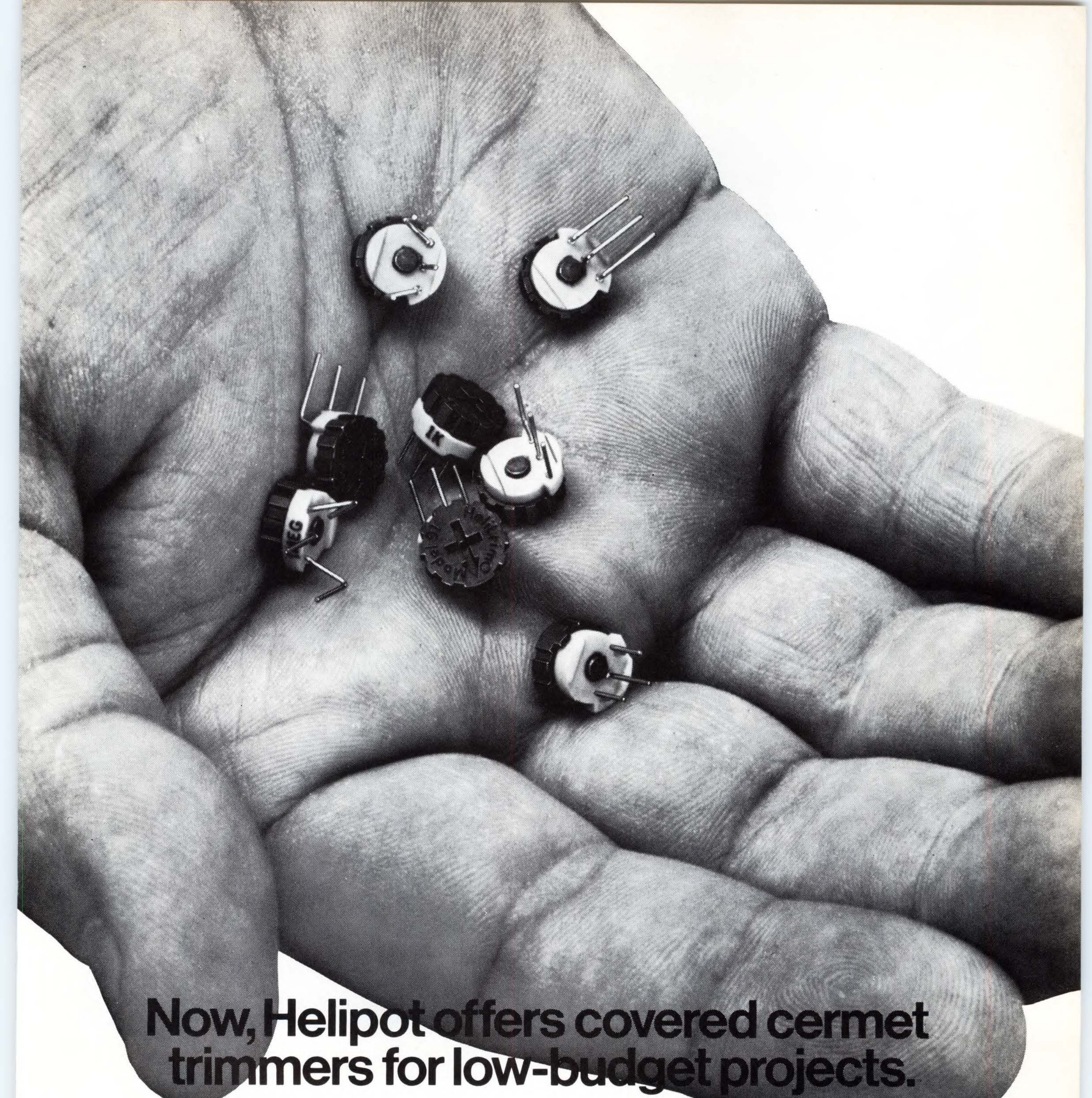

There's not much sense in using cheap wirewound or carbon trimmers anymore. Not when the new Helipot Series 91 Cermet Trimmers are available *off-the-shelf* for a few cents more.

These single-turn, 3/8", covered trimmers come in 10 different mounting styles and 19 standard resistance values from 10 ohms to 2 megohms. Covered construction helps protect against moisture, corrosive atmospheres, dust, oil and other contamination. Which means, in addition to cermet stability and better resolution, you get long-term dependable performance.

The breakthrough price is just 35¢ each in the 50,000 piece quantity, and they're equally well-priced in other quantities.

Send now for complete data on the Series 91 Trimmers . . . the finest of their class. We've made them for your projects where the budget may be tight, but you don't want to compromise performance.

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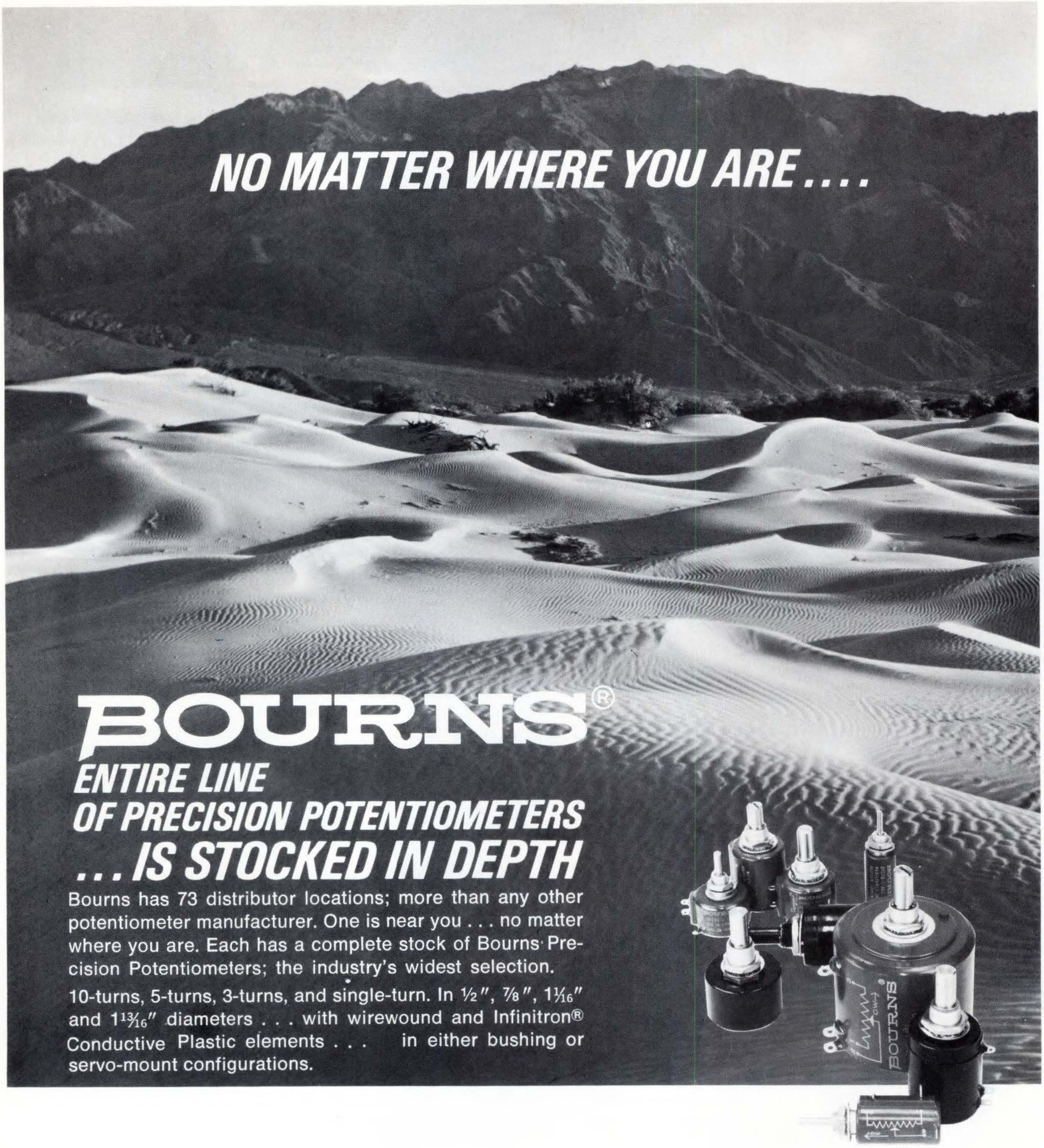
CIRCLE NO. 9



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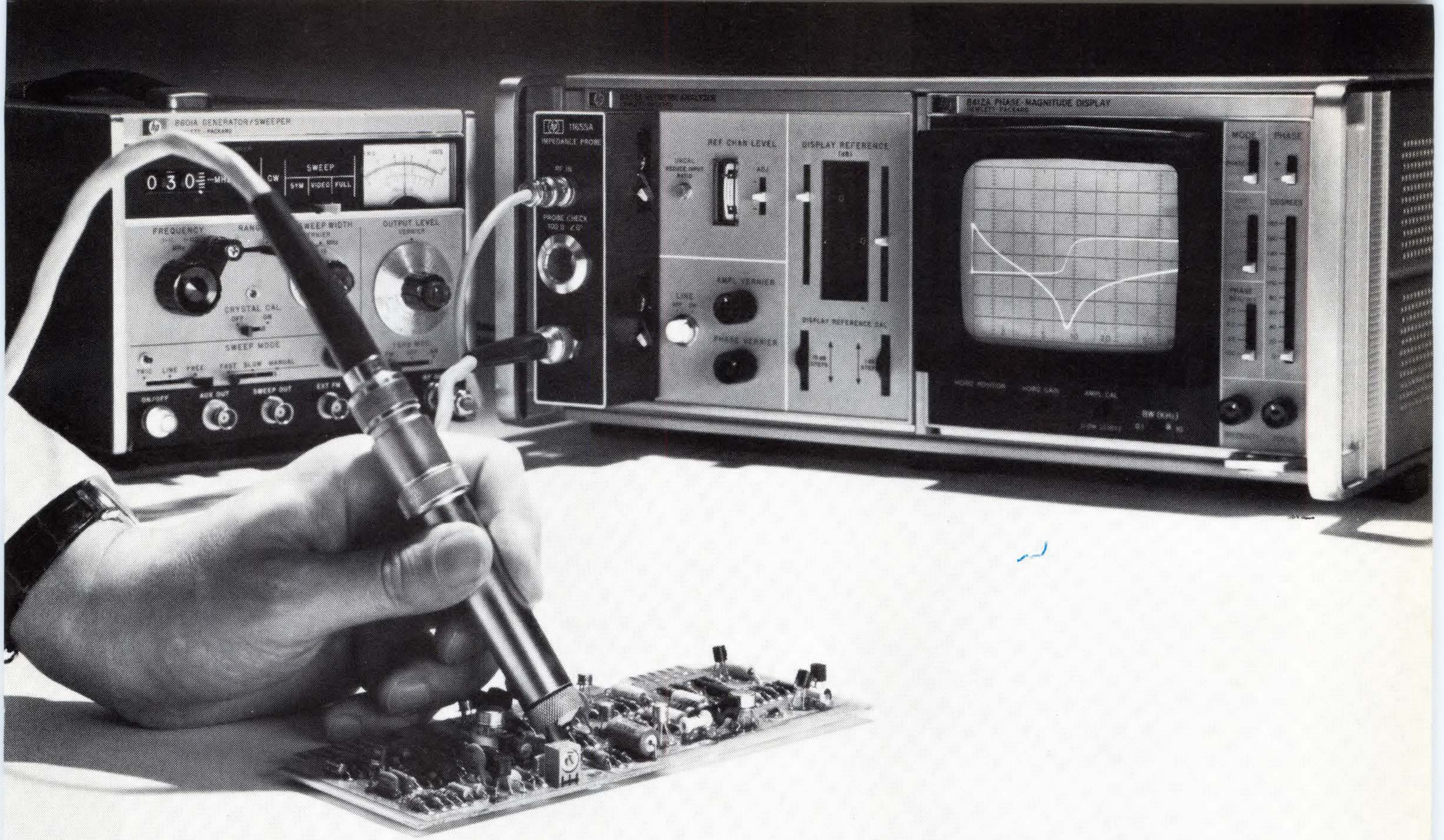

Introducing "touch & see" swept impedance measurement. Now the "do-everything" RF test system does even more.

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The 8407A Network Analyzer with the 8412A Phase-Magnitude Display costs \$4650. The new impedance probe (Model 11655A) costs \$750. Other accessory kits for circuit probing and for general measurements in coaxial systems are also available, priced from \$325 to \$500.

To learn more about how our "do-everything" network analyzer can help you in design and production test applications, call your field engineer or write Hewlett-Packard, Palo Alto, California 94304; Europe: 1217 Meyrin-Geneva, Switzerland.

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NETWORK ANALYZERS

CIRCLE NO. 11

SJCC has mis-match between exhibits and papers, but is still worth attending

It used to be that you could justify travelling to the big conferences like IEEE, Wescon and the East and West Computer shows on the basis that both the technical sessions and the exhibits would provide a one-stop survey of what was going on in the industry. Now it seems that not only are there glaring gaps in the coverage of the exhibits, but the exhibits and the technical sessions aren't even related to each other.

This year's Spring Joint Computer Conference (SJCC) being held May 16-18 at Atlantic City's convention hall is no exception to this unhappy trend towards "mis-matched" shows. The exhibits will only be a faint echo of the full spectrum of the technology most visitors hope to see. The papers being presented in the technical sessions will do a far better job of upholding their part of the conference's reputation for being the major Eastern show of the computer industry.

The main gap in the exhibits will be the complete absence of large computer mainframes. IBM, Honeywell, Control Data, and Univac won't exhibit. There won't even be many minicomputers. One of the few new computers to be announced at the show will be a hybrid analog-digital machine from Electronic Assŏciates, Inc.—perhaps because E.A.I. is up the New Jersey Coast from Atlantic City. Hewlett-Packard, that hardy exhibitor that remains with so many exhibits, will be showing small computers, and Data General will be showing its minicomputer. But most other computer makers, large and small will be conspicuous by their absence.

The one type of hardware that will be well represented at the exhibit is magnetic-memory systems for peripherals. There will be cassettes, cartridges, reels and discs drives and add-on cores. Much of the other hardware at the exhibits will be for time-share and communications terminals.

The best reason for a design engineer to go to this year's SJCC is that it is still the best place to rub shoulders with professional computer operators. As the name of the sponsoring society, AFIPS, or American Federation of Information Processing Societies, Inc., implies, the core of the attendees will be computer installation managers and programmers. Obviously, any engineer trying to design new computer systems or hardware ought to be intimately familiar with the likes and dislikes of this group.

The technical papers have been selected to please this software-oriented group, EDN was told by Prof. Jack Schwartz of New York University's computer science department (Courant Inst.), head of the technical program committee. The only change from last year's thrust, Schwartz said, will be to stick more closely to serious technical topics in software. We will have very few of the "social conscience" papers we had in '71.

The advance program indicates a heavy dosage of such insider topics for programmers as, "Large-Scale Scientific Computation," (Session 2), "Formal Algorithmic Analysis," (Session 15), and "Language for Special Applications," (Session 10). All throughout the meeting there is a heavy emphasis on very large systems, with just an occasional polite nod here and there to minicomputers. One would gather that, at heart, the professional programmer likes large computers—probably on the basis that the larger his computer, the larger his empire. There is no session exclusively devoted to the peripheral equipment that will be so prominent in the exhibits, bearing out again our complaint of a mis-match.

We note a group of sessions on the implications of LSI (11, 22, and 34). According to Schwartz, although these are hardware papers, they are not directed at the design engineer, but at keeping the software people aware of what can be expected in future hardware. □

Visitors to the "big" computer show on the boardwalk this year may be discouraged by the limited range of the exhibits.

Technique yields high-quality holographic images from ordinary light sources

A major problem in the development of holographic data storage systems has been the requirement for a monochromatic light source, with its inherent expense, for reconstructing the stored images.

A new technique for reconstructing holographic images using simple light sources may lead to a solution to this problem. The method, developed by IBM engineers, produces clear, high-quality images with inexpensive, broadband light sources.

By applying well-known optical principles of color correction to holography, the developers of the technique have eliminated the large color blurring that would otherwise accompany an image reconstructed with broadband, non-monochromatic light (**Fig. 1**). As in previous broadband schemes, a grating or holographic lens is used next to the hologram to eliminate lateral blurring of the image. To eliminate the remaining first-order color blurring, the IBM engineers added a dispersive imaging lens between the hologram and the plane of the reconstructed image. The result is a clear, well-defined image, free from all first-order chromatic aberrations.

With the technique, high-quality images have been produced from Fresnel holograms using a high-pressure xenon arc lamp. Other possible sources include laser diodes, light-emitting diodes and CRTs. ▭

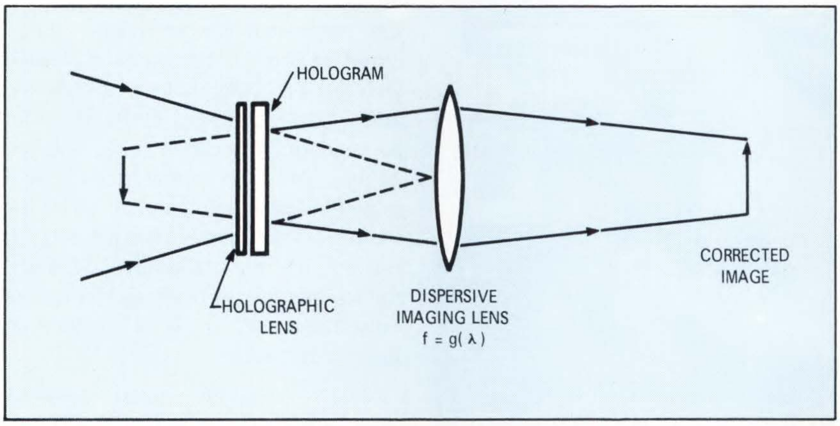
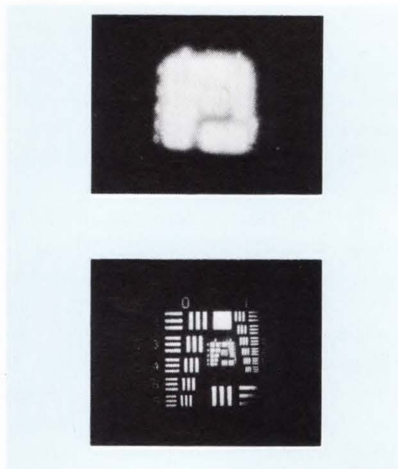


Fig. 1—The addition of a dispersive imaging lens to correct first-order blurring produces high-quality holographic images with simple, broadband light sources.

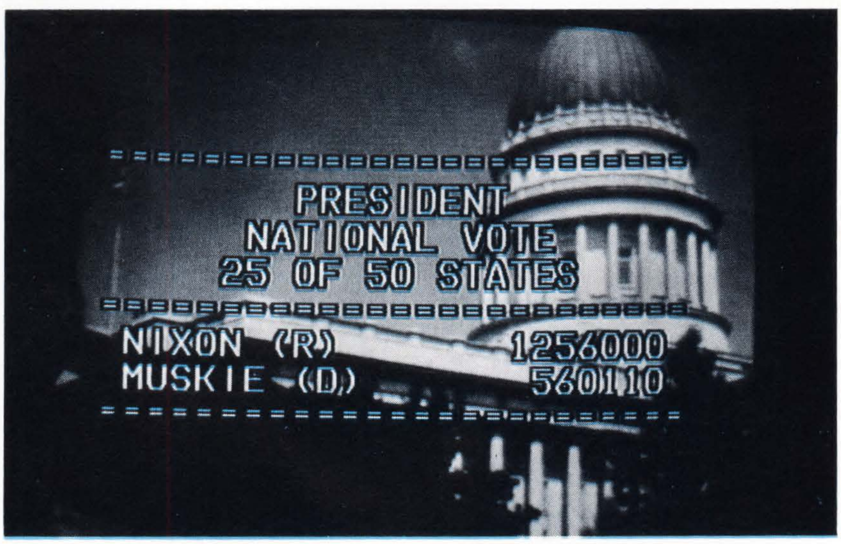


Without the dispersive imaging lens, a non-monochromatic light source produces the holographic image of a test target as shown in the top photo. With the dispersive imaging lens, the image in the lower photo is produced.

Coming on TV: Faster and more informative election-night returns

When the election results start to become available this fall, many TV stations will be ready to display them more swiftly and effectively than ever before, thanks to a new system designed by Telemation, Inc., of Salt Lake City.

Named "TED-1", the new election reporting system automatically receives, processes and displays election voting information. System input may be simple typed messages increasing voting totals and number of districts reporting, or properly formatted messages from election computers. System output consists of electronically-generated NTSC standard pages of highly legible characters. These may be displayed alone on the TV screen or, as shown in the photo, can be matted over other program



With the TED-1 Election Reporting System, election data can be either matted over other program material, as shown here, or displayed alone on the TV screen.

material in the system. Each "page" of the display has a maximum of 14 lines that contain 25 character positions each.

Equipment that comprises the system includes a minicomputer, a character generator "television typewriter" with a 2000-line random-access disc memory storage, a control keyboard, a 100-page selection panel and a teleprinter keyboard-printer/tape-reader punch. Completing the system is a comprehensive computer program tailored to each individual system. This program is provided on paper tape for insertion into the computer. Program loading is automatically accomplished under pushbutton control. (By using a stored-program operating mode, the system allows both easy updating and practical conversion for other applications, such as sports coverage, automatic news and weather reporting).

One of the valuable capabilities of the system is that it can be used to save any one (or all) of the pages at any selected time, allowing recall of them for comparison with later (or final) results. This recall can be performed over and over. □

Solid-state video camera promises improvements in size and performance

Bell Laboratories' engineers have built an exploratory model of a new solid-state video camera that has the potential for markedly outperforming existing video cameras.

The new device does not need the electron scanning beam, high voltages, and vacuum envelope needed by conventional video cameras to convert an optical image into an electrical signal in a video format. It consists of a flat chip of silicon covered with an insulating oxide over which is an array of metal electrodes.

The camera demonstrates a major application of charge coupling, a semiconductor principle first announced by Bell Laboratories just two years ago.

The new exploratory system is a two-dimensional array of 128×106 light-sensitive cells. The active area of the device is 3×5 mm and is largely covered with metal electrodes 9 μm wide and spaced 20 μm apart.

The present exploratory model generates an image having 1/4th the detail of the Bell System's current Picturephone camera. However, Bell engineers say construction of devices capable of much greater detail appears quite feasible.

Recently, Scientists at the RCA Laboratories in Princeton, N J, developed an experimental video camera whose solid-state sensor is approximately the same size as that of the Bell Laboratories' unit—4.83 by 3.56 mm. However, the RCA sensor contains only 32 rows of 44 elements, or 1408 light-sensitive elements spaced on 3-mil centers.

The new charge coupled device (CCD) operates by manipulating small packets of electrical charge within a solid slice of silicon. Light incident on the silicon is absorbed, creating electrical charge which is stored locally at the surface of the silicon under the metal electrodes. The amount of stored charge is proportional to the incident light flux.

Video image is produced by camera using charge-coupling principle. A Bell Laboratories' engineer adjusts the video display produced by the camera held in his right hand. The heart of the camera is a 3-X-5-mm silicon chip that contains an array of 128-X-106 light-sensitive cells. The sensor chip is self-scanning, eliminating the need for high voltages, vacuum systems and electron beams associated with conventional video cameras.

Charge coupling makes it possible to move the packets along a well-defined path to an output electrode. There the charge becomes an analog electrical signal which represents light variations along the scanned line. The packets are moved very precisely within the silicon by varying the voltages on the extremely fine electrodes on the surface of an oxide covering the silicon. The electrode pattern defines the path of the charge motion.

To produce a video image, the camera focuses the image on half the device's silicon area and integrates an image on 64×106 light-sensitive cells. The integrated frame is then transferred to a 64-×-106-element storage area on the other half of the device and is shifted down, line-by-line, to be read out through a serial register. At the same time, a new frame is integrated in the imaging area. By the time the new charge pattern has formed, the preceding frame has been read out and the storage area is ready to receive the new frame. This cycle is repeated 60 times a second.

Other solid-state video cameras have been built prior to this device. However, these earlier cameras have required complex integrated circuitry to scan the image and were of little practical importance. The new CCD camera is self-scanning and achieves solid-state video imaging with much simpler external circuitry. In addition, it provides a more uniform picture than earlier solid-state cameras.

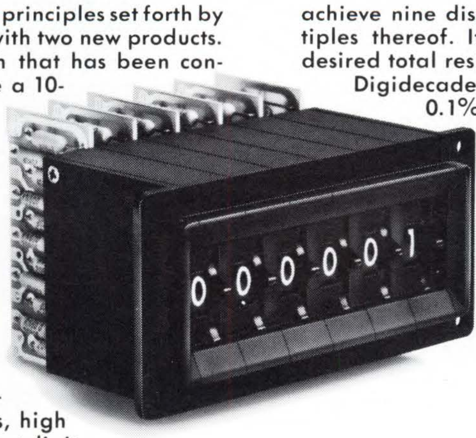
Several advantages are available over vacuum-tube video cameras—the type commonly used in current TV systems. Since CCD imaging devices do not have an electron beam, they will not be susceptible to electronic damage such as "burn-in" that degrades performance of most video tubes. Even the silicon-diode camera tube, also invented by Bell Laboratories and used successfully in the last Apollo moon flight, has a slight amount of electron beam burn-in. This particular tube is now used in the Picturephone station set.

CCDs are also not subject to lag—or smearing—caused by moving bright areas, as occurs in the televised image generated by vacuum-tube cameras. □

Digivider/Digidecade...the great idea by Kelvin, Varley, Poggendorff and Porter.

Hank Porter (front), used some of the principles set forth by his distinguished friends to come up with two new products.

Digivider is a thumbwheel switch that has been converted into a voltage divider. It's like a 10-turn potentiometer. When you dial the voltage you want, that's precisely what you get. The large digits, however, give you simplicity and greater accuracy. No fine, hairline settings are necessary. Digivider accuracies range from 0.1 to 0.01% full scale voltage ratio. All are available with resolutions to 0.0001% and input impedances from 100 to 100,000 ohms.



Other available features: Overrange. 12 and 16 position voltage division in the most significant digit. Plus, high resolution trimming in the least significant digit.

Digidecade is a thumbwheel switch converted into a resistance decade. Actually, one version of the Digivider can be used, only instead of dialing the voltage, you dial the resistance you want. Again, accurate and with visual ease.

The Digidecade also comes as a resistance decade utilizing a weighted code of 1-2-2-2-2, using five resistors to achieve nine discrete steps of resistance from (0-9) or multiples thereof. It is a linear progression that yields the desired total resistance.

Digidecades are available with accuracies from 1% to 0.1% of setting, resistance ranges from 10 ohms to 1 megohm and step sizes of 1 to 100,000 ohms.

As with all DIGITRAN products, you can count on stability and quality. You won't get more than a 5 milliohm change in contact resistance through 100,000 accurate switching operations.

