Minicomputer architecture — it's changing, but slowly. The latest diagnostic routines help increase mini reliability, while LSI chips and µPs improve performance by easing the CPU's burden. Further progress in architecture hinges on availability and cost of standardized components. To see what's building, go to p. 26.
A new space saver from Bourns.

Now there's a new dimension in space savings... the Model 20 Trimpot® SIP Cermet Trimmer... a standard SIP, designed to meet your high density PC board needs.

With no sacrifice in performance, the Model 20 trimmer occupies only 25% of the precious board space used by comparable DIP configurations and only 50% of that used by conventional 3/8" rectangular trimmers. Featuring .100-inch spacing and a lower board profile... only .185-inches off the board... it's priced at a modest 75¢* in 1,000 to 4,999 quantities. And, it's available in 18 standard resistance values ranging from 10 ohms to 5 megohms.

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TRIMPOT PRODUCTS DIVISION, BOURNS, INC., 1200 Columbia Avenue, Riverside, CA 92507. Phone: 714 781-5050 — TWX: 910 332-1252.

The Model 20 SIP trimmer... machine insertable and compatible with automatic test equipment for significant cost savings.

*Domestic U.S.A. price only.
Our Model 3001 starts at $2,980. For that you get a signal generator that's already frequency programmable with 0.001% accuracy over the 1 to 520 MHz frequency range. If you also want to program your output power, we have a programmable attenuator option available for $500.

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Here's another advantage. If you need to get on the bus (now or later), our new Model 3910 Converter makes you GPIB compatible. But before you spend anything on any signal generator, get a demonstration of our Model 3001. That won't cost you a cent.

SPECIFICATIONS
Frequency Range: 1-520 MHz
Accuracy: ± 0.001%
Resolution: 1 kHz

Stability: 0.2 ppm per hour
Output Range: +13 dBm to −137 dBm
Flatness: ±0.75 dB
AM Modulation: 0-90%
FM Deviation: 0-10 kHz and 0-100 kHz
Internal Modulation Rates: 400 Hz and 1 kHz

WAVETEK Indiana Incorporated, P.O. Box 190, 66 North First Avenue, Beech Grove, Indiana 46107, Phone (317) 783-3221, TWX 810-341-3226.

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Of course, our one-year guarantee applies to these units.
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110  Quantize the feedback in a/d converters. With microprocessor control, you trade inexpensive program-storage space for crucial speed and accuracy.
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Cover: Photo by George Young, courtesy of Hewlett-Packard.
Mostek's 64K ROM sets new standards for speed and power.

Pin compatibility, from 8K to 64K, means easy system upgrade in density and performance.
Mostek's newest ROM was developed by a design and process team with years of experience in dynamic RAMs. Their goal was to produce the industry's highest density ROM with all the features you expect in Mostek RAMs.

They met that goal with the MK36000 65,536-bit Read-Only Memory. It sets new standards with the industry's highest density, fastest access, and lowest power.

**Speed and power.** Mostek's MK 36000-4 offers 250 ns access time max! It's ideal for fast microprocessor applications like Mostek's 4MHz Z80, as well as storage for higher level languages. With speeds like this you might expect a sacrifice in power. Not from Mostek. The MK 36000-4 requires only 200 mW active power max. Automatic standby power is just 25 mW typical.

**Greater system performance and efficiency.** Mostek's ROM family now includes 8K, 16K, and 64K organizations. All are pin-for-pin compatible so you can easily upgrade your existing designs in both density and performance. (With each increase in bit density a chip select input is replaced by the necessary address pin.) The 36000 is pin-compatible with existing EPROMs also allowing upgrades to higher density at much lower costs.

Mostek's Edge-Activated design concept provides many other features including ±5V only power with ±10% tolerance, on-chip address latches, totally static operation and direct TTL compatibility with common I/O.

In applications with Mostek's Z80 microcomputer and Mostek 4K static RAMs you can activate the entire system with one common timing signal achieving a 75% reduction in device operating power for an automatic standby power mode.

**Proven technology for lower cost, greater reliability.** The proven technology for high performance and volume production is N-Channel, Silicon Gate MOS. Mostek's years of experience with Poly I™ process allow confident planning of next-generation products like the 36000. Now, Mostek process engineers can quickly move these designs from R&D to full production with proven reliability in millions of circuits.

There's more information on Mostek ROMs. Contact your nearest field sales representative or Mostek Corporation, 1215 W. Crosby Road; Carrollton, Texas 75006, (214) 242-0444. In Europe contact Mostek GmbH, West Germany; Telephone, (0711) 701096.
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Across the desk

Engineering decisions from nonengineers

Basically, I agree with Mr. Morrone's comments (see "Sons of Laetrile," ED No. 23, Nov. 8, 1977, p. 14). But I do believe that several aspects of the problem should be restated. For example, what can the individual do when companies refuse to let engineering decisions be made on a sound engineering basis? Too often nonengineering managers box us in by making these decisions, and too often price is not a controlling factor.

I will note just a few examples:
1. The use of "n" to designate the following kinds of devices:
   - npn silicon transistors
   - npn germanium transistor
   - Enhancement FETs, p type
   - Depletion FETs, both types
   - npn silicon transistors
   - npn germanium transistor
   - Enhancement FETs, n type
   - Dual diodes
   - Darlington pairs, all types
   - Unijunctions
   - Depletion FETs, n type

   The "n" could easily be replaced by a two or three-letter code that would identify all of these by type.

2. The use of beta as a prime characterizing parameter for bipolar transistor devices, it being a small difference of large numbers.

3. Failure to recognize the importance of transconductance-per-unit-current efficiency as it relates to small-signal and power-circuit design.

4. Inept characterization of all solid-state devices I know of. This has been true since electron tubes first came on the market. Tube transconductance as a function of plate current is an important parameter with these devices (and the corresponding relation for both bipolar and field-effect transistors), whereas transconductance as a function of control-grid bias is indefensible.

Yet no tube manufacturer credits this parameter with its true importance, and one of the major manufacturers still presents such data as it gives as a function of grid bias, a singularly unreliable relation.

5. Integrated-circuit manufacturers' turning out special-code IC's by the millions, using "MOSFET" technology. These get out onto the market by the millions, too, and you can't even find out the pinout or supply-voltage requirements. Manufacturing says, "Get the dope from our customer," but doesn't even take the trouble to tell you who the customer is. The result? You don't even dare try to test the stuff, it is so delicate and sensitive!

All we need to do is to get some checks and balances that will assure that the views of a spectrum of engineer and technician users are fairly considered in the decision-making process, instead of having governance controlled completely by the manufacturers themselves. Otherwise, we will continue to require that Naderites, Common Causers and others of their ilk scream for more government regulations. And since we apparently won't police our own operations adequately, we really can't argue much about their views, even though they really aren't sound.

Keats A. Pullen, Jr. E.D.
Box 381
Jerusalem Rd.
Kingsville, MD 21087

Rise time probed

The assumed input-circuit topology of "Let Your Scope Measure Its Own Rise time—Almost," by Raymond Pizzi (ED No. 24, Nov. 22, 1977, p. 130) is not valid for most oscilloscopes. But the mathematical derivations are interesting.

At the risk of divulging a scope-
(continued on page 10)

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

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CIRCLE NUMBER 6

ELECTRONIC DESIGN 6, March 15, 1978
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At $3 in OEM quantities, our new 8021 is quite simply the world's lowest priced 8-bit microcomputer. It's a cost reduced version of our 8048, the microcomputer which won industry acceptance for the single-chip system concept. Then there's our new top-of-the-line 8049, the microcomputer that sets a new standard for single-chip system performance.

The entire line of MCS®-48 microcomputers is priced right and designed to lower your total system cost. For example, they all operate from a single 5V power source, and the 8021 has the broadest operating range in the industry (4.5V to 6.5V).

The 8021 also has an internal clock generator that lets you control system timing with a single 27 resistor. Built-in zero cross detection enables the 8021 to accurately control system
chip microcomputers without compromise.

timing operations and perform time-of-day accumulation.

For sheer performance, there's not a single-chip microcomputer anywhere that can catch our new 8049. With twice the on-chip memory of the 8048, the 8049 enables you to economically perform complex functions that previously required more costly multi-chip systems. And it's a drop-in replacement for the 8048, so you can upgrade 8048-based products with no redesign.

We've made MCS-48 microcomputers the easiest to use, too. Our 8748, for example, provides on-chip erasable and reprogrammable EPROM. That enables you to beat the ROM turnaround cycle during design and field testing. And its 100-piece prices start at just $39, making the 8748 economical for low to medium volume production. To ensure maximum flexibility, all members of the MCS-48 family are software compatible.

If you've taken advantage of our high performance multi-chip microcomputers, the 8080 and 8085, you know that Intel delivers the most in-depth and advanced development support. Now you don't have to go without that support, even for your most budget-minded applications. It starts with our PROMPT™ Design Aid. Then there's Intellec®, the industry's most powerful microcomputer development system, with resident MCS-48 Macro Assembler and ICE™ In-Circuit Emulation with symbolic debugging. Plus applications assistance worldwide, full documentation, training classes, design seminars and a rapidly expanding users' software library.

The more important economy is to you, the more important it becomes for you to evaluate the 8021, 8049 and other members of Intel's MCS-48 economy microcomputer family. They're all available now through your nearest Intel distributor: Almac/Stroum, Component Specialties, Cramer, Hamilton/Avnet, Harvey Electronics, Industrial Components, Pioneer, Sheridan, L.A. Varah, Wyle/Elmar-Liberty and Zentronics. For complete technical information use the reader service card or write: Intel Corporation, 3065 Bowers Avenue, Santa Clara, CA 95051. Telephone: (408) 987-8080.

MCS-48 Microcomputers

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*Designed for easy expansion of program/data memory and I/O.

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CIRCLE NUMBER 83

Across the desk

(continued from page 7)

industry "secret" about times 10 probes, let it be known that a typical probe is constructed by shunting the 9-MΩ resistor with a capacitor. This configuration, when joined to a 1-MΩ, 10-pF oscilloscope input, forms a compensated voltage divider, and is not the primary determinant of oscilloscope rise time. Once a compensated probe is employed, the bandwidth and rise time depend upon other things, including the amplifiers that drive the CRT. It is not difficult to cite examples of oscilloscopes with virtually identical input characteristics but widely different bandwidths: the TEK 453 and 475A at 60 MHz and 250 MHz, respectively.

Calvin Diller
Dennis Feucht

Tektronix, Inc.
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Misplaced Caption Dept.

If tests on a pilot production item show that our new design just isn't making it, our engineers accept the setback philosophically and adjust the design parameters appropriately.


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Modern Digital Communications—E.J. Foss, Tab Books, Blue Ridge Summit, PA 17214, 308 p. $7.95 paperback, $10.95 hardbound.

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After termination, there are more savings. You can buss from point to point without disassembling or breaking existing cables. And there's no need to redesign or rework first generation components. This Scotchflex system mates perfectly with all standard miniature ribbon connectors.
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In addition, there is less assembly cost. Greater board density. Improved reliability. And, the TMS 2532 is a dollar saver compared to 8Ks and 16Ks.

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MORE MEMORY CAPACITY results from state-of-the-art design techniques that keep the TMS 2532 EPROM chip only slightly larger than an 8K chip (foreground).

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Like all EPROMs from TI, the new TMS 2532 continues the fully static tradition that makes designing much easier. There are no clocks. No timing signals. No hassles. Cycle time equals access time.

Low-power operation

The TMS 2532 also sets new standards in energy saving. At 840 mW maximum power (worst case—T = 0°C), it uses less power than a 2708. Yet it has four times the memory capacity. And when the TMS 2532 is deselected, it automatically assumes a low power mode—50 mW typical.

Matching 32K ROM

When programming is finalized and you're set for volume production, you can readily switch over to TI's TMS 4732, a 32K mask-programmable, production-proven read-only memory.

It's a direct plug-in for the TMS 2532. Note on the illustration that they utilize practically identical pin configurations. In fact, when you order the TMS 4732, merely specify that Pin 20 be active low (CS1) and Pin 21 be active high (CS2) to achieve plug-in compatibility.

Wide-choice EPROM family

With the addition of the TMS 2532, TI now offers you a broad selection of compatible EPROMs. All available in 24-pin packages. All having speeds of 450 ns. All sharing the same production-proven N-channel process. All having the same basic pin configuration. Which paves the way for increasing memory capacity in the future should your needs so dictate.

This wide-choice EPROM family includes the 8K TMS 2708, the low-power 8K TMS 27L08, and the cost-effective 16K TMS 2716 (see table below). And more members are on the way.

For additional information on the first 32K EPROM, as well as on other family members, write Texas Instruments Incorporated, P. O. Box 1443, M/S 669, Houston, Texas 77001.

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**TI's Growing EPROM Family**

<table>
<thead>
<tr>
<th>Device</th>
<th>Complexity</th>
<th>Organization</th>
<th>Operating Supplies</th>
<th>No. of Pins</th>
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<tbody>
<tr>
<td>TMS 2708</td>
<td>8K</td>
<td>1K x 8</td>
<td>+12 V, ±5 V</td>
<td>24</td>
</tr>
<tr>
<td>TMS 27L08</td>
<td>8K</td>
<td>1K x 8</td>
<td>+12 V, ±5 V</td>
<td>24</td>
</tr>
<tr>
<td>TMS 2716</td>
<td>16K</td>
<td>2K x 8</td>
<td>+12 V, ±5 V</td>
<td>24</td>
</tr>
<tr>
<td>TMS 2532</td>
<td>32K</td>
<td>4K x 8</td>
<td>+5 V</td>
<td>24</td>
</tr>
</tbody>
</table>
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Electron-beam-addressable memories will offer capacities of thousands of megabytes at two to five milliccents per bit, thanks to a technique that deflects the beam twice, then passes the beam through an array of lenses. Memory systems storing 256 Mbytes will be available within two years, and gigabyte memories will follow, says Don Smith, who heads the technical side of Micro-Bit Corp., a Lexington, MA, firm that has been studying electron-beam addressable memories for nearly a decade.

An 8-Mbyte system, already developed by Micro-Bit (recently acquired by Control Data Corp. in Minneapolis), incorporates 22 single-deflection tubes—16 for data and six for parallel Hamming-code error correction and detection. But this system is slower than and as expensive as MOS random-access memory and will not become commercially available, explains Smith, who has prepared a paper on electron-beam addressable memories for the IEEE Computer Society International Conference (Compcon '78) in San Francisco.

The next generation of electron-beam addressable memories will use a coarse deflector and a lens/fine deflector array to increase density and drop costs below those of MOS memories, says Smith, adding: “The constraining limitations on single-channel electron optics imposed by deflection can be pushed outward by several orders of magnitude by employing two-stage deflection and an array of lenses known as the ‘fly’s eye’ configuration.”

The coarse deflector aims the beam at one of the lenslets in the array, and the fine deflector addresses the memory target area under each lenslet. “By subdividing the deflection into two stages, we can access a much larger target area and the limitations on capacity set by deflection aberrations and deflection voltage inaccuracies can be overcome,” claims Smith.

In the double-deflection tube, the first part of the tube is about 11 in. long and 2 in. in diameter and contains the electron gun, condenser and collimating lenses, and deflection blanker. These are identical to those used in single-deflection tubes, and operate at the same cathode potential—10 kV.

The second half of the tube, about 8 in. long and 4 in. in diameter, includes the coarse deflector, the lens and deflector array, and the silicon target. The coarse deflector is an electrostatic structure, and the array lens consists of three aligned plates, each having a 32 x 32 array of holes plus extra holes around the periphery to preserve field symmetry. Lens tolerances, particularly the roundness of the holes, are tightly controlled to minimize spherical aberrations.

The fine-deflector array consists of two successive arrays of parallel bars at right angles to each other to achieve x-y deflection. Construction stability is important to minimize the memory’s sensitivity to vibration, but mechanical tolerances are not particularly stringent because of the nature of the target.

The target is a 4 x 4-cm slab of silicon that is homogeneous in the plane perpendicular to the beam—there is no structure imbedded in the material. Instead, the target has just four layers: p-type silicon, n-type silicon, an oxide insulator, and a metal front surface. Only two leads, one on each side, are required to write and read data.

In operation, positive charge is normally stored in the oxide layer, and this charge is removed by exposure to the beam. Data storage is represented by charge or no-charge states, or transitions between them, and is nonvolatile.

The writing beam also acts as a reading beam. Signals are capacitively coupled through the oxide to a differential sense amplifier. The MOS target acts as an amplifier because each penetrating electron from the incident beam generates several thousand electron-hole pairs.

The first double-deflection tubes will have a capacity of 128 Mbits so that a memory system of 22 such tubes will have a 256-Mbyte capacity. Systems four times as large are already in the conceptual stage, according to Smith, who foresees per-bit prices an order of magnitude less than that of similarly large MOS RAM arrays.

**RAM cell promises 64 k with existing rules**

A dynamic RAM cell described at the recent International Solid State Circuits Conference promises 64-k dynamic RAMs that can be made with existing fabrication techniques. With this cell, 256-k RAMs should be possible in a couple of years. Today, any RAM larger than 16-k requires special manufacturing techniques.

Each cell, typically 10 x 15 µm, has internal gain, which means that sense amplifiers can be simple inverters. Not only that, but dynamic RAMs using these cells will need fewer sense amplifiers than current designs, whose cells have output in the millivolts and require fairly elaborate sense amplifiers. Readout in the new concept is nondestructive, and refresh intervals are expected to be comparable with existing dynamic RAMs.

Access time is limited not by cell speed, but by the multiplexing required to use a limited number of address-input pins for a large address.

The cell concept, called the Stratified Charge Memory, was invented by Dr. Darrell M. Erb, of Mountain View, CA (PO Box 4113, Zip 94040). Dr. Erb, who is currently self-employed, owns the rights to a forthcoming patent.

Erb’s structure is like one transistor with two “gates” in series, one for storing the bit, the other for enabling writing and readout.

An array of Erb’s cells contains orthogonal polysilicon row and column electrodes that are simply stripes with straight-sided outlines. The array also has diffused n+ source and drain buses, both running parallel to the column electrodes. Sense amplifiers are connected to the ends of the drain buses. The crosspoint between a row electrode and a column electrode is adjacent to the drain bus, and a bit is stored beneath this overlap.

To store a bit, the column electrode for the selected location is made relatively negative for a ONE, and relatively positive for a ZERO. By properly
biasing the row electrode for that location, holes will be attracted to the oxide-silicon interface beneath the crosspoint to store a ONE. For a ZERO, no holes are attracted.

Changing the bias on the row electrode "traps" the holes, which become surrounded by a positive electric field. Readout doesn't affect this "trapping," so data aren't destroyed.

To read, the row and column electrodes for the selected location are biased to new values. An n-type inversion layer forms under the row electrode, which behaves like a gate enabling writing and readout. The presence or absence of the stored holes under the column electrode has the effect of the other gate and determines whether or not an electron current will flow from source to drain. Current in the drain bus is picked up by the sense amplifiers.

The Apple printer-control card's ROM has all the card's control and driving software in Basic. This software not only handles the printer timing and interfacing to a wide variety of printers, but also handles all of the interfacing to the Basic language in the \( \mu C \). So for printing, all a user has to do is tell the card how many columns he wants to have printed, and then type in PRINT.

The Communications Interface card, or modem controller, provides full-duplex operation at 110 or 300 Baud, which is selected by software. The Basic program to control the modems or the Apple II computer is contained in on-board ROM. This feature permits a distributed system—say, in a factory—to bring data to a central location. How? By allowing the user to load and control remote units from a central microcomputer.

**\( \mu C \) programming easier with ROM interface cards**

Two microcomputer-interface cards, one for printer control and another for communication, are the first to have their on-board intelligence in the form of ROMs. The 256-byte ROMs carry the driver and control software in Basic language. Putting this on-board intelligence into the ROMs simplifies programming, because for most other \( \mu C \) cards to run, a machine-language program must be loaded into the microcomputer itself, or perhaps even written.