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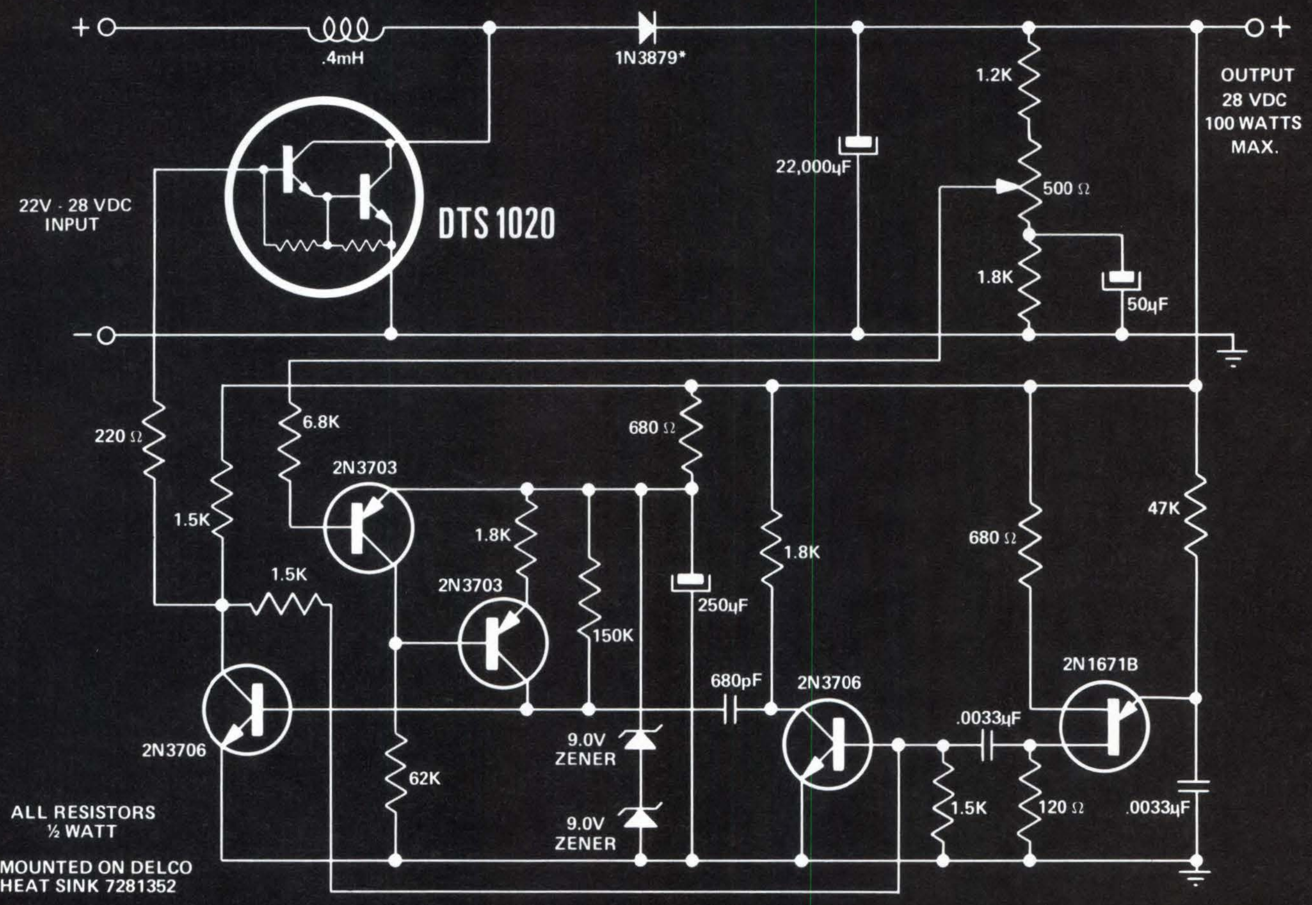
CIRCLE NO. 12



SWITCHING REGULATOR

	V_{CEO} @ 0.1 mA	V_{EBO} @ 50 mA	$V_{CE(SUS)}$ @ 500 mA	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.

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

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CIRCLE NO. 13

Buying a minicomputer? Ask these questions first.

There is a lot more to consider than just capacity, cost and speed. These questions and answers will help you to select what you really want and need.

Lawrence Seligman, Data General Corp.

Choosing a minicomputer system has become more challenging as manufacturers offer wider selections of mainframes, software, and peripheral equipment. At the same time, system engineers are building small computers into large, ambitious systems that demand more performance, storage capacity, and reliability than earlier models could deliver. Minicomputer users, faced with both increased diversity in mainframe characteristics and broader system requirements, are asking a lot more questions before they buy equipment. Here are some of the most common ones.

What architecture is used in minicomputers?

Minicomputers' word lengths usually run from 8 to 24 bits, with a few going as high as 32 bits. Longer words cost more. However, since machines with longer words store more data or more instructions, they are faster and more powerful. A shorter word length requires more memory to store data and programs, thus, any cost advantage may be lost in anything but the simplest of applications. A minicomputer with a word-length that is a multiple of 8 has an inherent advantage over others since this is the basic unit around which most industry-wide standards have been established. For example, a 16-bit word is powerful enough to handle the data of most users, and a high performance (800 nsec) 16-bit computer can easily manage, with few

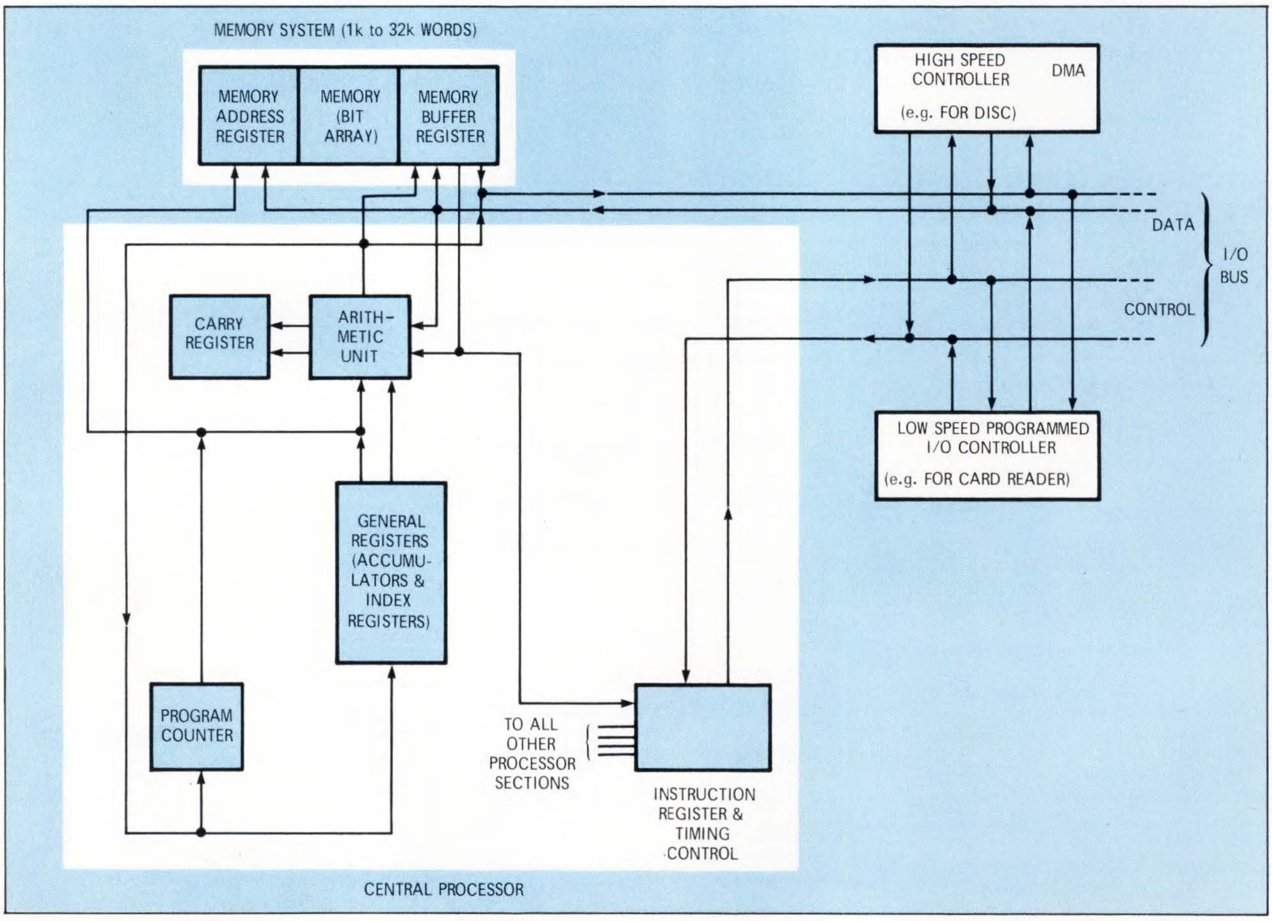


Fig. 1 Architecture of a typical minicomputer is a flexible combination of data handling techniques for most efficient operation.

exceptions, all the processing that a 24 or 32-bit midi-computer can handle.

The ready availability of MSI and LSI circuitry has now made it economical to build minicomputers with multiple accumulators. Accumulators provide locations in the CPU in which an operand can be temporarily stored and later retrieved quickly when needed. Therefore, several operations can progress at once; data flow within the computer is easier, and programming is more convenient than in a single-accumulator machine. Your concern should be whether the machine has single or multiple accumulators, rather than exactly how many accumulators it has.

The minicomputer's relatively short word length makes it impractical to directly address all but a few memory locations since few bits would be left over for instructions or data. Therefore, it is best to reach most locations by other than direct means. With index registers, the effective address is the given address as modified by the contents of the

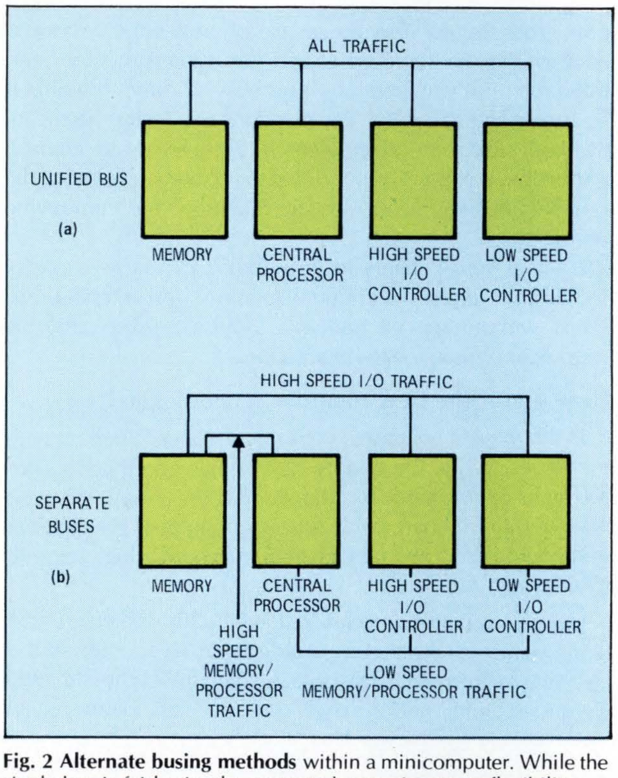


Fig. 2 Alternate busing methods within a minicomputer. While the single bus is fairly simple, separate buses give more flexibility.

index register. Use of indirect addressing requires the program to go to an intermediate address to find the location of the effective address; however, multiple word instructions allow more bits for direct addressing. Relative addressing allows a movable block of locations some distance ahead and behind the location of the instruction to be addressed directly. Thus, machines that use some flexible combination of these techniques would be the best choice (**Fig 1**).

A common definition of a computer's architecture is the relationship between its major subsystems. One method of connecting the pieces of a minicomputer is for the CPU to talk to the memory over a memory bus, and to all external devices over an I/O bus. However, some minicomputers treat the memory as an external device and talk to it over the same I/O bus, just like it would to a paper tape reader or CRT display (**Fig 2a**). The apparent advantage of putting the memory on the I/O bus is simplicity and modularity. Unfortunately any malfunctioning I/O device can tie up all other I/O devices as well as all memory/CPU functions with this approach. Separate I/O memory buses give the advantage of putting critical, high-density memory/CPU traffic on its own set of optimized data paths, while less predictable I/O traffic is handled over a general purpose I/O bus (**Fig 2b**).

Overall, a number of architecture alternatives are available, but recent trends have been toward 16-bit multi-accumulator machines employing a variety of addressing schemes.

What instruction sets come with minicomputers?

When evaluating minicomputer instruction sets, you should decide on the degree of complexity needed. A very complex instruction includes more than one function and uses more than one word. Using these macro-instructions, you can write programs with a minimum number of instructions. However, in most situations other than custom applications, they are relatively inefficient. Because they are more than one word long, macro-instructions require a relatively long time for execution, and the total amount of memory used is usually more than it would have been with single-word instructions.

Micro-instructions are very simple and can be quickly executed. They occupy less than a single word, leaving several bits available for addressing. Micro-instructions make it possible to write very economical, precise programs. However, their extremely abstract nature presents a formidable obstacle to all but the most accomplished programmers. They also use a great deal of memory.

Between macro and micro instructions there is a wide area called general-purpose instruction sets which most minicomputer manufacturers have adopted. A general-purpose instruction fits into a single word and contains a complete operation.

How is speed evaluated in a minicomputer?

Machines currently available specify memory cycle times ranging from under 0.5 μsec to 2 or 3 μsec. But a high performance memory alone is not enough. Does the processor keep the memory busy? If the processor is not fast enough to use memory efficiently, the effective speed of the machine can be considerably lower than the "inflated" memory specification would imply.

Be careful to make the distinction between memory access and full cycle time. With core memories, access time is the time it takes to read the data at a specific core location, while cycle time is the time required to read and restore the data, and typically is double the access time.

Cycle time however is only the beginning. One machine might take two or more cycles to execute an ADD instruction, while another does it in one cycle. If the cycles of the memory and processor are not locked together, a lot of time will be lost as one subsystem waits for the other. Look at the actual execution times for the computer's instructions.

Benchmark programs for applications similar to yours can be valuable. Compare the total execution time and the total memory size required for each computer. This is a good test for the computer's speed and the effectiveness of its instruction set for a specific type of application. However, don't let benchmarks mislead you. To be useful, a benchmark program should be long enough to test the computer in a variety of situations; at least 100 words of code is probably needed. Also insure that the benchmark is

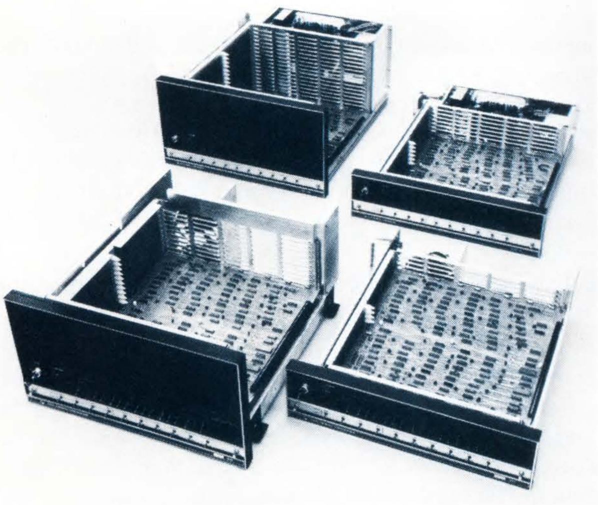


Fig. 3 Compatibility and expandability are important factors to consider. Sufficient space should be provided in a chassis to allow future memory expansion, and ready addition of interfaces.

designed to suit your application, not just a particular machine. A manufacturer may be able to alter your benchmark to take advantage of the strengths of his machine without affecting the usefulness of the program. This is a realistic approach and should be allowed.

How important is compatibility?

In any family of computers you should evaluate compatability of instruction set and software, I/O devices, and mechanical packaging (**Fig 3**). Compatability of I/O devices means the I/O bus must remain logically consistent throughout the family. Mechanical compatability means the bus must be physically the same.

An original equipment manufacturer (OEM) has a large investment in equipment and software other than the minicomputer so it's unrealistic to expect him to build in the newest, fastest minicomputer if it means that he has to rebuild the rest of his system. However, if he can simply substitute a faster, compatible computer without modifying any other hardware or software, he in turn can offer his customers a compatible line of products at different price/performance levels.

An end-user buying a single minicomputer for long-term use might not find compatibility within a family of mainframes as critical, although the insurance of compatibility is invaluable. If he does buy more computers in the future, having truly compatible machines will allow most of his older systems to be used with the new computer.

Both end-users and OEMs will benefit if their computers are compatible with the complete line of peripherals and software available for the manufacturer's product line. Peripherals and software offered for one model won't necessarily be offered for all new models. Often in such a case, the effort to rewrite a complex piece of software or to design a new interface is impractical.

What's "basic" and what's optional at extra cost?

There are marked differences in the hardware you get in a "basic" minicomputer configuration, in spite of the highly competitive pricing in the industry. You should get a chassis, a central processor, a memory module, input/output bus facility, all necessary power supplies, and an operator console with a complete set of status indicators and control switches. Also available are "less than basic" machines, usually with minimum memory, no operator console, and no expansion capability. Generally, they don't save money over a stripped-down version of a standard model.

A basic minicomputer usually includes one 4096-word memory module. Keep in mind the word length, for 4096 8-bit words will store only half as much data as 4096 16-bit words. You should know whether a teletypewriter terminal interface is standard or an extra cost option.

A Direct Memory Access (DMA) data channel is important for most systems with high-speed I/O requirements. It is standard on some minicomputers, but can cost as much as $1000 for others.

A number of other common features can be standard equipment or options. Be alert for: power fail protect and automatic restart, hardware multiply/divide, automatic program load, and automatic interrupt source identification. You should also be aware of how much room is available in the standard chassis for adding memory and interfaces. If it's inadequate, how easy or difficult would it be to expand capacity? The standard expansion hardware available for some computers is expensive and clumsy. Others have expansion modules that cleanly plug into the original chassis, thus preserving reliability and eliminating wiring costs.

If the system is likely to grow quickly, a large capacity model that accepts additional memory and interface circuitry without special hardware options, is probably the most economical longterm solution.

How about the new memory technologies?

In the majority of cases, your initial concern will be with memories. While the quality of core has continued to improve, its performance has stabilized. Cores smaller than 18 mils (500 to 600 nsec cycle time) don't appear practical for minicomputers. The main advantage of core is high reliability at low cost.

Semiconductor memories will eventually achieve higher performance at costs comparable to today's cores. Bipolar devices currently available to the minicomputer field yield very high performance, but are still expensive in

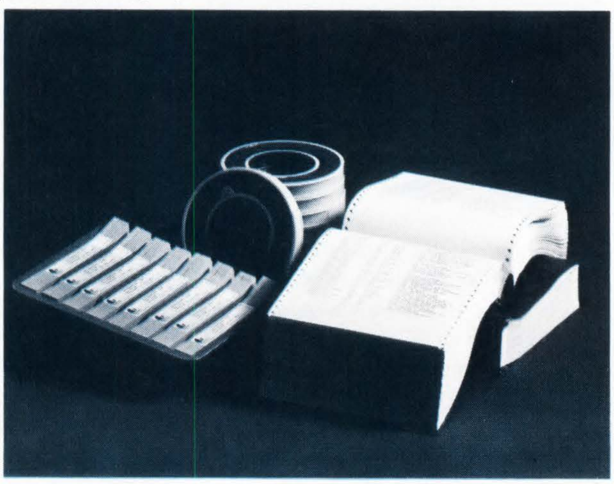


Fig. 4 A wide variety of system software comes with minicomputers. It ranges from bare essentials such as assemblers, editors and loaders to comprehensive ALGOL and FORTRAN compilers and disc operating systems.

terms of both price and power consumption. MOS devices are simpler and less expensive than bipolar devices but currently do not offer any significant speed advantage over core. However, price/performance improvements in both technologies are expected; therefore, semiconductor memory may ultimately be the right choice for your application. For high-performance applications, look at the possibility of mixing core with semiconductor memory. The use of small blocks of very fast semiconductor memory to store critical, frequently used subroutines or loops, can yield substantial improvements in overall system performance.

How much software is included?

Some minicomputers have only the barest essentials (assembler, editor, loader), while others offer a compatible selection of the same sort of software that is available on large machines (**Fig 4**). In some cases, packaged applications software is available. In a few situations, software is priced separately so those costs should be added on top of the hardware price.

If you write your own application programs, then the availability and quality of the developmental software is important. You will need assemblers, editors, loaders and a complete set of arithmetic and utility programs (floating point software is often important). The assembler should take no more than two passes. When comparing assemblers, consider memory requirements, throughput speed, size of the symbol table, input format flexibility, and features such as pseudo commands, relocatability, and interprogram communication. The editor should provide the programmer with the maximum tools for manipulating his programs. Look for character-editing features, string search capability, and the availability of pointers.

If you have access to a large-scale scientific computer, the availability of a cross assembler will speed your development programming considerably, and keep the minicomputer free for production work. Source codes for the minicomputer can be assembled on the large-scale computer, taking advantage of its high processor speed, large memory capability, and high-speed peripherals.

Higher level tools such as FORTRAN, ALGOL, and BASIC compilers are important for general purpose programming. The quality of compilers available varies widely; therefore, examine the amount of memory required and features offered. Many minicomputer compilers are very limited versions of standard software, while others include the standard language features as well as powerful extensions. Smaller versions usually occupy much less memory but they are also less useful.

If your system requires mass storage and multiple peripherals, a Disc Operating System (DOS) provides an orderly means of managing data files and peripheral devices. A good operating system should also include extensive diagnostic and debugging capabilities. Similarly, for real-time applications, a real-time operating system (RTOS) or real-time features in a DOS can relieve the user programs from the details of I/O timing, data buffering, priority handling, and task scheduling. RTOS gives you parallel processing capability and both intertask communications and synchronization facilities. Key points to look for are modularity and re-entrant capability, which allow you to add special device handlers easily.

A consideration in evaluating all software is the amount of memory it occupies and therefore, the cost and ease of adding more memory. Modular designs which allow reliable plug-in addition of core offer an obvious advantage when you expand software.

Thorough diagnostics should be provided for the computer (including individual tests for all subsystems) and for each peripheral. They should be able to pinpoint a problem to a specific component, not just to a function.

In a few cases, software packages are supplied for specific applications. These are usually turn-key systems for unsophisticated users in well-defined applications. These systems must be evaluated in terms of cost, memory requirements, specific application-oriented features, and the level of customizing required. Quite often, an application package must be modified to fit the precise equipment configuration it will control (e.g., a specific combination of machine tool and controller in a machine tool tape preparation system).

If the needed software is not supplied by the minicomputer manufacturer, you will have to write it yourself, or buy it from a software house. Both cases add cost.

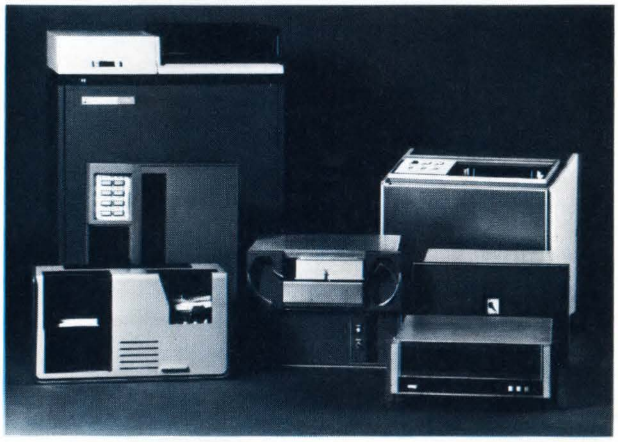


Fig. 5 Line printers, fixed and moving-head discs, tape transports and paper tape and card equipment are typical of standard peripheral equipment used with minicomputers.

Are any peripherals available for minicomputers?

Almost every type of device used with a large computer can be connected to a minicomputer (**Fig 5**). In most cases the only peripherals of concern are ones you think you need. However, requirements do change, and computer systems tend to expand. Therefore, if a broad line of peripherals is offered by a given manufacturer, it will be easier to meet future requirements with minimum design compromises.

No manufacturer is able to offer every peripheral, but there are some critical areas in which lack of support can be a real problem. The manufacturer you buy from should offer a line of paper tape products, several models of teletypewriter terminals, and a variety of alternative methods of mass storage, including industry-compatible magnetic tape and disc units. Off-the-shelf multiplexers, modems, and multiline controllers are essential in communications applications, and a complete set of A/D and D/A devices is required in real-time, data acquisition applications. CRT units, card punch equipment, plotters, printers, and other peripherals are also available.

Some units (e.g. small line printers) are designed primarily for use with minicomputers, while others are standard industry-compatible products. Although the peripheral doesn't have to be a special mini model, make sure that it's a reasonable match for the computer you pick, and that its design includes a good balance of performance, reliability, and cost.

Sometimes, a minicomputer manufacturer simple resells equipment bought from peripheral manufacturers. In other cases, he builds it himself, either totally or in part. Either approach works well, but you should be certain that you understand how much support the minicomputer manufacturer will commit himself to for a given peripheral. If he does not support the complete system including peripherals and interfaces, you the user may have a very difficult time solving problems that may develop.

What about interfacing to the minicomputer?

A good interface offers simplicity, has well-defined I/O bus signal lines with independent meanings and requires no complex sequencing of signals. Simplicity makes it easy to distinguish between hardware and software design errors for special OEM products, and also to isolate failures. The more parallel and direct the interface, the easier it will be for you to build and debug your logic.

Standard I/O interfaces built by computer or peripheral manufacturers should mount in the basic chassis without need for an additional extender chassis. In fact, you should be able to add several interfaces before needing an additional chassis. Interfaces should be physically simple, and preferably mounted on a single pc board (**Fig. 6**). Ideally, it will simply plug into the chassis through a reliable connector. If any wiring is required, wiring locations should be easy to reach and be clearly marked. Clear and complete documentation, including logic diagrams and diagnostic programs, should be offered for each standard interface.

The minicomputer manufacturer should provide a variety of general purpose interface products on which custom interfaces can be developed, tested, and implemented. The mainframe chassis should provide for mounting custom interfaces as conveniently as for standard products. If you're an OEM, custom interfaces should be easy to remove and to install in another computer for check-out. This keeps systems that are in production from getting tied-up in testing, and allows you to make last minute installations in systems about to be shipped.

How can input/output capability be assessed?

Minicomputers interface to many different kinds of peripherals and there is no need to sacrifice speed or flexibility in the I/O department.

The computer's data transfer rates should be as fast as the system's I/O devices, and the I/O facility must be able to handle the number of I/O devices you need. I/O word length (usually the same as the machine's basic memory word length) should be a good match for the data word lengths of the I/O devices.

Your minicomputer should be capable of handling both types of data transfer typically used: program-controlled data transfer through the I/O bus, and direct memory transfer. Program controlled data transfer is mostly used to service low-speed peripheral devices (teletypewriters, paper-tape readers, card readers). This type of data transfer is relatively slow (up to 30K words/sec). It is also inexpensive. An I/O bus facility is offered as standard equipment by all major manufacturers.

Data transfer across a Direct Memory Access (DMA) channel services high-speed devices such as disc memories or CRT displays. Data is transferred directly between main memory and the peripheral device in blocks, at rates up to one word each memory cycle (one million words/sec if basic memory cyle time of 1.0 msec). DMA is an extra-cost option on most minicomputers, but is standard on some.

Which priority interrupt scheme is best?

Relative priority among several pending device-generated interrupts can be established using either hardware selected or programmed interrupt levels. Hardware levels are generally faster, but less flexible. The number of priority levels available varies from single-level, where the nearest device to the processor is serviced first, to dozens of levels. While the single-level scheme may be inadequate in a complex system, more than 16 levels are often irrelevant. Even in complex communications networks, there are rarely more than a few significantly different levels of priority. Flexibility is really more significant than multiplicity. For example, if a system includes a highly critical device which requests service only infrequently, the interrupt scheme should be flexible enough to give that device high priority when it makes a request.

Can a minicomputer be expanded very much?

Maximum memory capacity of most minicomputers is 32K words, and they can be interfaced to several peripheral devices at once. However, no more than 8 or 12K of memory and one or two interfaces can be built into the box most computers come in. An expansion chassis is required if more memory or interfaces are needed. A few minicomputers accept up to 32K of memory and accommodate interfaces to multiple peripherals within a single chassis.

How can hardware reliability be measured?

Start by looking at the manufacturer's mean-time-between-failures (MTBF) figures however difficult they are to compare.

Medium-scale and large-scale integrated circuitry (MSI

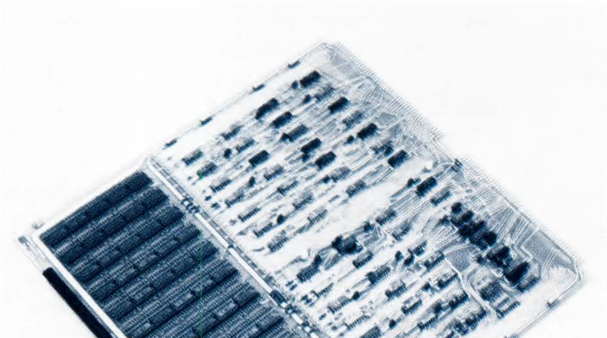


Fig. 6 Both general purpose and custom interfaces should be offered in a form that is easy to handle and implement. The one shown plugs conveniently into the minicomputer chassis.

and LSI) increases a minicomputer's inherent reliability. This advanced circuitry allows specific functions to be implemented with fewer components. For example, Data

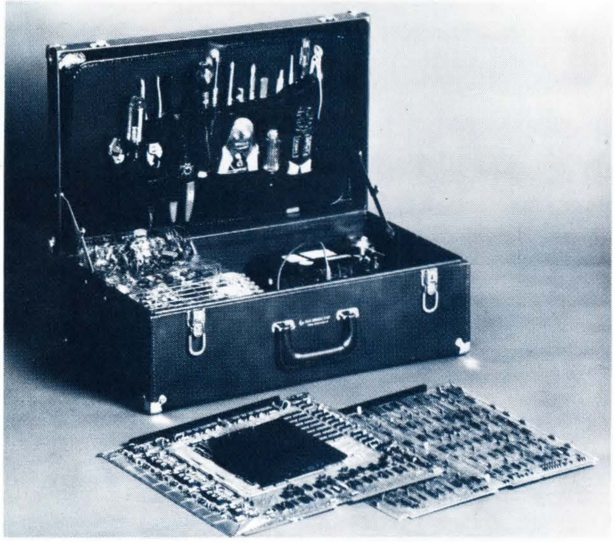


Fig. 7 Remote minicomputer installations require on-the-spot repair capabilities. The modularity of a minicomputers design, along with the manufacturers service capabilities, determine how long a malfunction will keep a computer shut down.