The cards, from Apple Computer Inc. (Cupertino, CA), are aimed for use with the Apple II microcomputer. While the intelligent ROM is only a 256-byte device, it appears to the computer to be much larger, because it is linked directly to machine-language routines already in the Apple II monitor.

Both Apple cards do more than simplify programming. In fact some of their features are new to the \( \mu C \) field, according to Apple.

For example, the Parallel Printer Interface control board can handle printers up to 255 characters wide at 5000 characters per second. The Communications Interface board, or modem controller, does more than provide a serial link to allow computers to talk to each other—as most modems and controllers do. With its intelligence, the board permits one Apple computer to take control of another—particularly useful for running remote diagnostic programs.

**Dual laser carves out objects of any shape**

A two-laser method of chemical machining does what no conventional machine tool can do—readily produce any pattern or shape required. The method promises to prove useful in precision casting and IC technology, and may even lead to 3-D oscilloscopes.

Two laser beams of different wavelengths are projected into a volume of photosensitive material that reacts only where the beams intersect. After the desired shape is created by the coordinated movement of the beams under computer control, solvents or a vacuum can remove the excess unreacted material. Since the dual-laser system can duplicate a solid object sensed by other lasers, it is called a replicator. It has been patented by Omtec Replication, Berkeley, CA.

"As to its usefulness for ICs, it's all a question of the resolution that can be achieved," says research chemist Dr. Robert Schwerzel of Battelle Memorial Institute. Battelle's Columbus Laboratory is now defining the research necessary to make the concept commercially feasible.

In February, inventor Wyn Kelly Swainson, President of Omtec, executed agreements permitting Battelle to obtain industrial sponsors for the research, which may be under way in a few months.

Castings manufacturers large and small have shown very enthusiastic response, says Schwerzel. The laser approach potentially can do in hours or days the complex pattern-making jobs that now require months.

The feasibility of a 3-D oscilloscope display was demonstrated in 1971 by Carl Verber, another research chemist at Battelle. Swainson's concept, notes Verber, would add a hard-copy output.

Estimating the ultimate impact of the concept, Arthur C. Clarke, renowned author of science fact and fiction, told the Congressional Clearinghouse on the Future last October about a machine that could make a copy of anything in its three-dimensional form, in all its detail.

"Imagine my astonishment when I learned that the first patent for the replicator had been put out by a company in California called Omtec."

**Minicomputer emulates most minis or micros**

A new minicomputer can expand a system's performance by being microprogrammed to run the instruction set of practically all mini or microcomputers.

The T-1000 from Dynamic Sciences, Van Nuys, CA, has an architecture specifically designed for efficient emulation. It uses a variable-size microprogrammable memory to store microinstructions, says Earl Kanter, vice-president for corporate development. This, coupled with the T-1000's architecture and interpretive controls, enables it to emulate computers with 8, 12, 16 or 32-bit word lengths.

Operating typically at 500,000 operations per second, the T-1000 is several times faster than a MOS microcomputer. In addition, up to 65,536 words of memory can be directly addressed, and 262,000 words of extended addressing are available. The T-1000 contains 16 full-word (16-bit) registers and operates off a single +5-V supply.

The basic CPU is contained on a single small printed-circuit board, but much more capability is available on additional boards—extra memory, programmed I/O, various interfaces and a series of data option modules, such as memory management and floating-point arithmetic.

To retrofit an existing system and to upgrade its performance, Dynamic Sciences will fit the T-1000 into the card-cage slot of the less-powerful computer being replaced. "We will customize the boards to fit the mechanical requirements of the customer," notes Kanter. Prices start at $1000 in 100-up quantities.
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Minicomputer architecture: advancing, but with caution

Much of the improved data-processing capability of minicomputers stems from architectural changes made possible by advances in semiconductor technology. Yet the basic architectures themselves haven't undergone any tremendous face lifts. For one thing, designers are leery about putting in new devices before their technologies are proven—and that takes time. In addition, manufacturers often cannot get low-enough costs or standardized packaging for new devices.

As a result, minicomputer architecture in several notable cases has not been changed dramatically to improve performance. For sure, minicomputer families are evolving. But each new member first derives benefits from the original architecture, then gains the advantages of improved hardware based on tried-and-true technologies.

Architecture—do not disturb

For example, Data General's Nova family, designed for the standard minicomputer market, has used the same basic architecture since its inception 10 years ago. This has not prevented advanced features like a hardware multiply and divide, a floating-point processor and an increased memory capacity from being built into the newest members.

Meanwhile, the philosophy at Hewlett-Packard is "to enhance the performance without throwing away the architecture," according to David Carver, Products Manager of the Data Systems Division. Thus, the new HP 1000 Series (HP-21MX) minicomputers are architecturally compatible with machines made way back in 1966, while offering much greater processing power.

Compatibility to Vernon Smith, Senior Vice President at Microdata, means that "the hardware evolves under the software, so the customer can continue to use the same software package." This is called "software transparency," and to a user it means that while newer members of a machine family offer better performance, their programming is similar to the older models.

Since up to 50% of the development cost of a minicomputer can be tied up in software, sweeping architectural changes that would affect software don't make sense. On the other hand, computer performance is being upgraded by using software in new ways. One of the most recent innovations, user-accessible microcode or microprogramming, provides powerful instructions that replace many normal programming routines. A microprogramming instruction word can be extremely wide—up to 56 bits—and contain several commands that can be executed in one machine cycle.

Not too surprisingly, then, minicomputers with microprogrammed architecture are becoming more popular than older, hardwired designs. Nevertheless, the basic architectural structures of both types have much in common.

Microprogramming is coming on

To execute machine code, hardwired and microprogrammed computers begin an instruction cycle the same way. Through the control section, an instruction is fetched from main memory, then loaded into an instruction register.

At this point, paths diverge, with a hardwired computer executing the word via its control logic, and a microprogrammed computer operating on microinstructions located in a special memory called a control store.

The contents of a location in the control store are fed to a microinstruction register, which holds the
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control signals until they are ready for execution. Moreover, control signals to allow execution also come from the control store, under the direction of a simple clock that generates the sequence of operations.

Unlike a hardwired controller's instruction set, the instruction set of a microprogrammed minicomputer can be altered by changing the locations of microinstructions in the control store. To do the same thing, a hardwired machine's control section would have to be redesigned radically.

But for high-performance applications, where execution speed is critical, hardwired logic works faster than software. So machines with logic controllers should be around for some time.

Whatever the architecture, minicomputers must operate at increasing- ly higher speeds to execute the complex programs that result from sophisticated instruction sets. But the burden doesn't have to fall on their CPUs alone. Microcomputers are coming to the rescue.

Microcomputers share the load

A minicomputer designed for speed has a better chance of achieving higher throughput rates if a microcomputer becomes part of its architecture. By giving up control tasks to a microcomputer, the mini's CPU can perform its primary mission processing data, faster and more efficiently. And the burden of I/O operation, by which a CPU controls and communicates with its peripheral units is shouldered efficiently by a microcomputer.

But microcomputers aren't restricted to improving speed. Microcomputers can help minis in the field operate reliably by providing diagnostic capabilities to detect malfunctions in both the CPU and its peripherals. For example, a microdiagnostic unit can test the operation of CPU components, and, with a special code indicated on front-panel LEDs, identify the malfunctioning section. Thus, error diagnosis is taken out of the hands of field-service engineers, which means lower mean time to repair failed equipment and lower service costs.

Microcomputers are just one part of the growing semiconductor arsenal that includes large-scale integrated circuits. With greater levels of gate integration available, features that were previously unheard of can now be built into existing architectures. However, putting LSI to work in mainframes leads to some not-so-obvious problems.

LSI pros—and cons

LSI devices offer some clearcut reliability advantages on a system level in minicomputers. But many machines still rely on older medium-scale integration to implement control-section logic. For one thing, it's difficult to break the often complex logic of hardwired control sections into blocks that can be implemented with standard LSI devices. And standard LSI in suitable package configurations is not far enough along to be used in architecture.

One way around this problem—although it's far from an ideal solution—is LSI circuits specifically designed to perform the logic functions of the architecture. Unfortunately, procuring such circuits isn't easy. And the custom LSI circuits won't be cost-effective unless an extremely large batch is needed.

Nevertheless, the attraction of LSI, with its potential for reducing both package count and interconnections between circuits, pulls strongly on manufacturers interested in improving overall system reliability.

Where it's difficult to use LSI devices in control logic, LSI memories pose no such problem. Random-access-memory bit densities have steadily increased from 16 bits in 1970 to the 4-k sizes available today. So memory-oriented microprogramming architectures are gaining popularity. Access times are in the neighborhood of 150 to 300 ns, but newer MOS technologies such as HMOS and VMOS offer the possibility of future RAMs with access times as low as 70 ns.

Old memories not forgotten

On the mainframe-memory front, meanwhile, established technologies will be hard to overtake. Most minicomputers today use either core memory, or a combination of both. And there's no mystery behind the reasons. Newly developed charge-coupled devices and bubble memories are not yet price-competitive or, in some cases, not commercially available.

Moreover, minicomputer manufacturers place a premium on component reliability—and CCDs and bubbles don't even have a track record. Couple that with the fact that the reliability of established technologies for disc storage isn't standing still, but is approaching 15,000 hours MTBF.

"Another problem facing replacement memory technologies is that they are chasing a moving target in terms of the minimum memory capacity they

(continued from page 26)
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CIRCLE NUMBER 20
must replace plus the changing cost of alternate technologies," says Robert Grossman of Data General. Because today's requirements call for sophisticated software and operating systems, the minimum mass memory being ordered is increasing—a trend that will continue. At the same time, the cost per bit of rotating magnetic mass memory is continuing to drop significantly. But CCD add bubble memory costs are technologies harder to achieve.

CCD add bubble memory costs are Grossman of Data General. Because continue. At the same time, the cost per memory size makes the cost goals of the emerging technologies harder to achieve. If cost isn't enough to dampen interest in new memory technology, perhaps the following will: Minicomputer performance can be upgraded by incorporating design techniques into memories that make better use of established technology. Cache memories—fast, bipolar, small-capacity devices that serve as front-ends for the main memory—speed up processing time. The cache contains data that a CPU is most likely to request, and makes the information available faster than if it had come from main memory.

Another reason that caches improve speed performance is that they can read at the same time that the CPU is writing into main memory.

Still, minicomputers have benefited from developments both in basic technology and design innovations. One big result is that minicomputer languages now offer a level of sophistication and data-management capability that grows with the size of memory itself.

**Speak to your computer**

The proliferation of languages spoken by new minicomputers would tax the abilities of a linguist. Most machines can now execute operations in well-known high-level languages like Fortan, Basic and Algol.

From Microdata comes the Royale, a data management minicomputer that speaks ENGLISH. While it's not exactly spoken English, users can program the Royale with sentences made up of verbs, nouns, adverbs and adjectives, all stored in dictionary-type files.

Data General's Eclipse family understands a host of high-level languages, including real-time Fortran IV, Extended Basic, Business Basic and Extended Algol. To bring this sophisticated languages to the user, instruction sets have been expanded to include words that are considerably longer than the old 16-bit words. HP's 21-MX minis use an instruction word of 32 bits, as does Digital Equipment's PDP 11/34. And among microinstruction words, bit lengths of 48 and 56 bits are not uncommon. But the old 16-bit word may not be dead yet. Minicomputers still take the longer-bit words and bite them off in 16-bit chunks.
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CIRCLE NUMBER 21
Airborne TV systems are jammable, but µPs may be part of a solution

Microprocessors may help the Air Force solve the problem of transmitting video signals from its TV-guided airborne vehicles, missiles and gliding bombs without fear of jamming.

The trouble is that for TV pictures to be sent back to earth with techniques that defeat jamming, the 4 or 5-MHz video signals must be squeezed down to a few hundred kHz. But so far, complex mathematical operations needed for such bandwidth compression cannot be performed without extensive hardware. And the airborne system must be small, light, power-stingy and low-cost.

Analog systems developed to minimize bandwidth suffer from analog-multiplier instability. And custom digital systems generally have proven to be power-hungry, expensive, or too slow to process video signals in real time.

But now, for the first time, off-the-shelf microprocessors have been configured for powerful mathematical capability. Moreover, these low-cost devices have been demonstrated to be feasible for the Air Force's airborne TV application (see Fig. p. 34).

Two microprocessors built around three Advanced Micro Devices 2901 4-bit-slice, low-power Schottky chips are used in a laboratory setup developed for the Air Force by Data/Ware Development Inc. of San Diego to evaluate digital compression-expansion of TV signals. The µPs provide enough mathematical power and speed to perform the necessary complex TV-signal bandwidth-compression transforms and their inverses in real time.

One of the microprocessors simulates an airborne TV system, in which the signal-compresing takes place. The other µP simulates a ground-site receiving system where the signal is expanded for display on a standard TV monitor.

One advantage this setup has over analog systems is that it is digital. Communications between airborne vehicles and base stations are digital, so the system does't require additional hardware for conversion to that form. Moreover, it's more stable.

A PDP-11/40 minicomputer simulates the link between airborne and ground systems. Normally, the compressed airborne video signal is fed to a modulator and transmitter, picked up on the ground by the receiver, and demodulated for expansion. The microprocessors performing the compression-expansion are tied to the minicomputer's Unibus (see Fig. below). As a result, the minicomputer can control all subsystem operations for evaluating different configurations.

**Redundant data removed**

Basically, the TV-picture data are compressed by removing redundant information, explains Richard V. Keeple, vice president of Data/Ware. Keeple is co-author with Ronald A. Belt (USAF Avionics Laboratory, Wright-Patterson Air Force Base) of "Digital TV Microprocessor System," which he presented at the recent National Telecommunications Conference in Los Angeles.

If the compressed video bandwidth can be reduced to some 200 kbits/s, Keeple maintains, the video information can be transmitted over a spread-spectrum link in which the narrowband video is distributed across a broadband spectrum. This makes jamming difficult.

Redundant information in a TV picture can be rejected because it changes

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**Diagram:**

The modems and rf links between the airborne and ground microprocessors are simulated by a PDP-11/40 minicomputer. The DEC machine's Unibus permits a maximum transfer rate of 5 Mbytes/s between the processors. This setup allows the mini to control all subsystem operations for evaluation.

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Heinemann Re-Cirk-It protector. Just press the button to reset.

The fuse is passé.

At last there's a modern, reliable way to protect your product—Heinemann's Re-Cirk-It® pushbutton circuit protector. It protects like a fuse, is cost-competitive with fuses and fuse-holders, but can be quickly reset with just a push of the button.

Re-Cirk-It trips instantaneously on short circuits, and with delay on sustained overloads. It's available in a wide range of current ratings from 0.25A through 10A. And, of course, it's UL-recognized and CSA-approved as a component circuit protector.

There's a good chance today that your product will be used by non-technical personnel who may not know a spent fuse from a dead battery. But when Re-Cirk-It trips, the button pops out, exposing a white band around the pushbutton shaft. So Re-Cirk-It forever ends the frustration of blown fuses, eliminates the danger that your customer will use a wrong size replacement, and can save you from an expensive, unnecessary service call.

The Re-Cirk-It protector can only be electrically tripped. It can't be turned off, can't be held on against a fault, and there is no confusing mid-position trip-point. It is easily installed, and fits into the same panel space as conventional ¾"-diameter fuseholders. And it's attractive enough to be placed on a front panel.

If you want more information, request Bulletin KD-4001. But do it now, before you or your customer blows another fuse.

SPECIAL OFFER
Send us a blown fuse and $1.00 and we'll send you a 3A or 5A* Re-Cirk-It to try.

*Other ratings available under this offer on special request.
very slightly, if at all, from frame to frame. Picture data can be compressed by employing only the frequency changes that occur as the camera scanning beam picks up edges such as lines or rapid variations in light levels.

The information is squeezed down further with transforms of the horizontal and vertical-image frequencies. On the receiving end, the information is subjected to an inverse transform and the picture is reconstructed.

Transform algorithm helps

The key to the microprocessors' providing the computing power necessary to perform the transforms and their inverse operations is a transform algorithm that is the most efficient to date. It was developed at Data/Ware by P.J. Erdelsky and G.G. Murray.

In the Data/Ware system, the standard TV format is modified so that each field consists of 256 lines of 256 picture elements, or pixels. This means that the horizontal pixels are slightly longer than they are wide, so horizontal resolution is slightly, but not noticeably, lower than the vertical. Since odd and even fields are treated as identical, 256 lines of information are obtained from the 525 lines of the standard TV picture. And gray scales are quantized on a 6-bit level.

To reduce the bandwidth even further, the Data/Ware system employs a frame slowdown that dissects and sends the picture out in vertical stripes 32 pixels wide and 256 pixels high—an eighth of a picture frame—at a time. These stripes are stored in a frame-store memory at the receiving site until the full frame is received. Then the frame is sent to a d/a converter and to the video monitor (see Fig. below). A 32-pixel strip is transmitted during one field period. The slowdown is 8-to-1, but the picture produced at the ground station is acceptable for typical airborne applications. The stripes are processed from left to right, and updated 7.5 times a second.

With Data/Ware's encoding method, each line is processed as it is generated by the TV camera. As the information on one line comes into the microprocessor, a discrete cosine transform is performed on it to extract coefficients.

(continued on page 38)
Controls your DEC LSI-11* Moving Head Disc System

Plug-in compatibility too!

Moving Head Disc Controllers are not new. But this one is... it's the Model DI-C03. What makes it new is its single quad size, made possible with a bipolar microprocessor and other exclusive Dynus circuitry. The module provides direct interface with your new or existing LSI-11... and it's transparent to DEC's RT-11* & RSX-11S* operating systems.

Capabilities offered by the Dynus Controller include control of up to 20 megabytes of online storage • compatibility with standard 2315 or 5540 cartridge drives • storage of 2.5 to 5.0 megabytes per cartridge • DMA transfer rate of 6.4 microseconds per word • an eight word FIFO buffer for DMA latency • and two additional address bits for 128K words of direct addressing for upward compatibility to future LSI-11s.

In addition to complete interface compatibility with the LSI-11, the DI-C03 mates with any industry standard 1500 to 2400 RPM disc drive having 100 or 200 TPI capability.

Write or call for complete details or a demonstration. Discover how easily you can control your DEC LSI-11 Moving Head Disc System.

3198 G Airport Loop Dr., Costa Mesa, CA 92626
Telephone: (714) 979-6811

*Trademark Digital Equipment Corp.
THE WORLD'S MOST IMITATED OEM COMPUTER JUST PULLED A FAST ONE.
The new direct-map cache memory for the PDP-11/34.

2K bytes of high speed RAM. A hit rate of almost 90%. It all adds up to make the fast, powerful PDP-11/34 up to 60% faster. Our new high-speed cache is available in a system now or as a field enhancement.

Deliveries in May.

Will the competition ever cache up?

How fast are you driving?
That sign on the overpass knows

A radar-operated sign flashes on to warn motorists they’re speeding—and tells how fast they’re going. But to get the sign’s X-band Doppler radar to work reliably from overpasses (see photo) or from overhead sign posts, two major problems had to be overcome: fluctuations in the Doppler returns because of multipath cancellations from cars approaching the sign, and interference caused by bidirectional traffic flow. The sign was developed by John B. Flannery, president of Transportation Safety Associates, North Billerica, MA.

A 100-mW, 10.525-GHz radar mounted in the lower end of the sign measures the speed of approaching vehicles up to 800 feet away. Doppler speed signals of 31.5 Hz per mph are converted by special circuitry into BCD signals that turn on 14-in.-high neon numerals, which display the speed.

Radar polices drivers

As a vehicle approaches, the radar takes measurements that are stored and updated every two seconds. If the car’s speed is within a preset value, say 55 mph, the sign remains dark—as it does with no traffic. But if the speed exceeds that value by 1 mph or more, the exact speed is displayed for two seconds, turned OFF for two seconds, and then ON for two seconds in a repetitive cycle.

During the “on” portion of the cycle, the reconstituted one-eighth-picture-stripe information to the frame-store memory. The stripes are stored until a complete picture arrives in the memory. The picture is then sent to the TV monitor during retrace so that it doesn’t disturb the readout of the frame-store memory as it updates the TV picture.