General's newer computer models use fewer components in the processor than do earlier Novas, yet they contain 64-bit scratchpad memories in place of 16-bit scratchpads, read-only memory for program load, and quad 3 input complementing multiplexers. High performance models, in particular, make extensive use of complex ICs. Because MSI and LSI components are at least as reliable as the less advanced circuits they replace, the net result is higher inherent reliability for the specific function.

Reliability is also increased when a number of functions are combined. The integrated back panel, power supply, and resistor board on the Nova line of computers, as an example, combines three subassemblies that once were manufactured separately, tested separately, and then mated. When these were integrated on a single board, the interconnections among them were eliminated along with an entire class of possible malfunctions—those caused by connection difficulties.

Simple organization also means easy access for maintenance. If major sybsystems are contained on single boards, a malfunction can be isolated very quickly and the mean-time-to-repair is minimal.

Are field service and training programs available?

Several types of field service contracts are available which range from straight time and materials arrangements to round-the-clock on-site coverage. You must establish your own requirements. If you don't require in-depth field service support, you won't be concerned if it is not available. However, if a manufacturer can't offer a range of field service contracts, he may have trouble supplying even a little timely support when it's critical.

If your computer is used at a remote site, you probably should buy a complete set of spare parts and make sure that someone at the installation can handle maintenance. Reliability, ease of maintenance, good documentation, and a thorough set of diagnostics for both mainframes and peripherals is essential in such a case (**Fig 7**).

Minicomputer manufacturers usually include training with each machine they sell such as a programming course and a hardware course, each one man-week long. Additional training is often available and held at the manufacturer's plant. You will pay your own expenses for these. Such courses are a useful review of the details of a specific machine for those with previous experience. Anyone with a general computer background but with little knowledge of minicomputers, will find the courses absolutely necessary as an introduction to the special characteristics of small computers. Unsophisticated users will probably find the courses too advanced and would benefit by first taking some introductory computer courses.

The best way to evaluate the available courses is to read the course descriptions. The software course should include a thorough grounding in the practical features of the most important software in a new installation: e.g. loaders, diagnostics, utility programs, debuggers, arithmetic routines, and assemblers.

The hardware course should also concentrate on the basics of installation, interfacing peripherals, troubleshooting and other typical service routines.

Who should I buy from?

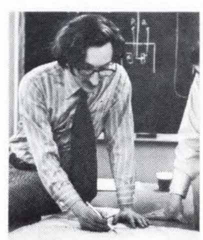
The original equipment manufacturer sells minicomputers as part of the equipment he manufactures and the final buyer is often not even aware that a computer exists within the system. The computerized model is usually the most sophisticated and expensive system he sells.

The OEM can be the best vendor to deal with if his packaged system fully satisfies your requirements. He will have a good understanding of the problems involved, and if he sells a large number of computerized systems, he should be able to offer the best support and price for the whole system.

If you can't handle an overall system development project yourself, and you can't get a packaged solution, you might go to a systems house—a company specializing in assembling hardware, software, and interfaces to solve a specific problem. These are usually custom systems. The major advantage of the systems house is that it can devote a full-time professional effort to a specific problem until it is solved, then you stop paying for it.

If you are confident that you can match a computer, peripherals, and software to your specific problem, you should buy directly from the minicomputer manufacturer. He should be able to offer the best price and the best support for the computer, peripherals and software which he provides. Many manufacturers can also provide systems interfaces and application-oriented software. ☐

Author's biography



Lawrence Seligman has been a member of the technical staff at Data General Corp., Southboro, MA, for 3 years serving as project manager for the Supernova, Nova 800, and Supernova SC. He previously worked at Digital Equipment Corp. Larry received his BSEE and MSEE in 1964 from MIT.

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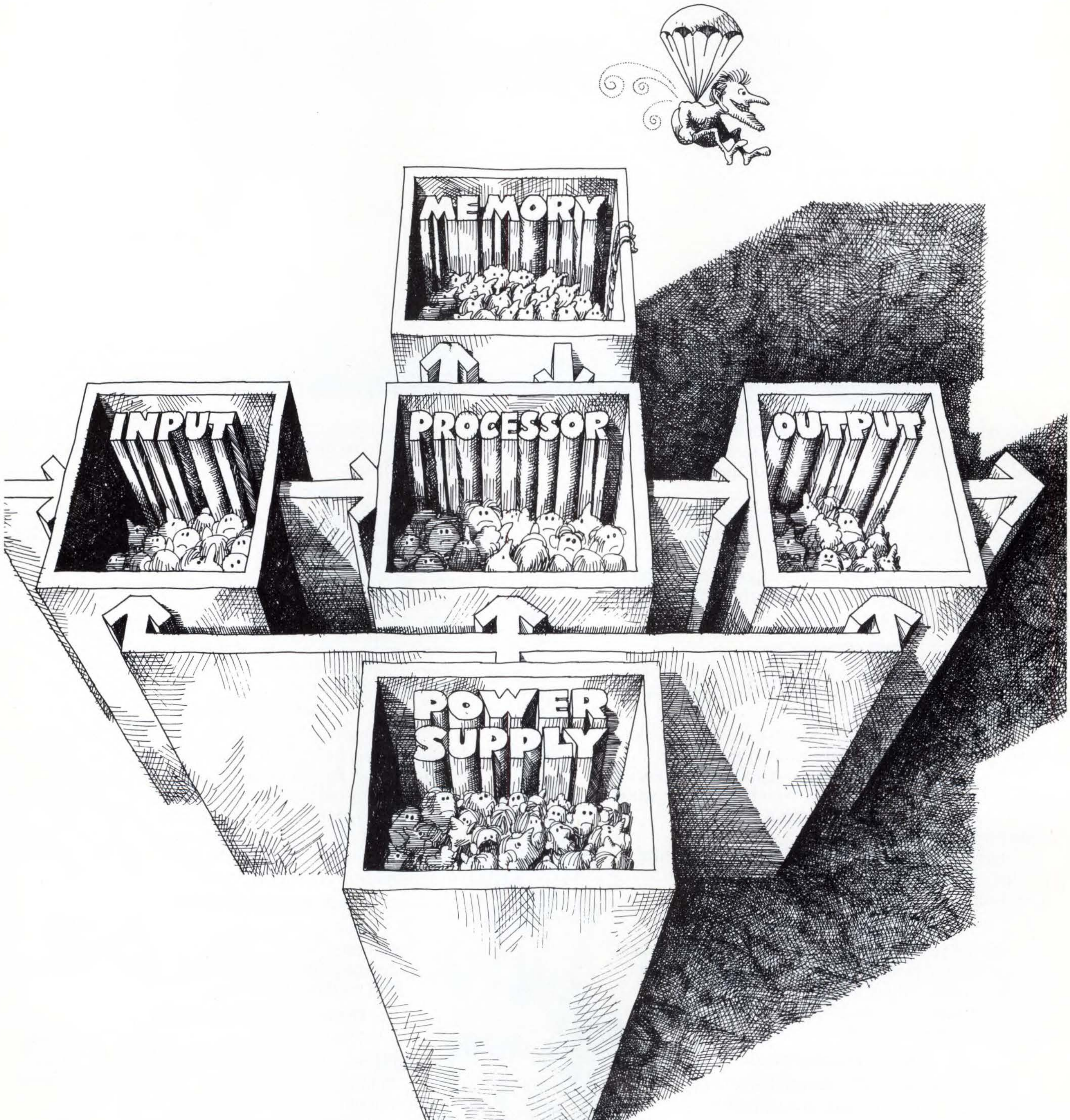
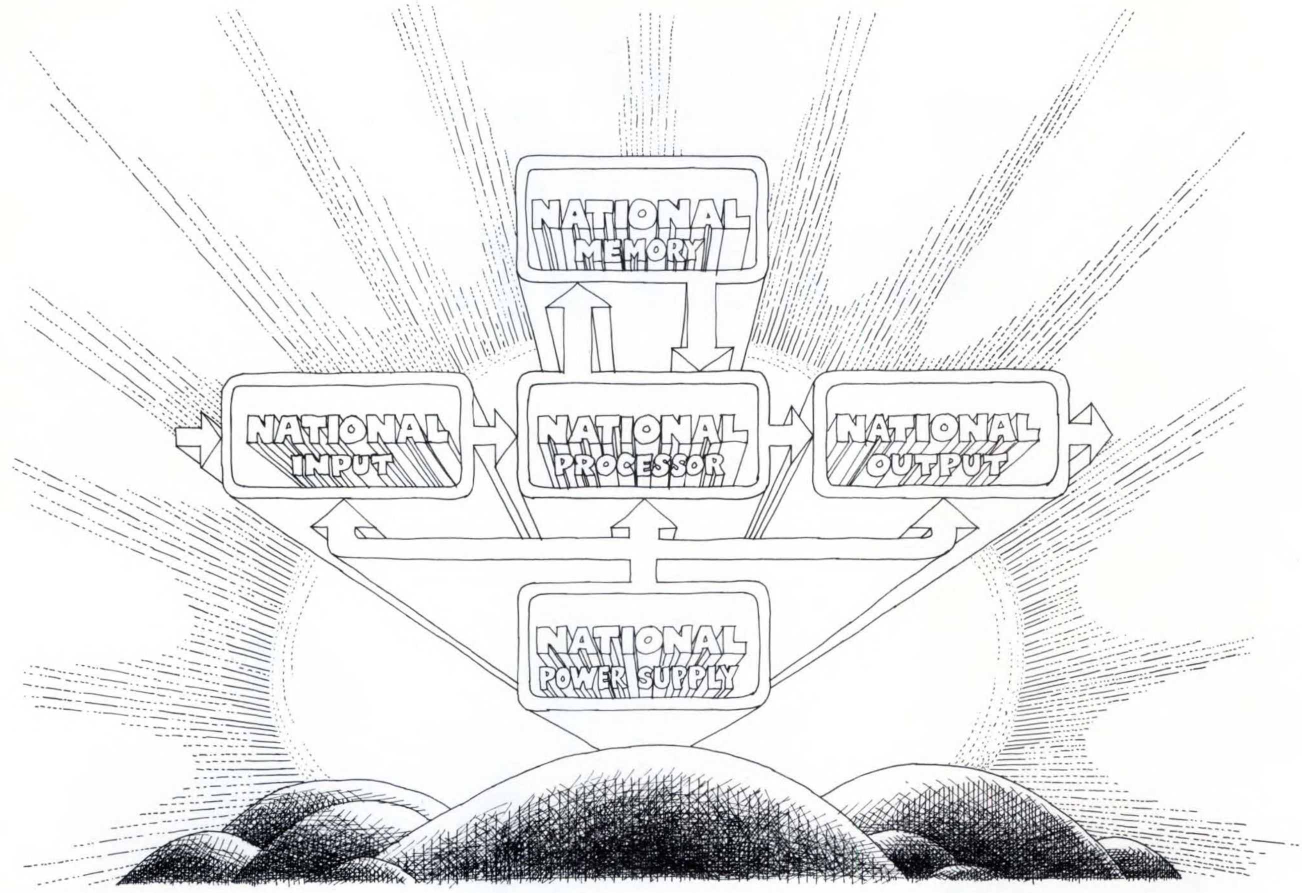
CIRCLE NO. 14

HOW TO BEAT THE SYSTEM.





For the most part, until recently, system design consisted of linking together a string of components, with little or no regard toward the cost effectiveness of the system as a total integrated unit.

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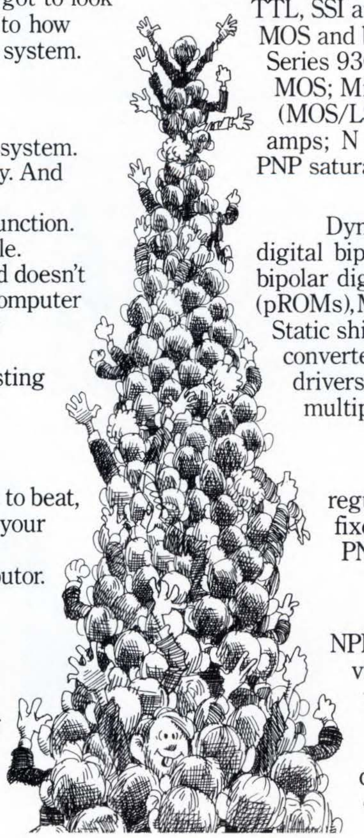
INPUT INTERFACE CIRCUITS

Single or dual NPN low level amplifiers; Single or dual N-channel low noise amplifiers; Code converters; Table look-up devices; Analog switches, hybrid and monolithic; Operational amplifiers; Comparators and buffers, linear and digital; EIA line receivers; Digital line receivers; MOS transmitter/receivers; Bus line transceivers; VHF and UHF oscillators.



PROCESSOR CIRCUITS

Series 54/74 TTL, SSI and MSI; Series 54/74 Compatible Tri-State* (TSL) Logic, SSI and MSI; Series 54S/74S TTL, SSI and MSI; Series 54H/74H TTL, SSI and MSI; MOS and bipolar ROMs and RAMs; Series 10,000 ECL; Series 930 DTL, SSI; CMOS, Series 54C/74C; Custom MOS; Microprogrammable Arithmetic Processor (MOS/LSI); Linear communications circuits; RF/IF amps; N and P channel FET switches; NPN and PNP saturated switches.

MEMORY CIRCUITS

Dynamic RAMs, MOS; Static RAMs, MOS and digital bipolar; Read Only Memories (ROMs), MOS and bipolar digital; Programmable Read Only Memories (pROMs), MOS and bipolar digital; Dynamic shift registers; Static shift registers; Character generators; Code converters; NPN and PNP core memory drivers; Clock drivers; Sense amplifiers; Peripheral drivers; 54/74 multiplexers, comparators and control circuits.

POWER SUPPLY CIRCUITS

Voltage regulators, ± tracking; Voltage regulators, fixed positive; Voltage regulators, fixed negative; Operational amplifiers; NPN and PNP medium power amplifiers.

OUTPUT INTERFACE CIRCUITS

NPN and PNP general purpose amplifiers; NPN and PNP RF amplifiers; NPN high voltage video output amplifiers; Custom MOS; Operational amplifiers; Comparators/buffers; Peripheral drivers; Display drivers; Hybrid power amplifiers; Hybrid level shifters and digital drivers; Sample and hold hybrid circuits.

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FOR EXAMPLE:

MAIN FRAME COMPUTER

MEMORY
Sequential Access Memory
"Silicon Disc" MM5012, MM5013, MM5025 Series
MOS Random Access
MM1101 Series, MM1103, MM5260, *MM5262
Bipolar RAMs & Scratch Pad
DM7489, DM8599, DM74200, DM8551, DM8553
Memory Drivers & Sense Amps
MH0025, MH0026, LM75451, LM75452, LM75453, LM7520 Series, LM7534 Series

INPUT
Telecommunication Receiver
LM1489A EIA
Local Line Inputs
DM8820A
Bus Inputs
*LM130, *LM131 Series, DM8093, DM8094, *DM8095 Series

PROCESSOR
Microinstruction Decoders
DM74187, DM8597, *DM8596 ROM's
Arithmetic Logic Unit
DM7483 Fast Adder, DM74181 ALU, DM74182 Look-Ahead, DM8875 4-Bit Mult.
Counters
DM8281, *DM8556
Random Logic
DM8093, DM7442, DM10,000 Series ECL, DM74S Series

OUTPUT
Display Drivers
LM350, LM75450 Series, DH0011 Series
Line Drivers
LM1488 EIA, DM8831, *LM131 Series

POWER SUPPLY
Voltage Regulators
LM100, LM104, LM105, LM109, LM723, LM376
Transistors
Process 12 & 67 Medium Power Transistors
Control Amplifiers
LH0052, LM108A, LM112, LM741

*To Be Announced

CARD READER

MEMORY
Rubber Band Accumulator (RAMs)
DM74200, MM1101, MM1103, MM5260, *MM5262
First In/First Out Memory (Static Regs)
MM5050, MM5051, MM5052, MM5053, MM5054, *MM5055, *MM5056, *MM5057
Memory Drivers
MH0025, MH0026

INPUT
(From Optical Data & Card Position Sensors)
Dark/Light Comparators
LM710, LM111, Process 52 & LH0042 FET Amps, Process 83 Dual J-FET Amplifiers

PROCESSOR
Memory Control
DM8281, DM7493, *DM8556, DM7483, DM74181
Card-Code Converters
To ASCII MM5230BO
To EBCDIC MM5230QW
Random Control Logic
DM7400 Series, Tri-State Logic
Bus Address Comparator
*DM8131

OUTPUT
Data Output Bus Drivers
*DM7438, DM7405
Transmitters/Receivers
DM7830, DM7831, DM7832
Bus Transceivers
*LM130 Thru LM136
Card Position Drive
DH0006, DH0008, DH0028, DH0034, Process 12 & 69 Drive Transistors

POWER SUPPLY
LM100, LM105, LM376, LM723, *LM140, LM109, LM104, Process 46 Medium Power Transistors

*To Be Announced

MODEM

INPUT
EIA Input From Terminal Equipment
LM1489A
Balanced Input From Data Access Arrangement (Telephone Lines)
LM301A, LM307

PROCESSOR
Bias Level Conditioner
LM301A, LM307, LM709
Active Notch Filter
LM373, LM374
Phase Locked Loop
LM565
Voltage Controlled Oscillator
LM567
Random Logic & Transistors
74 Series, Process 20 & 63 Medium Pwr Transistors

OUTPUT
600 Ω Balanced Output Driver
LM101, Process 12, 20, 63 & 67 Medium Pwr Transistors
Phase Locked Loop Control Voltage Transistor
LM711
EIA Line Driver
LM1488

POWER SUPPLY
LM300, LM304, LM305, LM309, *LM340, LM376, LM723, Process 12 & 67 Medium Pwr Transistors

*To Be Announced

AM/FM STEREO – PHONOGRAPH

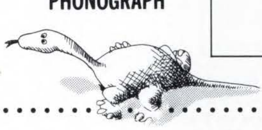
INPUT
AM Front End Oscillator Mixer
Process 46 Amplifier Transistor
FM Tuner
NF 506, LM1496, Process 43 & 44 Oscillator/Mixer Transistors
Record, Tape, & Microphone PreAmp
LM1303, LM381, LM382, Process 52 Low Noise Transistors

PROCESSOR
AM IF Strip
LM372, LM373
FM IF Strip
LM373, LM703, LM3075, LM2111, LM1351, LM2113, Process 47 IF Transistors
Buffer & Demultiplexer
LM1304, LM1305, LM1307, *LM1800, Process 27 Small Signal Transistors, Process 52 Audio FET Transistors
Tone Controls
LM381, Process 27 Transistors

OUTPUT
Left & Right Audio Power Amps
LM380, *LM383, *LM377, Process 12 & 67 Medium Pwr Transistors

POWER SUPPLY
*LM340, LM376, Process 12 & 67 Transistors

*To Be Announced



VIDEO DISPLAY SYSTEM

MEMORY
Static Buffer Registers
MM5050 Thru MM5057
Line Memory
MM5001, MM5006, MM5018, MM5054, MM5020, MM5021
Page Memory
MM5012, MM5013, *MM5017, MM5025 Series
Memory Drivers
MH0025, MH0026

INPUT
Keyboard Scanners (LSI)
MM5704 Serial, *MM5740 Parallel
(MSI)
DM74150 Series, DM8309, DM8312, DM8322, DM8123, DM8214
Line Input (Local)
DM8820A, *DM8131, LM131 Series
(Remote)
DM8822, *DM1489

PROCESSOR
Formatting
DM8570, DM8590, *DM86L90
Character Generator ROMs
MM5240, MM5241, *DM8596, DM74187
Sync Generator
*MM5320
Memory Page/Line Control
DM8093, DM8094, DM8095 Series, DM8123, DM8322
Line Counter
DM7490, DM7492, DM7493, *DM8555

OUTPUT
Horizontal & Vertical Oscillator/Driver
Process 48 HV Video Output Transistors
Z Axis Driver
Process 48 HV Video Output Transistors
Deflection Drivers & Amps
LH0021, LH0041, Process 12, 14 & 67 Medium Power Transistors

POWER SUPPLY
LM300, LM304, LM305, LM309 Series, LM376, *LM340

*To Be Announced

COLOR TELEVISION

INPUT
UHF Tuner Oscillator
Process 43 & 47 Transistors
VHF Tuner Oscillator
Process 43, 44 & 47 Transistors
Automatic Fine Tuning
LM3064
IF Discriminators
Process 27 & 47 Transistors

PROCESSOR
Sound & Video IF's
LM3075, LM3065, LM2111, LM1351, Process 45 & 47 RF/IF Transistors
Video Processor
*LM1845, Process 27 & 63 Transistors
Luminance
Process 20 & 63 Transistors
Chrominance
LM3070/LM3071, LM3066, Process 27 & 71 Small Signal Transistors, Process 45 & 47 AGC/IF/RF Transistors
Chroma Demodulator
LM746, LM3067, Process 27, 71 & 47 Transistors

OUTPUT
Audio Amplifier
LM380, Process 12 & 67 Transistors
Video Output
Process 48 High Voltage Transistor
Vertical & Horizontal Output Drive
Process 12, 14 & 67 Medium Power Transistors

POWER SUPPLY
*LM340, LM376, Voltage Regulators, Process 12 & 67 Medium Power Transistors

*To Be Announced

NOTE: Detailed block diagrams are available for the systems shown, as well as the following systems: ECM Receiver, MOS/Bipolar Calculator, Credit Verifier, Telemetry, Process Controller, Printer and Digital Voltmeter.

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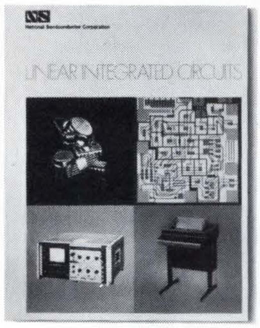

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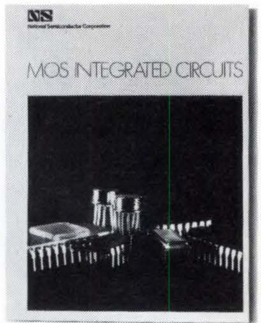

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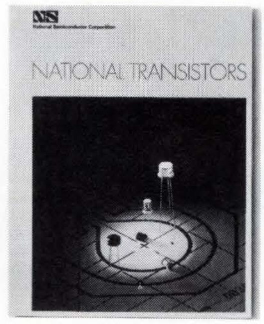

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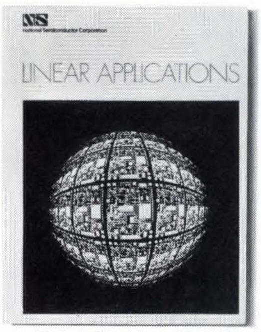

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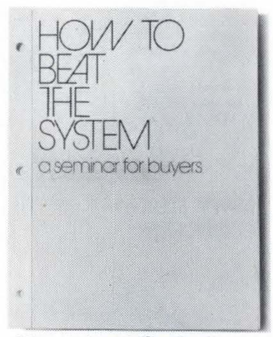

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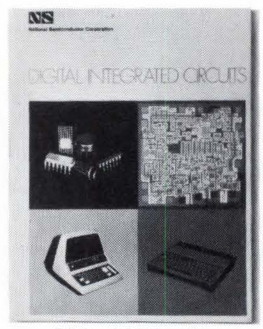

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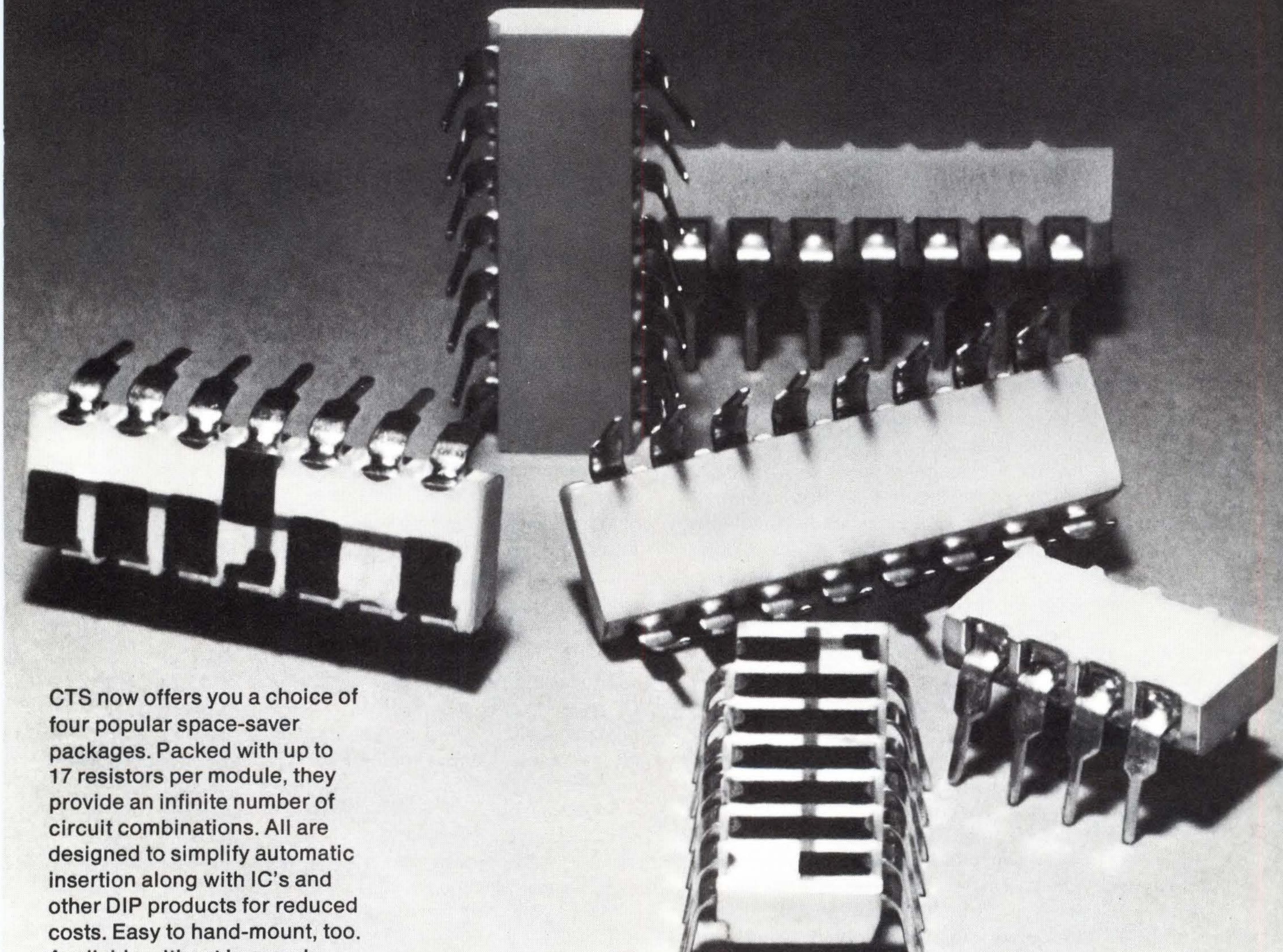

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CIRCLE NO. 16

Know the pitfalls of modular power-supply applications

Thermal considerations and input/output connections are important systems factors. Their proper evaluation can assure maximum systems performance.

Glenn Green, Hewlett-Packard Co., Berkeley Div.

Modular power supplies offer some of the best solutions for many system dc power requirements. They provide the convenience and economy of complete, prepackaged units ready to install and tend to make up a larger percentage of total system volume and cost as time goes on. This is particularly true in digital equipment and the day may well be gone forever when a power supply was "the first item needed and the last one considered."

But use of a modular power supply can result in some trying moments unless certain basic power-system guidelines are followed. Determining the nature of the load and specifying the power-supply operating characteristics and conditions are only two of many steps in arriving at a satisfactory dc power system. Two very important system design considerations that should not be overlooked are:

- Cooling requirements.
- Load and input ac connections.

Cooling requirements

Operating efficiency is a major determinant in power-supply size. Adequate volume must be allowed for heat sinks and cooling air circulation to keep power-supply components within their temperature rating for a given set of conditions. Manufacturers specify maximum continuous current ratings for different ambient temperatures in order to keep components within their rated temperatures. Typically, full-output current is rated at 40 or 50°C ambient. Specified output current is then derated (reduced) for an increased ambient temperature. In some cases, this is done to compensate for changes in supply efficiency—usually due to a different input frequency (i.e., 50 Hz instead of 60 Hz).

To maintain a 40 or 50°C ambient may at first glance seem easy, since the dc power utilized may be only a few hundred watts within an enclosure. But this is only the tip of the iceberg. Series-regulated supplies are not particularly efficient power converters, and hence produce considerable heat. Typical efficiencies range from 20 to 25% for fixed 5V supplies to 30 to 40% for fixed 48V supplies in the 20-to-80W output range. Thus for every dc watt utilized, the equipment enclosure must dissipate 2.5 to 5W while maintaining a maximum permitted ambient temperature. Provision must be made to remove this heat to maintain the required ambient temperature.