The transform computations on the 32-line pixels and on the vertical-stripe lines must be executed by 63.5 microseconds less in the ground system. The microprocessors have pipelined architecture and a fast instruction time—150 ns—which is more than adequate for the purpose. And both µPs operate under microprogram control from a 48-bit wide RAM microstore to which the PDP-11/40 has access.

The micorporcessor speed is achieved not only from its pipelined architecture but also from its low-power Schottky elements. Propagation delays have been matched in the system using data latches. And parallel transfers are possible.

The Data/Ware system can not only compress images, but enhance them as well, according to Richard Keeple. This flexibility can be useful in enhancing low-contrast elements like medical X-ray pictures, among other applications. This has already been proved experimentally.

The PDP-11/40 is interfaced with the microprocessors so that various key registers of the subsystem appear as high-speed core-memory locations in the DEC computer. As a result, the minicomputer can directly modify the control-store contents within each microprocessor and directly interrogate or modify the various microprocessor registers. As a result, the µPs can be controlled directly by the minicomputer for simulation runs.

At present, the microprocessors require about 60 W, which is too much. But a CMOS silicon-on-sapphire equivalent looks like it will be available from at least two companies soon, Keeple says, which would solve the power problem.

A 100-mW Gunn oscillator provides the CW power for this radar-based speed sign. Doppler signals from approaching cars are selected by the asymmetrical magic tee and passed on to counting and decoding circuits.

(continued from page 34)
MICRO-DIP...10 and 16 position miniature binary coded DIP switch designed to be mounted directly to PC Boards. Ideal for address encoding, presetting, PCB programming...every area of digital electronics.

Packaged in a color coded, glass-filled nylon housing with terminals on 100 x .300 centers. It occupies only one half of a standard 14-pin DIP socket.

Screwdriver slot is rotated in either direction to desired setting. Gold contacts protected by dust-seal design.

Positive detenting 10 position BCD, 16 position binary with separate common to not true bits, repeating 1 and 2 pole codes. Guaranteed life of 10,000 detent operations. Operating temperature range of -10°C to +85°C, contact resistance of 25 milliohms max. initial.

One year warranty.

MINI-DIP...new from EECO. Form A and C contact arrangements ideal for positive on/off switching and programming.

Easily actuated, positive wiping, gold contacts are packaged in a dust free glass-filled nylon housing.

Interference-fit of terminal pins and one piece housing prevent contamination. Larger cross section pins allow positive insertion into sockets and P.C. Boards.

New locking design in which .035 diameter locking rod is inserted through rocker, insures against accidental actuations.

Guaranteed life of 50,000 cycles. Operating temperature range -10°C to +85°C, contact resistance 25 milliohms max. initial.

Standard 100 x 300 centers allows retrofitting of other major brands of DIP switches. Available in 2:10 station Form A, 1:5 station Form C contacts.

One year warranty.
A car approaching a radar sign installed in New Hampshire is being clocked at 60 mph, five miles over the legal speed limit. Legends in 8-in.-high neon letters also flash on to tell the driver: “YOUR SPEED IS...” and “REDUCE SPEED.”

But the speed readings can be wrong—usually low—if multipath cancellations, or fluctuations in the received microwave energy, aren’t corrected. These dropouts are caused by the interference of microwave energy reflected from the road with that reflected directly from an auto.

Besides developing the sign, Flannery came up with the solution to the cancellation problem. To begin with, the speed is determined by shaping the sine-wave Doppler output of the radar receiver and producing a string of pulses with it. These pulses are applied to gating circuits and counted for a specific gating period that is crystal-controlled.
When a multipath cancellation causes the Doppler-return pulses to drop out, a voltage-controlled oscillator (VCO) that tracks the Doppler pulses momentarily supplies the missing pulses. When the Doppler pulses reappear, they are compared with the VCO pulses. This comparison takes place at least five times during every two second “off” period. If the rates differ, the display is updated.

**Opposing traffic problems**

Another problem had to be solved: What to do where the sign is used over a road whose traffic goes in opposite directions. Doppler signals from the cars going away from the sign can interfere with those approaching it. Because the Doppler signals (1000 to 3100 Hz) are such a small percentage of the 10.525-GHz carrier frequency, they cannot be separated by rf frequency filters. Flannery’s solution, originally developed for a vehicle collision-avoidance radar, is to use an asymmetrical magic tee that is inserted between the receive/transmit isolator and the demodulator circuits (see Fig.). This proprietary device separates the approaching and receding signals on the basis of phase difference. It rejects the receding signals, and passes the approaching signals on to the demodulator circuits.

The radar sign is usually placed over high-speed lanes of highways, and the antenna beam width is shaped so that the vehicle in that lane will be the only one whose speed is measured. Amplitude gating is incorporated to ensure that the auto closest to the sign is measured.

The system can measure and display speed from 30 to 99 mph. But, usually the upper limit is set at 75 mph to prevent the hot rodders from checking their speed up to 100 mph. The displayed speed is accurate to ±1 mph. Optional outputs are available, such as printers to give the date, time, and speed of the offenders, and counters to measure traffic density.

The sign is being used effectively in several states. At Dulles Airport in Virginia, drivers have maintained slower speeds for up to five miles after passing a sign. In Iowa this slow-down effect has been measured up to 20 miles.

While the radar sign uses the x-band radar it can be updated with the newer Ku band units.

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**of counters**

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**Two new instruments from Hewlett-Packard give you capabilities you've never had before.**

**5342A Microwave Counter**

Now, a more useful high-performance microwave counter—and for 20% less than you might expect to pay. Microprocessor-controlled, 18 GHz range. Superior FM tolerance. Amplitude discrimination. For the first time, measure input signal level simultaneously with frequency using just one instrument. And via the keyboard, define your frequency or your power offsets to be added to or subtracted from the measurement. $4500*; add $1000* for amplitude option.

**5370A Universal Time Interval Counter**

Now, a new standard of time interval measurement with the highest single-shot resolution of any counter, ±20 ps. Plus all the features you need to make this resolution meaningful: jittered time base, optimized input amplifiers and automatic calibration. Plus, a keyboard with statistics computation for more complete time interval characterization. All this for $6500*.

**HP—Your Real Choice In Counting.**

Fifteen HP counters span a capability range no other manufacturer even approaches. From the usual, simple, low cost frequency-only units to the most sophisticated high-speed universal counters with performance that is simply unmatched anywhere.

*U.S. Domestic price only.
Now we can announce it—the multi-disk drive System Three Computer.

A fast Z80 microcomputer with up to 512 kilobytes of RAM, 4 disk drives and 1 megabyte of disk storage—with CRT terminal and fast printer. Even an optional PROM programmer. Strong software support, too, like FORTRAN IV, Extended BASIC, and Macro Assembler.

PROFESSIONAL GRADE—FOR PROFESSIONALS
Chances are you've already heard that there is a Cromemco System Three Computer. We've proudly previewed it at WESCON on the West Coast and NYPc on the East Coast.
It's a complete system—processor, CRT terminal, line printer.
First it's fast—1 microsecond nominal execution time and 250 nanosecond cycle time.
Its equally fast RAM memory is large and enormously expandable—32 kilobytes expandable to 512 kilobytes. No danger of obsolescence from inadequate RAM capacity.

THE ONLY MICROCOMPUTER OFFERING 4 DISK DRIVES
Further, the System Three comes with two disk drives to give you 512 kilobytes of disk storage. Soft-sectored IBM format. Optionally, you can have four drives with 1 megabyte of storage.
There's disk protection, too, since in the LOCK position disks can't be ejected while they are running.

21-SLOT MOTHERBOARD
This new CS-3 is a computer that won't be outdated soon. It has a 21-card-slot slide-out motherboard and an S-100 bus so that you can plug in all sorts of support circuitry. The heavy-duty 30-amp power supply can easily handle all this.

BROAD S-100 SUPPORT
The S-100 is the bus that Cromemco so strongly supports with over a dozen plug-in circuits ranging from analog I/O to high-speed RAM memory with our bank-select feature.

TRULY POWERFUL SOFTWARE
You have to have software. And Cromemco is far in front there, too. Our FORTRAN IV, for example, is equal to the FORTRAN compilers on large mainframes. Further, it (and our other software) is low-priced.
Our 16K Z80 BASIC is one of the fastest and most capable. Full 14-digit precision.
There's also our Z80 Macro Assembler and Linking Loader. Uses Z80 mnemonics. Allows referencing FORTRAN common blocks.

SEE AT YOUR DEALER
You have to see the CS-3 to fully appreciate it and its low prices starting at $5990 in the rack mount version.
Better contact your dealer now.
Display Technology just took a giant step forward.

With the M4408 by Motorola. Like some of our others, it's a 15" raster scan CRT display module, but that's where the similarities end. The M4408 was specifically developed for systems that demand displays of up to 6,300 upper and lower case, clearly readable characters.

With its unique horizontal or vertical mounting capability, the M4408 can display a full typewritten page (96 characters x 66 lines) or a wide page printer format (132 characters x 48 lines...or 43 if you prefer). And those are only two examples. The M4408 is the optimum display for any high performance, high density character application.

The cost? Not much more than conventional 15" 80 x 24 type displays—considerably less when you consider cost per character. And the M4408 doesn't require high speed, expensive logic either.

When you compare features, we think you'll agree that the Motorola M4408 is the price performance winner.
Give your product with Burroughs SELF-SCAN® II gas plasma displays—

Burroughs SELF-SCAN displays provide bright, easy-to-read alphanumeric readout that will enhance the saleability of your product. Over one-quarter million have been built into everything from word processors to data terminals to paint matching machines.

And now they’re easier than ever to use. Optionally available microprocessor-based controllers save you most of the time normally spent to “design-in” a display.

Give your product the visual excitement and dependability of SELF-SCAN displays. You’ll benefit from each of these features:

- Thin cross-section (under 2” with electronics) to keep your product’s design efficient and low-cost.
- Neon-orange characters are uniformly bright, flicker- and distortion-free, easy-to-read in high ambient light and at night without eye strain.
- Easy interface with microprocessor-based systems.
- Any of over 100 languages can be displayed with many special effects possible (such as word blinking).
- Low power requirements, low heat buildup.

COMPARE BURROUGHS’ NEW LOW-COST ALPHA-NUMERIC SELF-SCAN II PANELS OFFER LARGER, BRIGHTER CHARACTER PICTURES IN A DATA TERMINAL DISPLAY SIZE. YOU’LL SAVE AND REDUCE COST AS WELL. YOU OWE IT TO YOURSELF TO FULLY EVALUATE THE MANY POTENTIAL BENEFITS OF SELF-SCAN II PANELS.
visual superiority
now available with microprocessor control.

• Fewer connections required than with other displays.
• Long service life even where vibration, temperature and high humidity are present.
• No danger of implosion or X-ray radiation.

Choose from our complete line. SELF-SCAN panels are available in both single and multi-line displays with and without memory. Our single-line models, in 16, 20, 32 or 40 characters, are compact, low-cost and extremely dependable. The 20-character panel is stackable and buttable for creating large message panels. Single-line panels range in price from $112 in 100-unit quantities.

Low-cost SELF-SCAN multi-line displays in 240 and 480-character sizes are rapidly replacing many CRT displays. They give you excellent message readability, big space and weight savings, plus 3 times the life of most CRT's. Prices range from $311 in 100-unit quantities.

Give your product the visual advantages of SELF-SCAN displays. Write or call for specifications.
Burroughs Corporation, Electronic Components Division, P.O. Box 1226, Plainfield, NJ 07061 or call (201) 757-5000.

FOR GENERAL INFORMATION CIRCLE 30
FOR DETAILED SPECIFICATIONS CIRCLE 31
About that 'new' kid on the block...

Actually, he's not that new. He's been around for quite a while now. Other vendors keep announcing miniature cylindrical ceramic capacitor 'innovations', but Sprague Electric, the pioneer in layer-built ceramics, can state with pride that this type of capacitor was introduced by Sprague more than ten years ago.

Sprague Type 292C MONOLYTHIC® Capacitors are the industry's best-constructed axial-lead capacitors, thanks to MFT*, a closely-monitored material modification of electrode metal and ceramic reacted with glass. The result—less capacitance change with temperature change, improved stability with life, and improved impedance with frequency characteristic.

These low-cost miniature capacitors feature a dimensionally-precise molded construction and can be ordered taped and reeled for automatic insertion. They are available in body formulations to meet characteristics ZSU (general-application), X7R (semi-stable), and COG (NPO).


* Modified Formulation Technology

SPRAGUE®
THE BROAD-LINE PRODUCER OF ELECTRONIC PARTS
THE MARK OF RELIABILITY

CIRCLE NUMBER 32

Electronic Design 6, March 15, 1978
Cruise missiles will cost over $8-billion

The air, land and sea-launched cruise missiles proposed by the Defense Department will cost $8.1-billion, the Department has reported to Congress in its latest Selected Acquisitions Report. The SAR, a quarterly analysis of major weapon-system costs, does not reveal how many cruise missiles will be ordered, but previous estimates have placed their cost at about $1-million each.

The ship-launched Tomahawk and a variation, the Ground Launched Cruise Missile, will be built by General Dynamics Corp., in San Diego, which is competing with the Boeing Co. in Seattle to build the third type, the Air Launched Cruise Missile. The Tomahawk will cost $2.4-billion, according to the latest SAR, while the GLCM, to be launched from combat vehicles, will cost $1.5-billion.

To determine the winner of the Air Force's ALCM, each company will build 18 test missiles for a competitive fly-off in 1979. That program, which is intended to supply strategic cruise missiles to be launched from B-52 bombers, is expected to cost $4.2-billion. The ALCMs must be operational by early 1980, according to the Defense Department, to fill the gap created when the B-1 bomber was canceled.

The McDonnell Douglas Astronautics division in St. Louis is supplying terrain-contour-matching (Tercom) guidance systems for all the cruise missiles.

Defense Dept. eyes new high-energy laser for weapons

The Defense Department has begun experimenting with a new “free electron” laser that is believed to be more lethal than conventional lasers. And it wants more money to develop high-energy laser weapons—from $150-million this year to $184.1-million in fiscal 1979.

Currently, lasers require a solid or gaseous lasing medium. But the essential physical interactions of the new laser occur within a spiraling, relativistic electron beam.

“This could provide a new option for high-energy lasers, with three times the efficiency previously achieved,” according to Dr. William J. Perry, undersecretary for defense research and engineering. Speaking before Congress, Perry went on to say that the free-electron laser would be tunable from ultraviolet to infrared—unlike present systems, which are not continuously tunable.

The Air Force has already demonstrated lasing with the new technique. And if potential weapons based on the new laser prove effective, they could be used to defend ships, aircraft and satellites, according to Perry.

New ASW helicopter approved for development

Full-scale engineering development of a new antisubmarine warfare (ASW) helicopter has been approved for the Navy by the Defense Department—despite cost overruns that have driven up the price of one to $18.7-million.

The YSH-60B, also known as the Light Airborne Multi-Purpose System (LAMPS) Mark III, is a variation—with more avionics equipment—of the Army's Blackhawk troop-carrying utility helicopter. One Blackhawk costs $3.26-million.

Besides antisubmarine warfare, LAMPS is expected to be used for over-the-
horizon targeting for the Harpoon cruise missile and possibly the Tomahawk. The helicopter will carry the new Control Data AYK-14 standard airborne computer and the Texas Instruments APS-124 long-range radar, as well as two torpedoes and 25 sonobuoys. The Federal Systems Division of IBM is the prime contractor and system integrator.

Development was approved by the Defense Systems Acquisition Review Council (DSARC) despite a report to Congress that program costs had jumped from $2.7-billion to $3.9-billion. The Navy attributes the increased costs to inflation, additional support requirements and schedule slippage.

The DSARC development decision will permit the airframe contractor, the Sikorsky division of United Technologies Corp. (Stratford, CT), to begin building the first prototypes. The company is already building Blackhawks.

The program will remain in the development phase until the fall of 1981, when the DSARC is scheduled to meet again to rule whether or not the LAMPS should be produced. The Navy is requesting funds for 209 LAMPS helicopters (including five prototypes), and the first flight is scheduled for late 1979.

Coast Guard seeks new helicopters

The Coast Guard wants a search, rescue and recovery helicopter, and is evaluating proposals from two American and two European manufacturers under a program expected to be worth $180-million.

Coast Guard officials say they want a helicopter that is already in production in order to eliminate costly research and development, but insist they won't be procuring it "off the shelf." The helicopter must have improved avionics, such as search and weather radars—which current search and rescue helicopters don't have—an area navigation system, and the latest technology autopilot.

One American competitor, the Sikorsky division of United Technologies Corp., is proposing its new S-76 commercial helicopter. The other, Bell Helicopter Co., a Textron division in Fort Worth, TX, is proposing its Model 222. Great Britain's Westland Helicopters is offering its Sea Lynx WG-13 and France's Aerospatiale a version of its Model 365. Whichever helicopter is chosen will have to be modified extensively for the Coast Guard's special requirements, such as the advanced avionics and a hoist for rescue operations.

The Coast Guard expects to make its selection in early 1979 and receive the first fully certified helicopter two years later. Funds for the first 10 have been appropriated in this year's Transportation Department budget, and authority to procure five more is being requested in the fiscal 1979 budget. The Coast Guard expects the procurement to be completed within five years after the initial deliveries.

Capital Capsules: Fairchild Space & Electronics Co., Germantown, MD, has been selected to build the first two Landsat-D earth-resources survey satellites, to be launched in 1981. The contact, still being negotiated with the National Aeronautics and Space Administration, is expected to be worth $10.3-million and to include options to produce four additional spacecraft for future programs....The Air Force now confirms that it plans to buy 20 of the new TR-1 spy planes, which will fly at 430 miles per hour, with a range of more than 3000 miles and a ceiling described only as "above 70,000 feet." The Air Force will buy them from Lockheed Aircraft Corp., Burbank, CA, as part of its plan to reopen the U-2 production line there (see Washington Report, ED No. 5, Mar. 1, 1978, p. 31). The first six TR-1s will be procured in fiscal 1980, which begins Oct. 1, 1979. To do that, the Air Force plans to seek $97-million in addition to the $10.2-million being requested for fiscal 1979.
Fast Relief for the "Typical Spec" Headache

"Typical Specs" Are a Pain

The next time you're searching through component spec sheets for a characteristic best suited to your design, the word to watch out for is "TYPICAL." Typical specifications can be devilish creatures. Ask any design engineer who has ever believed in them. When you need answers in black and white, they turn gray and disappear in the fog. Until you determine what the MIN., MAX., or typical value really is, you've got headaches. Headaches not just for you, but for everyone on down the reliability line—from QC to your field service people.

Curve Tracer A Quick Cure

There's an age-old cure for the headaches caused by typically elusive specifications. It's called a Curve Tracer. TEKTRONIX Curve Tracers aren't new. We introduced our first one in the days of vacuum tubes. Since then Curve Tracers have performed wonders for semiconductor manufacturers, component evaluators, incoming QC inspectors and reliability engineers. We prescribe them for design engineers because the earlier you can diagnose a problem, the less of a problem it will be.

A Picture of Health

If you need to examine a component, it's a good idea to start with its vital signs—current and voltage. And we all know that the best way to understand the voltage/current relationship is to look at a graph.

Two Op Amp gain curves at different sensitivities in the storage mode.

TEKTRONIX Curve Tracers graph voltage vs. current in digital and linear ICs, 2- and 3-terminal devices...transistors, diodes, rectifiers, thyristors, optoisolators and more. At a glance, you can pinpoint parameters such as an Op Amp's offset drift at various loads, or zero in on the actual breakdown voltage in a power transistor.

With a Curve Tracer, you can assign proven values to several components and select the one that you know performs best in the environment you've created. Just think of it as a little preventive medicine to help you and your organization avoid headaches in the future.

Why Prolong Suffering

Fast relief can be on its way. For detailed information—application notes, specifications, a demonstration and the prices of our Curve Tracers and their Test Fixtures simply call your Tektronix Field Engineer. Or, write:

Tektronix, Inc.
P.O. Box 500
Beaverton, OR 97077

In Europe: Tektronix, Limited,
P.O. Box 36, St. Peter Port,
Guernsey, Channel Islands.