Natural convection cooling is normally used when a few hundred watts of heat are involved and when there are moderate ambient temperatures. Forced-air cooling may be required when there is insufficient natural air flow for a group of supplies, or where compact system design is paramount.

Since system power requirements have a tendency to grow rather than shrink during design, some reserve power provision may also be required for future system additions. The first power and heat estimates should be on the generous side and be reviewed and refined as the design progresses. The early design phase is the best time to contact power-supply manufacturers. Not only can they provide technical information on standard products, but they may also provide valuable applications assistance during the time when there is a choice among alternate solutions.

Load and input ac connections

By making improper wiring connections to a power-supply's input or output, a user can inadvertently degrade the supply's performance capability. At best, this can result in excessive output ripple, a tendency toward oscillation, poor load and line regulation, and unnecessary degradation of stability, temperature coefficient, and transient-recovery specifications. At worst, the result can be supply failure and potential shock hazards. Careful attention to the following guidelines will improve the safety and usefulness of modular power supplies.

Ac-power input connections. Input ac connections to a power supply should be carefully scrutinized. Accidental interchanging of ac and safety ground leads may elevate the power-supply chassis to an ac potential equal to the line input voltage. This could result in a potentially lethal shock hazard if the chassis is not grounded; or blown fuses if the chassis is grounded.

Most ac input line regulators should not be used with well-regulated power supplies without first checking with the power-supply manufacturer. Such regulators tend to increase the impedance of the line in a resonant fashion, and can cause malfunctioning of power supplies. This is because the control action of most line-voltage regulators is accompanied by a change in the output waveshape which is just as effective in causing output-voltage changes of the power supply as the original uncorrected line voltage amplitude changes.

When connecting ac voltage to a power supply, it is not only necessary to use a wire which is rated to carry the maximum input current, but it must also retain a sufficiently low impedance from the service outlet to the power supply input terminals, particularly if a long cable is involved. As a general guideline, input cables should employ a wire size sufficient to insure that the IR drop at the maximum rated power-supply input current will not exceed 1% of the nominal line voltage.

Load connections. The simplest and most common example of improper load wiring is the technique of directly paralleling power-supply loads in sequence (often called "daisy chaining"). With this connection method,

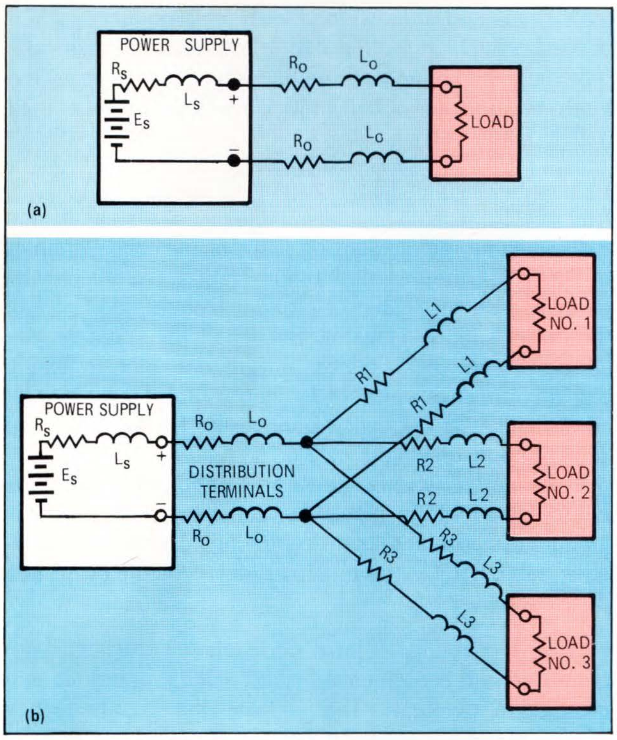

Fig. 1—The equivalent circuit of a power supply should include the equivalent source resistance as well as the equivalent source inductance (**a**). The equivalent circuit for multiple power supplies is shown in (**b**).

each load sees a power-supply voltage which is dependent upon the current drawn by the other loads. Since most power-supply loads draw a current which varies with time, a time-varying interaction among the loads results. In many cases this interaction can be ignored. But in some applications, the resulting noise, pulse coupling or tendency toward inter-load oscillation is undesirable and often unacceptable.

Dc distribution terminals. For proper power distribution to the load, a single pair of terminals designated as the positive and negative "dc distribution terminals" can act as the power-supply output, the B+ at the load or as a separate pair of terminals established expressly for distribution. Their proper location results in improved overall performance and reduced mutual coupling effects between separate loads using the same power supply.

If remote sensing is not used, these terminals should be located as close as possible to the power-supply output terminals. For optimum performance, the power-supply output terminals should be used as the distribution terminals. If remote sensing is employed, the distribution terminals should be located as close as possible to the load terminals. Sensing leads should then be connected from the power-supply sensing terminals to the distribution terminals. Only a single pair of wires should be connected directly from the power-supply output terminals to the distribution terminals and a separate pair of leads from the distribution terminals to each load.

Load wire rating. As an absolute minimum, each load wire must be of sufficient size to carry the power-supply short-circuit output current. However, impedance and coupling considerations usually dictate the use of wire larger than the minimum required to satisfy current rating requirements.

Most well-regulated power supplies have an upper limit on the load current IR drop beyond which remote sensing cannot be accomplished without losing regulation. This maximum limitation is typically 0.5, 1 or 2V and may apply to the positive, negative, or both the positive and negative output leads. In addition, the voltage lost in the load leads reduces the voltage available for use at the load. This is usually not significant at high voltages, but a typical 5V power supply will only have 3V left for load use if 1V is dropped in each load lead—remote sensing does not increase the total voltage available from the power-supply rectifier and regulator. Either of these two factors will in some cases lead to a wire size selection which is larger than that dictated by consideration of wire temperature rise, current rating or impedance only.

Every regulated power supply has a small output impedance at low frequencies which increases with higher frequencies. Thus a more exact power-supply circuit model than the usually-thought-of battery-and-line-equivalents in a schematic includes an equivalent source resistance and inductance as shown in **Fig. 1A**. R_s is the power supply output impedance at dc, and is found by dividing the load regulation by the current rating; for example, a power supply which has a load regulation of 10 mV for a full-load change of 10A has an equivalent R_s of 1 mΩ, a typical value. Similarly, a power supply with an output impedance of 0.2Ω at 100 kHz and 2Ω at 1 MHz has an equivalent high-frequency output inductance L_s of 0.3 μH—again, a value typical of high-performance power supplies.

Connecting lines on a schematic represent ideal connections between two points, but the physical wires used are characterized by distributed resistance, inductance and capacitance. For determining necessary load-wire sizes, it is usually sufficient to consider only the equivalent lumped constant series resistance and inductance (L_0, L_1, L_2, . . . and R_0, R_1, R_2, . . .). Given the wire size and length, these lumped equivalents can be determined from wire tables and charts.

In general, the power-supply performance degradation seen at the load terminals becomes significant whenever the wire size and length result in a load wire impedance

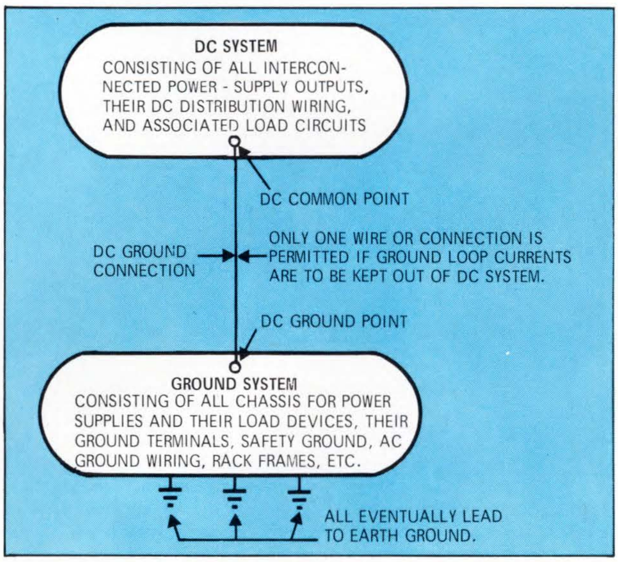

Fig. 2—To avoid conductive paths in common with ground currents, connect the dc distribution system to ground with one wire.

comparable to or greater than the equivalent power-supply output impedance. With one load, this degradation can be evaluated by comparing $2R_0$ with R_s, and $2L_0$ with L_s. The total impedance seen by the load is

$$Z_T = (R_s + 2R_0) + j\omega(L_s + 2L_0),$$

and the variation of the dc load voltage caused by a sinusoidal variation of load current is

$$E_{ac} = I_{ac}Z_T.$$

If load current variations are more pulse or step-shaped than sinusoidal, then the resulting load voltage spike will have a magnitude of

$$e_L = L_T\left(\frac{di}{dt}\right)$$

where

$$L_T = L_s + 2L_0$$

and di/dt is the maximum rate of change of load current.

If these calculations indicate that the resulting variations in dc voltage provided to the load are greater than desired, then shorter and/or larger load leads are required.

With multiple loads (**Fig. 1B**), it is necessary to consider separately the common or mutual impedance seen by the loads, Z_T, and the added impedance seen by each load individually,

$$2(R_1 + j\omega L_1),\ 2(R_2 + j\omega L_2),\ \text{etc.}$$

Connecting remote sensing leads to the load terminals of **Fig. 1A** or the distribution terminals of **Fig. 1B** has the effect of reducing R_0 by a factor equal to the loop gain of the power-supply regulator, usually of the order of 10^3, 10^4, or 10^5. However, remote sensing does not in general alter the effective value of L_0 seen by the load, since L_0 predominates at frequencies above the bandwidth of the power-supply regulator.

Since remote sensing affords little or no reduction in the effective load wiring impedance at high frequencies, some amount of capacitive load decoupling is sometimes desirable, particularly when multiple loads are connected to a power supply.

Load decoupling. A local decoupling capacitor, if required, should be connected across each pair of load and distribution terminals. This reduces the high-frequency

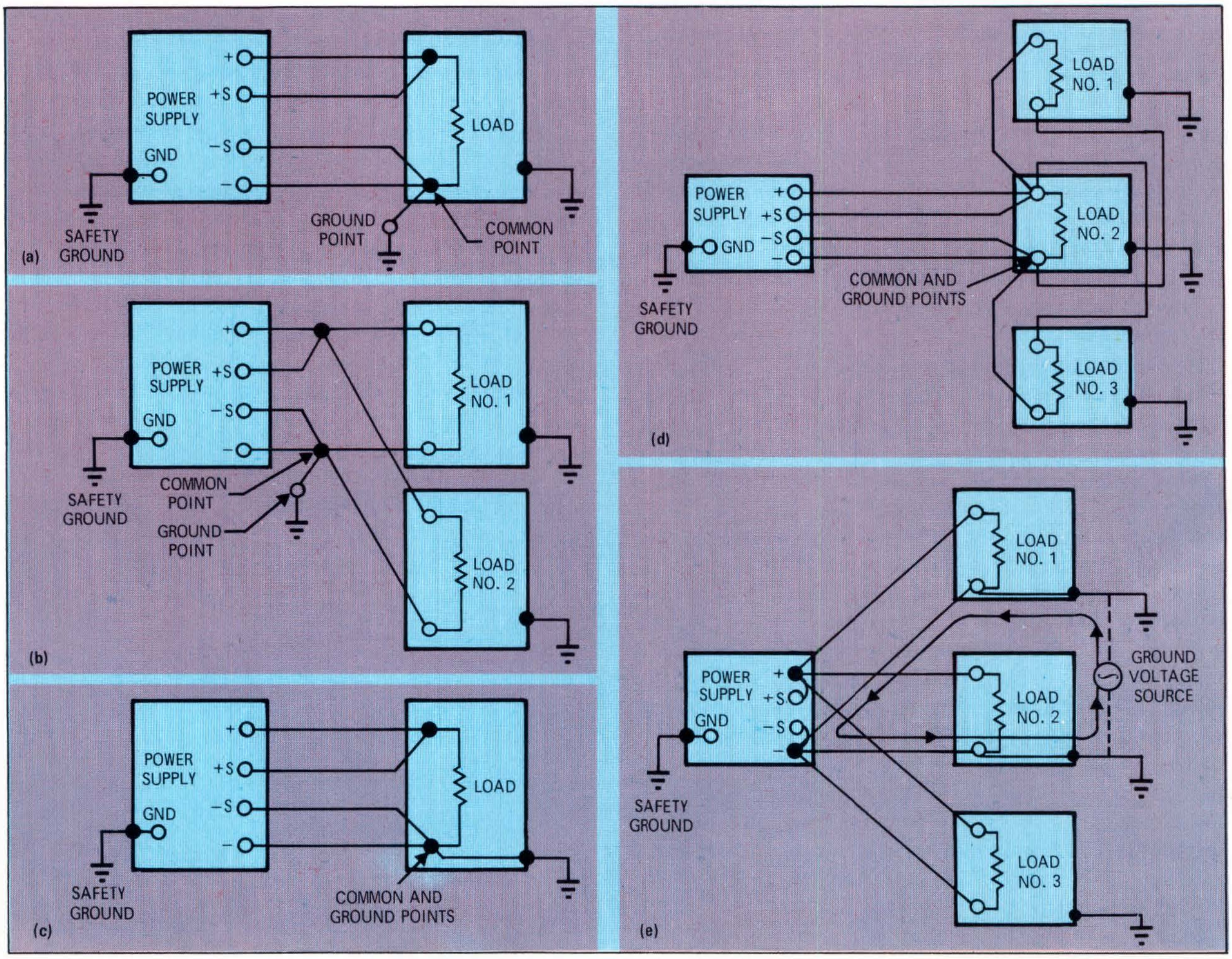

Fig. 3—Selecting the best dc common point for various types of loads. Either positive or negative load terminals will do as the common point (**3a**) when remote sensing is to be employed and the load terminals serve as the dc distribution terminals, with single isolated loads. **Fig. 3b** shows the preferred ground connections for multiple isolated loads. For single grounded loads, the grounded terminals must necessarily be the common point as shown in **3c**. Where only one of a number of loads has an internal ground or chassis connection, use the circuit in **3d**. Where two or more loads out of a number of loads are grounded, **3e** is preferred.

impedance seen by any individual load looking back toward the power supply. Decoupling capacitors are often employed with multiple loads drawing pulse currents with short rise times. Without local decoupling, these current changes can cause spikes which travel down the load-distribution wires and falsely trigger one of the other loads.

To be effective, the high-frequency impedance of local decoupling capacitors must be lower than the impedance of wires connected to the same load. A decoupling capacitor must be chosen with care, with full knowledge of its inductance and effective series resistance, as well as its capacitance. Moreover, the shortest-possible leads should be used to connect local decoupling capacitors directly to the load and distribution terminals.

Ground loops. The ideal concept of a single "quiet" ground potential is misleading. No two ground points have exactly the same potential. The potential difference in many cases may be small, but even a difference of a fraction of a volt will cause amperes of current to flow through a complete ground loop.

To avoid ground loop problems, there must be only one ground return point in a power-supply system. The selection of the best dc ground point is dependent upon the nature and complexity of the load and dc wiring. However, practical problems in large systems sometimes tend to force compromises with the ideal grounding concept. For example, a rack-mounted system consisting of separately mounted power supplies and loads generally has multiple ground connectors—each instrument usually has its own chassis tied to the third "safety ground" lead of its power cord, and the rack is often connected by a separate wire to "safety ground." With the power supplies fastened to the rack frame, circulating ground currents are inevitable. When these ground currents are confined to the "ground system" and do not flow through any portion of the power-supply dc distribution wiring, the effect on system performance is usually negligible.

The only way of avoiding conductive paths in common with ground currents is to connect the dc distribution system to ground with only one wire, as illustrated in **Fig. 2**. Dc (and signal) currents circulate within the dc system, while ground loop currents circulate within the ground system. With only one path between the two systems, ground-loop currents are isolated and have no affect on the power-supply dc output and load circuits. Any magnetic coupling between the dc system and ground system, or any capacitive coupling from the dc system to ground, can provide a return path for ground-loop current to link both the dc system and ground system. Consideration must also be given to reducing stray coupling between high and low-level wires as well as to ground.

Common dc point. One of the dc distribution terminals should be designated as the "dc common point." There should also be only one dc common point per dc system. Here are some additional suggestions for selecting the best dc common point for five different classes of loads:

(a) Single isolated loads: Select the positive or negative dc distribution terminal as the dc common point. A single isolated load exists when a power supply is connected to only one load and that load circuit has no internal connections to the chassis or ground. If remote sensing is to be employed and the load terminals serve as the distribution terminals, then either the positive or negative load terminals will do as the common point as shown in **Fig. 3a**.

(b) Multiple ungrounded loads: Select the positive or negative dc distribution terminal as the dc common point. This alternative is applicable when there are two or more separate loads with separate pairs of load leads, and none of the load circuits has internal connections to chassis or ground (**3b**).

(c) Single grounded loads: The load terminals of single grounded loads must serve as the distribution terminals and the grounded terminal of the load must necessarily be the common point (**3c**). This method of common-point selection is followed when there is only one load which has an essential (internal) connection to ground or chassis; or when there are multiple loads and only one of them has an internal connection to ground or chassis (**3d**).

(d) Multiple loads, two or more of which are individually grounded: This is an undesirable situation and must be eliminated if at all possible. Ground-loop currents circulating through the dc and load wiring cannot be avoided as long as separate loads connected to the same power supply (or dc system) have separate ground returns (**3e**). One solution is to break the circuit connection to ground in all of the loads and then select the dc common point following alternative (**b**); or break the circuit connection to ground in all but one of the loads and treat it as in alternative (**c**). In other cases the only satisfactory solution is to increase the number of power supplies, operating each grounded load from its own separate supply, and treating each combination of power supply and load as in alternative (**c**). However, in this case any conductive path remaining between the loads may degrade load performance, and any conductive path between power supplies (except via their respective load grounds) will probably degrade both power-supply and load performance.

(e) Load systems floated at a dc potential above ground: In some applications it is necessary to operate the power-supply output at a fixed voltage above (or below) ground potential. Here, it is advantageous to designate a dc common point and couple it to the dc ground point through a 1-μF capacitor. In certain applications such as bridge-load circuits, neither conductive nor capacitive grounding of the dc load distribution system is appropriate, since such grounding would also short out the desired

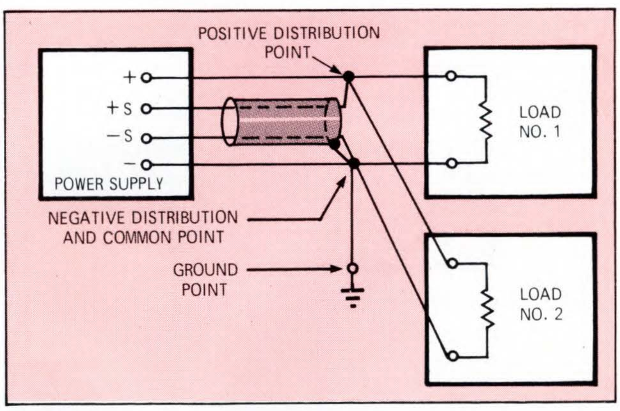

Fig. 4—Remote-sensing connections. Connections between the power-supply-sensing and output terminals should be removed and through the use of a shielded two-wire cable, the sensing terminals should be hooked up to the dc distribution terminals.

output signal being generated by the bridge.

Dc ground point. The terminal connected to ground should be designated as the dc ground point. This point may be any single terminal, existing or added, which is conductively connected to "safety ground" of the building wiring system and eventually to earth ground.

The common should be connected to the ground point as shown in **Fig. 3a** through **3d** (unless one load is already grounded), making certain there is only one conductive path between these two points. This connection should be as short as possible, and the total impedance from the dc common point to the dc ground point should be small compared with the impedance from the ground point to earth ground.

Remote sensing. A power supply achieves its optimum load performance and its regulation achieves it lowest output impedance, drift, ripple and noise and fastest transient-recovery performance at the power-supply output terminals. If the load is separated from the output terminals by any lead length, some of these performance characteristics will be degraded at the load terminals—usually by an amount proportional to the impedance of the load leads compared with the output impedance of the supply.

With remote error sensing, a feature included on many modular power supplies, it is possible to connect the feedback amplifier directly to the load terminals so that the regulator performs its function with respect to these load terminals rather than with respect to the supply's output terminals. Thus, the voltage at the power supply output terminals shifts by whatever amount necessary to compensate for the IR drop in the load leads, thereby keeping the voltage at the load terminals constant.

Connections between the power-supply sensing and output terminals should be removed, and using shielded two-wire cable, the power-supply sensing terminals should be connected to the dc distribution terminals as shown in **Fig. 4**. Do not use the shield as one of the sensing conductors. For clarity, the diagram shows the load leads as straight lines. However, some immunity against pick-up stray magnetic fields is obtained by twisting each pair of plus and minus load leads.

Typically, the sensing current is 10 mA or less. To insure that the temperature coefficient of the sensing leads will

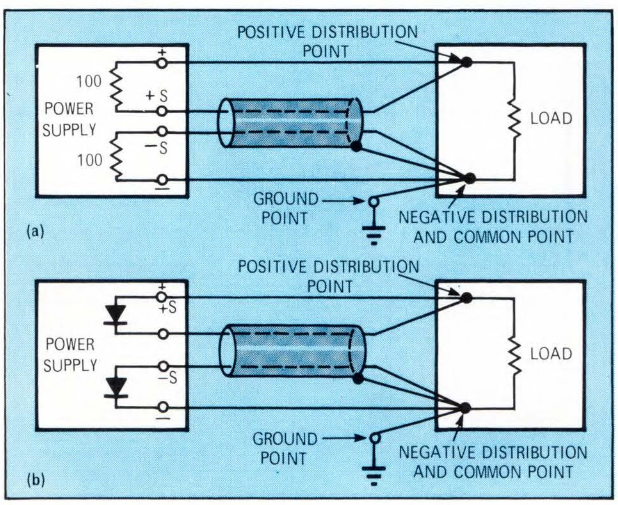

Fig. 5—To reduce output overshoot due to accidental opening of the remote-sensing connections, use resistors (**a**) or small silicon diodes (**b**) for proper protection.

not significantly affect the power-supply temperature coefficient and stability specifications, it is necessary to limit the IR drop in the sensing conductor to less than 20 times the power-supply temperature coefficient (stated in mV/°C).

The possibility of an open remote sensing path, which might occur on either a long-term or transient basis, should be avoided. Such open-circuit conditions are likely if the remote sensing path includes any relay, switch or connector contacts. When a sensing open occurs, the regulator circuit within the supply reacts as though the load voltage were zero—usually, the output voltage corrects this deficiency by climbing rapidly toward the maximum rectifier voltage, a value which is significantly larger than the power-supply's maximum output voltage. Even if the power-supply output circuitry is designed to withstand this extreme, the chances are that the load is not.

To reduce the degree of output overshoot which can result from accidentally opened remote-sensing connections, many regulated power supplies include internally wired resistors or small silicon diodes as shown in **Fig 5a** and **5B**. If these components are not included in the power supply, and if the application involves any likely cause of even momentary open-circuits in the remote-sensing paths, then the user should add them on.

Output oscillation. The possibility of power-supply oscillation must be considered when a supply is for remote sensing in a system. The impedance of the load leads is included inside the power-supply feedback loop. In remote-sensing applications involving small or long load wires, there is a tendency for power-supply oscillation to occur due to the phase shift and added time delay associ-

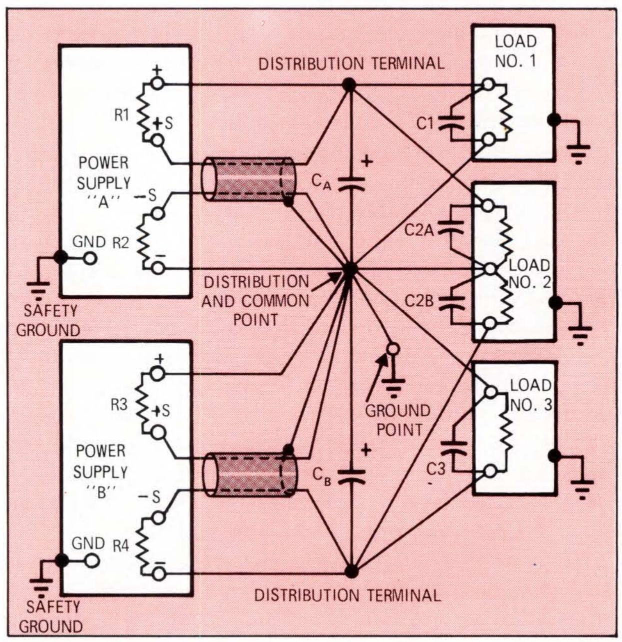

Fig. 6—For multiple power-supply connections, loads can be hooked up as configured above.

ated with the load and sensing leads. Removal of such tendency toward oscillation is usually done empirically. In some cases readjusting a "transient-recovery" or "loop-stability" control inside the supply can prove adequate; in more severe cases the power-supply loop equalization may have to be redesigned for the application.

An output capacitor, internally connected directly across the power-supply terminals, is commonly included in order to suppress load transients and reduce the power-supply impedance at the load at high frequencies. However, the capacitor must be chosen with care if power-supply oscillation is to be avoided, since any capacitor resonances or other tendency toward high impedance within or near the bandpass of the power-supply regulator will reduce loop stability. It is therefore common in extreme remote-sensing applications to remove the output capacitor from the power supply and connect it directly across the load.

Current limiting. Proper current-limiting operation is often a problem when the power supply is connected in the system for remote sensing. With some power-supply designs, the resistance used for current-carrying leads adds to the resistance used for current-limit monitoring, thereby reducing the threshold value at which current limiting begins. As a check for proper operation, the current limit value should not change significantly while shorting the negative sensing terminal to the negative output terminal and the positive sensing terminal to the positive output terminal, at the power supply.

Load connections for multiple power supplies. The extension of the preceding single-power-supply concepts to multi-power-supply systems (**Fig. 6**) is simple and direct, requiring only the application of the following guidelines.

First, there must be only one point of connection between the dc outputs of any two power supplies in the multiple power-supply systems. This point must be designated as one of the two distribution terminals for both power supplies.

Second, one of the distribution terminals, determined in accordance with the preceding paragraph, must be designated as the common point for the system. There can by only one common point per system—the distribution terminal which is to be held at ground potential.

Third, there must be only one ground point per multiple power-supply system. This rules out the possibility of connecting two grounded loads in the same system.

Finally, the system common point must be connected to the system ground point (unless one load is already grounded), and it must be verified that there is only one conductive path between these points for the entire system. □

Author's biography

Glenn Green is Product Manager for power supplies at Hewlett-Packard's New Jersey Division in Rockaway, New Jersey, where he's been employed since 1966. Prior to joining H-P, he worked on manufacturing process and test-system design. Glenn studied engineering and marketing at Lehigh University, where he received his BS degree in 1962.

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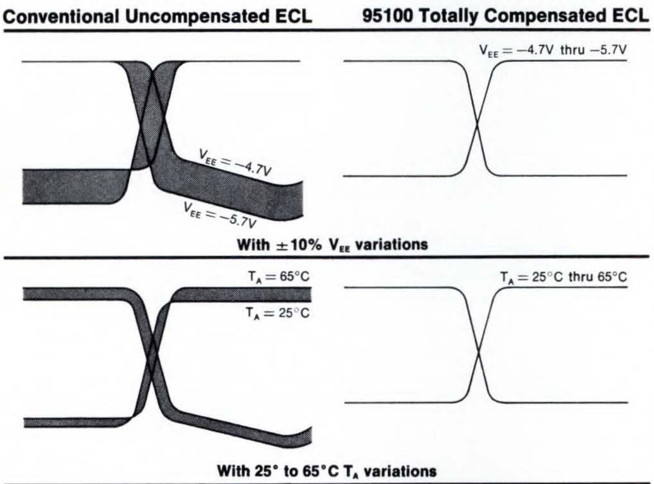
Noise Margin Comparison

V_{IN} and V_{OUT} transfer characteristics



These diagrams indicate the effect on ECL logic levels of variations in power supply and temperature.

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95100 ECL Devices and Availability

Device	Description	Available
95102	Dual OR/NOR Gate	Now
95103	Triple OR/NOR Gate	"
95104	Quad OR/NOR Gate	"
95101	Dual 2 Wide OR-AND/NAND Gate	2nd Qtr. '72
95105	4 Wide OR-AND/NAND Gate	"
95106	Dual 3 i/p, 3 o/p OR Gate	"
95108	Quad 1 i/p OR/NOR Gate	"
95109	Dual 3 i/p, 3 o/p NOR Gate	"
95110	Synchronous Decade Counter	"
95116	Synchronous Hexadecimal Counter	"
95128	Dual D Flip Flop	"
95141	4 Bit ALU/Function Generator	"
95134	Quad Latch	2nd Half '72
95138	One-of-8 Decoder	"
95178	Quad Exclusive OR	"
95179	Quad 2 i/p Multiplexer	"
95180	Triple 2 i/p Multiplexer	"
95196	Quad ECL-TTL Level Converter	"
95197	Quad TTL-ECL Level Converter	"

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Match your power supply to your system's needs

Overspecifying a power supply can lead to increased systems costs without the benefit of improved systems performance.

Joshua A. Hauser, Lambda Electronics

Virtually all electronic equipment requires some device to transform available ac line voltage into dc output voltages which are isolated from the ac line. This device is known as a power supply. There are several performance criteria which may be used to evaluate a power supply. These generally indicate how close a power supply approximates a zero-output impedance dc voltage source that is completely independent of the input line, output load and ambient temperature. This is the case for an ideal power supply. (In the case of the less-frequently used constant-current power supply, the ideal unit has infinite output impedance.)

As is the case with most things, the closer you approach the ideal power supply, the more money you need to spend. Therefore it is important that you evaluate your needs carefully. Overspecifying a power supply can lead to increased system costs without necessarily achieving improved system performance.

For example, if all you're interested in as far as your system is concerned is a power supply that has roughly 0.1%

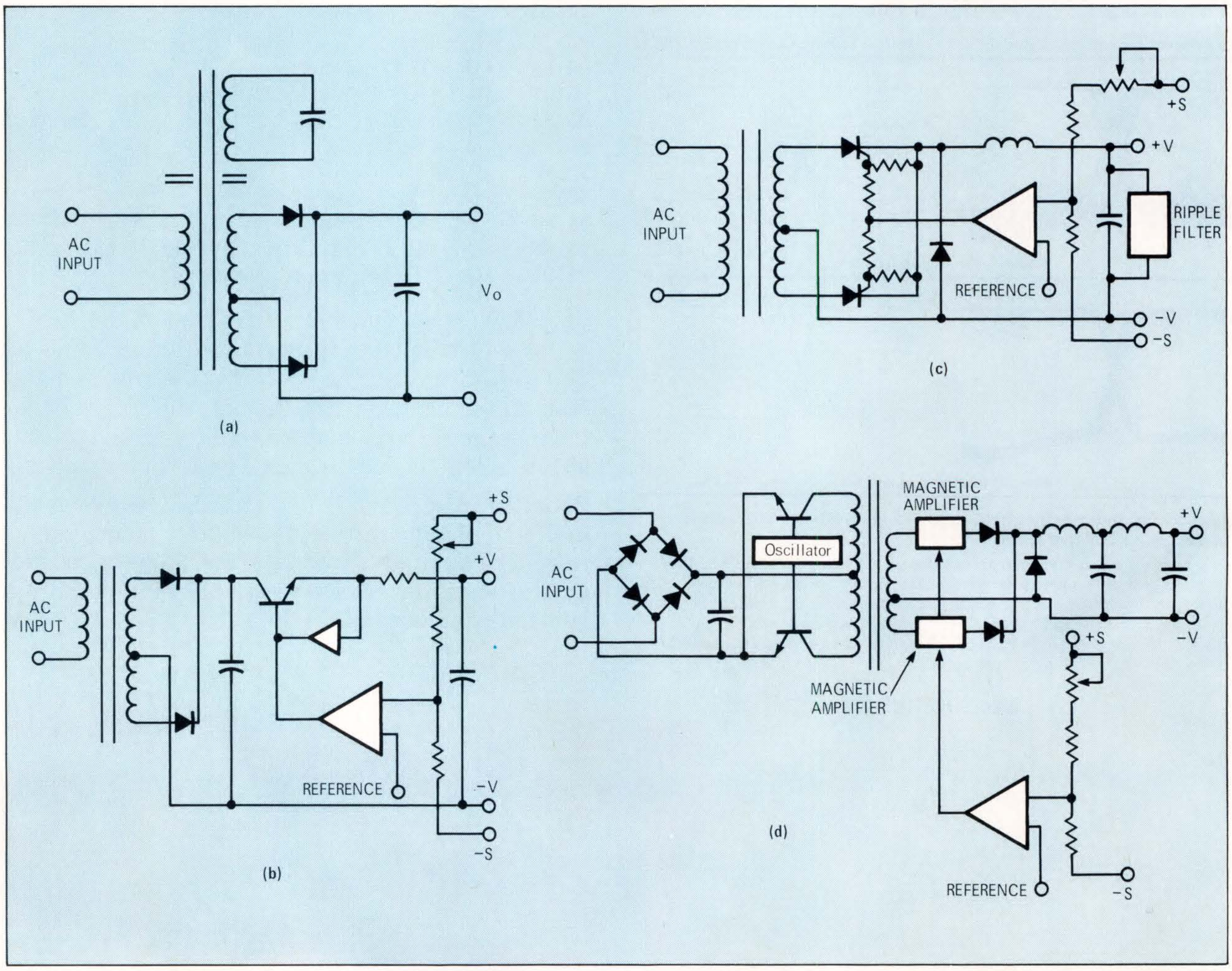

Fig. 1—The four common methods of getting regulated dc voltage from an ac voltage source. The least-expensive is the ferro-resonant supply (**a**) which also provides relatively course regulation and high output ripple. The second method (**b**) uses a linear or series regulator which is more expensive but provides fine regulation. It is also low in efficiency. The third and fourth methods make use of switching regulators, either with SCRs (**c**) or ultrasonic square-wave oscillators (**d**) respectively. The use of SCRs allows for a tradeoff between cost and performance. Supplies with ultrasonic oscillators are small in size but cost the most.

regulation and supply efficiency is mildly important, specifying a supply that uses SCR control elements gives 0.15% line and load regulation and 45% efficiency, yet can save you 35% in cost over ones using dc-to-dc converters. The latter types may provide 0.1% regulation and are slightly more efficient (50%), but they also cost quite a bit more (**Table 1**). Of course they can provide other advantages such as faster transient response and less weight, but these parameters may not be justified in a system given the additional cost.

Power supply methods

There are essentially four methods of providing regulated dc voltage from an ac source (**Fig. 1**). The simplest and least expensive method consists of a ferro-resonant transformer, rectifiers and a dc filter capacitor. As can be seen from **Table 1**, this method provides relatively coarse regulation with high output ripple. There is also no way to adjust the output voltage without changing transformer windings. And the output voltage is very dependent upon the line frequency (2.4% per hertz of line change for a 60-Hz transformer.)

The second method is the linear or series regulator which consists of a linear transformer, rectifiers and filter capacitors followed by a dissipative pass element. This type of supply provides fine regulation but relatively low efficiency. It is also relatively costly.

The third and fourth methods differ from the linear or series regulator in that the regulation is not provided by a linear dissipative element but from some type of duty-cycle control. These two methods employ what is generically known as switching regulators. Here, the regulator is generally a high-efficiency switch followed by some type of integrating network, usually a low-pass LC filter which allows only the average or dc component of the switched waveform to reach the output.

The first of these last two techniques utilizes line-frequency phase control, usually with SCRs as the power control elements. Supplies using this method provide a tradeoff between cost and some performance parameters.

The second switching-regulator method takes the ac line voltage and rectifies it to high-voltage dc which is then used to power an ultrasonic square-wave oscillator. The oscillator output is rectified and regulated, usually with a magnetic amplifier as the controlling device. The high-frequency operation of this dc-to-dc converter allows a great reduction in the size and weight of the magnetics and filter components but is usually the most expensive in cost.

How they compare

In applications where the input frequency range is very narrow, the ferro-resonant supply will be satisfactory. If, however, wide input frequency variations are anticipated, this type of supply is not usable.

Of the three remaining approaches, what are the performance areas which require critical examination? If extremely fine regulation, low ripple and noise, and fast transient response to step load changes are required, the series regulator represents the only solution. When considering regulation requirements, the system user must recognize that even with remote sensing, the power supply can only

TABLE 1. POWER SUPPLY TYPES

	Linear	SCR with dynamic filter	Ultrasonic	Ferro-resonant
Rating ($/W) @ 5V	$1.75	$1.25	$2.00	$0.80
Line regulation	0.01% to 0.1%	0.15%	0.1%	2%
Load regulation	0.01% to 0.1%	0.15%	0.1%	5%
Ripple (pk-pk)	5 mV	100 mV	35 mV	
(rms)	1.5 mV	10 mV	10 mV	1%
Temperature coefficient	0.03%/°C	0.03%/°C	0.03%/°C	0.05%/°C
AC input (V ac)	105-132V	105-132V	105-132V	105-132V
(frequency)	47-440 Hz	57-63 Hz	47-440 Hz or 145V dc ±10%	59-61 Hz
Temperature range	−20 to +71°C	0 to +71°C	0 to +71°C	−20 to +55°C
Protection				
Overload	Yes	Yes	Yes	Yes
Over-voltage	Maybe optional	Maybe optional	Maybe optional	Inherent characteristics
Thermal	Yes	Yes	Yes	Yes
Efficiency (@ 5V output)	25%	45%	50%	75%
Storage time after line failure	5 msec	1 msec	20 msec	1 msec
Weight (lbs/A) @ 5V	0.9	0.8	0.4	0.6
Transient response	100 μsec	100 msec	2 msec	25 msec
W/in³	0.4	0.6	1.0	1.0

Commonly used power supply terms

AMBIENT TEMPERATURE:

The temperature of the air surrounding the power supply, generally taken to be the room temperature. Care must be exercised here in interpreting this term, as some supplies may produce very high-temperature ambients of their own when not properly cooled.

CONSTANT-CURRENT SUPPLY:

A supply that provides a fixed output current regardless of changes in its output voltage, line voltage and ambient temperature.

CONSTANT-VOLTAGE SUPPLY:

A supply that maintains a fixed output voltage regardless of changes in its output current, line voltage and ambient temperature.

CONSTANT-CURRENT/CONSTANT-VOLTAGE SUPPLY:

A supply that behaves as a constant-voltage source for relatively large values of load resistance and as a constant-current source for relatively small values of load resistance. The crossover point between these two modes of operation occurs when the value of the critical load resistance (R_c) equals the value of the supply voltage setting (E_s) divided by the supply current setting.

EFFICIENCY:

The relative percentage of the output power delivered at the supply's output terminals divided by the power delivered to the supply needed to produce this output power. The ideal supply would be 100% efficient.

LOAD REGULATION:

For a constant-current supply, it is the change in the steady-state value of the output dc current due to a change in load resistance from a short-circuit current (zero resistance) to a value which results in the maximum rated output voltage.

For a constant-voltage supply, it is the change in the steady-state value of the output dc voltage due to a change in load resistance from an open-circuit condition (infinite resistance) to a value which results in the maximum rated output current.

LINE REGULATION:

The change in the steady-state value of the output dc current (for a constant-current supply) or the output dc voltage (for a constant-voltage supply) caused by a change in the ac input line voltage from maximum to minimum or minimum to maximum specified levels.

RIPPLE AND NOISE:

The superimposed residual ac component on the output dc voltage of a supply. Ripple and noise are generally specified in terms of rms or pk-pk values. Switching-regulator type power supplies can however have very-large-amplitude spikes in the output that may not show up in any rms or pk-pk noise specifications. A wideband instrument should be used to measure noise to indicate the presence of these large-amplitude and high-frequency spikes.

TEMPERATURE COEFFICIENT (TC):

The maximum change in a supply's output voltage (for a constant-current supply) or output current (for a constant-voltage supply) per degree of change in ambient temperature, given a constant ac input voltage and a constant load value. The TC is sometimes calculated by taking two temperature extremes and plotting their voltages to give a TC slope. This method can be misleading as it does not indicate what happens during the temperature change or between the two extreme temperature points.

TRANSIENT RESPONSE OR RECOVERY:

The time it takes a supply's output voltage to recover to within a few millivolts (usually specified) of the nominal output dc voltage, following a sudden change in load current (usually the supply's maximum rated current).

regulate to one point. If the load is distributed in a large system, the precision load regulation will not be attained for all load points. This can only be accomplished by using multiple point-of-load regulators which are fed from a coarse dc source.

In most logic applications, there are many logic boards, each with its own decoupling networks. Even though the individual gates may be changing states very rapidly, the total load current seen by the power supply is fairly constant. Thus in an application of this type, the full-load transient response of the power supply is a meaningless parameter. Most applications of this type find either the SCR phase-control or the ultrasonic supply adequate.

At present the SCR supply represents a less-expensive source of power than either the linear or the ultrasonic types. The ultrasonic one does have some advantages which are unique. It offers a relatively long storage time, something useful in many computer applications. It is, of course, smaller and lighter than any other method, which is important in any application when space is at a premium. In addition, it can run from battery power, which is useful in many situations.

Author's biography

Joshua A. Hauser is Director of Engineering at Lambda Electronics, Mellville, New York. Joshua began working at Lambda in 1967 where he was Project Engineer until 1970. From 1970 to 1971 he held the position of Manager of Project Engineering. During 1971 to 1972, he was Manager of Micro-Electronics Engineering. Joshua holds a BSEE which he received from Columbia University in 1966 and an MSEE from the same school in 1968.

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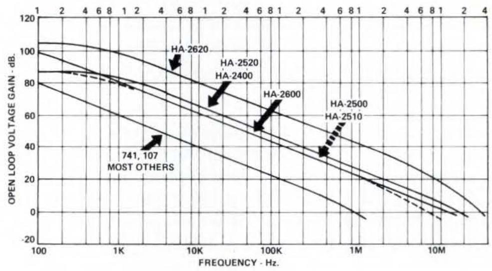

Then take our designs. We employ a single gain stage to provide better behaved frequency response. Our bias networks are a bit more complex for uniform performance over a wide range of supply voltages and temperature ranges, and our output stages have better output current capabilities. In testing we're different too—more thorough. In fact, we were guaranteeing slew rates and rise times long before other manufacturers did. Consider just two examples:

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- Much lower closed loop phase shift, lower gain error, and lower distortion at all frequencies.
- Superior response at higher gains.
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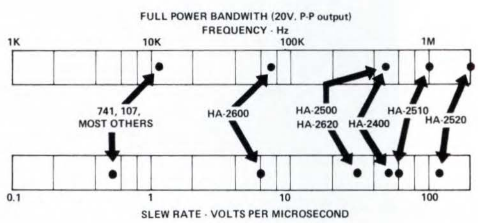

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CIRCLE NO. 20

Switching, plain and not so plain

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

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

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

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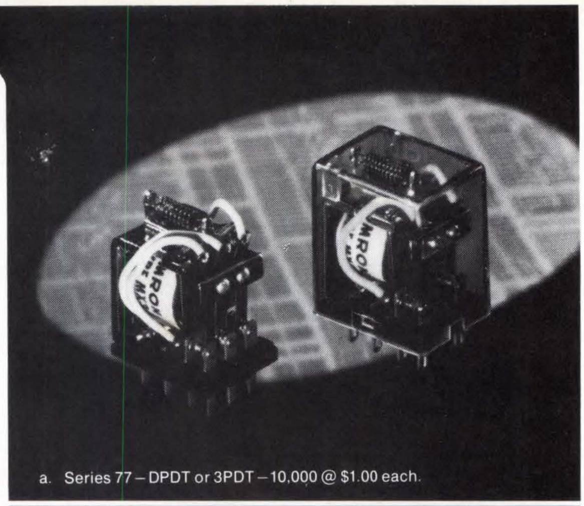

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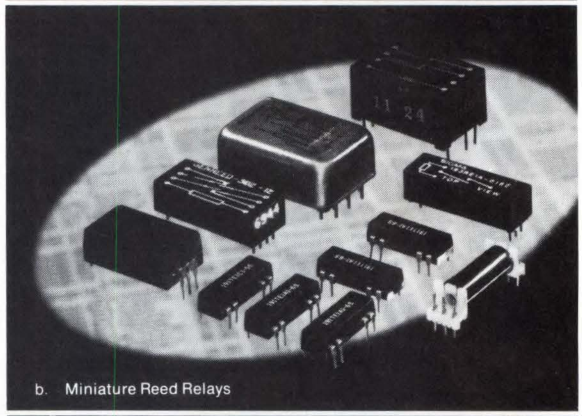
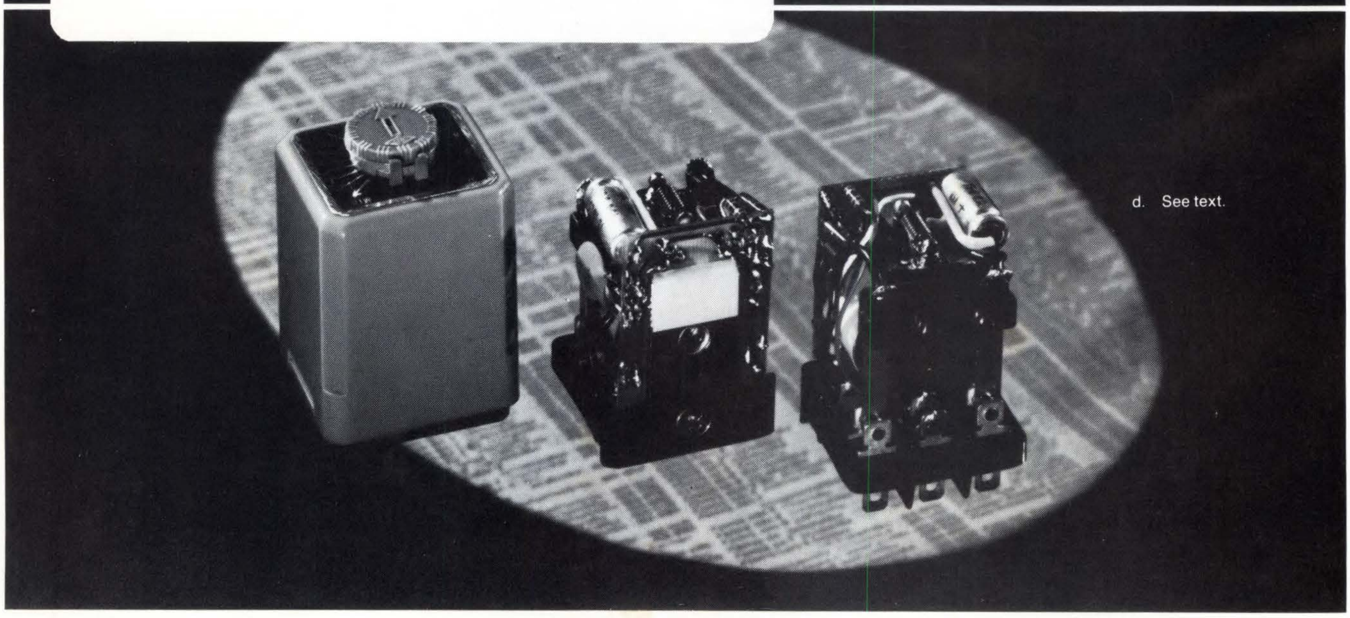


b. Miniature Reed Relays

c. See text.



d. See text.

CIRCLE NO. 21

ECL arithmetic unit performs high-speed binary multiplication

With an ECL 4-bit arithmetic unit you can reduce both package count and interconnections in a ripple multiplier and achieve very fast multiply times

Tom Balph, Motorola, Inc.

Digital communications equipment and fast arithmetic processors often require high speed multiplication of binary numbers. This high speed multiplication has usually been implemented with a ripple processor using various algorithms. Unfortunately, this has meant large numbers of interconnects and parts.

Parallel multiplication, on the other hand, requires large numbers of high speed adders. By utilizing the fast add time (4-bit add in 7 nsec, typical) and the versatility of the control functions of an arithmetic unit, package count can be significantly reduced, since only dual adders were previously available in ECL.

An example of a 4-bit by 4-bit multiplier using a simple "add-shift" algorithm is shown in **Fig. 1**. Each level of logic performs an add function followed by a hardwired shift. The equivalent numerical tabulation for this operation is also shown in **Fig. 1**. The first add operation is performed by a gate package because no carry can result at that level. Each succeeding logic level forms the next partial product until the final product is reached.

The many functions available on the MC10181 simplify implementation of the algorithm in the secondary logic levels. Among other functions, the arithmetic unit has the ability to sum (word A) + (word B), or to sum (word A) + ("ZERO") depending on the state of the control inputs (S0 thru S3). This feature is used to "mask" the multiplicand (word B) and add "ZERO" to the previous partial product or to multiply the multiplicand by the appropriate bit of the multiplier and then add, to form the next partial product.

The diagram of the ripple multiplier is shown in **Fig. 2**. Note that this diagram differs from the block diagram of **Fig 1** in that the one's complement of the multiplicand and multiplier are used to provide the one's complement of the product. This is necessary because of the basic NOR function definition of the MC10181.

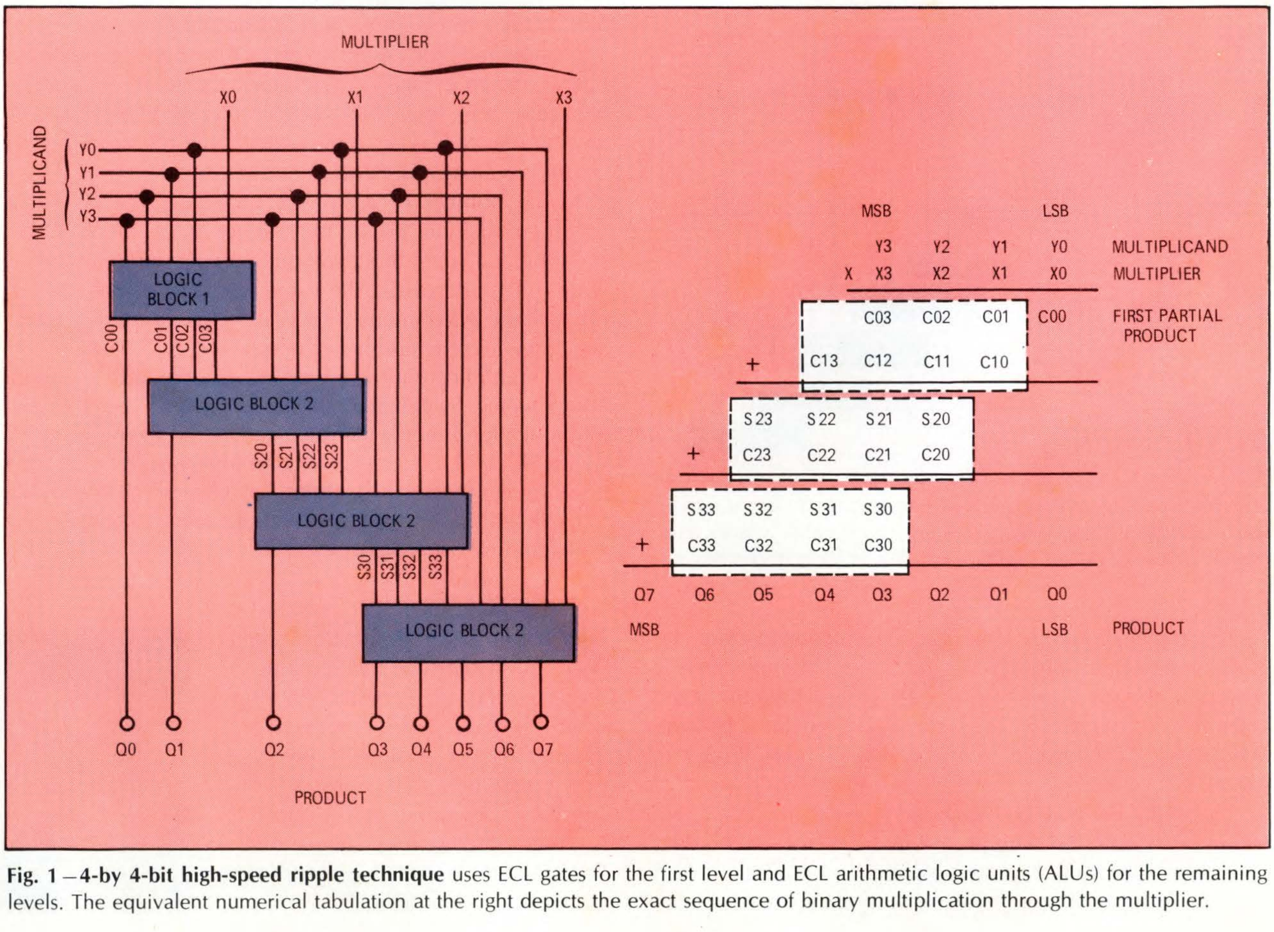


Fig. 1—4-by 4-bit high-speed ripple technique uses ECL gates for the first level and ECL arithmetic logic units (ALUs) for the remaining levels. The equivalent numerical tabulation at the right depicts the exact sequence of binary multiplication through the multiplier.

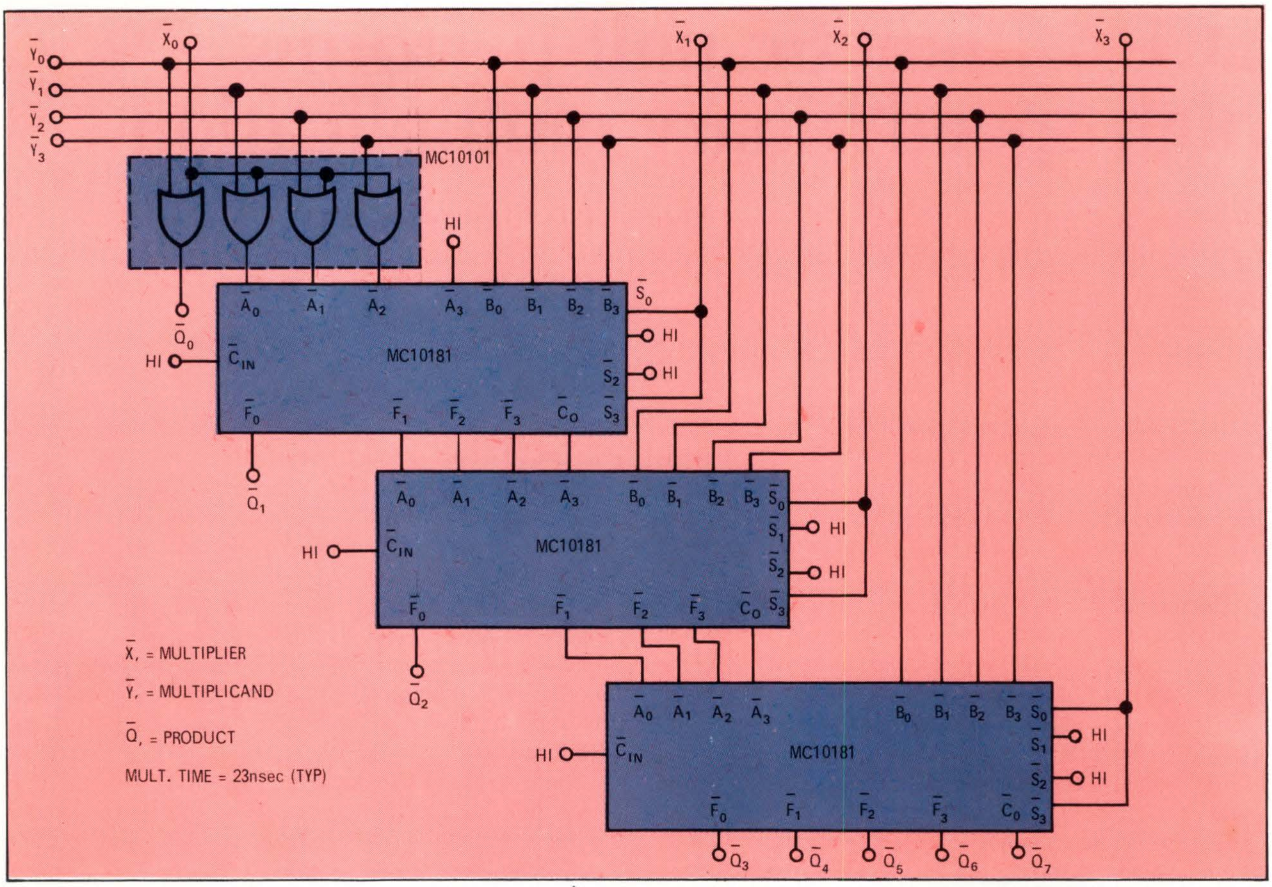


Fig. 2 – One's complement of multiplier and multiplicand must be used, in practice, with the ECL ALU multiplier. The product output is also inverted, thus $\bar{X}$, $\bar{Y}$ and $\overline{Q}$ functions replace the X, Y and Q functions used for illustration in **Fig. 1**.