CAUTION

TEKTRONIX Curve Tracers are mildly habit-forming. Once you use one, you'll wonder how you ever survived without it.

Tektronix
COMMITTED TO EXCELLENCE

So put down those aspirins and take one Curve Tracer.
When you need illuminated switches, or more than illuminated switches...

Dialight is the first place to look. We make just about any kind of illuminated push button switch that anyone could want... Single lamp, dual lamp, neon, incandescent, LED lighted, you name it.

Perhaps you're looking for snap action switches with silver or gold contacts, or wiping action switches with gold contacts for low level applications.

And if you're looking for rear panel or front bezel mounting switches, switches with momentary or alternate actions, or high quality switches for computer applications, we have them.

You'll find that Dialight switches are not only available at a reasonable price, they're also available with some very attractive features. Lamp removal is from the front so you don't have to remove an entire switch just to change a lamp. And you never have to use anything more complicated than your fingers for replacement or installation.

Along with outstanding variety and design, you get superior Dialight quality. Most Dialight switches are Underwriter's Laboratory listed and CSA approved.

And Dialight distributors are widely located throughout the United States, Canada and worldwide.

Call or write Dialight today. We'll send you our free switch catalogs so you can select a quality switch that's American made and Dialight guaranteed.

Dialight meets your needs.

Dialight, 203 Harrison Place, Brooklyn, N.Y. 11237 (212) 497-7600

CIRCLE NUMBER 35
The frozen mind

I was discussing power supplies with Charlie the other day. We were arguing the relative merits of linear and switching supplies, and though he knew, or should have known, that I had been studying power supplies for many years, he remained adamant. He had apparently made up his mind years ago and wouldn’t budge. He adhered rigidly to his old opinions and seemed unable to accept my facts.

I had a similar problem with Jack, and we weren’t even discussing something that affected us professionally. I don’t remember what it was that we argued about. It may have been apartheid in South Africa, the Food and Drug Administration, the value of Vitamin E in treating burns, or the relative merits of Chinese and French cuisine. I do remember that Jack was thoroughly rigid and his mind was closed. He had done some reading on the subject and didn’t realize that his authors were biased—despite my showing him that, from my reading, I knew the facts.

It’s sad to relate that my experience with people who confront my facts with their opinions is not limited to Charlie and Jack. Indeed, I’ve had such experience with dozens of people on dozens of subjects. And though I would expect them, in time, to develop some humility, they still suffer from the illusion that they are right.

I find the problem particularly rampant in our industry. Engineers frequently make design decisions based on insufficiently considered opinions and faulty evidence. And executives make business decisions the same way. That’s unfortunate. Things would be lots better if they’d ask me.

GEORGE ROSTKY
Editor-in-Chief
Keep those cards
For some, it would be enough to establish industry standards. Like our LM 317.

Or to build an unusually large assortment of “building block” parts.

But, you see, we keep getting telephone calls. And notes on the back of old napkins and such.

“Hey,” they’ll say, “why don’t you make a linear huffle muffle? Boy, could I use that?”

So we did.

Introducing
3-Terminal Negative Adjustable Regulators.

Per request. The LM 337.
Output voltage adjustable from $-1.2$ to $-37V$. $1.5A$ output guaranteed. Excellent thermal regulation $-0.002\%/W$. $100\%$ burn-in, for improved reliability; $100\%$ tested for short circuits and thermal shutdown.

Introducing
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Diagnose computer ills
with an analog monitor. It's inexpensive, very easy to build, and does not interfere with computer operation.

When you want to locate and correct computer-system bottlenecks or look for unused capacity, consider using an analog monitor. It doesn't cost much to build and operate, it monitors the system continuously, and its accuracy isn't as limited as that of other methods. For example, digital simulation techniques require a high level of detail to be accurate, and software monitors are limited by their sampling rate.

Like the monitors in an intensive-care hospital ward, an analog monitor measures vital signs—in this case, a computer's. In fact, the charts it produces, even look very much like electrocardiograms or encephalograms.

The analog monitor's measurements are automatically plotted in real time (Fig. 1). You don't need an expensive minicomputer, nor additional analysis on your host computer. Because the plotter records two traces simultaneously, you can also examine Boolean relationships.

These graphs can help the computer designers in locating and correcting system bottlenecks, and similar problems, as will be demonstrated by six case studies.

A do-it-yourself "encephalograph"

Connect a monitor to your system with a high-impedance, passive probe. It won't affect your "electronic brain's" operation (Fig. 2). Heat-shrinkable tubing (broken lines) protects the external resistors and capacitor.

The selected probe circuit components smooth out high-frequency digital signals. Resistors $R_1$, $R_2$ and $R_n$ along with capacitor $C$, form a low-pass filter. If the probe is connected across a low-impedance indicator bulb, the chosen component values provide a time constant of about 15 s, which corresponds to a moving average over approximately one minute ($4T = 58.67$ s). A very high output impedance at the test points increases the averaging time to 88 s. If you prefer a faster response, use lower-value resistors or capacitors in the probe (Fig. 3). Larger component values expand the averaging interval.

Before you assemble the probe, check the ZERO and ONE voltage levels at the connecting points, and use a capacitor rated for the appropriate voltage range. The capacitor in the parts list is rated at 10 V, which is an adequate choice for most applications. You can minimize noise pickup by keeping the probes short and—where feasible—using low-impedance connection points such as indicator bulbs. Test points can be as far as 50 ft from one another, provided you can place the chart recorder midway between them.

To speed up measurements, connect several sets of probes to the host system simultaneously, and connect the chart recorder periodically to different probes. You can leave the probes connected to the "patient" even when you remove the chart recorder at the other end.

Pick the right recorder

The monitor requires a recorder with high-impedance floating inputs, and zero adjustment as well as sensitivity controls. A Heath-Schlumberger Model SR-206 dual-pen strip-chart recorder or its equivalent works well, because it's versatile, reliable, and reasonably priced. Along its vertical axis the chart is ruled in 5% increments, and chart speed is most convenient at 0.1 in/min.

While the recorder can handle logic levels ranging from millivolts up through several hundred volts, probe-circuit components have to be modified at higher voltage levels. A chart recorder with separate calibration controls and independent floating input for both channels can accommodate both negative (ONE more negative than ZERO) and positive (ONE more positive than ZERO) logic.

To calibrate the monitor, place the chart paper for the correct time reading. If one pen is offset with respect to the other to avoid pen interference, note
to which pen the time scale applies.

Calibrate the two recording channels separately because they may have to be adjusted for different logic levels (e.g. if the probes go to different parts of a system). First check that the polarity is proper for the probe's electrolytic capacitor by making sure the voltage at the red banana plug is always positive with respect to its black companion. If it isn't, reverse the test clip connections.

Now adjust the null control at logic level ZERO, and then the gain control to full scale with a logic-level ONE input. Chart-recorder drift is usually small enough so recalibration is needed infrequently.

You're now ready to start with the analysis. The monitor probes can frequently be connected directly across indicator bulbs or light-emitting diodes (LEDs). An IBM 370/155 system-control panel contains almost 500 bulbs, and with the help of dial switches they can display the status of approximately 1500 bits of information. It is very likely that some subset of these indicators will satisfy your monitoring needs. If a computer manufacturer has taken the trouble to provide an indicator lamp for a function, you can

1. A dual-pen strip-chart recorder like this Heath SR-206 is the heart of the described analog monitor. The chart plots total CPU utilization (red) and an application program's contribution (blue) to show supervisor overhead (see also Fig. 4f).

---

**Micro Grabber test clips**
- 2 black: model 4233-0
- 2 red: model 4233-2

**Guard resistors**
- 6 resistors, 100 kΩ, 1/4 W, 1% accuracy (Allen Bradley cermet film)

**Tantalum capacitors**
- 2 tantalum capacitors, 220 µF, 10 Wdc (Sprague type CSR-13)

**Conductor**
- 50 ft 2-conductor shielded #22 stranded wire conductor size: (Alpha type 3221)
- Heat shrinkable tubing:
  - 1 ft 3/16 in.
  - 1 ft 1/2 in. (Voltrex type FPS)
- Banana plugs:
  - 2 red
  - 2 black
  - 2 green

2. The probe schematic and parts list show how easily the analog monitor can be assembled.
assume that function is important. Look for pertinent signal indicators on the processor, control units, and peripheral devices.

Take a spare indicator bulb and modify it to provide a monitor connection that can be conveniently plugged into one of the front panel indicator sockets: Join the electrical connections from its base to a second "piggybacked" indicator lamp, and attach the probes in-between.

If there is no convenient indicator for the desired signal, you may have to access the host system's backplane or logic gates. Your probe connections will frequently be test points used for troubleshooting, and field service personnel can help you locate them.

As long as the test point impedances for logic levels ZERO and ONE are either equal, or both are under 2 kΩ, the chart scale accurately indicates channel utilization from 0 to 100%. Otherwise, you may have to interperse a lamp-driver IC, such as the Texas Instruments SN75450B, between host and monitor.

**Put your system on the couch**

The six following examples show how the monitor can diagnose system bottlenecks or imbalances.

**CPU waiting for I/O (Fig. 4a):** The negative correlation between CPU and channel readings indicates that the CPU waits for I/O completion before it resumes processing. Simultaneous processor and I/O activity would be much more desirable.

**Excessive overhead (Fig. 4b):** This virtual memory system has a very heavy operating-system overhead and a high paging rate. Turnaround and response times degrade because of contention for real memory and heavy disc activity. Reducing the number of initiators would remove the overload, and increase operating efficiency. Another solution is to disable the system resource management program. Although this program is supposed to optimize system performance by controlling critical resources, it can hog CPU cycles for itself. So when CPU activity gets extremely high, disabling the program entirely lowers CPU use, and improves system performance. Adding real memory would also reduce channel activity, as would restructuring of programs so that associated portions of code are on the same "page."

**Unbalanced multiprocessor (Fig. 4c):** Periods of very high utilization at any processor in a multiprocessor system degrade the over-all system performance. Job throughput drops and turnaround times increase. Time-sharing response time and batch turnaround would both benefit from a more balanced distribution of the workload, which could be accomplished by more judicious job scheduling.

**Unbalanced multiplexer (Fig. 4d):** Disc multiplexer channels are unbalanced so that the 60% utilization of channel 1 degrades over-all performance. At such high channel utilization, the rotational-position sensor of IBM 3330 discs misses reconnect slots, thus delaying data access for another complete revolution. Data sets and disc packs should be redistributed over the drives, to achieve greater channel overlap. Concurrently used data sets belong on separate drives. And string switching should be implemented to help equalize channel utilization by providing alternate paths to the discs.

**Channel hardware problem (Fig. 4e):** For efficient operation, disc channels disconnect during seek and latency times. The utilization of a block-multiplexer channel is ordinarily much less than the sum of the utilizations of its discs. In the 10-min time span of Fig. 4e, I/O operations are initiated primarily on the monitored disc. Yet channel and disc utilizations almost coincide because the channel is being tied up during seek and latency times. A hardware problem causes this block-multiplexer channel to operate in the selector mode.

**Excessive supervisor overhead (Fig. 4f):** Total CPU utilization is the sum of application and supervisor-state processing. In Fig. 4e, total CPU utilization peaks at 90% (40% application plus 50% supervisor). It is often difficult to determine which—if any—application tasks can be attributed to supervisor processing. So make certain that all definitions are clear, and that you know what CPU time is being charged to which program before drawing conclusions. (The actual recording from which Fig. 4f has been extracted is shown in Fig. 1.)

Effective as analog monitoring is, it does not replace more sophisticated measurement techniques. Digital monitors, for example, are much more expensive, but they can perform logic operations and permit connection of many probes to the host system. While you may end up using a digital monitor, it's only sensible to try the inexpensive analog approach first. The greatest dollar improvements in computer performance often occur early in the project, and analog monitoring can pay big dividends by helping you to find and overcome problems. As a bonus, management gets an early indication whether the computer meas-

\[ T = \frac{(R_1+R_2)R_3}{R_1+R_2+R_3} \]

\[ T = \frac{(R_1+R_2)R_3}{R_1+R_2+R_3} \]

\[ \begin{align*}
R_1 & = R_2 = R_3 = 100 \ \text{kΩ} \\
C & = 220 \ \mu\text{F} \\
T & = 14.67 \ \text{s}
\end{align*} \]

3. The equation for the monitor's time constant is valid if the test-point impedance is much lower and the recorder impedance much higher than 100 kΩ.
4. System problems discovered by the monitor include: CPU waiting for I/O (a), excessive overhead (b), unbalanced multiprocessor (c), unbalanced channels (d), channel hardware (e), and high supervisor overhead (f).

Bibliography


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CIRCLE NUMBER 39
Take advantage of powerful instructions in the PIC-1650 microcomputer chip. Its 12-bit instruction size and the register-file architecture make a potent pair.

Based on register-file architecture, the PIC-1650 all-in-one microcomputer uses a 12-bit instruction word, which gives the processor a powerful instruction set. The processor also has an 8-bit arithmetic-and-logic unit, 31 directly addressable 8-bit registers and a 512-word (12-bit size) ROM space.

Programming the PIC-1650 is both easy and economical—all nonjump instructions can be written in a single line, including both operator and operand, and executed in 4 µs (assuming the processor operates at a 1 MHz clock). Jump instructions take twice as long. There are 30 basic instructions in the processor’s command set—18 arithmetic and logic operations, eight literal functions, and four individual bit operations.

Manufactured with General Instrument’s n-channel ion-implant process, the 8-bit PIC-1650 requires just a 5-V supply. Packaged in a 40-pin DIP, the chip has 32 user-defined I/O lines, a clock generator that provides all internal timing, and an 8-bit counter/timer. (The PIC-1650’s software-compatible smaller cousin, the PIC-1655, has 20 I/O lines and comes in a 28-pin DIP.)

Besides the 32 I/O lines, there are just eight more lines to connect into a system—and three of those are for power and ground. The other five are for an oscillator input, clock output, counter/timer input, master clear, and an unused pin (Fig. 1).

Internal workings of the PIC-1650

The 1650’s register-file architecture permits simple commands for bit, byte and register transfer operations. The processor’s three major sections—the register file, an ALU and the control ROM—are all linked by an 8-bit bidirectional bus (Fig. 2).

The register file is divided into two functional groups that total 31 8-bit registers. The first eight registers, F₁ to F₈, are operational registers and the rest are general-purpose registers (F₉ to F₁₄). Register F₁ works as the real-time clock/counter and can be incremented by an external signal; F₂ is a 9-bit program counter (the ninth bit comes from one bit of the F₃ register). F₃ is the status-word register; F₄ forms an indirect addressing register; and F₅ to F₈ are I/O registers that function as directly addressable TTL-compatible I/O ports.

The eight operational registers are similar to the general-purpose registers in that they can be loaded, incremented and logically operated on by any instruction servicing any of the registers.

The timer/counter (register F₁) can be used to keep track of elapsed time since it can be updated or read via software control. It accepts external pulse inputs...
The PIC-1650 instruction set

Even though the PIC-1650's instruction set has only 30 basic commands, there are many features that are hidden because of the large word size. For example, most instructions execute in a 4-µs period unless a conditional test is true or the program counter is changed as a result of an instruction. In these two cases, the instruction execution time climbs to 8 µs.

There are two addressing modes available to the 1650—direct and indirect. In the direct mode, the address of the register being addressed is contained in the instruction. For the indirect mode, the program instruction contains the address of a register that, in turn, contains the address of the instruction or data to be acted upon. The indirect mode is handy for operations that must be carried out repetitively to data stored contiguously in memory, since only the contents of the indirect register must be incremented to point to another location.

To use the indirect mode, the F0 file must be accessed (this is the 32-file register). The F0 register is not an actual register in the processor—however, when F0 is specified in an instruction, the instruction decode logic interprets the register number as the register pointed to by the file-selector register (F4). The 30 instructions of the PIC family of microcomputers are in the accompanying table. Various abbreviations used in the table include k to represent an 8-bit constant or literal value, f to represent a file-register designator, and d to represent a destination designator. If d is zero, the result of an operation is placed in the 1650's W register. If d is one, the result is returned to the file register specified in the instruction. If the d operand is omitted, the f register is assumed to be the destination.

When the PIC assembler is used, f and d may be numbers, characters or symbols. Additional abbreviations used in the table include C, which represents the carry bit; Z, which represents the zero bit; and DC, which represents the BCD-digit carry bit.

<table>
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<th>General file register operations</th>
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<td>Mnemonic</td>
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<td>NOP</td>
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<td>MOVWF</td>
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<td>CLRW</td>
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<td>CLRF</td>
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<td>RRF</td>
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<td>RLF</td>
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<tr>
<td>SWAPF</td>
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<td>INCFSZ</td>
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<tr>
<th>Bit level file register operations</th>
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<td>BCF</td>
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<tr>
<td>BSF</td>
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<tr>
<td>BTFSC</td>
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<tr>
<td>BTSSS</td>
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<table>
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<tr>
<th>Literal and control operations</th>
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<tbody>
<tr>
<td>RET</td>
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<tr>
<td>RET LW</td>
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<tr>
<td>CALL</td>
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<td>GOTO</td>
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<td>MOV LW</td>
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<tr>
<td>IORLW</td>
</tr>
<tr>
<td>ANDLW</td>
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<tr>
<td>XORLW</td>
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at up to 250 kHz. Keeping track of the program flow, program counter (PC) F₂ automatically increments after each program instruction. It is nine bits wide so that it can address the full 512 words of ROM-based control memory. However, aside from being fed directly to the ROM address inputs, the output of the PC cannot be read by the processor.

Holding all the flag information from logic and arithmetic operations in bits 0 to 2, status word F₃ (Fig. 3) has four more bits allotted for future expansion. The eighth bit is used as bit nine of the PC. Bit 0 stores an arithmetic carry (C) and acts as a link bit on rotate operations. Bit 1 stores the carry-out of the four lower-order bits for decimal arithmetic operations (DC) and is used to simplify operations done with BCD arithmetic. Bit 2 gets set to ONE when the result of an operation is zero (Z). The function of bit 3 has not yet been defined.

Each of the I/O lines on “ports” F₅ to F₈ have a fanout of one standard TTL load, and a sink capability up to 14 mA (which enables them to drive LEDs directly, among other things). However, to provide the high drive, you need a 10-V supply on the VXX line to turn on the chip’s drive transistors.

Since the ports are really registers, they can be directly incremented (to provide a counter output), shifted (to do display scanning), or bit set or tested (to provide single-line logic control or sensing). And, of course, they can be operated on by logic and arithmetic commands.

The 512-word ROM on the chip is custom-programmed at the factory according to the pattern defined by the user during program development. For program development, another chip is available, the PIC-1664, which is a ROM-less version of the 1650. Housed in a 64-pin package, the 1664 has ROM address lines for external use, so that programs can be developed with either fusible-link or ultraviolet erasable PROMs.

You can get more addressing capability. Just make I/O lines function as address lines by using the Bit Set and Bit Clear instructions. Instructions pointed to by the program counter are transferred from either the internal ROM or external PROM via a 12-bit-wide bus to the instruction decode and control section of the processor.

Also in the processor is a two-level push-down stack for storing the current value of the program counter before a subroutine is accessed. The subroutine CALL operation code is contained in the first four bits of the instruction and the address of the subroutine in the other eight bits.

**Programming the processor**

Program development can be supported with an assembler that responds to 26 additional instructions (Fig. 4). For instance, the instruction “BTFSC 3, 2” skips on bit 2 of file 3 in the same way as “BTFSC 30, 2” skips on bit 2 of file 30—except that in the first case bit 2 of file 3 is the zero bit of the status register and the operation is the same as a Skip on Zero. As a result, the assembler uses a SKPZ instruction as the equivalent of the “BTFSC 3, 2” command.

Any operation can be performed with any file, except for the program counter, which can be written to but not read. The result of an operation can go either to the referenced file or to a working register. Thus, the assembler instructions like Test File can be generated by a “MOVF f, F” (Move file f, leaving the result in the file rather than in the working register). The assembler mnemonic “TEST f” is interpreted to mean the same as a “MOVF f, F” instruction.