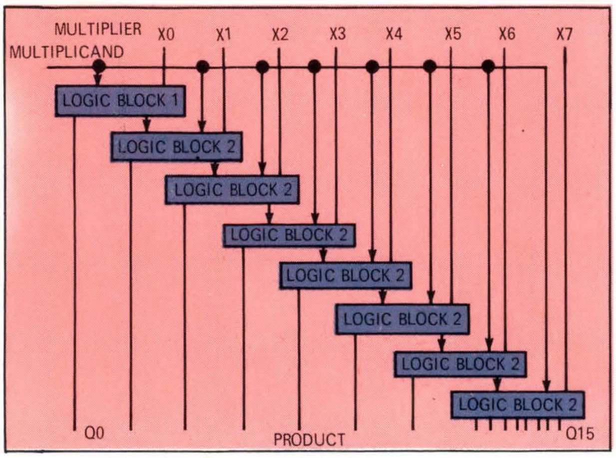


Fig. 3 – Expansion of basic multiplier to 8-by-8-bit unit, or n-by-n-bit is very straightforward, requiring type-one logic blocks, consisting of gate packages, and type-two logic blocks of ECL ALUs.

The typical multiply time can be calculated from the worst delay path through the multiplier. Multiply time is equal to one gate propagation delay, plus three times the "word-A-to-function-out" propagation delay of the MC10181. The delay is typically 2 nsec + (3 × 7 nsec) = 23 nsec.

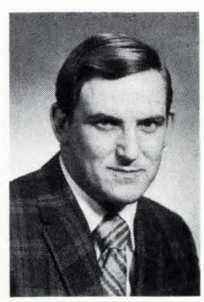
The multiplier may be expanded to accommodate larger numbers of bits. To multiply n-bits by n-bits, each adder must be n-bits wide. Also, there will be n logic levels, with the first logic level implemented with gates, and n-1 secondary logic levels implemented using ALUs.

A simplified block diagram of an 8-by-8-bit ripple multiplier is shown in **Fig. 3**. Logic block 1 consists of two gate packages, and logic block 2 consists of two arithmetic units connected as an 8-bit adder. Multiply time for this circuit is typically 56 nsec.

As the number of word bits increases, the algorithm used here may not be the most effective technique. Other squaring and summing techniques prove more efficient as word length increases. The same ALU can still be used in many of these techniques, and will help to minimize package count and the number of interconnects.

The multiplication technique used in this article can be implemented somewhat similarly using TTL, although multiplication times will be longer. As an example, using standard 54/74 TTL, multiplication time would be about 4 times longer for a 4 × 4 multiplier. Using high speed 74S TTL, multiplication time is still about twice as long as the time required using ECL. □

Author's biography



Tom Balph is an applications engineer at Motorola Semiconductor Products, Inc., in Phoenix, Arizona, where he has been employed for three years. He is directly involved with computer applications of semiconductor devices, and this article is a direct outgrowth of that activity. Tom earned his BSEE degree from the University of Cincinnati.

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TTL pipeline multipliers double multiplication rate

Ripple multipliers and pipelines each have their specific advantages. Pipelines are slower from input to output, but can process twice as many operands.

John Springer, Advanced Micro Devices, Inc.

In the ordinary ripple multiplication method, multipliers are connected in an array, where each row in the array produces a partial product based on the full multiplicand and two bits of the multiplier. An array of AM2505s connected as a ripple multiplier is shown in **Fig. 1**. The internal adders are used to sum all the partial products, so the delay through the array is basically the sum of the delay through n/2 adders, where n is the number of bits in the multiplier. Ripple techniques are best used when delay through the array is important or when the initial product is required before the next multiplication can begin.

Very-high-speed multiplication problems, such as those encountered in fast Fourier transforms, where all data is available and must be processed quickly, often require only a high rate of multiplication, rather than a short delay from application of operands to generation of product. In this type of application, pipelining techniques such as the one shown in **Fig. 2** offer the best approach.

While the 2505 multiplier in a standard ripple array will perform a 16-bit multiplication in 265 nsec, the rate of multiplication can be increased substantially by using the 2505 in conjunction with an Am2506 4-bit arithmetic logic unit. The Am2506 is functionally identical to the 74181 and 9341 four-bit ALUs, but has the additional feature of a four-bit latch built into the outputs. In this system the internal adders in the multipliers are not used. Instead, each row of 2505s generates a partial product independently

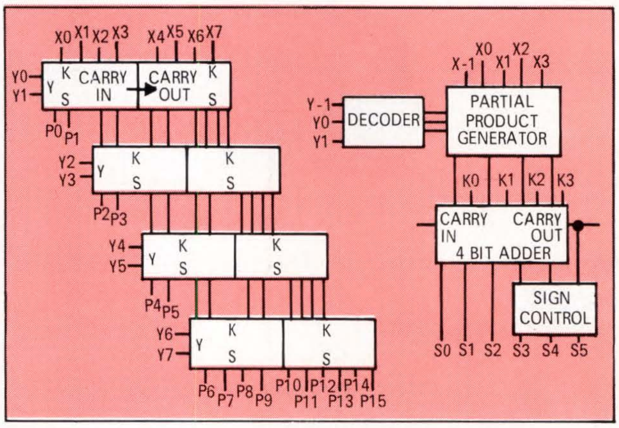

Fig. 1—8- by 8-bit ripple multiplier array, shown here with AM2505 multipliers, can also be implemented with 9344s or standard TTL techniques. Twice as many 9344s would be required, and signed multiplication would not be possible. Typical delay from input to product output with this array is 135 nsec, a significant improvement over standard TTL designs.

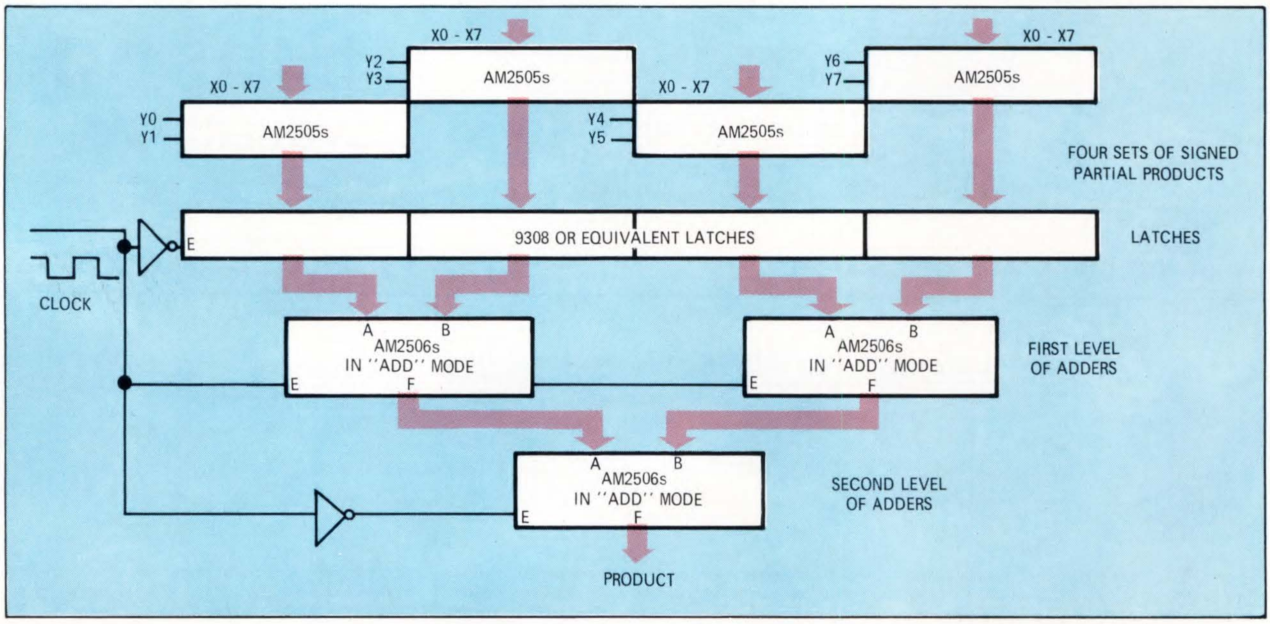

Fig. 2—8- by 8-bit pipeline multiplier can accept new operands each time the latches in Row 2 are set (each 67 nsec), even though total time from input to product output is 200 nsec. The pipeline illustrated here uses a 2506 arithmetic logic unit which is equivalent to a 74181 ALU with a built-in latch. The same circuit can be implemented using 74181 ALUs and 9308 latches.

based on two bits of the multiplier. The partial products are all stored in latches which feed them to the ALUs for addition.

As soon as the latches have stored the partial products, the enable can be closed and a new set of operands can be applied to the multiplier chips. While the new set of partial products are being formend, the first level of adders adds together pairs of partial products from the latches. When the new partial products are ready, they drop into the latches, and the output latches in the ALUs are closed, holding the sums from the first addition and feeding the next level of adders.

The process is repeated until a final sum is produced. The latches at each level (9308 latches following the multipliers and internal latches following the adders) are enabled on alternate states of a single "clock" line, so that data drops synchronously through the system.

The system illustrated in **Fig. 2** provides 8-bit multiplication, but the extension to 16-bit multiplication is simple, requiring eight rows of four multipliers (2505s) each, instead of four rows of two each, because one more level of addition will be required. For 16-by-16 multiplication, this method can accept new operands every 95 nsec compared to the 265 nsec required for the same function by the ripple technique in **Fig. 1**. □

Author's Biography

John Springer is an applications engineer for MOS and memory products at Advanced Micro Devices, Sunnyvale, Calif. He was previously a member of Fairchild Semiconductor's applications department. John received his BSCh from College of Idaho and MSCh from Oregon State University.

IC multiplexer puts zip into digital switching matrix

Incoming signals can be controlled by arranging toggle switches in a 2-D array. But if speed is needed, then the IC multiplexer is the best choice.

Thomas R. Zwaska, Drexel University.

In some designs a number of input signals must be switched to any one of several destinations. One obvious solution is a 2-D array of toggle switches located at each X-Y crosspoint. Although this scheme is feasible, it is impractical for high-speed operations. In such designs, digital multiplexing ICs do the job best and almost any size matrix is possible.

Although matrices designed in this manner will only handle digital signals, applications that process analog signals need not be excluded. By connecting the appropriate A/D or D/A converters to the input and output devices, this scheme will lend itself to both types of signals.

Building an array

The digital multiplexer is a device in which any one of a number of input signals appears on the output when the appropriate code is applied. A functional diagram of a 4-input multiplexer is shown in **Fig. 1**.

Using these multiplexers, it is possible to design an array in which data fed into any of the X-input terminals is switched to any of the Y-output terminals (see **Fig. 2**). The inputs of each multiplexer are connected to a series of bus bars that form one axis of the matrix. The output terminals of the multiplexers then form the other axis. Application of the proper encoding closes a particular crosspoint within the array and permits data to pass through the matrix.

The array can be expanded in the Y-direction by connecting the inputs of additional multiplexers to the X-input bus bars. However, expanding the array in the X-direction cannot be as easily handled. Multiplexers having up to 16 inputs are readily available and are suitable for large arrays up to 16-by-16. However, expansion beyond this point must be handled in the manner shown in **Fig. 3**. In this scheme, the output of each multiplexer is gated through a NOR gate that forms the Y-output of the matrix. Thus, an array of almost any size may be constructed. As the matrix size increases, the complexity of X-Y select code increases, and the loading factors of the ICs become more critical.

Using the array

Many applications, such as automatic testing of ICs, require that a response to an input signal be accessible for

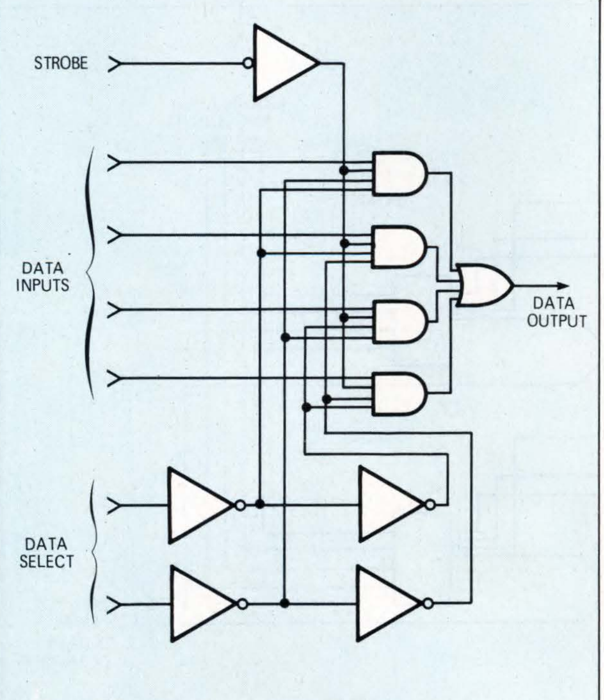

Fig. 1—Composition of a 4-input digital multiplexer includes decoding as well as logic.

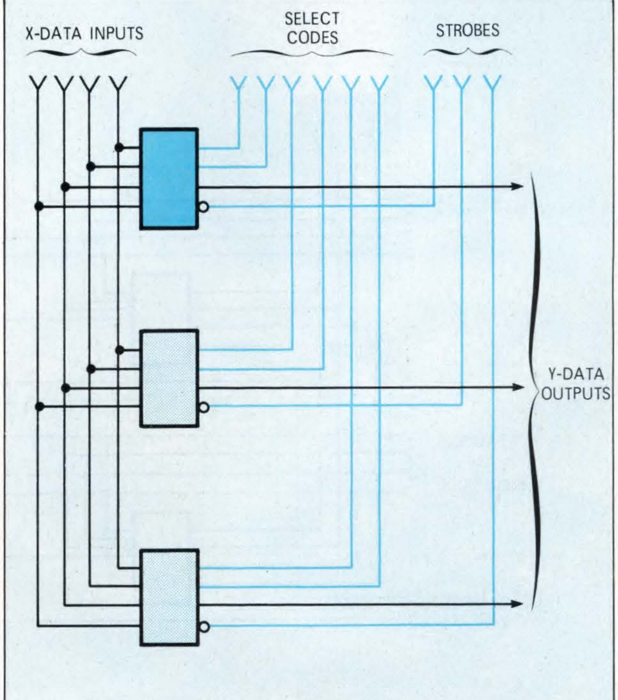

Fig. 2—Additional multiplexers tied to the X-input bus expands the array in the Y-direction.

evaluation by a controlling processor or device. This bidirectional exchange of data requires only two arrays—one for each direction. A dual 4-line to 1-line multiplexer (**Fig. 4**) simplifies the circuit somewhat. Although both arrays are addressed simultaneously, data in either direction need not be concurrent because each array is strobed individually. Expansion of this bidirectional scheme may be handled in the previously discussed manner.

In all of these circuits, the select code must be applied during the exchange of data. This might be handled by clocking the select code instruction into a binary latch connected to the multiplexer. Thereafter, the multiplexer is strobed enabling the exchange of data to occur.

It should be noted, that more than one data path may exist at any one time within the matrix. In other words, an input signal connected to any X-input terminal may be connected to any number of Y-outputs, and simultaneously another input signal applied to a different X-input will be connected to any of the other Y-outputs. Therefore, it is necessary that the select code instructions be issued prior to strobing the multiplexers.

If all of the strobe terminals on the individual multiplexers are connected to a common bus, then all data paths are made or broken concurrently. However, it may be necessary to individually latch the strobe terminals. When this is done, a data path may be made or broken without disturbing any other data path that might exist.

This switching technique offers the designer all of the advantages of digital integrated circuits including speed, reliability, noise immunity, low power consumption and a rugged mechanical package suitable for automatic assembly on printed circuit boards. The matrix, limited only in size by the application, switches either digital signals or analog signals (with proper signal conversion). This approach should be very useful in many designs. □

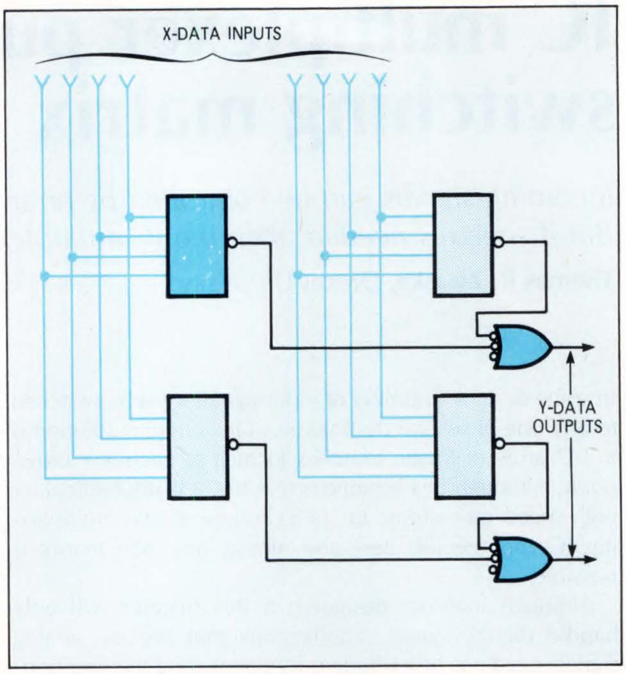

Fig. 3—Expanding the matrix in the X-direction requires a NOR gate to combine the outputs of the additional multiplexers.

Author's biography

Thomas R. Zwaska is a senior at Drexel University, Philadelphia, PA. Mr. Zwaska is pursuing a Bachelor of Science Degree in Electrical Engineering.

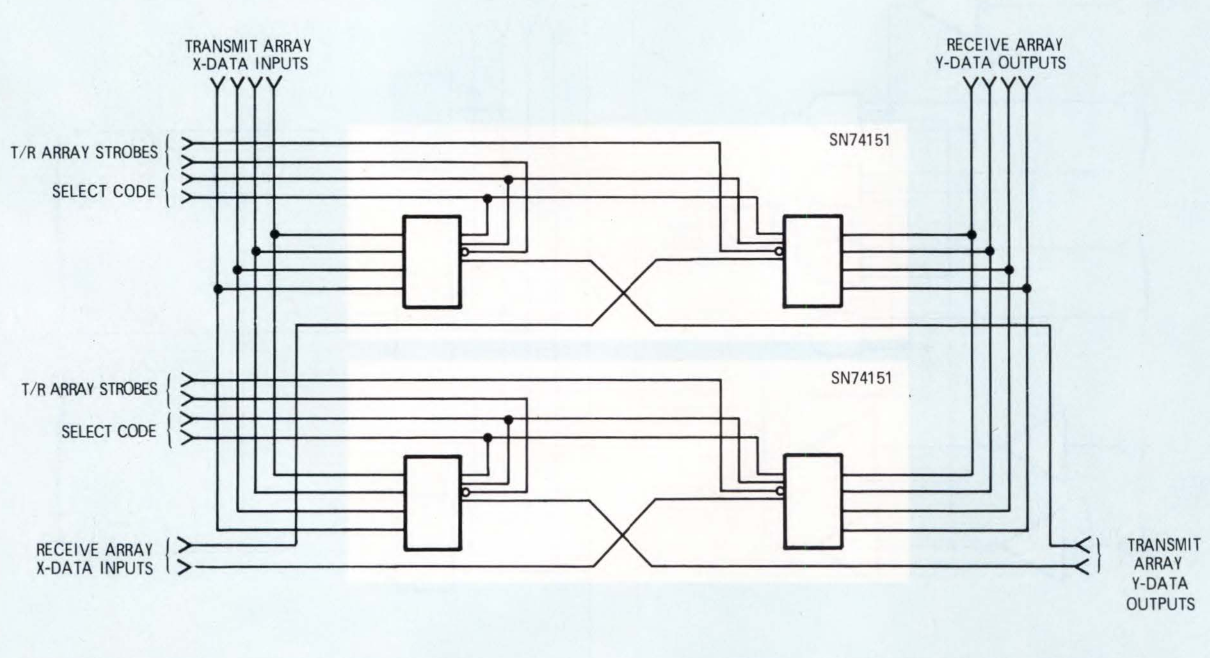

Fig. 4—A matrix for bidirectional exchange of data uses a dual 4- line to 1-line multiplexer. (Texas Instruments SN74-153).

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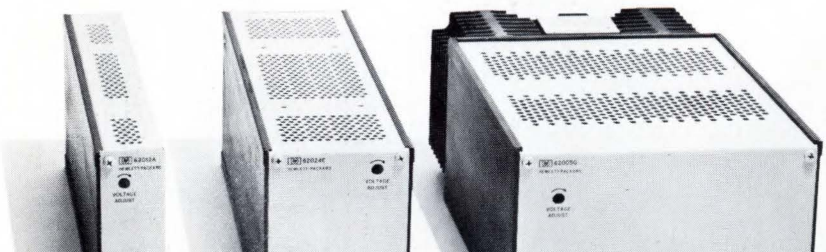

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CIRCLE NO. 28

CIRCUIT DESIGN AWARDS

Gating circuit detects positive or negative peaks

Clark S. Penrod and **W. T. Adams**
Applied Research Labs., Austin, Texas

The following circuit provides a method of detecting and sampling the positive or negative peaks of a voltage waveform. The circuit is amplitude restricted only in that the input voltage should not exceed the maximum for the comparator or analog switch. Frequency sensitivity is determined by the Q of the phase lag network. Duration of the sample time is controlled by the monostable. The output of the circuit is a pulse of the same amplitude as the input but only as wide as the monostable "ON " time.

The circuit works as follows. An input voltage is compared to a delayed version of itself. Whenever the voltage is increasing, it will be larger than the delayed version. When the signal begins to decrease, the delayed version will become larger, since it follows, in a time sense, the input. When this happens, the output of the comparator changes state and triggers a monostable. The monostable output drives an analog switch which samples the input for the duration of the monostable. The circuit shown will sample the positive peaks. Negative peaks may be sampled by driving a monostable with the output at point B.

When the attenuator is unnecessary, a more accurate representation of the peak voltage may be obtained by sampling at point A instead of the input. If this is done, care should be taken not to load the output of the phase lag network.

This circuit has been constructed at our facility with the simple RC phase lag network and FET switch shown in **Fig.1**, and was used to detect peaks in the waveform of a sonar video signal.

To Vote For This Circuit
Circle 150

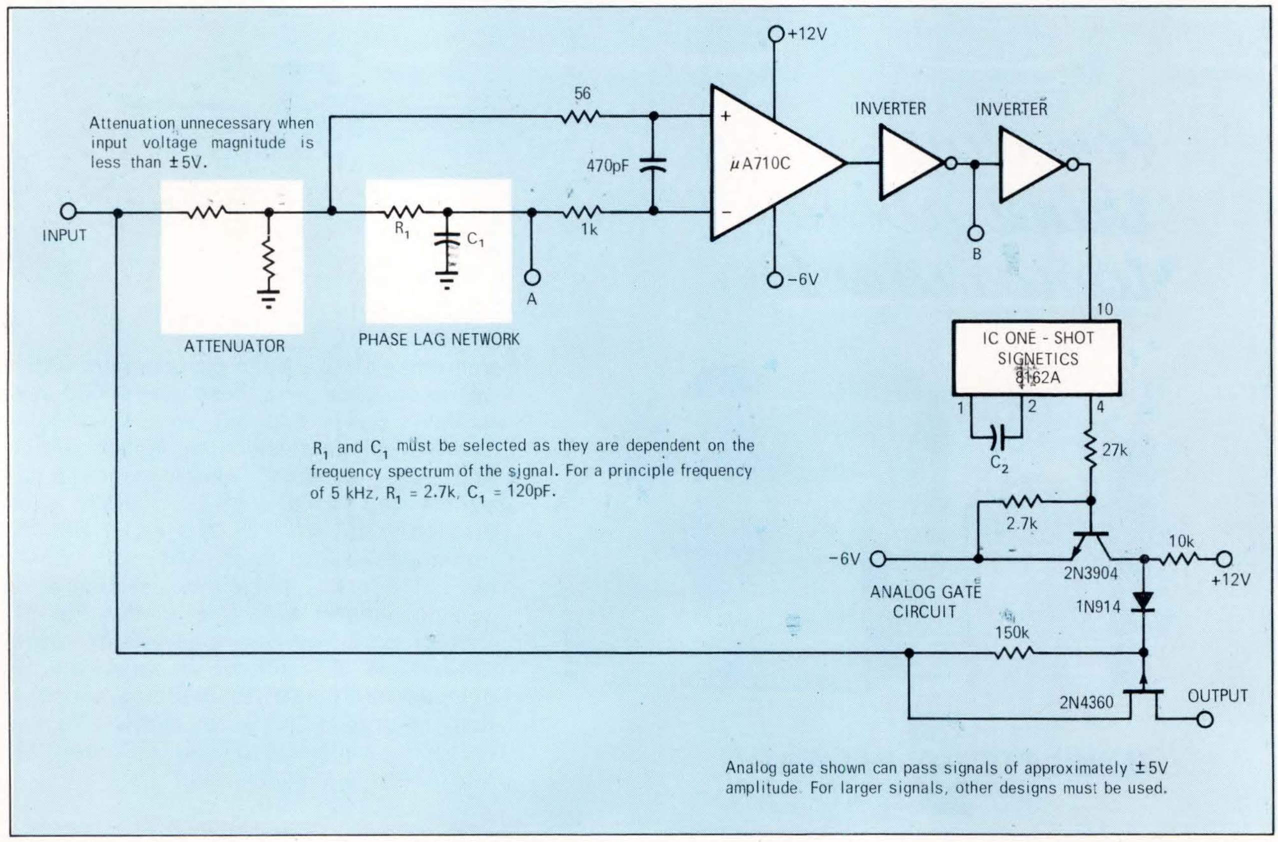


Fig.1 – Waveform peaks are detected with this circuit by comparison of the waveform with a delayed version of itself. Detection of a positive peak is triggered when the original input falls below the voltage level of the delayed input.

Extra IC insures oscillator start-up

Steve Rummel
San Jose, CA

Want a cheap oscillator that always starts? Here is one that only uses one quad 2-input nand gate, two capacitors and two resistors.

Gates Number 1 and 2 compose a standard multivibrator design. The timing resistors R_1 and R_2 are chosen so that: R = Vin (zero)/Iin (zero). This ensures that the gate inputs can go to a "ZERO" level.

The values of C_1 and C_2 are chosen so that:

$$\tau = \frac{\text{Period}}{2} = R_1C_1 = R_2C_2$$

This is the standard design for a multivibrator. However, this does not guarantee that it will start, especially when power is applied slowly. This is where gates 3 and 4 come in.

If the multivibrator does not start oscillating, gate number 1 and 2 outputs will go "HIGH" because the inputs will go "LOW" through R_1 and R_2. In this case both of gate 3's inputs will be "HIGH", resulting in a "LOW" output from gate 3. This is inverted to a "HIGH" by gate 4. Gate 2's input will then be toggled from a "LOW" to a "HIGH" state. At this point the pulse is coupled to gate 1 through C_1 and gate 3 output is returned to a "HIGH" state, inverted by gate 4 which goes "LOW", and returns control back to gates 1 and 2. As long as gates 1 and 2 are operating as a multivibrator, gate 3 will be inhibited.

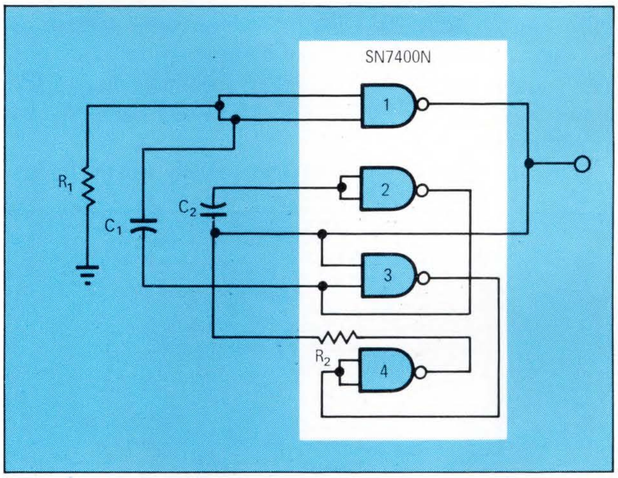


Fig.1—Standard NAND-Gate oscillator composed of gates 1 and 2, cannot fail to start. Gates 3 and 4 will supply a starting pulse if the oscillator does not start, but are inhibited during normal operation.

To Vote For This Circuit
Circle 151

DPM makes self-contained digital thermometer

Maxwell Strange, NASA,
Greenbelt, MD

Either of these circuits can be built into, and powered by, an inexpensive digital panel meter to produce a compact, accurate electronic thermometer.

The circuit in **Fig. 1** uses a Yellow Springs Instrument Co. linear thermistor network whose resistance is a linear function of temperature. The op amp biases this sensor at a constant current, so that the output voltage is proportional to temperature. Any 3-1/2-digit DPM having a 100 mV range will indicate temperature directly in degrees F with 0.1-degree resolution.

The Yellow springs 44203 sensor network is precalibrated to be interchangeable and linear to within 0.27°F over the entire range from −22°F to +122°F. The network actually uses 2 thermistors to achieve this linearity and a simple equation supplied on the spec sheet sent with each sensor shows the networks resistance value for any temperature within its range. This equation is based on temperature in degrees Centigrade, and that information has been converted to degrees Fahrenheit here. Thus, the circuit can be set up simply by replacing the sensor with a resistance decade box set for two known temperatures. There will be no interaction between these adjustments if the offset is set first with the "0° set" potentiometer R_4 and the decade box set for 0°F (R_t = 14435Ω). Next the gain should be set for 100°F with the 100° set potentiometer R_6 and the decade box set for 100°F (R_t = 7374Ω). Typical meter overrange capability provides readings well beyond the 0 to 100°F range.