Available software-development aids (see table) include the PIC 1650 assembler, which permits symbolic source programs to be developed. The assembler translates the source program into object code and produces a binary paper tape that, in turn, can be used to generate the ROM mask pattern to program the chip. Two versions of the assembler are available—one is written in Fortran IV and can run on most popular minicomputers and larger systems; the other runs on General Instrument’s Gimini development system for the 16-bit CP1600 MP.

### Software and hardware support

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
<th>Cost</th>
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<tbody>
<tr>
<td>Gimini</td>
<td>16-bit development microcomputer based on CP 1600 — General Instrument microelectronics’ 16-bit microprocessor</td>
<td>$2995</td>
</tr>
<tr>
<td>PIC assembler</td>
<td>2-pass mnemonic assembler. FORTRAN version available that will run on 16-bit microcomputers and large machines</td>
<td>Free with Gimini</td>
</tr>
<tr>
<td>PIC simulator</td>
<td>Software simulator of PIC 1650 including mnemonic assembly and disassembly as well as breakpoint and other debug facilities. FORTRAN version available that will run on 16-bit microcomputers and large machines</td>
<td>Free with Gimini</td>
</tr>
<tr>
<td>PIC 1664</td>
<td>64-pin version of PIC 1650 with ROM off chip, thus allowing external program to be run from RAM, PROM, or EAROM</td>
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<tr>
<td>Development System (DB 1650)</td>
<td>Machine-code development system with debug facilities</td>
<td>$700</td>
</tr>
<tr>
<td>PIC field demo system (FD 1664)</td>
<td>PC card with PIC 1664 and PROM sockets. 40-pin plug emulates PIC 1650</td>
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*Available software-development aids (see table)*

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<thead>
<tr>
<th>Type</th>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>PIC 1650</td>
<td>16-bit microcomputer with ROM off chip, thus allowing external program to be run from RAM, PROM, or EAROM</td>
<td>$99</td>
</tr>
<tr>
<td>PIC 1664</td>
<td>64-pin version of PIC 1650 with ROM off chip, thus allowing external program to be run from RAM, PROM, or EAROM</td>
<td>$99</td>
</tr>
<tr>
<td>Development System (DB 1650)</td>
<td>Machine-code development system with debug facilities</td>
<td>$700</td>
</tr>
<tr>
<td>PIC field demo system (FD 1664)</td>
<td>PC card with PIC 1664 and PROM sockets. 40-pin plug emulates PIC 1650</td>
<td>$220</td>
</tr>
</tbody>
</table>
2. **Inside the PIC-1650** are 31 randomly accessible registers, an 8-bit counter/timer, storage space for up to 512 words of program memory, an ALU and a clock-generator circuit. Other versions of the processor are available with more program storage space, fewer I/O lines, or no internal program storage.

Another aid, the PICSIM simulator program, lets you debug programs rapidly by communicating interactively with the processor. Besides simulating the PIC-1650 processor, the PICSIM allows breakpoints to be set and can do comprehensive on-line debugging. It also includes both assembly and disassembly capability to permit programs to be modified at the mnemonic rather than at the object-code level.

PICSIM executes on a Gimini microcomputer with 8 kwords of RAM and a teletypewriter console. It comes as a relocatable load module that can be loaded into the Gimini system with the help of the resident monitor. A Fortran IV PICSIM is also available.

For hardware development, the FD-1664, a printed-circuit card that contains the PIC-1664 chip and provisions for either fusible-link or UV-erasable PROMs, and the DB1650, a fully interactive debug system, are available. The card comes with a ribbon cable that terminates in a 40-pin CIP plug that can plug directly into the socket of a PIC-1650.

The DB-1650 provides in-circuit emulation. Built on a single PC board, the system contains a PIC-1664 with external memory to emulate your processor. A second, preprogrammed, processor on the board, a PIC-1650, acts as the controller. It is programmed with PICBUG, a comprehensive debug program for memory and register examination/modification, single-step tracing, and serial-communications-channel control for communicating interactively with a terminal and paper-tape reader/punch.

3. **File register F3** contains all the status information generated by operations in the processor. Four of the eight bits have not yet been assigned for functions.

---

Electronic Design 6, March 15, 1978

65
<table>
<thead>
<tr>
<th>Instruction (Octal)</th>
<th>Name</th>
<th>Syntax</th>
<th>Equivalent Operation(s)</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>0100 000 0011</td>
<td>Clear Carry</td>
<td>CLRC</td>
<td>BCF 3, 0</td>
<td>—</td>
</tr>
<tr>
<td>0101 000 0011</td>
<td>Set Carry</td>
<td>SETC</td>
<td>BSF 3, 0</td>
<td>—</td>
</tr>
<tr>
<td>0100 001 0011</td>
<td>Clear Digit Carry</td>
<td>CLRDC</td>
<td>BCF 3, 1</td>
<td>—</td>
</tr>
<tr>
<td>0101 001 0011</td>
<td>Set Digit Carry</td>
<td>SETDC</td>
<td>BSF 3, 1</td>
<td>—</td>
</tr>
<tr>
<td>0100 010 0011</td>
<td>Clear Zero</td>
<td>CLRZ</td>
<td>BCF 3, 2</td>
<td>—</td>
</tr>
<tr>
<td>0101 010 0011</td>
<td>Set Zero</td>
<td>SETZ</td>
<td>BSF 3, 2</td>
<td>—</td>
</tr>
<tr>
<td>0110 000 0011</td>
<td>Skip on Carry</td>
<td>SKPC</td>
<td>BTFS 3, 0</td>
<td>—</td>
</tr>
<tr>
<td>0110 000 0011</td>
<td>Skip on No Carry</td>
<td>SKPNC</td>
<td>BTFS 3, 1</td>
<td>—</td>
</tr>
<tr>
<td>0110 001 0011</td>
<td>Skip on Digit Carry</td>
<td>SKPD</td>
<td>BTFS 3, 2</td>
<td>—</td>
</tr>
<tr>
<td>0110 001 0011</td>
<td>Skip on No Digit Carry</td>
<td>SKPD</td>
<td>BTFS 3, 1</td>
<td>—</td>
</tr>
<tr>
<td>0110 010 0011</td>
<td>Skip on Zero</td>
<td>SKPZ</td>
<td>BTFS 3, 2</td>
<td>—</td>
</tr>
<tr>
<td>0110 010 0011</td>
<td>Skip on No Zero</td>
<td>SKPNZ</td>
<td>BTFS 3, 2</td>
<td>—</td>
</tr>
<tr>
<td>011000 1 ffff f</td>
<td>Test File</td>
<td>TSTF f</td>
<td>MOVF f, 1</td>
<td>Z</td>
</tr>
<tr>
<td>000000 1 ffff f</td>
<td>Move File to W</td>
<td>MOVFW f</td>
<td>MOVF f, 0</td>
<td>Z</td>
</tr>
<tr>
<td>000001 1 ffff f</td>
<td>Negate File</td>
<td>NEGF, f,d</td>
<td>COMF f, 1, 1</td>
<td>Z</td>
</tr>
<tr>
<td>000010 d ffff f</td>
<td>Add Carry to File</td>
<td>ADDCF f, d</td>
<td>BTFS 3, 0</td>
<td>Z</td>
</tr>
<tr>
<td>000010 d ffff f</td>
<td>Subtract Carry from File</td>
<td>SUBCF f,d</td>
<td>BTFS 3, 1</td>
<td>Z</td>
</tr>
<tr>
<td>010000 1 00011</td>
<td>Add Digit Carry to File</td>
<td>ADDDCF f,d</td>
<td>BTFS 3, 1</td>
<td>Z</td>
</tr>
<tr>
<td>010000 1 00011</td>
<td>Subtract Digit Carry from File</td>
<td>SUBDCF f,d</td>
<td>BTFS 3, 1</td>
<td>Z</td>
</tr>
<tr>
<td>011000 1 00011</td>
<td>Branch</td>
<td>BK</td>
<td>GO TO K</td>
<td>—</td>
</tr>
<tr>
<td>0110 00000011</td>
<td>Branch on Carry</td>
<td>BC K</td>
<td>BTFS 3, 0</td>
<td>—</td>
</tr>
<tr>
<td>001010 d ffff f</td>
<td>Branch on No Carry</td>
<td>BNC K</td>
<td>BTFS 3, 0</td>
<td>—</td>
</tr>
<tr>
<td>0111 00000011</td>
<td>Branch on No Carry</td>
<td>BNC K</td>
<td>BTFS 3, 0</td>
<td>—</td>
</tr>
<tr>
<td>0111 00000011</td>
<td>Branch on No Carry</td>
<td>BNC K</td>
<td>BTFS 3, 0</td>
<td>—</td>
</tr>
<tr>
<td>0110 00000111</td>
<td>Branch on Digit Carry</td>
<td>BDC K</td>
<td>BTFS 3, 1</td>
<td>—</td>
</tr>
<tr>
<td>0110 00000111</td>
<td>Branch on No Digit Carry</td>
<td>BNDC K</td>
<td>BTFS 3, 1</td>
<td>—</td>
</tr>
<tr>
<td>0110 01000011</td>
<td>Branch on Zero</td>
<td>BZ K</td>
<td>BTFS 3, 2</td>
<td>—</td>
</tr>
<tr>
<td>0111 01000011</td>
<td>Branch on No Zero</td>
<td>BNZ K</td>
<td>BTFS 3, 2</td>
<td>—</td>
</tr>
</tbody>
</table>

if x = 0, address is in page 0.
if x = 1, address is in page 1.

4. **The PIC-1650 assembler** can count on these additional commands to simplify substantially programming operations. All these commands are just special cases that merely extend the normal instruction set, as can be readily seen by examining the equivalent mnemonic codes in the "Equivalent Operations" column.
5. Using the PIC-1650 to form a successive-approximation a/d converter simply requires a comparator and resistor ladder network (a). The flow chart for the conversion uses a test word that is shifted right one position every time another bit in the converter's output is filled in (b). Written with the help of the assembler, the program necessary to perform the 8-bit a/d conversion requires just over a dozen instructions (c).
To perform a successive-approximation a/d conversion, the system must be programmed according to the flow chart outlined in Fig. 5b. First, set the most significant bit of the output word equal to ONE, then determine whether this word has an equivalent analog value greater or smaller than the analog value being input. If the test bit gives a word that is smaller than the analog value, the bit remains set. If the word is bigger than the analog value, it is cleared, and the next most significant bit is set and tested—and so on until all eight bits have been determined.

The entire program for digitizing is shown in Fig. 5c. Each bit is tested by means of a utility register (F₅), which is initially set to 10000000. The set bit corresponds to the bit under test. After it is tested, the contents of the register are shifted right one position, and the next bit position is tested. When the set bit drops out of the utility register into the carry bit, the conversion is complete.

Each bit is tested in the following manner: The contents of the utility register are added to the output register and a comparison made between the incoming analog signal and the output of the ladder network.

In the conversion program, the first three instructions initialize the PIC-1650 (all instructions are numbered in octal). Instruction 0 sets pin 0 of file control register 6 (called CONTL, COMPIN in the program). This operation is necessary whenever an I/O register is used as an input. If the output were set to 0, the I/O pin would be held at ground by the output latch, regardless of the input value. (This provides a wire-AND capability.)

Instruction 1 sets the contents of register 5 equal to zero, which initializes the trial digitized value. The carry flag, which in this program is used to indicate the end of conversion, is cleared by instruction 2, a Bit Clear command to set bit 0 in register 3 to 0.

Instruction 3 loads the literal 10000000 into the working register and instruction 4 transfers it from the register into a utility register (F₅) where it will be manipulated by a rotate operation. (Any of the available general-purpose registers, F₅ through F₃¹, could have been selected.)

Before testing the first bit, instruction 5 reads the contents of the utility register back into the working register. The next command adds the contents of the working register to the output register and leaves the result in the output register. A destination-designator bit, d, specifies where the result of this operation will be stored. When it is set to ONE, the result is returned to the file register specified in the instruction. When the bit is set to ZERO, the result remains in the working register. If the d operand is omitted in the assembler, the result is left in the file register.

Instruction 7 takes advantage of the bit-handling capabilities of the PIC-1650 by testing the comparator's output through an examination of bit 0 in register 6. If the comparator output is ONE, the bit under test remains set, and the next instruction, a GOTO command, is executed to direct the program flow to instruction 12. If the comparator's output is ZERO, the digitized output is greater than the analog signal to be digitized and the program skips to instruction 11, which resets the test bit.

Instruction 11 does the resetting by subtracting the contents of the utility register from the output register. Since the utility-register contents were loaded into the working register in instruction 5, instruction XORWF performs an Exclusive-OR operation between file register 5 (the output register) and the working register, and leaves the result in the output register (the destination designator bit is set to ONE). The XORWF instruction was used instead of SUBWF, the subtraction command, since the latter would set the carry bit in two's complement arithmetic and would then require an extra clear instruction for the carry bit.

Now the program is ready to test the next bit. In preparation, the contents of the utility register are shifted right one place through the carry bit by means of the Rotate Right command (RRF). Instruction 13 and 14 prepare to finish the conversion program by first checking to see if the carry bit is set. If the bit is not set, the program branches back to instruction 5. If the bit is set, the program is finished and instruction 15 is executed, which returns program control back to a master program.

The a/d-conversion example makes use of direct program addressing. However, the PIC-1650 also has an indirect-addressing capability that can be useful in multidigit display multiplexing and other applications. For indirect addressing, the F₆ register must be called; thus, the next instruction will be carried out with the F₆ register as the address pointer.

The file-select register can be used as any of the other registers, except that the three most-significant bits are always set to ONE. For display scanning, the data for each digit or pair of digits could be stored in consecutive locations that aren’t addressed directly, but are pointed to by the address stored in the file-select register.

Two special instructions, DECSZ and INCFSZ (Decrement and skip if zero, and Increment and skip if zero), help keep timing loops short by performing two instructions in the space of one. Also available is a swap instruction (SWAPF), which permits decimal operations to take place by swapping 4-bit sections of the file registers.

Two other important features, the bit set and test operations, are especially useful when used in conjunction with electromechanical operations such as switch closures. The instruction SPO contains operations that can clear a bit, set a bit, skip if the bit is cleared, and skip if the bit is set. When a switch is polled to detect its state, the bit test or skip instructions can divert the program flow. Or, in the case of setting a bit, the processor can be used to turn on a relay, lamp or display segment.
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In a conventional mini or microcomputer system (Fig. 1a) the central processing unit (CPU) interacts with peripheral units (PUs) through a peripheral controller (PC). But because µPs are so inexpensive, they can be used in PCs as well as in CPUs. For example, µP_p is part of the PC in Fig. 1b. This µP works as a controller, by executing a program stored in its own memory, and controlling the peripheral through its I/O ports. The central processor, µP_c, sends data and I/O commands over a data bus to µP_p, which responds by transmitting its status, and data if any are ready. However, the architecture of Fig. 1b suffers at least two serious drawbacks: Memory overhead costs are doubled, and the communication between µP_p and µP_c is complex and time-consuming.

An improved multiprocessing architecture (Fig. 1c), well-known but still not widely used, solves a number of problems. The memory bus serves also as a direct-memory-access (DMA) channel (Fig. 2). The smart PC units execute programs stored in central memory rather than locally. And the system's throughput can be increased by attaching a second "central processor" to the same bus.

In such a multi-microprocessor system, one µP, for instance, can take care of data manipulation or arithmetic functions, while the other one controls the system's I/O. The number of central processors and allocation of tasks depends on the system's purpose, characteristics, and peripheral units.

Division of labor helps

The tasks to be performed by a system don't depend on how the system is implemented. Before µPs became popular, intelligence was usually concentrated in the central processor, which not only manipulated data but also controlled the I/O devices step-by-step because the peripherals were dumb.

In the architecture of Fig. 2, however, intelligence is distributed, and the expression "central processor" is incorrect, unless it's applied to the µP responsible for data handling and task scheduling. The others µPs are assigned dedicated tasks like file processing, floppy disc control or data transmission.

The data-manipulating processor works on data located in central memory. But when new data are needed, or results must be recorded, the I/O-control

---

Kalman Rozsa, Senior Engineer, Facit AB, Data Products Development Dept., Stockholm, Sweden
processor is awakened and manages the data flow to or from I/O devices. This processor either directly controls slow peripherals, or tells a PC unit what to do by assembling an I/O command. The \( \mu \)P in the PC unit then acts as a controller and handles the peripheral device on the character or bit level.

**Processors communicate by mail**

The central memory not only provides program and data storage, but also serves as the communications link between the microprocessors. An assigned part of the memory becomes the "mailbox" where the sending processor places information. The receiving processor then executes the task specified by the message in the mailbox. When the task is completed, the receiving processor responds by leaving a new message.

The simplest way to initiate \( \mu \)P operation is by **polling**. The receiving \( \mu \)P looks at a mailbox flag, which is either a hardware device (flip-flop) or the content of a memory location. Polling works well if there aren't too many \( \mu \)Ps, or if only one of them may initiate an action. But you can get higher efficiency if any \( \mu \)P is allowed to activate any other. For this method, the software must be able to manage priority among processors, as well as multiple requests and queue handling.

The hardware naturally gets to be more complex in this system. Interrupts, though not always desirable, are commonly used to notify the receiving \( \mu \)P that the mailbox contains a message. Several interrupt levels with various priorities must be reserved for interprocessor communication. The microprocessors form a matrix: If \( N \) is the number of processors, in theory every \( \mu \)P must have \( N-1 \) interrupt levels required is lower.

The processors' ability to prompt each other improves the system's throughput substantially. For example, the contents of a CRT display can be printed out while a file-searching program is in progress. A star or matrix configuration describes the \( \mu \)Ps' behavior and the logical data flow. Physically, however, every \( \mu \)P is connected to a common bus.

How many \( \mu \)Ps can work together effectively in a multimicroprocessor system, intelligence is distributed, but one \( \mu \)P is assigned to task scheduling. Peripherals are grouped by speed and complexity.
5. The functioning of the memory controller is easier to understand when you bypass the priority logic.

6. With priority logic disregarded (Fig. 5), every μP is connected to central memory with two rows of gates (one gate for each line), and an 8-bit latch.

7. During a read operation, the ATM signal gates the data into a latch because the DBIN signal is too late.

8. Data are written into memory under the control of the DTM signal, which occurs when both address and data are valid.

The memory bus combines a data bus, address bus and control bus. The data bus is a two-way, 8-bit-wide data path, but the width of the address bus depends on the size and configuration of the memory. While the number of address lines usually equals the number of address bits, it can be lower or higher. Thus, the addressable memory is virtually unlimited. In Fig. 3, both \( \mu P_A \) and \( \mu P_B \) access 64 kbytes of memory but only their lower halves (memory A+B) overlap. This part holds the common data areas as well as the mailbox. Memories A and B are accessible only by \( \mu P_A \) or \( \mu P_B \), respectively, and they serve as their program or data storage. A wider address bus not only provides access to a larger memory, it also allows protected areas, accessible to only one \( \mu P \).

The control bus synchronizes the data flow between memory and processors. Since there is only one memory bus, the processors must obey certain rules when accessing the memory. Each \( \mu P \) is provided with four signals which control when a \( \mu P \):
1. Must put an address on the address bus (ATM, address to memory),
2. Fetch data from the data bus (DFM, data from memory),
3. Gate out data onto the data bus (DTM, data to memory),
4. Suspend the data bus's activity when the memory bus is busy filling requests from a higher-priority device (RDY goes low).

The control signals are derived from the microprocessors' status signals. The memory-controller network interprets the status signals as memory-access requests and synchronizes the data flow by generating \( \text{ATM}_n, \text{DFM}_n, \text{DTM}_n \), and \( \text{RDY}_n \) (Fig. 4). The suffix \( n \) identifies the \( \mu P \).

If two devices request a memory bus operation at
the same time, the device with higher priority gets immediate service while the other one has to wait. So, analyze your needs thoroughly before you assign priority to different processors.

Priority can be variable or fixed. Variable priority is either "rotating," or assigned by hardware or software in some other way. Fixed priority is easiest to implement, but in some cases more complex arrangements are necessary. A very fast device like a rigid disc requires the highest priority, but only while reading or writing. Head positioning, on the other hand, doesn't depend on immediate memory response, and deserves only low priority.

Very high priority can be used to disable all the other devices. If the read circuits in the disk controller are directly connected to the memory bus under top priority, you can achieve very high transfer rates, up to 2 Mbytes per second.

An 8080-based system

Intel's 8080A is not really designed for multiprocessing, but by adding a few circuits you can design very powerful architectures with it. While other µPs are better suited for multiprocessing systems, the 8080A's availability and low price often outweight its drawbacks.

While neither task allocation nor communication between µPs depends on the µP model used, you should choose a µP with a suitable number of interrupt levels to avoid complex interrupt-handling hardware outside the µP. The 8080A's interrupt handling capability is fairly good, though some third-generation µP's are better. Communication between µP and memory, on the other hand, is very device dependent, and warrants thorough analysis.

The most crucial part of any multiprocessing system is the memory controller. Its performance must be matched to the system's purpose, speed and projected cost. Usually, it is built from random TTL circuits and some MSI circuits.

The memory controller's main purpose is to time-multiplex the memory bus, making the memory available to all µPs. Time-multiplexing is done by defining one machine state (clock cycle) as the memory-access cycle, and assigning it to a µP that asks to write or read.

The memory controller contains three blocks: read/write request logic, priority logic, and memory-bus control logic. The R/W request logic interprets the µP's status and generates three signals: RREQ (Read request), WREQ (Write request) and WREQD (Write request delayed).

The memory-bus control logic contains latches and a few gates; it distributes the memory bus control signals to the three-state gates that isolate the µP from the memory bus. Assume for the moment a single-µP system which doesn't need priority logic (Fig. 5).

Fig. 7 illustrates the timing of a read operation. The ATM signal gates the address onto the address bus and data is clocked into a latch by DFM's trailing edge. The latch is necessary because the µP's DBIN signal occurs somewhat later. Fig. 8 shows how data to be written pass the DTM gate. The gates are standard three-state bus drivers and the 8-bit latch is an 8212 with three-state output.

Priority logic allows several µPs to share the same memory bus (Fig. 9). It collects the request signals, determines the highest priority, outputs ATM, DFM or DTM to the selected µP, and stops the others by setting RDY, low. In the solution for three processors shown in Fig. 9, µP1 has the highest priority and µP3 the lowest. The timing is shown in Fig. 10.
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Choosing a scope to measure time? Look at some relative pulse-width and delay measurements, and you’ll see that wider bandwidth doesn’t necessarily mean better results.

When you select an oscilloscope to make time-interval measurements, don’t just look for the scope with the widest bandwidth you can afford. Although bandwidth is related to time-interval accuracy, larger bandwidth doesn’t necessarily mean more accuracy.

The need to measure time intervals at varying duty cycles and with different logic families places increasing emphasis on resolution and accuracy. Obviously, the more reliable the timing measurements, the faster or more reliable the end system.

Know your scope’s limitations

Bandwidth is certainly a major source of scope errors in timing measurements. But so is time-base accuracy. When rise and fall are considerably slower than a scope’s response, errors are negligible and determined primarily by the time base, usually 3 to 6% for standard scopes, 1% for delta-time units and about 0.002% for a time-interval-counter scope. As the transition times approach the scope’s response time, however, errors begin to creep in. But to what degree?

Luckily, scopes tend to have many very-high-frequency poles, with the dominant ones determined by the CRT deflection amplifiers. Therefore, a scope can be approximated by a shunt-peaked amplifier. The time-interval accuracy achievable with, say, a 100-MHz unit can be analyzed, along with its induced distortion, with an exponential input signal having different fall and rise times (see box). With that signal, it is easy to vary the transition times, and—as shown by the scope’s amplitude response derived in the box—the mathematics is simplified.

To compute the time-interval error of a 100-MHz scope when measuring pulse width, use a pulse with a fixed rise time and a fall time that can be adjusted from one to 10 times the rise time. Select leading-edge rise times corresponding to major logic families: ECL pulse $t_r$ is 2 ns, so $t_r$ varies from 2 to 20 ns; Schottky TTL (STTL) pulse $t_r$ is 4 ns, so $t_r$ varies from 4 to 40 ns; and low-power Schottky (LPSTTL) rise time is 7 ns, so fall time varies from 7 to 70 ns.

Now compare the actual interval of the input signal.

Walt Fischer, Oscilloscope Engineering Manager, Hewlett-Packard, P.O. Box 2197, Garden of the Gods Rd., Colorado Springs, CO 80901.
Analyzing the oscilloscope as a shunt-peaked amplifier

\[ i_m = \frac{1}{C} \cdot \frac{s + \frac{R}{L}}{s^2 + s \frac{R}{L} + \frac{1}{LC}} \ \text{and} \ \gamma = \frac{1}{\gamma} \cdot \frac{1}{s(s+\gamma)} \]

If \( K = R \),

\[ Z(s) = \frac{1}{C} \cdot \frac{s + \frac{K^2}{\tau_0}}{s^2 + s \frac{K^2}{\tau_0} + \frac{K^2}{\tau_0^2}} \]

\[ e_o(s) = i(s) \cdot Z(s) = \frac{1}{C} \cdot \frac{(s+\frac{K^2}{\tau_0})}{s(s+\gamma)} \]

If \( a_o = \frac{K^2}{\tau_0}, \alpha = \frac{K^2}{2\tau_0} \),

\[ \gamma = \frac{1}{\tau_5}, \quad \beta = \frac{2}{\tau_0}, \quad \beta = \frac{K^2}{2\tau_0} \sqrt{\frac{4}{K^2} - 1} \]

\[ e_o(s) = \frac{\gamma}{C} \cdot \frac{s + a_o}{[(s+a)^2 + \beta^2]} \cdot s(s+\gamma) \]

If \( K<2 \),

\[ e(t) = \frac{1}{C\tau_5} \left\{ \frac{a_o}{\beta} + \frac{\gamma - a_o}{\beta} \frac{e^{-\gamma t}}{\gamma - \gamma^2 + \beta^2} \right\} \]

\[ \frac{1}{\beta^2} \left[ \frac{(a_o-\alpha)^2 + \beta^2}{(\gamma-\alpha)^2 + \beta^2} \right] e^{-\alpha t} \sin(\beta t + \psi) \]

\[ \psi = \tan^{-1} \frac{\beta}{a_o-\alpha} - \tan^{-1} \frac{\beta}{\gamma - \alpha} - \tan^{-1} \frac{\beta}{-\alpha} \]

---

2. **Errors contributed by a scope's** time base depend on the time interval being measured. Accounting for bandwidth adds more inaccuracy.

How the 100-MHz scope stacks up

Measurements made at the 50% points are within ±150 ps for ECL 10 k and STTL and within ±100 ps for LPSTTL and slower logic families, TTL and MOS. And, if the rise and fall times differ by less than 5:1, the 100-MHz unit can achieve an accuracy of ±100 ps on ECL 10 k and STTL as well as LPSTTL.

Since most devices and pulse widths are specified at the 50% points, the 100-MHz scope is entirely satisfactory for timing measurements in logic families up to and including ECL 10 k, and offers accuracies better than ±200 ps (Fig. 2). But compare time-base errors, and you'll see that if bandwidth is considered for the 100-MHz scope, you must add 200 ps for ECL 10 k and STTL and 100 ps for LPSTTL (Fig. 3).

Figs. 2 and 3 compare pulse-width measurements on ECL 10 k with bandwidth limitations for 500, 200 and 100-MHz scopes. The 500 and 200-MHz instruments, using an analog time base, provide delta-time measurements while the 100-MHz scope offers a time-interval averaging counter that ties measurement accuracy and resolution to a crystal oscillator.

So what good is a wide bandwidth? In general, it provides more fidelity—an important for viewing unwanted narrow pulses and glitches. Obviously, a 1-ns-
3. **When bandwidth errors are added** to time-base errors, and intervals are taken at the 50% points, add errors of 50, 150 and 200 ps, respectively, for curves a, b and c.

4. **See how two scopes of different bandwidths** respond to identical pulses generated on ECL-driven, open transmission lines of 15.2 cm (a) and 45.7 cm (b). The response for a 500-MHz scope is shown on the left, while that for a 100-MHz unit is on the right. Sweep speed is 5 ns/div.

**Looking at impulses**

Most narrow impulses come from system reflections created by poor or unterminated coaxial or printed-circuit connections. See what happens when an ECL gate drives two open, printed-circuit traces, one 15.2 cm (6 in.) long and the other 45.7 cm (18 in.) long. The waveforms are shown in Fig. 4.

The 15.2-cm trace should show a reflection approximately 2 ns after the gate output starts to rise. Because the rise is slew-rate-limited, the reflection returns while the gate output is still rising. The result is a slight slope error on both the 500 and 100-MHz (text continued on page 82)
5. Although an impulse shows up a bit larger on a 500-MHz scope (left) than it does on a 100-MHz unit (right), the latter's display is good enough for many purposes. Here an ECL 10 k gate drives a shorted transmission line.

6. Bandwidth isn't always crucial for pulse measurements. 500-MHz displays (left) are of the narrowest impulse responded to by (top to bottom) ECL 10 k, STTL and LPSTTL. 100-MHz scope photos are at right.
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(continued from page 80)

displays. With the 45.7-cm trace, the reflection should occur approximately 6 ns after the gate output starts to rise, and produce a step on the leading edge.

The step is more pronounced on the 500-MHz scope, but the 100-MHz unit, if nothing else, shows that a reflection exists. Notice that the interval between the 10% and 90% points is close enough to indicate the relative delay of the pulse top caused by the reflection.

With a 45.7-cm open trace driven by an STTL gate, the displayed differences between the 100 and 500-MHz scopes are very small. Even if a short impulse were to be generated, the slew rate of the logic limits the amplitude. The resultant distortion, even with ECL 10 k, can be viewed adequately with a 100-MHz scope.

Now consider the shortest impulse that can be generated and still have enough amplitude to pass through the ECL 10 k threshold. The 100-MHz display, even with less amplitude than the 500-MHz, adequately shows the impulse and certainly calls attention to a potential problem (Fig. 5).

**The narrowest observable pulse**

To determine a minimum pulse width, rule-of-thumb says to note the transition time of the fastest logic family in your system and increase that number by 100%. For example, ECL 10 k's rise time is approximately 2 ns; therefore, it can generate 4-ns impulses—large enough to pass through the threshold levels of other 10 k components in the system.

Keep in mind that this rule-of-thumb is for minimal output loading, that is, fanouts of one or two. As the fanout increases to four or six, the transition times can increase to 3 or 4 ns for minimum pulse widths as wide as 6 to 8 ns.

To determine if a logic family can respond to a very narrow input pulse, consider an ECL 10 k gate, which acts as a slew-rate-limited linear amplifier when driven by signals that last only a few nanoseconds.

As the input pulse width is varied, the output passes through the threshold level when the input gets to be 3 to 4 ns wide, or approximately twice the transition time.

Therefore, the answers to “Can a system generate extremely narrow impulses?” and “Will the logic family respond?” revolve around the transition-time specifications of the fastest logic family in your system. With ECL 10 k, you will observe impulses of 3 to 4 ns, with STTL, impulses of 4 to 5 ns, and so on.

Trace photos taken on 100 and 500-MHz scopes show displays of ECL 10 k, STTL and LPSTTL impulses for each scope (Fig. 6). The differences in the photos between each scope are so small, you should ask yourself: Is wider bandwidth really worth the additional cost?
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CIRCLE NUMBER 241
The bandwidth of phase-lock loops for synchronous data transmission should first be wide, then narrow. Solve the dilemma with a modified loop.

If you want to recover the timing signal in synchronous data systems with a phase-lock loop (PLL), you need a filter bandwidth around 10 Hz for good noise rejection. But in the search mode the filter must be wide enough to accommodate the pulling characteristics of the oscillator crystal. This sounds contradictory, but there are three ways to do it:

1. Divide both the input frequency and VCO output-frequency by N, ahead of the phase comparator (see box for PLL basics). This method reduces noise bandwidth by a factor of N, and increases the lock range by the same factor. Unfortunately, it also multiplies the steady-state error by N, and the acquisition time by N², which may be unacceptable.

2. Replace the phase comparator by a phase-frequency comparator that gives different steady-state outputs for input frequencies below, above, and equal to the VCO frequency. However, phase-frequency comparators using digital gates fail to operate satisfactorily if some of the input transitions are missing — i.e., when the input consists of random data. Only very complicated phase-frequency comparators operate satisfactorily with random data.

3. Use variable bandwidth PLLs implemented by digital gates. The normal loop bandwidth is extremely narrow; but once out-of-lock condition is detected, the bandwidth can be made large to help lock the loop as quickly as possible.

The best of both worlds

To implement the third—and preferred—alternative, you can use a voltage-controlled crystal oscillator, designed to recover the clock signal from a random PCM data channel. To operate properly, the circuit has to meet the following criteria:

- The input data rate must be within the lock-in range of the loop. The filter bandwidth should be large enough so that the lock-in range is essentially determined by the pulling characteristics of the crystal and its associated circuitry.
- The input signal must contain a sufficient number of data transitions per second.

The input data must be return-to-zero binary. The oscillator and the integrator filter are designed conventionally. A crystal oscillator is shown in Fig. 1, but an LC oscillator of the same frequency can be used instead. The PLL performance is determined by the loop bandwidth and not by the crystal characteristics.

In Fig. 2, the phase detector operates under steady state conditions. As long as the data input is ZERO, there is no output from the phase detector. When the input is one, gate output A goes high while output B goes low. So the input to the filter is a doublet of current pulses (Fig. 3).

If you ignore component variations and assume the gates' LOW voltage to be ZERO, then the amplitude of the current pulse is given by

\[ I = \frac{V/2 - V_d}{R} \]

1. A practical PLL circuit uses a crystal-controlled VCO that is fed by a phase comparator and filter. The active filter's bandwidth remains constant.
2. A phase detector's output is determined by the status of the NAND gates. The currents are measured at points A and B in Fig. 1 before they are combined.

3. The output current from the phase detector is an asymmetrical doublet composed of a symmetrical doublet and a variable pulse (a). Within the filter's bandwidth, the spectrum of the pulse contributes most of the power.

---

**Loop circuit fundamentals**

The basic schematic of a second-order phase lock loop contains a phase comparator, an active filter, and a voltage controlled crystal oscillator. The first basic loop equation is the transfer function:

\[ H(s) = \frac{\theta_i(s)}{\theta_o(s)} = \frac{\omega_n^2}{s^2 + 2\rho\omega_n s + \omega_n^2} \]  

where \( \omega_n \) is the natural frequency and \( \rho \) is the damping factor of the loop. Furthermore,

\[ \omega_n^2 = K_o \cdot K_v \cdot f \]  
\[ \rho = \frac{\tau_2 \cdot \omega_n}{2} \]  
\[ \tau_1 = R_1 \cdot C_1 \text{, and} \]  
\[ \tau_2 = R_2 \cdot C \]  

The steady phase error

\[ \theta_o = \theta_i - \theta_o = \Delta \omega / K_v \]  

where \( \Delta \omega \) is the difference between input frequency, \( f_i \), and the free-running frequency, \( f_0 \), of the local oscillator, and \( K_v = A \cdot K_o \cdot K_v \) is the dc gain of the loop.

A fundamental loop parameter is the noise bandwidth. If the input to the loop has phase noise of uniform density \( \Phi \), then the output noise power for that input is given by

\[ e_{no}^2 = \frac{\Phi \cdot \alpha}{2 \pi} \int_{-\omega_n}^{\omega_n} |H(\omega)|^2 d\omega \]  

The integral in the equation is defined as the noise bandwidth \( B \) of the loop:

\[ B = \frac{1}{2 \pi} \int_{-\omega_n}^{\omega_n} |H(\omega)|^2 d\omega \]  

The value chosen for \( \rho \) is usually from 0.5 to 1 to ensure good transient behavior of the loop.

Another parameter, equally important, is the lock-in range, given by:

\[ \Delta \omega_L = 2 \rho \omega_n \]  

The lock range indicates the largest difference permitted between \( f_i \) and \( f_0 \), at which the loop will lock-in rapidly. Equations 4 and 5 show conflicting requirements: For a wide lock-in range, \( \omega_n \) should be large; on the other hand it should be small for maximum rejection of input jitter.

The problem in designing a phase-lock loop, then, is to keep the noise bandwidth as small as possible, yet maintain a wide lock-in range for the loop.
4. A modified PLL circuit controls the VCO through a new gate and filter (highlighted area). The original gates and

where V is the gate supply voltage for gate B, V_d is the diode forward drop, and R is the current-determining resistance.

Normally, the clock transitions should be in the middle of a pulse. If \( \tau \) is the length of the input pulse, and \( \Delta \) the steady-state time deviation from nominal, then the positive current pulse lasts for \( \tau/2-\Delta \), and the negative pulse \( \tau/2+\Delta \).

You can interpret the asymmetrical doublet to be a symmetrical doublet plus a narrow unipolar pulse with duration \( \Delta \) and amplitude 2I. These narrow pulses produce the correction voltage that maintains lock. Proper servo operation requires that

\[ \tau = K_i T, \quad K_i < 1, \]

where

\[ T = \frac{1}{f_i}, \]

and

\[ f_i = \text{the data bit rate}. \]

Thus, return-to-zero (RZ) data are needed. If the input data are nonreturn-to-zero (NRZ), they must be converted to RZ by generating a pulse of duration \( \tau \) for every data transition, because NRZ data contain no timing information.

Reducing the phase error

To predict the steady-state phase error, you first must convert the phase computation \( (\theta_e = \theta_i - \theta_0) \) to time:

\[ \Delta = \frac{T \Delta \omega}{2\pi p K_v} \]

where \( p \) is the probability that ONEs occur.

You can make the phase error as small as you want by increasing \( K_v \). The equation for \( \Delta \) also shows that the phase error is inversely proportional to the proba-
Table 1. Performance of three clock extraction circuits

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Resonant circuit*</th>
<th>Conventional PLL</th>
<th>Modified PLL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Realizable Q</td>
<td>100</td>
<td>1500</td>
<td>&gt;15,000</td>
</tr>
<tr>
<td>Noise BW</td>
<td>15 kHz</td>
<td>1 kHz</td>
<td>&lt;0.1 kHz</td>
</tr>
<tr>
<td>Steady state error</td>
<td>12°</td>
<td>≈0</td>
<td>≈0</td>
</tr>
<tr>
<td>Long term stability</td>
<td>0.5%</td>
<td>Excellent</td>
<td>Excellent</td>
</tr>
<tr>
<td>Necessity for manual alignment</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>during manufacturing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shop cost</td>
<td>$5</td>
<td>$6</td>
<td>$7.50</td>
</tr>
</tbody>
</table>

*Mistuned by 0.1%

bility of transitions in the input data. If you use an op amp for the integrator, the phase error has to supply only the bias current of the op amp. If the input data were periodic, the power spectrum at the filter output would consist of only discrete lines, namely the harmonics of the bit rate. Random data, however, produce a continuous power spectrum in addition to the discrete lines.

You can separate the continuous spectrum into a component produced by the symmetrical doublet, and one by the unipolar pulses of width $\Delta$. The doublet has very little energy in the passband of the loop filter; the output jitter of the PLL is primarily caused by the low-frequency power in the spectrum due to the time error, $\Delta = K_2 T$.

Over the bandwidth $B$, the input spectrum is nearly uniform and is proportional to $K_2^2 / f_r$. The output noise is given by

$$e_{no}^2 \approx \frac{K_2^2}{f_r} B \alpha \frac{K_2^2}{Q_e}$$

Variable $Q_e$ is the "quality factor" of the loop: $Q_e = \frac{f_r}{B}$.

The output noise, or jitter, originates from:

1. The randomness of the input data; you can reduce the effect of this source by making $\Delta$ very small.
2. Modulation of the input phase, hence of $\Delta$, due to input timing-jitter; eliminate noise from this source by reducing the noise bandwidth of the loop.