This circuit was built with a Weston 1290DPM that had ±6.2V references available internally which could easily support the extra load of about 2 mA. Other voltages can be

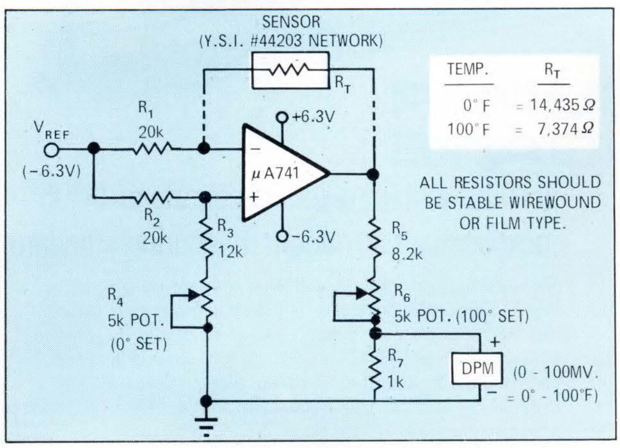


Fig. 1—Accurate temperature-to-voltage converter can be built into a panel DPM. The sensor is a linear thermistor connected in the resistance mode for easy calibration.

used (with appropriate resistance changes) as long as V_{ref} is stable. Sensor current should be less than 0.5 mA to minimize the self-heating error.

An "economy" circuit which uses the linear temperature coefficient of a forward-biased silicon diode for sensing is shown in **Fig. 2**. The diode is biased at about 0.3 mA. The current through R_2, R_3 and R_4 produces a voltage drop across R_3 which cancels the diode drop at 0°F to zero the DPM. The Weston 1290's internal adjustment is used to set the gain; a voltage divider may be required for other meters. This circuit is best calibrated by alternately dipping the sensor in crushed ice (32°F) and warm water monitored by a mercury thermometer.

In use, the two circuits behave identically, but the thermistor has somewhat better long-term stability and is easier to calibrate. These thermometers can replace thermocouples in most test setups, and provide better accuracy and readability. The diode circuit used with an inexpensive 2-digit DPM makes an ideal desk-top indoor/outdoor thermometer.

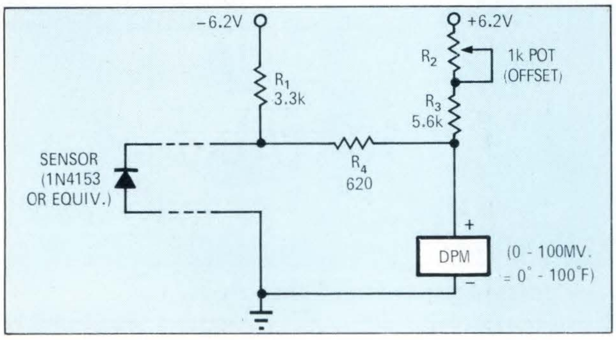


Fig. 2—Economy version of the thermometer circuit uses silicon diode as a temperature sensor. Internal DPM gain adjustment is used for overall gain calibration

To Vote For This Circuit
Circle 152

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

Vote now, by circling the appropriate number on the reader inquiry card.

Submit your own circuit, too. Mail entries to Circuit Design Program Editor EDN, 221 Columbus Ave., Boston, MA 02116.

Readers have voted:

Stephen A. Jensen winner of the February 1 Savings Bond Award. His winning circuit was called, "High-voltage source follower." Mr. Jensen is with Radiant Industries, Inc. North Hollywood, Cal.

Tiny, high-performance log/antilog amplifier has a low $55 price

PROGRESS IN PACKAGED CIRCUITS

Purchasing a high-accuracy log/antilog amplifier that has good log conformity together with low-drift and bias-current has not been difficult providing the user was willing to pay the price—typically in the $100 range. Analog Devices, Inc., of Norwood, Mass., has now introduced a low-drift and low-bias-current log/antilog amplifier for only $55 (1 to 9 units).

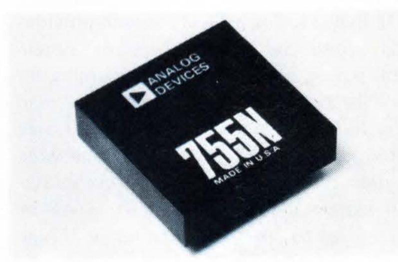
Its Model 755 with a built-in FET op amp features an offset voltage drift of ±10 μV/C and maximum input bias current of just 10 pA. Dynamic range of the 755 is ±2% with a four-decade 1-mV-to-10V input voltage range and a six-decade 1-nA-to-1-mA input current range. The input offset voltage is trimmed to ±20 μV.

Available in two versions—755P for negative inputs and 755N for positive inputs—the amplifier provides a choice of three scale factors (2V, 1V and 2/3V per decade) and log or antilog operation through appropriate pin connections.

An added bonus is the amplifier's small size of just 1-1/2 by 1-1/2 by 0.4 in., which is about one-half the size of competitive units.

Accuracy of log conformity (referred to the input) is broken down as follows: ±1% for the 1-nA to 10-nA and 100-μA to 1-mA ranges and ±0.05% for the 10-nA to 100-μA range. For input voltages, it is ±0.5% for the 1-mV to 1V range and ±1% for the 1V to 10V range.

The 755 is rated to operate over the temperature range of 0 to +70°C and has a rated output of ±10V at 10 mA. It requires ±15V dc ±1% at 10 mA for operation.



Low price and small size are two key features of the 755N log/antilog amplifier.

Applications include data compression, transducer linearization, exponentiation and root extraction.

Analog Devices, Inc., Rte 1 Industrial Park, Norwood, MA 02062. Phone (617) 329-4700. **256**

Portable 4-1/2-digit multimeter with 14 ranges introduced at $650

PROGRESS IN INSTRUMENTATION

Dana Laboratories has introduced a 4-1/2-digit multimeter that features an impressive price of $650. The rugged (made of Lexan) instrument can operate either from the ac line or from a rechargeable Ni-Cd battery ($100 option) and weighs just 7-1/2 lbs with the battery (5-1/2 lbs without).

The 100%-overranging multimeter, Model 4300, has 5 dc voltage ranges from 0.1 to 1000V full scale, 4 ac voltage ranges from 1 to 1000V rms full scale, and 5 resistance ranges from 1 kΩ to 10 MΩ full scale. Accuracy is ±0.03% of reading ±0.01% of full scale for dc voltages. Ac voltage accuracy is ±0.2% of reading ±0.03% of full scale (50 Hz to 10 kHz) and ±0.5% of reading ±0.08% of full scale (10 to 20 kHz).

Dana's newest 4-1/2-digit multimeter costs $650. The 100%-overranging instrument includes 5 dc voltage, 4 ac voltage and 4 resistance measurement ranges.

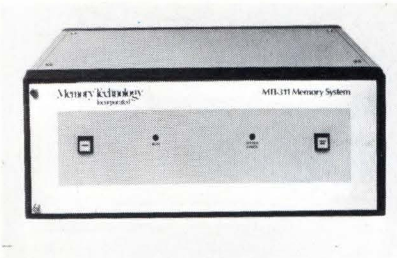
The 4300 is not designed for systems applications. It does not have autoranging or BCD output. Rather it is intended for use as a bench instrument or for field servicing applications. Even without these systems features, its $650 price is impressive.

The 4300's LED display includes an adjustable automatic intensity control.

Battery operation is available for up to 8 continuous hours. The batteries can be fully recharged in 16 hours while the meter operates from the ac line. A switch position is available to provide a readout of the battery voltage. Coupled with an available chart, the readout can be used to compute the approximate unused battery time remaining. Should the battery voltage drop to a predetermined level, the meter shuts off automatically.

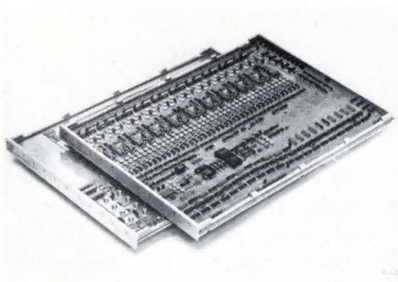
Protection is abundant on this new multimeter. Overvoltage protection is 1000V for any ac or dc voltage range and 250V for the resistance ranges. In addition, the operator needn't be afraid of selecting an improper combination of ranges and functions since the 4300 uses rotary cam switches that protect against this.

Dana Laboratories, Inc., 2401 Campus Dr., Irvine, CA 92664. Phone (714) 833-1234. **257**



SEMICONDUCTOR ADD-ON MEMORY FOR PDP-11. The MTI-311 system provides high speed and low cost. (An 8K system with power supply and rack mounting for $4990.) System speed is 450 nsec for read access, 600 nsec for read cycle, 800 nsec for write cycle and 400 nsec for the write portion of a read/modify/write cycle. System storage is available from 4K words by 16 bits, up to 28K words in a single 7" high enclosure. Memory Technology Inc., 83 Boston Post Rd., Sudbury, MA 01776. Phone: (617) 443-9911. **170**

DATA TERMINAL HAS CALCULATING CAPABILITY. Model 2113 is designed primarily for data entry applications that require addition or subtraction capability in a manual or a batch mode. It sells for $4960 with a 1024-word read only memory. Field upgrade kits will also convert presently installed systems. Viatron Computer Systems Corp., Route 62, Bedford, MA 01730. Phone: (617) 275-6100. **171**



CORE MEMORY FEATURES 500 NSEC ACCESS TIME. Model 688 is a 20-bit word by 32K (or 65K by 10-bits) memory on a single 15 × 21.5-in. board. It may be field-expanded to 65K, 128K, 256K, or 512K with up to eight modules operating from a single timing and control assembly. Full cycle time is 1.2 msec and architecture is 3D, 3-wire. Fabri-Tek, Inc., Memory Products Div., 5901 South County Road 18, Minneapolis, MN 55436. **172**

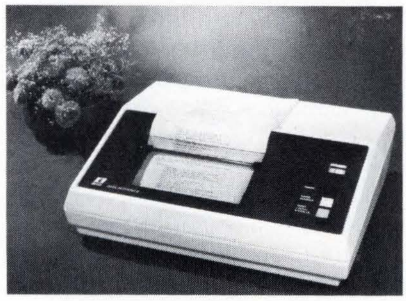
COMMUNICATIONS CONTROLLER INCLUDES PROGRAMMABLE PROCESSOR. The IBM 3705 coordinates data transmission on as many as 352 telephone lines. The 3705 stores, decodes and assembles data from terminals into complete messages before releasing them to the computer. Memory capacity ranges from 16K to 240K characters in increments of 32K characters. Almost all the terminal devices offered by IBM can be linked to the 3705. Rental charges are about $1200 to $9500/month. IBM 1133 Westchester Ave., White Plains, NY 10604. Phone: (914) 696-1900. **174**

OFF-LINE PRINT STATION FOR IBM USERS works with IBM system/360, system/3 and 1130 computers utilizing the 2314 or 5440 disc memory equipment. Model 50 and Model 53 include either a 2314 or 5440 type disc drive, a mini-computer with 8K core memory, and a 600 LPM-132 column impact printer. Model 50 cost is $59,750 and Model 53 is $49,750. Diva Associates, 58 Maple Ave., Redbank, NJ 07701. Phone: (201) 842-6500. **173**

MULTIPLEXED MODEM PROVIDES FIVE OUTPUTS. Model UDS-202-M5 Modem provides up to five fully isolated and buffered RS-232C digital outputs and is competitively priced with single output models. It replaces up to five modems and line terminations in polled 1200/1800 BPS terminal installations. Telephone line matching and RS-232C terminal interface outputs ensure total system compatibility. Universal Data Systems, 4306 Governors Dr., S.W., Huntsville, AL 35805. **175**

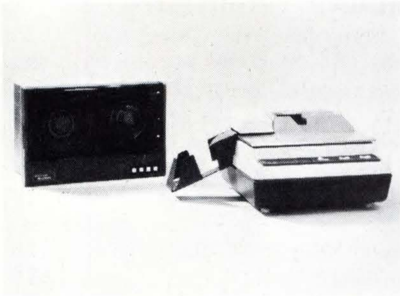
LOW COST DISC MEMORY STORES 21 MILLION BITS. Series 10 head-per-track magnetic disc memories stores from four million bits to over 20 million bits. All models feature a patented head lifting mechanism, and include self-clocking electronics, ultra short self-generated sector preamble for highest storage efficiency, and built-in power supplies. For complete information, contact Alpha Data, Inc., 8759 Remmet Ave., Canoga Park, CA 91304. Phone: (213) 882-6500. **176**

MEMORY SYSTEM FEATURES 20-BIT WORDS. The new Super ExpandaCore system can be expanded from a minimum of 8192 words in pluggable 8K modules up to a maximum of 72K words. One control card controls up to 9 8K storage cards The memory stacks are of planar design using lithium cores with a cycle time of 850 nsec. A basic 8K Super ExpandaCore is priced at $1600. Cambridge Memories, Inc., 285 Newtonville Ave., Newton, MA 02160. Phone: (617) 969-0050. **177**



MAGNETIC IMPACTLESS PRINTER USES PLAIN PAPER. The DI-240 prints dry on ordinary paper at speeds up to 240 characters/sec. The 96 ASCII characters are formed by a 10 × 12 matrix from a LSI character generator. Upper and lower case fonts can be changed to Russian, Hebrew or Greek by replacemnt of one component. It accepts serial or parallel data entry in ASCII or Baudot code and operates asynchronously at input rates up to 50,000 bits/sec. Data Interface Assoc. Box 33, Brookfield Center, CT. 06805. Phone: (203) 792-0290. **178**

CARD READER ELIMINATES ERRORS. Model 600 is an 80-column card reader that provides virtually error-free read rates up to 600 cards/min at a very low cost. A proprietary assembly uses only one moving part for picking, transporting and stacking cards with a minimum of adjustments. Damaged cards can also be handled. A reflective fiber optics read head insures error-free reading at demand speeds of 400 and 600 cards/min. Price is $1495. True Data Corp., 550 Newport Center Dr., Suite 905, Newport Beach, CA 92660. **179**

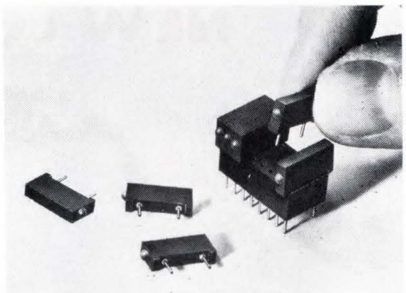


TAPE SYSTEM ELIMINATES KEYPUNCH. The Mark-Tape data collection system includes a Mark document reader, a digital tape recorder, and interconnecting cabling. It reads pencilmarked, keypunched and preprinted data entered on standard or elongated tab cards, or on page-size documents. Marked data is optically read, translated and written on a standard 8 1/2-in reel computer grade 1/2-in tape on either 7 or 9 tracks. Prices range from $9300 to $11,000. Bell & Howell, Electronics and Instruments Group, 360 Sierra Madre Villa, Pasadena, CA 91109. Phone: (213) 796-9381. **180**

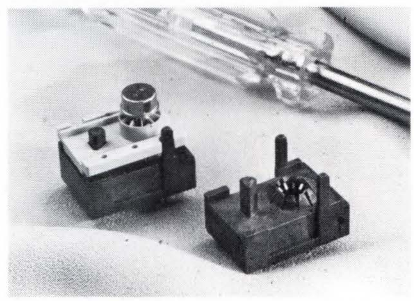
CARD READER MATES WITH DEC MINICOMPUTERS. The MR-300, an optical mark, medium speed card reader, is plug-to-plug compatible with DEC models PDP-8 and PDP-11. The MR-300 can read keypunched cards, pencil-marked cards or a combination of both at rates of up to 300 cards/min. A unique vacuum picking technique allows the MR-300 to pick and process damaged, bent or worn cards. United Business Communications, Inc., 6405 Metcalf, Shawnee Mission, KS 66202. Phone: (913) 362-5300. **181**

"HOLOGRAPHIC ROM STORES 12-MEGABITS IN ONE CASSETTE. Holoscan memory system consists of a holographic memory film cassette, a transport, a CW light source, read-out electronics and logic. Blocks of information are accessed in an average speed of 3 sec. Transfer rate is serial at 100,000 bytes/sec. Error rate is better than 1 part in 10^7 with parity. The film does not deteriorate with age and is non-volatile. Price is $1495. Optical Data Systems, Inc., 556 Ellis St., Mt. View, CA 94040. Phone: (415) 965-0455. **182**

COMPONENTS/MATERIALS



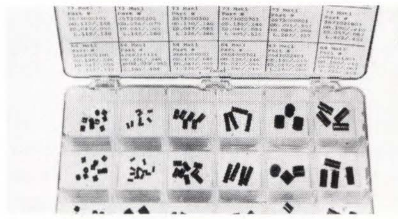
LED INDICATOR depicts logic state. This device can be used as a circuit fault finder, a signal light, and a binary data display for individual or multiple functions. This molded plastic two-pin device inserts into a DIP socket. Its design permits dense packaging, and can be mounted side by side with as many as 10 units to the inch. Devices can be driven from DTL and TTL logic and are available in voltages from 1.7 to 14V, and currents up to 20 mA. Price in quantities of 1000 is $1.37 each. DiaLight Corp. 60 Stewart Ave. Brooklyn, N.Y. 11237 **186**



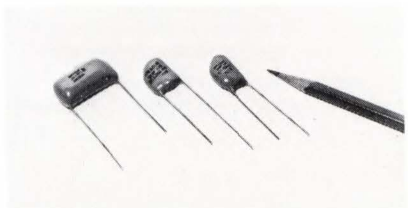
TEST CONTACTOR is designed to reduce contact damage for TO-5 style devices premounted in Barnes 132-01 Series protective carriers. The new units have contacts located behind the barrier, reducing the chance of damage. Carriers protect IC devices during testing and shipping while the contactors accept the carrier-mounted device for quick in-out testing. Barnes Div. of Bunker Ramo Corp., 24 N. Lansdowne Ave., Lansdowne, PA 19050. Phone (215) 622-1525. **187**

SUBMINIATURE RELAYS, the Series BW-21, feature stable contact resistance and a life of more than 5 billion operations. They are offered in single-side stable and bi-stable configurations, and are rated at 1 A. Operating times are 0.8 to 1.5 msec. Release time is approx. 1 to 2 msec. Operating power is 15 mW (bi-stable) and 30 mW (single-side stable). Babcock Control Products, 3501 N. Harbor Blvd., Costa Mesa, CA 92626. Phone (714) 540-1234. **188**

ALUMINUM ELECTROLYTIC CAPACITORS provide reduced series resistance. A new 100,000 μF, 5V dc capacitor in this series will handle 93A of ripple current at 65°C and 1 kHz. The extremely low ESR and impedance of Type 432D Compulytic Capacitors insures continued operation of logic circuits during momentary power outages. Sprague Electric Co., Marshall St., North Adams, MA 01247. Phone: (413) 664-4411 **189**

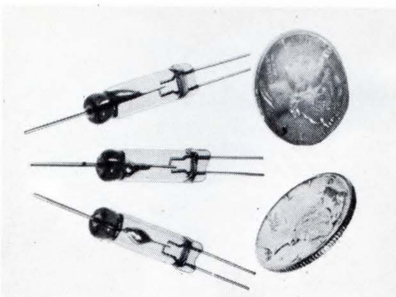


FERRITE BEAD KIT, containing 16 different shapes and lengths, provides the circuit designer with a simple yet effective component for getting rid of spurious transients without contributing to power loss at low frequencies. The ferrite shield beads can be used anywhere in a circuit simply by sliding them on the lead of a component or conductor carrying unwanted signals. Fair-Rite Products Corp., Wallkill, NY 12589. Phone (914) 895-2055. **190**



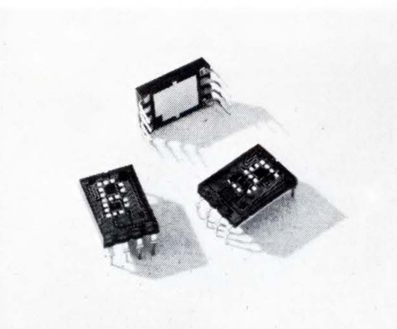
RC COMBINATIONS for contact arc suppression contain a metallized polyester-film capacitor section in series with a low-value, 1/2-watt composition resistor in a single package. Rated at 200 or 400V dc, Type 288P Arc Suppression Networks have both a resistance and capacitance tolerance of ±10%. The standard ratings include combinations from 0.1 to 0.47 μF and 22 to 470Ω. Sprague Electric Co., Marshall St., North Adams, MA 01247. Phone (413) 664-4411. **191**

COMPONENT MOUNTING CLIP, designated "Quick-Clip" B200139, permits rapid loading and unloading of life test trays and other applications requiring temporary component connections. The clips are priced at 0.63¢ in large quantities. Free evaluation samples available upon request. Micro Instrument Co., 12901 Crenshaw Blvd., Hawthorne, CA 90250. Phone (213) 679-8237. **192**



MINIATURE FORM-C REED SWITCH, MRC-DT, offers low contact resistance and high power capacity. It is ideal where contact bounce cannot be tolerated. The switches must be mounted in a position within 15 degrees of true vertical. Switching voltage is 28V dc at up to 0.5A. Physical dimensions are 0.214 in., maximum glass diameter, and 0.805 in., maximum glass length. Price is $4.50 in 1000 lot quantities. Hamlin Inc., Lake Mills, WI 53551. Phone (414) 648-2361. **193**

POLYSTYRENE CAPACITORS are especially impregnated and tested for ac applications. Suitable for operation to 100 kHz, and capable of carrying 10A with imperceptible self heating, the units have a dissipation factor less than 0.025%. The P1299 series offers a voltage range to 1500V RMS. Capacitance range in hermetically sealed tubes is up to 0.1 μF. Product bulletin and samples are available on request. PFC/Arco, Community Drive, Great Neck, NY 11022. Phone (516) 487-0500. **194**



SOLID-STATE INDICATOR converts standard 8-4-2-1 positive logic into single-character display showing up to 16 levels. The 5082-7340 Hexadecimal Indicator shows digits from 0 to 9 and letters A through F. Decoder/driver/memory electronics are built in. An important feature is blanking control. The digit may be turned off, but contents of the memory maintained. Price is $18 in 100 pc. quantities. Hewlett Packard, 1501 Page Mill Rd., Palo Alto, CA 94304. Phone (415) 493-1501. **195**

PRESSURE-SENSITIVE TRANSFER TAPE is designed for backing applications, and for mounting, adhering, splicing, holding and laminating. NELTAPE/100 is transparent and colorless and is available in thicknesses of 0.002 in. to 0.0023 in. Available in 1/4 in. or wider widths, and in 1/8 in. increments in 36 yd. rolls. Neltape, Div. of Dielectric Polymers Inc., 25 Crescent St., Glenbrook, CT 06906. Phone (203) 359-0429. or (203) 359-4018. **196**

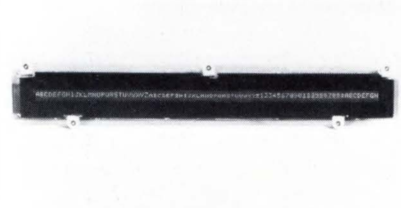
MINIATURE ALLIGATOR CLIPS use crimp-type connection, eliminating solder wicking, charred insulation, cold-solder joints etc. Designed to accept standard test lead wire, the crimp barrel includes a stress relieving insulation support for increased lead life. Serrated jaws and a preloaded spring give this clip positive gripping action. American Pamcor, Inc., Box 1776, Paoli, PA 19301. Phone (215) 647-1000. **258**

FLAT CONFIGURATION INDUCTORS offer inductance ranges, in fixed values, from 1.0 μH to 5.0 mH. These flat coils can be effectively used at audio as well as radio frequencies. Measuring 0.375 in. wide by 0.100 in. deep by 0.250 in. high, the flat coil configuration makes it ideal for use in high density PC board assemblies. Operating temperature is $-55°C$ to $+125°C$. Price in 1000 piece quantity is from $0.25 to $0.35 each. Renco Electronics, Inc., 240-A Old Country Rd., Hicksville, NY 11801. Phone (516) 938-0022. **259**

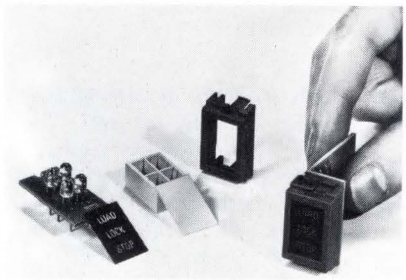
MAGNETIC SHIELDING FOIL is available with adhesive backing. The stock is fully hydrogen annealed to obtain maximum magnetic shielding properties. Netic or Co-Netic foil is stocked in 4 in. and 15 in. widths on 50 or 100 ft rolls, with nominal thicknesses of 0.002 in., 0.004 in., 0.006 in. and 0.010 in. Sheet stock is also available 30 in. wide in various thicknesses. Perfection Mica Co., 740 Thomas Dr., Bensenville, IL 60106. Phone (312) 766-7800. **260**

STRIPLINE TRIMMER CAPACITORS have "Q"s of up to 4000 at 250 MHz. They are designed for T and π matching network elements in transistor MIC's or variable feedback elements for microwave oscillators. They are self resonant up to X band. Capacitance ranges are 0.3 to 1.2 pF for model 7264 and 0.4 to 2.5 pF for model 7284. Price varies from $4.05 to $7.55 each. Johanson Manufacturing Corp., 400 Rockaway Valley Rd., Boonton, N J 07005. Phone (201) 334-2676. **261**

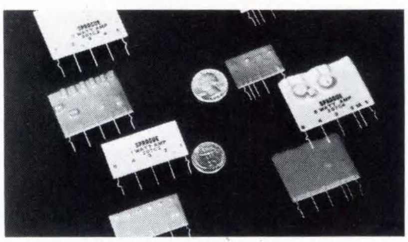
CIRCUITS



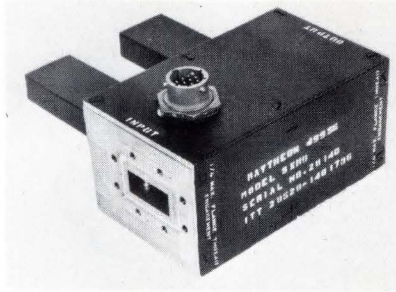
80-CHARACTER ALPHANUMERIC PANEL DISPLAY. The Self-Scan display comes in a single-line panel that is supplied with all necessary drive electronics and provides 0.2-in.-high characters on an 80-character-position single-row format. Provision is made for the addition of an optional second character generator which increases the character repertoire from 64 to 128 characters. Burroughs Corp., Electronic Components Div., Box 1226, Plainfield, N J 07061. Phone (201) 757-5000. **197**



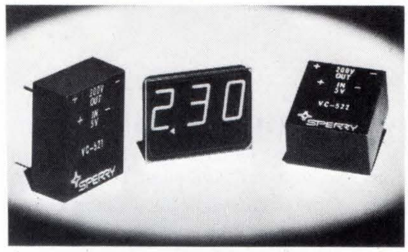
ADJUSTABLE STATUS DISPLAY MODULE with LED light sources can house up to six captions. The GaP LEDs are partitioned by adjustable barriers. Housing to the Series 730 display can be quickly disassembled without tools to provide convenient access to the legend and the light barriers. Price in 100-lot quantities is $7.80 (6 LEDs and legend) and $6.15 (4 LEDs and legend). Dialight Corporation, 60 Stewart Ave., Brooklyn, NY 11237. Phone (212) 497-7600. **198**



HYBRID AUDIO AMPLIFIERS are available in 1/2, 1, 3 and 5W output power models. The Series 207C power amplifiers are ceramic-based hybrid circuits. Total harmonic distortion of all amplifiers is less than 5% rms at rated output power. Frequency response is flat from 60 Hz to 15 kHz in the case of the 5W unit, with a higher frequency cutoff for the lower-wattage design. Sprague Electric Co., Marshall St., N. Adams, MA 01247. Phone (617) 664-4411. **199**

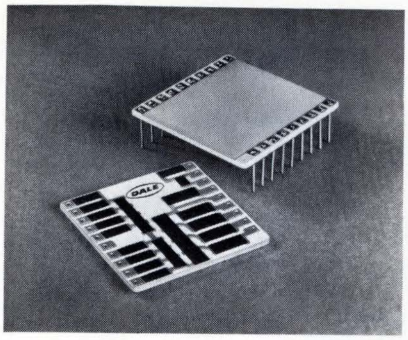


X-BAND FERRITE SWITCH SXH9 is a spst switch capable of handling 35W of average CW power. It features a 6% isolation of 40 dB minimum, and maximum insertion loss of 0.6 dB. VSWR is 1.20 and switching time is 3 μsec. The SXH9 is a latching junction type switch using WR-112 type connectors. Special Microwave Devices Operation, 130 Second Ave., Waltham, MA 02154. Phone (617) 890-8080. **200**



NEW VOLTAGE CONVERTER for use with Sperry SP-700 displays. Called the VC-520 Series, it is offered in two models: Model VC-521 for dc applications offers a nominal output of 190V dc from an input of 5V dc; and Model VC-522 for use in multiplexed or pulsed applications, offering a nominal output of 225V dc from 5V dc. Both units are priced at $11 in quantities of 1000 to 4999. Sperry Information Displays Div., Box 3579, Scottsdale, AZ 85257. Phone (602) 947-8371. **201**

ULTRA-LOW-BIAS-CURRENT FET OP AMP Model 1029 features a bias current of only 0.3 pA maximum. The differential-input unit features a 50-kHz full-output frequency and has a guaranteed CMRR of 10,000 over the full ±10V common-mode voltage range. Selected versions (1029/01) offer lower offset voltage TC (25 μV/°C) and lower bias current (0.1 pA). Prices for Models 1029 and 1029/01 are $37.50 and $47, respectively, in quantities of 100. Teledyne Philbrick, Allied Dr., at Rte 128, Dedham, MA 02026. Phone (617) 329-1600. **202**

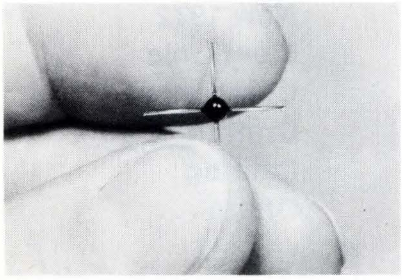


THICK-FILM BINARY LADDER NETWORKS in flatpack and DIP configurations are available in flame-retardant packages. Type TKR-36 networks have the following specifications: 1, 5, 10, 20, 50, and 100K ($\pm 5\%$ resistance); 1/2-LSB accuracy; 5Ω $\pm 2\%$ switch compensation (first four bits); -20 to $+80$°C operating temperature and input voltage of 20 to 25V maximum. Settling Time is $R \times 10^{-8}$ sec. Dale Electronics, Inc., Box 609, Columbus, NB 68601. Phone (402) 564-3131. **203**

A SOLID STATE THERMAL SWITCHING DEVICE enables data transmission equipment and automatic callers to operate directly with regular Touch-Tone telephone sets, or other tone generators, without need of an isolation transformer. Type TC-8 interface unit inexpensively ($2) facilitates electronic selection of the eight tone-signalling frequencies with complete dielectric isolation. Multi-State Devices, Superior Electronics Industries Ltd., 1330 Trans-Canada Highway, Montreal, Canada 740. Phone (514) 683-6331. **204**

PLUG-IN D/A CONVERTER Model NDAC provides a resolution of 10 binary bits with a settling time of as low as 50 nsec at accuracies of up to $\pm 0.05\%$. The module, which measures $2.6 \times 3.1 \times 0.6$ in., drives a 50Ω coaxial load and provides a short-circuit-proof output of 0 to 5V at 100 mA. The unit provides an internal reference signal and accepts a TTL input of one line with two loads per bit. ILC Data Device Corp., 100 Tec St., Hicksville, NY 11801. Phone (516) 433-5330. **205**

A/D CONVERTER MODULE Model ADC-uH features a 10-MHz word rate. It also features a small size of 2 by 4 by 1 in., low cost of $2495 and power dissipation of only 5W. The ADC-uH utilizes a parallel/serial conversion technique which combines the advantages of both conversion methods: parallel for speed, and serial for reasonable component count. Accuracy is 0.4% of full scale. Datel Systems, Inc., 1020 Turnpike St., Canton, MA 02021. Phone (617) 828-6395. **206**

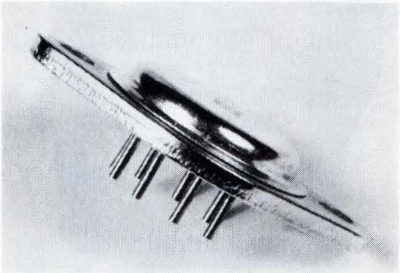


SUBMINIATURE EPOXY TRANSISTOR, only 0.090" in diameter and 0.060" thick, has been designed specifically to cut the cost of thick-film hybrid circuits. The MET transistors may be obtained with dual collector leads, or with C-E-B or C-B-E lead configurations if one of the dual collector leads is omitted. Both NPN and PNP versions of the silicon transistors are available. Sprague Electric Co., Marshall St., North Adams, MA 01247. Phone (413) 664-4411. **208**

SILICON DIODE CHIPS are glass passivated. These mesa junction devices are switching- and general-purpose diodes (500 mW to 3A), rectifiers (500 mW to 3A), zeners (up to 5W), and temperature compensated chips (TC as low as 0.001%/ °C). All are available in a variety of metallizations—soft solder, hard solder, silver, and gold. Also available are LID packages and channel or tab mounted chips (molybdenum, tungsten, and kovar tabs). Microsemiconductor Corp., 11250 Playa Ct., Culver City, CA 90230. **209**

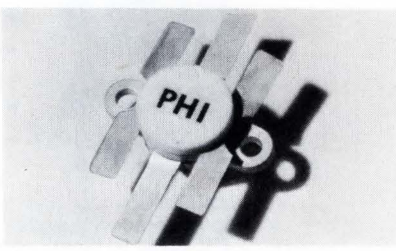
MONOLITHIC VOLTAGE COMPARATOR, the 8001, comes in two versions. The 8001M operates over a temperature range from −55°C to +125°C, and the 8001C for use between 0°C and +70°C. Input bias current for the 8001M at +25°C is 40 nA, typical, and 250 nA maximum. Power consumption is 30 mW, and response time is 250 nsec. Price, in 100-piece quantities, is $3.00 for the 8001, $11.50 for the 8001M. Intersil, 10900 N. Tantau Ave., Cupertino, CA 95014. **210**

IC DUAL DIFFERENTIAL AMPLIFIERS, the LM3026 and LM3054, consist of two independent differential amplifiers with associated constant-current transistors on a common monolithic substrate. The six NPN transistors that comprise the amplifiers are general-purpose devices which exhibit low noise and f_T in excess of 300 MHz. Bias and load resistors have been omitted to provide maximum application flexibility. Price is $2.06 each in small quantities. European Electronic Products Corp., 10180 W. Jefferson Blvd., Culver City, CA 90230. Phone (213) 340-7059. **211**

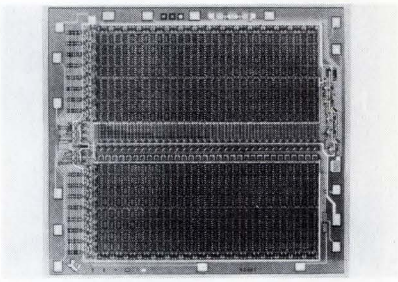


NPN/PNP DARLINGTON, identified as the SDM 3000 Series, is rated at 10A and is packaged in an eight-lead TO-3 case. Typical features include: V_{CEO} from 40 to 120V, multiple gain selections @ 1.0A and 5.0A, typical 5.0A H_{FE} = 5000 minimum and high speed (f_t = 40 MHz typical, rise and fall times 200 nsec typical). These dual monolithics represent a unique combination of power transistor capability and performance. The series is priced at $22.00 each in quantities of 1-99. Solitron Devices, Inc., 1177 Blue Heron Blvd., Riviera Beach, FL 33404. Phone (305) 848-4311. **212**

LOW COST SILICON PLANAR TRANSISTORS of the ECONOLINE series are packaged in JEDEC TO-92 plastic cases. The npn Type 2N3903 and 2N3904, and their pnp complements, Type 2N3905 and 2N3906, feature breakdown voltages of better than 40V, collector currents of 200 mA and power dissipation of 360 mW. Type NPS6512 through NPS6515 and their similar PNP Types, NPS6516 through NPS6519, are general-purpose audio and low-frequency amplifier devices and feature collector dissipations of 360 mW. Sprague Electric Co., Marshall St., North Adams, MA 02147. Phone (413) 664-4411. **213**



HIGH POWER TRANSISTOR, the PH 0540L, delivers up to 50W of RF power with MTBF exceeding 100,000 hours. Reliability is achieved by a proprietary gold metalization process and emitter finger ballasting which eliminates localized hot spots. This NPN transistor has 5-dB minimum gain and is designed for mobil communications applications. Power Hybrids Inc., 1742 Crenshaw BL., Torrance, CA 90501. Phone (213) 320-6160. **214**

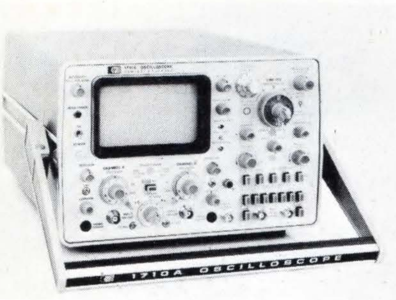


MOS/LSI 1024-BIT RAM, designated the TMS4062JC, features a 150-nsec access time and field-proven reliability. Cycle time is 250 nsec, with a three clock configuration. The unit uses a four-transistor storage cell and information is non-destructively read; but must be refreshed. Power dissipation is 180 mW operating and 2 mW standby. Price is $10.50 in 100-piece quantities. Texas Instruments Inc., 13500 North Central Expressway, Dallas, TX 75222. Phone (214) 238-2011. **215**

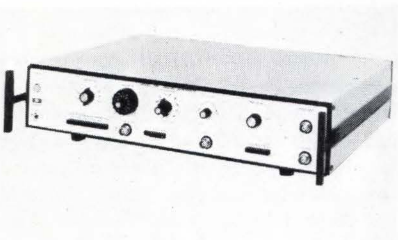
CHARACTER GENERATOR, UA3540, is a static MOS read only memory featuring 64 characters of 35-bits. It is intended for high-speed static operation with 500 nsec typical access time. No external resistors are required and only one additional power supply required when used with TTL/DTL. The UA3540 operates in the commercial temperature range (−25°C to +70°C) and comes in either a hermetically sealed 24 or 28 lead dual-in-line package. Solitron Devices, Inc., 8808 Balboa Ave., San Diego, CA 92123. Phone (714) 278-8780. **216**

IC DUAL COMPARATOR SUBSYSTEM can drive a wide range of relay or other control loads. The two comparators in the μA750 are completely independent except for common biasing and overload protection circuitry. Output current is specified at 125 mA per side, and the device operates with a single power supply over the range of +12 to +25V. The 100-999 price for industrial temperature range units is $5.95 each. Fairchild Camera and Instrument Corp., Semiconductor Components Group, 464 Ellis St., Mountain View, CA 94040. Phone (415) 962-5011. **217**

MONOLITHIC 6-BIT D/A CONVERTER has internal reference. The monoDAC-01HS includes a precision voltage reference, current switches, diffused R-2R ladder network and an internally-compensated high speed op amp on a single 70 × 106 mil silicon chip. Packaged in a 14-pin silicon dual-in-line package, it is priced at $8.25 each in orders of 100 or more. Precision Monolithics, Inc., 1500 Space Park Dr., Santa Clara, CA 95050. Phone (408) 246-9225. **218**



DUAL-TRACE PORTABLE 150-MHz SCOPE Model 1710A is designed for computer, peripheral and digital communications testing. Pulling out its intensity control gives a higher-intensity beam and doubles the writing speed. The 6-X-10-cm display decreases to 3-X-5 cm to show previously hard-to-see pulses. The 1710A offers switchable input impedances of 1MΩ/12 pF or 50Ω. Minimum deflection factor is 5 mV/div. Hewlett-Packard Co., 1501 Page Mill Rd., Palo Alto, CA 94304. Phone (415) 493-1501. **219**



MODEL 335 FUNCTION GENERATOR digitally synthesizes every cycle of each waveform with nearly 2000 bits of digital information. It has typical stabilities of 0.01% for 10 minutes and 0.02% for 24 hours. The 335 ranges from 0.00001 Hz to 50 kHz with a 1 μHz option available. It supplies sine, square, triangle, ramp, pulse, haversine and havertriangle outputs continuously or single shot and burst in the trigger and gate modes. Price is $1250. Exact Electronics, Inc., Box 160, Hillsboro, OR 97123. Phone (503) 648-6661. **220**

5/10-MHz FUNCTION GENERATORS series 500 feature an exclusive ECL quad switching technique for higher performance and cleaner response. The three units in the new line are the $395 Model 501 (5 MHz trigger/variable start-stop), the $495 Model 510 (10 MHz VCF generator) and the $695 Model 511 (10 MHz trigger/variable start-stop). Output waveforms are sine, triangle, pulse, ramp, squarewave, and dc. Microdot Inc., Instrumentation Div., 19535 E. Walnut Dr., City of Industry, CA 91748. Phone (213) 965-4911. **221**

RF SIGNAL GENERATOR Model 15022 with a 50W cw output has direct frequency adjustment from 10 to 2500 MHz with six plug-in oscillator heads. A single control sets frequency to within 1%. Frequency stability is ±10.003% per 10 minutes and power stability of 0.2 db per hour is achieved after warm up. MCL, Inc., 10 N. Beach Ave., La Grange, IL 60525. Phone (312) 354-4350. **222**

MICROVOLT-RESOLUTION TRUE-DIFFERENTIAL-INPUT DPM allows measurement to 1 μV/digit. Its amplifier provides 1/2-μV/°C zero-drift characteristics. Input impedance is 100 MΩ and bias current is less than nA. Specifications include ranges of 19.99 or 1.999 mV, accuracy of 0.1% of reading ±1 digit and size of 2.18-in. high by 4.50-in. wide by 6.32-in. deep. Price is $256. Digilin, Inc., 1007 Air Way, Glendale, CA 91201. Phone (213) 240-1200. **223**

PORTABLE SCR TESTER can test SCRs and Zener and standard diodes (within its ratings). The S-120 will determine the following SCR characteristics: V_{GF} up to 10V, I_{GF}, I_S, I_R and I_H up to 100 mA and V_{BO}, PRV and PFV up to 1000V. Price is $295. Faratron, 290 Lodi St., Hackensack, N J 07601. Phone (201) 488-1440. **224**

PROGRAMMABLE CLOCK GENERATOR MD-73 is an independent module for use with IC test systems. The unit has a basic rate of up to 6.7 MHz, a rate resolution of 10 ns and a pulse position resolution of 1 ns. It consists of the programmable basic rate and five programmable strobe sources, or clocks, with provision for a sixth clock. All clock pulses are strobed from the same 100-MHz source. Prices start at $9880 and delivery is within 30 days. Macrodata Co., 20440 Corisco St., Chatsworth, CA 91311. Phone (213) 882-8880. **225**

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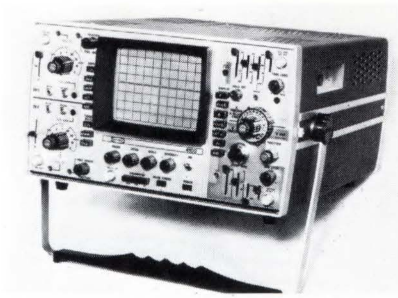
EQUIPMENT

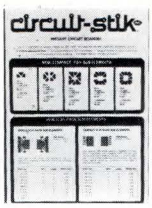


TWO NEW SCOPES with bandwidths of 35 and 75 MHz are the Model 3100 and 4100, respectively. The 3100 has a rise time of 10 nsec, sensitivity of 5 mV/div. at full bandwidth and sweep speeds to 20 nsec/div. The Model 4100 has a rise time of 4.7 nsec, sensitivity of 5 mV/div. at full bandwidth and sweep speeds to 5 nsec/div. Both scopes have 8-X-10-cm displays. Prices are $1675 and $1825 and availability is 2 to 4 weeks and 12 to 14 weeks, respectively. Raytheon Co., Lexington, MA. Phone (617) 862-6600. **226**

3-1/2-DIGIT CAPACITANCE METER simplifies measurements from 1 pF to 10 μF full scale. Model DP200/3202P obtains true-capacitance readings through the use of an internal circuit based on the charge-transfer method of measurement. Eight decade ranges are available and overranging on the six most-sensitive ranges is 40%. Price of the DP200/3202P is $690. Delivery of either model is from stock. Hickok Electrical Instrument Co., 10514 Dupont Ave., Cleveland, OH 44108. Phone (216) 541-8060. **227**

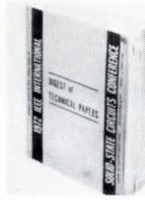
BRIDGE-TRANSDUCER SIMULATOR, Model 40, substitutes for your transducer in verifying system performance, or in amplifier drift and calibration tests. Features include 7 shunt calibration steps from 0.5 to 50 mV at 10V excitation (specified up to 30V), an internal reference that supplies ±1mV to determine system excitation voltage, bridge resistance of 350 ohms (other values available), drift of 0.25 uV/V°C, and a low price of $99.50. Fogg System Co., Inc. Box 22226, Denver, CO 80222. Phone (303) 758-2979. **228**

LITERATURE

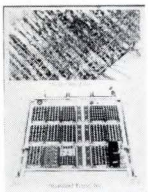


NEW CATALOG SUPPLEMENT introduces over 100 new compact patterns of pressure-sensitive circuit board subelements. The Circuit-Stik product line allows rapid assembly of prototype circuit boards of any required configuration by sticking the thin adhesive-backed copper patterns together in combination on a pre-punched epoxy-glass backing board. This supplement, No. 501-A, is available with a sample. Circuit-Stik, Inc., 24015 Garnier St., PO Box 3396, Torrance, CA 90510. **230**

ULTRA MINIATURE CONNECTORS are detailed in a two-color, illustrated catalogue. Designated No. UMI-C, this manual provides full data on the seven series of ultra-miniature connectors designed to meet ultraminiaturization in the electronics industry. The catalogue also informs of services which U.S. Components offers clients, such as R&D assistance, consultation and testing. U.S. Components, Inc., 1320 Zerega Ave., Bronx, NY 10462. Phone (2120) 824-1600. **233**



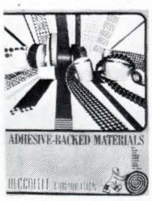
SOLID-STATE CIRCUITS CONFERENCE report—Digest of Technical Papers—with 256 pages and more than 500 captioned illustrations, features condensations of all papers—and a complete index. $15.00 per copy (IEEE members) and $20.00 (nonmembers), from H. G. Sparks, The Moore School of Electrical Engineering, University of Pennsylvania, Philadelphia, PA 19104. Orders for the Digest should be accompanied by remittance (in U.S. currency) payable to "Solid-State Circuits Conference." **236**



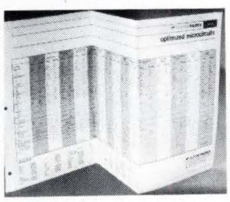
LOW-COST LOGIC PANELS—C·A·S·H Logic Panels, as described in a 10-page catalog, are designed for high-density packaging systems requiring DIP devices and discrete component circuitry. In addition, the catalog gives details on how the C·A·S·H packaging system is supported by Standard Logic's N/C Wiring Machine Service and Computer Aided Design (CAD) documentation program. Standard Logic, Inc., 1630 South Lyon St., Santa Ana, CA 92705. **232**

CONTROLS GENERAL CATALOG, No. 0200, contains descriptions, application information and specifications for over 70 varied industrial event control products. Featured are several new product lines, including low-speed, zero-speed, self powered and switching tachometers; and a complete line of precision power and temperature controllers. Airpax Electronics, Control Div., 6801 W. Sunrise Blvd., Fort Lauderdale, FL 33313. Phone (305) 587-1100. **238**

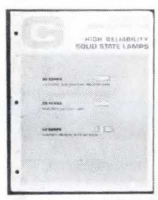
FREE BROCHURE describing VALOX(T) thermoplastic resins is available. The brochure focuses on the unusual combination of engineering properties found in VALOX resin. Some of these properties are: resistance to most organic chemical environments, low surface friction and wear, and dimensional stability. VALOX Resin Brochure, Plastics Dept., General Electric Co., 1 Plastics Ave., Pittsfield, MA 01201. Phone (413) 494-1110. **237**



ADHESIVE BACKED MATERIALS are presented in a new 4-page catalog which presents samples, specifications and information regarding the complete range of materials, adhesives and fabricating services available. Deccofelt Corp., 523 S. Vermont Ave., Glendora, CA 91740. **231**



MICROCIRCUIT OP AMP CHART features detailed specifications and package styles for Philbrick's 1300 Series op amps and compares specifications with those of the standard 741 op amp. The chart lists both typical and guaranteed specifications for fourteen such devices. A current price list is attached. Teledyne Philbrick, Allied Drive at Route 128, Dedham, MA 02026. Phone (617) 329-1600. **234**



SOLID STATE INDICATOR LIGHTS are described in a four-page brochure detailing the Eldema BD Series solid state B-Lites, CD Series solid state C-Lites and ED Series solid state E-Lites. Available on request from Eldema Div., Genisco Technology Corp., 18435 Susana Rd., Compton, CA 90221. Phone (213) 774-1850. **235**

Application Notes

NEW ADHESIVE LITERATURE available in a selection guide (Z-OEM) that assists in identifying and selecting 3M adhesives, coatings or sealants to meet production requirements in the original equipment market. An adhesives user guide lists over 90 different combinations of bonded materials. A coating and sealers guide lists various coating and sealer applications. Adhesives, Coatings and Sealers Div., 3M Co., 3M Center, St. Paul, MN 55101. Phone (612) 733-1110. **245**

SCR MANUAL consists of over 75% new text and includes comprehensive material on SCRs, Triacs, unijunctions and triggers . . . including device theory, operation, and practical "user oriented" applications. Copies can be obtained from any authorized G.E. component distributor, or by sending $3 plus applicable tax to General Electric Co., SCR Manual, Dept. "B", 3600 N. Milwaukee Ave., Chicago, IL 60641. Phone (315) 456-2021. **247**

SCHOTTKY TTL IC BROCHURE, Bulletin CB-147, provides 26 pages of aids for designing high-performance digital systems using state-of-the-art Schottky TTL ICs. Schottky TTL speed/power performance specifications, pin assignments, logic diagrams, package types, and fan-in/fan-out load factors are included for small-scale integration (SSI) and medium scale integration (MSI) circuits. A basic description of Schottky processing is given, as well. Texas Instruments Inc., P.O. Box 5012, Dallas, TX 75222. **249**

FUNCTIONAL TESTING for 1024 X 1 MOS RAMs is described in a new application note. The note covers all the ways in which failures can occur, such as shorts and opens in decoder gates, shorts between rows and columns in the memory matrix, and excessive propagation delay. Tests devised to detect these failures are then described. The tests are all performed under worst-case address change, refresh, and other applicable conditions. The complete report is available on request from Mostek Corp., 1400 Upfield Drive, Carrollton, TX 75006. **246**

RCA RF POWER TRANSISTOR MANUAL, Technical Series RFM-430, provides detailed information on the use of rf power transistors in a variety of power-circuit applications at frequencies that extend from the vhf range to well within the microwave region. The 176-page manual explains the basic design features, characteristics, and capabilities of commercially available rf power transistors. Copies can be obtained from RCA distributors or by sending $2.50 to RCA Solid State Div., Box 3200, Somerville, N J 08876. Phone (201) 722-3200. **248**

REMOTE CONTROL OF A DATA LOGGING SYSTEM. Application Note 133-2 tells how to operate the HP Model 3485A scanning unit by remote control. The scanner when used with an HP Model 3480A/B digital voltmeter collects data from up to 50 channels at rates to 1000/sec. The 20-page booklet contains programming examples and discusses internal triggering, cascaded operation and methods of improving programming and scanning speed. Accessories and connector diagrams are included. Inquiries Manager, Hewlett-Packard Company, 1601 California Ave., Palo Alto, CA 94304. **250**

REFERENCE COPIES AVAILABLE

Reference copies of the following articles are available without charge:

ADVERTISERS' INDEX

signals and noise

One engineer is making his fortune.

We got a tickle out of the following excerpt from Herb Caen's column in the San Francisco Chronicle:

Remember when all those electronics engineers were being laid off last year? Among them was Calvin Wong, who lost his job at Dalmo Victor in Belmont. Instead of moping around, he bought the Gim Shing Fortune Cookey Factory in Oakland, and the way this particular cookie crumbles is exceedingly fine: business is good mainly because his wife, Gerrye, is writing messages both relevant and fresh. Like "Be sociable today—speak to person in front of you in unemployment line," "Be more aggressive—apply for welfare," "Stop getting uptight, buy larger pajamas" and "Be a winner today—pick a fight with a four-year-old" (after a few drinks and a good dinner, they seem funnier . . . The Wongs are also putting out fortune cookies in three flavors—strawberry, lime and banana—and maybe you think THIS isn't shaking up the entire fortune cookie industry! It's what happens when you let an electronics engineer into the business.

Another method shown

Dear Sir:
In an otherwise good article ("IC Op Amps Simplify Regulator Design" EDN/EEE, January 15, 1972, page 30) author Carl Brogado left out the best approach to a good reference—that of putting the zener on the output side of the regulator. The zener then enjoys the environment of almost perfect regulation. Using a standard zener, regulation of $\pm 100\ \mu$V is easily obtained, over large V_{in} changes. If a T.C. zener is used, operation over large temperature changes is possible. This approach is also economical, since a cheap carbon resistor can replace a constant current source.

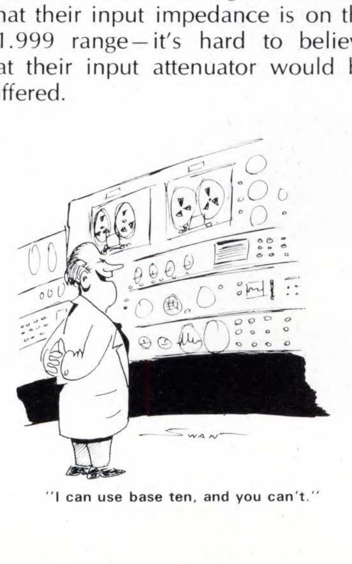
Your truly,
William L. Blowers
Electronics Engineer
Macbeth Division
Kollmorgen Corp.
Newburgh, NY

Not so, says manufacturer

Dear Sir:
The article "Tiny new DPMs operate from logic supplies" (EDN/EEE Feb. 1, 1972, p. 60), in our opinion, falls somewhat short of your stated editorial philosophy of completeness and objectivity. This article compares the new digital panel meters of Analog Devices and Analogic. The article presents a distorted and one-sided view of the two products. Though the article creates the impression that you talked to both companies, it is obvious to us that your editor talked only to Analogic. The fact is that, other than discussions with members of your staff at the press conference which we held to announce the AD2001, no one in a position of knowledge at Analog Devices has discussed the AD2001 vis-a-vis the AN2535. In order to present a more balanced picture of the two panel meters, we wish to make the following comments:

1. You state in the article that Analogic immediately counterattacked with its new AN2535. Actually, whereas the AD2001 was available immediately after it was announced, OEM quantities of the AN2535 are only now becoming available.
2. We have observed in our laboratory the Pinlite display. Any direct observation of the Pinlite display along side the RCA Numitron reveals that (a) both devices have the decimal point where it belongs, hence the meaning of the published vague phrase "less confusing location for the decimal point" completely escapes us; and (b) the RCA Numitron is much brighter and hence has a much wider ambient light dynamic range.
3. Your article states that both units have input impedances of 100 MΩ. The fact is that the AD2001 has an input impedance of 1000 MΩ.
4. The article implies that because we generate our power supply differently (actually our bipolar reference), we must have a fixed range of input. Actually, it's no more of a limitation for us than it is for Analogic. I wonder what their input impedance is on the ±1.999 range—it's hard to believe that their input attenuator would be buffered.
5. The comparison of the out-of-range signals leaves the reader with the impression that the Analogic method is superior. This is not so. The Analog Devices' method clearly and unambiguously signals to the user that he is in out-of-scale operation. The signal is a blinking overrange one with three least significant bits reading zero. The Analogic out-of-scale signal is: The overrange one is lit and the three least significant bits are blanked. This signal can mean one of two things—either the unit is out-of-scale or the least significant bits have failed.

Very truly yours,
Lawrence T. Sullivan
Vice President-Marketing
Analog Devices, Inc.



"I can use base ten, and you can't."

Watch those grounds

Dear Sir:
In Jan. 15, 1972 EDN/EEE, Harry Brown of Westinghouse Electric gave some very valuable data regarding stray currents between multiple grounds.

As a further example of these effects it has been found that in an aircraft fire detection system it is common practice to ground the continuous thermal senser at each and every connector. However, the detector unit is located elsewhere and has its own ground which is the signal reference point. Because there are diodes in the imput circuit, a stray ac voltage between senser ground and detector ground of 0.037 V will inhibit the fire alarm.

Sincerely,
E. U. Thomas
Syosset, NY

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