The modified PLL circuit (Fig. 4) has a bandwidth that is wide when out-of-lock, but drastically reduced after lock-in. Two phase detectors and filters operate in parallel: Phase detector 1 senses only the in-lock condition. Phase detector 2, inside the loop, has an associated filter with two time constants, determined by $C$ and $C_1$. Capacitor $C_1$ is switched into the circuit by FET $Q_2$ only when the loop is locked in.

Should phase lock be lost, the output of the first filter amplifier is designed to swing from extreme positive to extreme negative. As soon as the output is positive, transistor $Q_1$ switches on quickly to turn $Q_2$ off. When the lock is regained, the amplifier output is negative and $Q_2$ is switched off slowly because of the large time constant $R_3 C_1$.

Balancing the loop

Except for $C_1$ and its associated circuitry, the two phase detectors and the filters are identical. You may have to adjust one of the current-setting resistors, $R_1$, to compensate for bias-current differences in the two op amps.

The time constants of the loop filter may be changed either by adding resistance in series with $R_1$, or capacitance in parallel with $C$. But adding resistance will increase the phase error for any given amplifier bias current. Adding capacitance leads to redistribution of charges in the integrator. But, because the capacitor is switched in very slowly through a FET acting like a time-varying resistor, this should not cause any problems.

Under steady-state conditions, the signal-to-noise ratio at the output of the loop is determined by the input $S/N$, reduced by the loop bandwidth (which can be as small as you want). However, when the input noise is very large and at low frequencies, the output of the monitoring phase detector may become positive, and switch off $C_1$. This will cause sudden output jitter increase, and require a divider chain in front of the phase comparator to reduce the jitter.

To see whether the modified PLL method is worth the trouble, a comparison of three clock extraction methods is made in Table 1, which assumes an input bit rate of 1544 ±0.25 kb/s, and a required lock range of 300 b/s. "Shop cost" includes hardware (using only commercially available components), and manual alignment for the resonant circuit.

Although $Q$ should be large to minimize noise power, resonant circuits can only realize a Q of 70 to 100. Regular PLLs surpass even the best resonant circuit by a factor of 15, and a modified PLL is superior by at least another order of magnitude. The same ratios are reflected in the noise bandwidth.

References

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Modulo-N counter speed

is limited by the counter module's propagation delays. But asymmetrical clock inputs can raise the speed substantially.

Because the modulo-N counter has many uses, learning how to push its operating frequency to the maximum can return dividends. The modulo-N counter is found in such important applications as frequency synthesizers, phase-lock loops and many logic-system timing circuits.

Although a bidirectional synchronous counter such as a 74193 has a typical maximum count-frequency rating of 32 MHz, in a modulo-N circuit the frequency is no better than about one-fifth of this value. But you can break through this limitation by using asymmetrical clock inputs.

Modulo-N circuit revisited

In a simplified modulo-N counter (Fig. 1a), the input clock causes the 74193 modules to count down, toward zero. When zero is reached, a borrow pulse propagates to the last module's borrow output on the negative-going edge of the clock. The borrow pulse then loads the counters with the number N from the data-input bus, and the cycle repeats. The over-all result is an output pulse train of narrow, negative spikes occurring at a frequency of 1/N times the input clock.

Note in the timing-diagram sequence (Fig. 1b) for a single-stage modulo-3 counter that the loading operation quickly resets the borrow pulse to form a sharp spike. However, this simplified timing sequence doesn't contain the information that can tell you the speed limitations of Fig. 1a. The propagation delays detailed in Table 1 must be taken into account. Note the wide spread of delays an individual 74193 counter unit can have.

To determine maximum operating frequency for a symmetrical input clock, examine the negative-going portion of the clock pulse that generates a borrow/load signal. Fig. 2 shows a two-module counter with a set of worst-case propagation delays.

For a counter to perform reliably, the circuit must provide a minimum 20 ns between the trailing edges of the load and a clock signal. The minimum $T_N$ is $(24 + 24 + 55 + 20)$, or 123 ns. Therefore, for a symmetrical clock signal, the total clock period is 246 ns, which corresponds to a maximum operating frequency of 4.07 MHz. Generally, the minimum clock period for any number of counter modules is expressed by the following equation:

$$T = 2[K(T_{PCB}) + T_{PBL} + T_{LC}],$$

where

$$T = \text{Total minimum symmetrical-clock half-period.}$$
Table 1. Switching characteristics of a 74193

<table>
<thead>
<tr>
<th>Parameter</th>
<th>From input</th>
<th>To output</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>$f_{\text{max}}$ (clock)</td>
<td></td>
<td></td>
<td>25</td>
<td>32</td>
<td>50</td>
<td>MHz</td>
</tr>
<tr>
<td>$t_{\text{PLH}}$</td>
<td>Count-down</td>
<td>Borrow</td>
<td>8</td>
<td>16</td>
<td>24</td>
<td>ns</td>
</tr>
<tr>
<td>$t_{\text{PLH}}$</td>
<td>Either count</td>
<td>Q</td>
<td>13</td>
<td>25</td>
<td>38</td>
<td>ns</td>
</tr>
<tr>
<td>$t_{\text{PLH}}$</td>
<td>Load</td>
<td>Q</td>
<td>14</td>
<td>27</td>
<td>40</td>
<td>ns</td>
</tr>
<tr>
<td>$t_{\text{PLH}}$</td>
<td>QA (output)</td>
<td>Borrow</td>
<td>5</td>
<td>10</td>
<td>15</td>
<td>ns</td>
</tr>
<tr>
<td>$t_{\text{PLH}}$</td>
<td>Load</td>
<td>Borrow</td>
<td>20</td>
<td>40</td>
<td>55</td>
<td>ns</td>
</tr>
</tbody>
</table>

* $t_{\text{w}}$ (width of any input pulse): 8 15 20 ns

* $t_{\text{Lc}}$ (time between rise of load and rise of clock): 8 15 20 ns

Table 2. Maximum operating frequency of a symmetrical input clock

<table>
<thead>
<tr>
<th>Number of counter modules ($K$)</th>
<th>Maximum operating frequency (MHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Minimum delays</td>
</tr>
<tr>
<td>1</td>
<td>13.89</td>
</tr>
<tr>
<td>2</td>
<td>11.36</td>
</tr>
<tr>
<td>3</td>
<td>9.62</td>
</tr>
<tr>
<td>4</td>
<td>8.33</td>
</tr>
<tr>
<td>5</td>
<td>7.35</td>
</tr>
<tr>
<td>6</td>
<td>6.58</td>
</tr>
</tbody>
</table>

Table 3. Maximum operating frequency with 20-ns positive clock pulses

<table>
<thead>
<tr>
<th>Number of counter modules ($K$)</th>
<th>Maximum operating frequency (MHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Minimum delays</td>
</tr>
<tr>
<td>1</td>
<td>17.86</td>
</tr>
<tr>
<td>2</td>
<td>15.63</td>
</tr>
<tr>
<td>3</td>
<td>13.89</td>
</tr>
<tr>
<td>4</td>
<td>12.50</td>
</tr>
<tr>
<td>5</td>
<td>11.36</td>
</tr>
<tr>
<td>6</td>
<td>10.42</td>
</tr>
</tbody>
</table>

2. Studying the timing details of the negative clock-signal interval reveals the series of delay times that limit the counting speed of a modulo-$N$ circuit.

$K$ = Number of modules.

$T_{\text{PCB}}$ = Propagation delay, high-to-low level, of borrow output with respect to clock input signals.

$T_{\text{PLB}}$ = Propagation delay, low-to-high level, of borrow output with respect to load-input signals.

$T_{\text{LC}}$ = Minimum period between rise of load and rise of clock signals to guarantee operation.

Table 2 shows the results of solving Eq. 1 for minimum, typical and maximum values of the delays, but only the maximum-delay values can guarantee that all counter modules operate.

A test circuit for a one-module, modulo-8 divider built by this author operated properly up to an input clock rate of 13 MHz. From 13.7 to 24.8 MHz, however, the circuit consistently divided by 9. And between 13.0 and 13.7 MHz, the circuit divided by almost anything, with 11 and 15 predominating. The test was repeated for modulo-7 and achieved similar results. The 74193 used in this test apparently was faster than units classified as typical according to Tables 1 and 2.

The modulo-8 test results suggest that you can reliably operate a multimodule circuit in an $N+1$ mode at frequencies above the maximum. Unfortunately, by the time a minimum delay module starts to operate in an $N+1$ mode, Table 2 implies that another slower module would operate in an $N+2$ mode. So don’t try to operate above the values in the maximum column in Table 2 for truly reliable performance.

Another note of caution: Frequently, a symmetrical output pulse is required in modulo-$N$ applications. Obviously, you should set the data inputs to $N/2$ and feed the Borrow/Load output signal to a flip-flop. Note in Table 1, however, that the width of a borrow/load...
Table 4. Maximum operating frequency with maximum circuit delays

<table>
<thead>
<tr>
<th>Number of counter modules (K)</th>
<th>Symmetrical input</th>
<th>40-ns positive pulses</th>
<th>30-ns positive pulses</th>
<th>20-ns positive pulses</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5.05</td>
<td>7.19</td>
<td>7.30</td>
<td>7.30</td>
</tr>
<tr>
<td>2</td>
<td>4.07</td>
<td>6.14</td>
<td>6.21</td>
<td>6.21</td>
</tr>
<tr>
<td>3</td>
<td>3.70</td>
<td>5.35</td>
<td>5.41</td>
<td>5.41</td>
</tr>
<tr>
<td>4</td>
<td>3.40</td>
<td>4.74</td>
<td>4.78</td>
<td>4.78</td>
</tr>
<tr>
<td>5</td>
<td>3.14</td>
<td>4.26</td>
<td>4.29</td>
<td>4.29</td>
</tr>
<tr>
<td>6</td>
<td>2.92</td>
<td>3.86</td>
<td>3.89</td>
<td>3.89</td>
</tr>
</tbody>
</table>

A similar analysis for typical and minimum delays results in

\[ \text{T}_{\text{typ20}} = 96 + (K-1)16 \text{ (ns)} \]  \hspace{1cm} (3)

and

\[ \text{T}_{\text{min20}} = 56 + (K-1)8 \text{ (ns)} \]  \hspace{1cm} (4)

The results of applying Eqs. 2, 3, and 4 are shown in Table 3. Again, only the maximum-delay column will guarantee operation for all modules.

Clock pulses generated by a 74121 one-shot can produce pulses in the 30- to 40-ns range. If used to drive a modulo-N counter, the equations for operating with these one-shot pulse widths are as follows:

For maximum circuit delay in nanoseconds,

\[ \text{T}_{\text{max30}} = 137 + (K-1)24 \text{ (ns)} \]

\[ \text{T}_{\text{max40}} = 139 + (K-1)24 \text{ (ns)} \]

For typical circuit delays,

\[ \text{T}_{\text{typ30}} = 101 + (K-1)16 \text{ (ns)} \]

\[ \text{T}_{\text{typ40}} = 111 + (K-1)16 \text{ (ns)} \]

For minimum circuit delays,

\[ \text{T}_{\text{min30}} = 66 + (K-1)8 \text{ (ns)} \]

\[ \text{T}_{\text{min40}} = 76 + (K-1)8 \text{ (ns)} \]

Applying these equations with maximum circuit delays, you get the results summarized in Table 4. The values listed guarantee that all the modules will operate. For reliable performance at higher frequencies, you must use faster counters, such as the ECL types, or you can use logic circuits that incorporate look-ahead-borrow techniques.

References

3. Some of the specifications were furnished by Ron Natali of Texas Instruments, Stafford, TX.
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Today's increasingly sophisticated circuitry demands reliable base materials—with high electrical values, dimensional stability, and consistent performance.

This is why so many makers and users of circuit boards around the world stake their reputations on Norplex base materials. They have complete faith that quality will never vary ... will always meet, or exceed, all established specifications.

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Collect data via pulse-code modulation

in your next data-acquisition system. PCM handles bandwidths of 5 kHz, has a high s/n ratio and permits data manipulation.

In a data-acquisition system, analog signals with bandwidths below 5 kHz are often best handled with pulse-code modulation (PCM) techniques. Above 5 kHz, other ways to handle analog data, such as direct recording and frequency-modulated recording, have their own advantages, depending on the number of channels, the frequency range of the signals and the required accuracy of the recorded data.

Below 5 kHz, however, PCM offers many advantages: data are stored in digital form, thus guaranteeing accurate reproduction of recorded signals; the signal-to-noise ratio is better than 70 dB (about double that of many FM or direct recording methods); and the accuracy of recorded information is within 0.1% (about an order of magnitude better than most other methods).

PCM requires that analog signals be sampled at regular, discrete intervals and that the signal amplitudes be coded into a digital format (Fig. 1). Even though most data-acquisition applications are analog, to maintain accuracy and ease data manipulation, you are better off encoding the data digitally before recording. You also ensure that the desired signals are truly recorded and regenerated. PCM systems are typically 0.1 to 0.025% accurate—or even better, depending on the converter used.

PCM permits data manipulation

Since the data are stored digitally, a great deal of manipulation and control can be performed via digital techniques. Thus, a complete data-acquisition system, possibly microprocessor controlled, will contain the following features:

- Automatic or manual operation.
- Autoranging for analog inputs.
- Basic accuracy of at least 0.1%.
- Input capacity of at least four channels, but preferably more. (Channel capacity should be expandable.)
- Accurate timing to keep track of data.
- Incremental or continuous recording for good I/O capability.

The circuits that handle and control data flow can be broken down into four major building blocks:

1. Analog-signal handling, which includes the multiplexer.
2. Digitizing, which includes sample/hold amplifier (if used), a/d converter and autoranging circuits.
3. Addressing and timing, which includes clock and parity generation circuits.
4. Recording and transmitting, which includes the tape-drive and line drive circuitry and the motor control.

A basic data-acquisition system is outlined in Fig. 2. Many different companies offer subsystem compo-

1. Encoding an analog signal into digital form, PCM techniques provide the accuracy necessary to guarantee true reproduction of the analog signal when it’s played back. Digital encoding also permits the data to be manipulated easily for expansion or compression.

Stan Yalof, President, and Don Gregg, Principal Engineer, Tetrahedron Associates, 7605 Convoy Ct., San Diego, CA 92111.
nents such as input amplifiers, analog signal multiplexers, sample/hold amplifiers, a/d converters and digital logic, therefore the design to be discussed will only be covered in general form—specific devices must be selected by individual performance requirements.

Each input line actually consists of a signal-conditioning amplifier combined with a 2 to 12-pole aliasing filter. Each filter prevents signal components above the maximum transmission frequency (often 5 kHz) from getting through the multiplexer to form ghosts—lower-frequency signals caused by the periodic sampling of the data—that appear as real signals.

Once a signal enters the multiplexer, it is under digital control—from the channel switching of the multiplexer to the timing pulses and the parity bits used on the data words. The multiplexer connects each of the input channels, in sequence, to the sample/hold amplifier, which holds the analog signal long enough for the analog-to-digital converter to digitize the analog value.

There are several methods of formatting PCM, depending on individual objectives and available equipment—serial, parallel, two-phase and others. During formatting the data word is given its
3. Converting the analog input data to serial digital format, the input circuitry of the data-acquisition system (a) multiplexes the inputs, samples them, converts them to digital form, then serializes and encodes the data. To decode the data stored on magnetic tape, the entire recording process must be done in reverse (b).

4. One frame of digital data consists of a header to define the number of channels, the time code, a data word from each channel, and an end-of-frame indicator.

5. Organized around the data and address buses of the microprocessor-based controller, all sections of the data-acquisition system are treated as memory locations to simplify access and reduce hardware.

Automatic-ranging code label. Once labeled, the word gets a timing-address code, a parity bit and if necessary, an end-of-word label.

The entire recording process is shown in Fig. 3a. Each completed word is sent on to the recording circuitry where it is placed on tape usually in the form of flux reversals. Again, there are many ways to format data, but one way to keep the circuitry simple is to record four bits at a time and use a separate clock track for timing.

To recover the data, reverse the process

Recovering data is almost the exact reverse of recording, except that the clock is sensed to synchronize the reading of data (Fig. 3b). Flux reversals on the clock track are sensed and used to synchronize detection and storage of data on each track. If a flux reversal is sensed on a data track, a ONE is stored; if no reversal is sensed, a ZERO is stored—at least, that's the scheme used by Tetrahedron in the Data Manager data-acquisition system.

For data to be read from the tape, the gap between frames must first be sensed. This gap, just an absence of a clock signal over a short section of tape, indicates that no data are stored in that section of the tape and must be used when performing incremental recording. A frame is a complete sweep of all channels recorded on the tape, including the header, time information, channel data and end-of-frame signal (Fig. 4).

Before being passed on to the output circuits, data in each frame are examined to see if the following three questions can be answered affirmatively:

- Is parity met?
- Is the number of channels listed at the beginning the same as the number at the end?
- Is the number of clock pulses correct for the number of channels recorded?

To recover the data you want, use a frame sensor and set the control circuits to capture, say, the third word of every frame.

A microprocessor can perform the timing and control operations for both the data-recording and recovery sequences. For one possible µP-based organization, check Fig. 5. This system is bus-organized and based on a 6800 µP, which treats the I/O sections, tape recorder and front panel as memory locations. The control panel for the system (Fig. 6) is also treated as memory—the status of all switches read into the µP control module under software control and the displays that indicate time and other functions can be controlled by the processor as if they were memory locations.

A typical input board for the system contains a 16-channel multiplexer, a digitally controlled amplifier, a high-speed 12-bit a/d converter as well as the necessary gain-control logic and output registers (Fig. 7). A 74LS138, acting as an address decoder, initializes the gain to 1, selects the proper input channel, enables the output data bus and starts the a/d conversion.
With a fast a/d converter, you won't need a sample-and-hold amplifier since the signal to be converted is a relatively slow changing level compared to the a/d conversion time. The correct gain setting is the gain causing the encoded output to have a logic ONE in the most-significant-bit position (not including the sign-bit position).

Determining the correct gain usually takes two steps: First, set the gain to unity and have the a/d converter perform a conversion. Then the higher-order bits of the absolute value of the encoded output are examined by a priority encoder to determine how many binary \((\times 2)\) increases in gain are required to make the MSB a logic ONE. The gain setting on the input amplifier is changed by the required amount and the a/d converter then performs another conversion.

The output module operates in the reverse sequence—the digital data from the tape are restored to a full parallel format, then fed into a 12-bit d/a converter (Fig. 8). The converter's output, in turn, feeds a programmable-gain amplifier that provides the desired signal levels. A 74LS138 selects the proper register for accepting data, with the first byte selecting the MSBs and the scaling coefficient. This process is performed for both X and Y outputs, but not for the time scale, which has only the LSB and MSB bytes but no scaling coefficient.

**7. Handling analog inputs from microvolts to volts**, the 14-channel analog input module contains a programmable-gain amplifier, a high-speed 12-bit a/d converter and, of course, the multiplexer.
8. The analog output module contains three d/a converters, one for the X output, one for the Y drive and one for the TIME drive. The X and Y converters deliver signals to programmable-gain amplifiers.

9. Based on a 6800 µP, the controller includes all the timing and I/O circuitry that is necessary to manipulate and coordinate the various sections of the complete data-acquisition system.
10. To control a data-acquisition system, the 6800-based controller must follow a routine like this one to examine the front panel and follow the commands.

Coordinating all the functions of the data-acquisition system, the µP control section contains the control memory, the processor, the serial and parallel control lines and all the timing circuitry (Fig. 9).

A complex task becomes routine

Under ROM control, the 6800-based system performs the complex task of monitoring the front-panel controls and performing the indicated functions (Fig. 10). Each switch and display on the front panel has a unique address and can be accessed by the µP when an address is loaded onto the address bus. When a switch is accessed the setting is loaded onto the data bus for the µP to read. When addressing a display, the µP loads the contents of the data bus into the respective display register that, in turn, feeds a driver.

The system front panel should contain all controls and displays necessary for complete manual operation. On the Data Manager, the front panel is divided into three primary functions: Record, Replay and Time Search, and three secondary functions: Time Display, Offset and Time Calibrate. The Record function samples the selected number of analog input channels at the selected scan rate, autoranges the sample, digitizes the sample and records the data on tape. The signal is also reconverted into an analog signal that is available on a rear-panel jack.

The Replay function runs the magnetic tape in the direction selected, reads a block of data at the selected replay rate, tests the parity bit, and checks for an error. Then it outputs the data to the converter section for restoration to the analog form, and the time information to the time display. For the Time Search function, which is similar to the Replay, the tape is read at maximum R speed. Replay will stop when the corresponding selected stop time is read from the tape.

Additional control is supplied by the secondary functions. The Time Display shows the time word corresponding to each update of analog output signals. The time word represents the time each sample was taken, in seconds, during a Record operation. Initialization of the time to zero occurs when a Record operation is initiated, and increments occur at the selected scan rate.

To add a voltage offset to an analog signal, the Offset function performs the indicated function that is available on a rear-panel jack. The scaling also sets the reverse stop time to 0 V, and the forward stop time to between +5 and +10 V dc.

The processor section also controls the tape-unit interface. Two sets of signals are fed to the tape mechanism—the basic control sense lines and, of course, the data lines. Control signals activate the stepper motor, tension motors, solenoid and indicator lamps. Signals generated by the mechanism include status flags to the µP controller (file protect, cartridge in place, solenoid lifted, and end of tape) to help the processor in its decision-making routines.

Information can be collected, collected, and collected. But then what do you do with it? By taking advantage of PCM's high accuracy and reproducibility, data stored in one channel can be compared, scaled and compared, or reproduced at any time and compared with previously collected data without any errors. Fast or slow data can be replayed at either low or high speeds, for time expansion or compression, without sacrificing any accuracy. For example, the stress profile of a tanker ship, taken over several months, versus all pertinent collected variables can be compressed into a single graphic presentation within minutes.

References

ALL UNITRODE MAKES ARE POWER SEMICONDUCTORS.
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Unitrode makes power semiconductors. Period.
And when a company’s income relies totally on only one area of semiconductors, it better make them better than anyone else. We do.
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Take our unique PIC600 switching regulator power output circuits. A whole power circuit—already designed and built—for less than the price of its individual parts. To save you time in design, breadboarding, and debugging—as well as money.
Take our Barrier™ NPN power switching transistors. Ours give you half the fall times of conventional designs. And three times better $E_{o/f}$, with ratings up to 400V.
Take our exclusive ChipStrate™ thyristors. The revolutionary packaging concept for power SCRs and Triacs that bettered the form factor and lowered the cost. The line covers 3 to 55A and up to 800V.
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IN SEMICONDUCTORS, UNITRODE MEANS POWER.
Multilayer coil design is made easy with a programmable calculator. Not only are AWG numbers provided, but also wire material and tempco can be changed.

Multilayer coil design is laborious when done with tables, charts and complicated formulas. But now a programmable calculator like the TI-59 can handle the large number of steps needed to provide comprehensive calculations for rectangular and circular multilayer coils. Although the equations (Fig. 1) relating inductance to number of turns, dimensions, wire size, resistance and temperature are complicated, the program makes them easy to implement.

With its 795 steps, the TI-59 program can design a coil of a desired inductance, resistance or number of turns, given its dimensions. Also, the program selects the American Wire Gauge (AWG) number for the wire that will fill the coil's window and yield the maximum inductance possible for a given resistance, or the minimum resistance for a given inductance. In addition, the program can compute temperature effects on resistance and the effect of using wire materials other than copper.

The program's easy to use

To run the program, just enter the dimensions of the bobbin as in step 3 of the sequence (see table). Enter the known item—the inductance, the number of turns or the resistance—into labels A, B or C, respectively. After a few seconds the calculator displays the first of the three unknowns. The remaining answers are obtained, thereafter, by pressing R/S (steps 4a, 4b or 4c) until you have solved all the unknown parameters, including the AWG number.

Note that circular and rectangular coils have the same sequence, but rectangular calculations are performed with labels *A', *B' and *C'. And when the calculator is connected to a PC-100A printer, all values are printed and identified by name.

Furthermore, you don't have to press R/S to obtain the next answer; R/S is activated automatically as answers are printed. The program "knows" when the calculator is attached to the printer, and consequently doesn't halt after each intermediate answer. This programming sequence, which incidentally can be helpful in other TI-59 programs, is contained in steps

Sequence of operations

1. **Partition calculator**
   Enter 2 Press 2nd *Op 17 Display 799.19

2. **Load both cards:** all four sides

3. **Enter bobbin dimensions** in cm:
   Enter D$_1$ Press D Display D$_1$
   Enter D$_2$ Press 2nd *D' Display D$_2$
   Enter d Press E Display d
   (and for rectangular coils:)
   Enter D$_3$ Press 2nd *E' Display D$_3$

4a. **Enter inductance** (L) in henrys:
   For circular coils Press A
   For rectangular coils Press 2nd *A'
   **Press R/S** Display (N)
   **Press R/S** Display (AWG)
   **Press R/S** Display (OHMS)

4b. **Enter number of turns** (N):
   For circular coils Press B
   For rectangular coils Press 2nd *B'
   **Press R/S** Display (L) henrys
   **Press R/S** Display (AWG)
   **Press R/S** Display (OHMS)

4c. **Enter resistance** in ohms:
   For circular coils Press C
   For rectangular coils Press 2nd *C'
   **Press R/S** Display (AWG)
   **Press R/S** Display (N)
   **Press R/S** Display (L) henrys

**Perform automatically when used with PC-100A printer.**

---

**Program constants and codes**

<table>
<thead>
<tr>
<th>Registers</th>
<th>Contents</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0.4</td>
<td>space factor</td>
</tr>
<tr>
<td>01</td>
<td>D$_1$</td>
<td></td>
</tr>
<tr>
<td>02</td>
<td>D$_2$</td>
<td></td>
</tr>
<tr>
<td>03</td>
<td>D$_3$</td>
<td></td>
</tr>
<tr>
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</tr>
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<td>06</td>
<td>(used)</td>
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<td>07</td>
<td>1.</td>
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<td>08</td>
<td>1.724137931</td>
<td>relative resistivity of copper</td>
</tr>
<tr>
<td>09</td>
<td>0.00393</td>
<td>resistivity of copper at 20°C (µΩ-cm)</td>
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<td>20.</td>
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<tr>
<td>11</td>
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<td>12</td>
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<td>17</td>
<td>134322.</td>
<td>“(L)H”</td>
</tr>
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<td>18</td>
<td>(used)</td>
<td>“AWG”</td>
</tr>
<tr>
<td>19</td>
<td>(used)</td>
<td></td>
</tr>
</tbody>
</table>
280 through 289 of the program.

To enter the program into the calculator, you first
partition the calculator. In the calculator's notation,
20 registers for data (00 to 19) and 800 registers for
the program (000 to 799) appear as 799.19 on the
calculator's display. You obtain this partitioning by
pressing keys 2, 2nd, *Op 17, in that order. A space
factor is put into data register 00, and the other
constants and alphanumeric codes used in the program
are put into registers 07 to 17 (see table of

<table>
<thead>
<tr>
<th>Register</th>
<th>Code</th>
<th>Description</th>
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<td>ADV</td>
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<td>002</td>
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<td>ADV</td>
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010 ELECTRONIC DESIGN 6, March 15, 1978
**Program Constants and Codes.** They are permanently recorded, along with program steps 000 to 794, in banks 1 to 4 of two magnetic cards.

Unless instructed otherwise, the program assumes that the coil is wound with annealed copper having double-film insulation. Also, the program assumes that the resistance entered is the value at 20°C. But you can easily adjust the program from the keyboard for other types of metal and change the space factor or temperature simply by storing new values in the

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appropriate data registers.

For example, to design a coil wound with aluminum wire, change either the relative resistance in register 07 to 1.64, or the resistivity to 2.62 \( \mu \Omega \cdot \text{cm} \) in register 08, but not both. And you can change the temperature in register 10 to investigate the effects of temperature changes. 

References

The Complete Solution to your F3870 and F8 Design-In Problems

The Formulator Development System

The Formulator family is designed to allow easy, efficient software development and real time hardware simulation of F8 or F3870 based systems. It is supported by a complete line of functional modules including memory, I/O and simulation cards that plug directly into the Formulator cardframe.

The Formulator can, itself, be used as the system breadboard. It provides microprocessor hardware, plus card slots for breadboarding your system. Thus the entire system may reside within the Formulator or in a combination of external and internal configurations.

In-Circuit Emulation

To develop, test and debug F8 and F3870 based products, Fairchild offers simulation options that extend the functional features of the microprocessor from the Formulator to the 40-pin socket on your breadboard. This allows complete ROM firmware development, real-time symbolic debugging of your breadboard and freezing of ROM codes during the breadboard stage.

PROM Prototypes

The 3870 Emulator is a PROM-based substitute for the F3870 microprocessor. The Emulator measures 5" x 7" and contains two 2708 or 2716 EROMs in place of the F3870 so ROM codes can be verified and easily changed if necessary.

The Formulator-Floppy Disk Marriage

An inexpensive plug-in module interfaces the Formulator with up to four plug-compatible ICOM Floppy Disc Drives, providing over one megabyte of storage. If you prefer other Floppies an application note provides the information necessary to modify Drivers for your system.

And That Isn't All

There is a lot more to Fairchild's line of design aids: PCB modules, memory options, PROM programmer, application and peripheral options, design kits, one card microcomputers, software, user's guides and training courses.

Powerful and Complete Software

The software consists of an operating system, utility programs and diagnostic routines; a monitor, text editor, assembler and debug package. It includes linking loader and relocating assembler and will operate in interactive or batch mode. The result is an easy to use, reliable, fast and extremely efficient capability for microprocessor based system development.

No one offers the extensive F8 and F3870 support that you can get from Fairchild. Just ask us about it.

Fairchild Instrumentation and Controls, a division of Fairchild Camera and Instrument Corp., 1725 Technology Drive, San Jose, California 95110 (408) 998-0123, Ext. 220.
Total cpu control
High level command keys and binary/hexadecimal displays provide complete system control, easy operation.

Worldwide portability
μScope 820 is fully self-contained, with accessory storage space. Operates on all standard U.S. and worldwide power sources.

Preprogrammed diagnostics
Overlay memory socket enables designers to plug in and execute customized diagnostics for each end product.

Breakpoint control and trace memory
Built-in high level diagnostics speed and simplify isolation of even the most difficult system problems.

Human engineered
Extensive prompting simplifies operation for test and service personnel, minimizes training time.

Interchangeable front panels, personality cards and personality probes μScope 820 adapts to a variety of microprocessors. Probe plugs directly into system microprocessor socket.
Troubleshooting microprocessor systems is easier than ever with Intel's new µScope™ 820 Microprocessor System Console. It's a powerful, programmable, fully portable real-time diagnostic instrument. And it's designed specifically to speed and simplify system checkout of your microprocessor-based products.

µScope 820 is really the first test instrument of its kind. It's built around its own microprocessor, to provide a "smart" solution that's highly sophisticated, yet easy to use. Because it's user programmable with interchangeable plug-in ROMs or PROMs, it's like taking a design engineer along on every service call.

And because it's fully portable, the µ.Scope 820 console goes wherever the action is—to the design lab, the production line or into the field.

Unlike logic analyzers, the µ.Scope 820 console provides a genuine solution for test and service personnel. It provides the same inside look at system operation that you get with a logic analyzer. But the µ.Scope 820 goes far beyond the mere collection of data. Its internal microprocessor system can actually analyze the data it collects. It does that with diagnostic programs you design specifically for your end product.

Rather than passively watching system operation, the µ.Scope 820 console lets you execute application programs or diagnostics you develop, in real time or single steps. And it provides full breakpoint capability and a large trace memory.

High level command keys, operator prompting, and binary/hexadecimal display of all system registers, I/O ports and memory give you greater control and make it easier to use than any other test instrument.

Until now the only way to get this kind of diagnostic capability was to use your Intellec® Microcomputer Development System. Now we've taken the Intellec features that have proven most useful for field service and production-level system checkout and have packaged them in this self-contained 20-lb attache case. That's portability.

And we've enhanced that portability with a µScope 820 price of just $2000,* complete with personality probe and all accessories. So you can afford to put a µ.Scope 820 console wherever you need one, and free your development lab instruments to concentrate on development. No longer must you invest in in-house-designed custom test instruments for each of your end products. And the µ.Scope 820 console will be available with a selection of front panel overlays, "personality" cards and system probes to support a variety of microprocessors.

To get your copy of our µ.Scope 820 brochure and to arrange for a demonstration right in your lab, contact your local Intel distributor or sales representative. Or write: Intel Corporation, 3065 Bowers Avenue, Santa Clara, California 95051. Telephone (408) 987-8080.


*Domestic U.S. price only, quantities 1-10.
Quantize the feedback in a/d converters. With microprocessor control, you trade inexpensive program-storage space for crucial speed and accuracy.

If you’re designing a microprocessor-based a/d converter, you should try to benefit from quantized feedback. This can provide 18-bit resolution and half-second conversions in a two-chip system. Considering the 14 bits most two-chip systems strain for, or the 16 seconds that some dual-slope converters need, the 500-byte program required for quantized feedback doesn’t seem too much of a drawback.

For quantized feedback, a digital control system feeds fixed-charge packets (pulses of reference current) to an integrator. The number of pulses that bring the integrator back to a reference voltage in the presence of the input, is the conversion result.

The fundamentals are illustrated by the simplified schematic of Fig. 1. The processor examines the comparator at intervals and operates the up/down (U/D) switch appropriately. Thus, a current of ±Ir is gated to the integrator for a fixed interval. As a result, a specific number of counts can either be added to or subtracted from the counter (U/D switch open or closed, respectively). The flow chart of Fig. 2 describes the quantized-feedback process for one complete measurement interval.

The integrator sums it all up

Fig. 3a shows the integrator output during a measurement interval. Here, for simplicity, the converter is digitizing a zero voltage input. The waveform implies that eight-count blocks from the counter describes the quantized-feedback process for one complete measurement interval.

Gary Grandbois, Precision Monolithics, Inc., 1500 Space Park Dr., Santa Clara, CA 95050. (Formerly Manager of Digital Applications, Siliconix.)

1. The functional components of quantized-feedback systems are a current-to-voltage converter (buffer amplifier), an integrator, a comparator and a switch. With two current sources—one having half the magnitude of the other—a single set of contacts can switch the reference current polarity to measure either polarity input.
3. Integrator waveforms for no voltage input are simple triangles (a) in a 100% duty-cycle (basic) system. An LD120 under F8 control divides each eight-clock-time set into up and down ramps (b) lasting one-and-seven or seven-and-one clock times each. This 87.5% duty cycle fixes the number of switching transitions and eliminates offset errors that would result from differences in charge injection, turn-on-time and turn-off-time.

4. An LD120 chip has all the analog blocks for quantized feedback: integrator, comparator, voltage-to-current converter and reference switch. Also included: a reference buffer amplifier that lowers tempco, an auto-zero buffer amplifier that nulls offset errors, and analog switches that generate the negative reference with the auto-zeroing.

5. Converting analog inputs to 5½ BCD digits uses every functional block of the LD120, plus Q1 for zero-offset correction. The 3870, a single-chip F8, puts out a single scan of multiplexed data in BCD format.
6. This high-performance \(5\frac{1}{2}\)-digit DVM reduces last-digit jitter by replacing the LD120's input buffer with a lower-noise BIFET amplifier. The DG301 switch performs auto-zeroing and improves zero-offset correction.

7. In the complete conversion sequence, the analog input is coarsely digitized in the measurement interval. Fine-tuning to the correct number occurs during override as the integrator ramps down. With an F8 microprocessor, override ends when the processor is interrupted. Digit-scan and auto-zero precede a new conversion start.

When mated with an appropriate microprocessor such as Fairchild's F8, the LD120 can provide the 18-bit resolution and stability needed for a \(5\frac{1}{2}\) digit DVM (Fig. 4). Though many one and two-chip a/d converters are available for \(2\frac{1}{2}\) to \(4\frac{1}{2}\) digit DVMs (10 to 14-bit accuracy), only quantized feedback or dual-slope systems pack \(5\frac{1}{2}\)-digit precision into two chips.

The tradeoffs have changed

Dual-slope, the older technique, trades conversion speed for program simplicity. This is no longer a good exchange now that program bytes are relatively cheap. And the 20 to 40 machine cycles required by a \(5\frac{1}{2}\)-digit Add routine, severely limit dual-slope conversion speed (see table). Therefore, it's often better to trade program length for accuracy and conversion speed. And this is what quantized feedback does—while retaining all the noise-averaging properties and inherent monotonicity of other integrating converters.

Mainly, the easy control by a microprocessor makes quantized-feedback converters feasible. Here, software counters take the conversion count at the processor's cycle time. No external counters or logic elements are used. Pulses for integration are counted in groups—six at a time for \(3\frac{1}{2}\) digits, 14 for \(4\frac{1}{2}\) digits and 78 for \(5\frac{1}{2}\) digits. The resulting coarse count is corrected during a short override interval.

A quantized-feedback two-chip set, such as the LD120 and the 3870 single-chip version of the F8, isn't slowed down by limitations imposed on dual-slope systems. For one thing, the LD120 operates with a conversion algorithm well suited to \(\mu\)P control.

In addition, this analog-processor chip boasts an intrinsic linearity of 0.0025% and a typical tempco of 5 ppm/°C. The converter performs zeroing automatically and needs only one reference voltage to accept both positive and negative inputs. All this
Reprogramming this 5½-digit DVM development system is easy. The 2708 ROM can be erased under ultraviolet light. The system, including the liquid-crystal display, operates from ±5 and ±12-V power supplies.

The 3870, provides the LD120 with a 64-byte internal RAM, a crystal-controllable clock, four 8-bit bidirectional I/O ports and a vectored and maskable interrupt system. Moreover, the 3870 operates from a single +5-V supply and contains 2 kbytes of mask-programmed ROM.

The LD120 does require some additional hardware to interface with the 3870, as shown in Fig. 5. Nevertheless, this DVM system is simple. The MOSFET switch, Q₁, allows a digital-zeroing period to be added to the software. And external control of the input switch helps simplify the 5½-digit counter's auto-zeroing (AZ) system.

This zeroing routing dedicates an interval every 15 conversions to measuring the system offset with the input switch grounded. Succeeding conversions are corrected by subtracting this measured value. Zero drift is minimized by combining, in one a/d system, the offset-correction technique and the analog-AZ system. The digital system corrects for such analog-error sources as auto-zeroing system leakage and comparator drift.

Circuit stability is ±1 count on a 2-V scale. A modified circuit (Fig. 6) has less internal noise, hence better performance. An LF356 BiFET op amp replaces the chip's internal buffer amplifier, and lowers the noise to ± one half of the LSB.

It's BCD at the display interface

At the output side, the data format from the processor is a strobed single scan of multiplexed BCD, which occurs after each conversion except during the
digital-correction interval (Fig. 7).

When the output data are to be displayed on LEDs, latching the strobed data helps keep the noise manageable. With latched data, the display can be driven statically. And, of course, static drive eliminates the current spiking and interference that multiplexing would generate.

An interface to a liquid-crystal display is shown in the F8 prototype system of Fig. 8. The prototype system is complex because it provides the 2708 EPROM for system development. Fig. 9 shows the F8 I/O-port map for the analog processor and display signals. Since only two of the four available ports are used for the basic DVM, the two additional ports (plus 1500 bytes of ROM) are spares.

Still, software is the key to the converter's operating efficiently. Fortunately, F8 software can closely model the quantized-feedback algorithm used with single-chip analog processors, like the LD 110/111 and LD 120/121, which use 1-of-8 (12.5%) and 7-of-8 (87.5%) duty cycles. The instruction sequence for the 12.5% section of the algorithm takes at least 13 machine cycles. Since the 87.5% section takes 91 cycles, the total operation takes 104 cycles.

The single machine-cycle time of the Increment

10. This F8 quantized-feedback algorithm retains the 87.5% duty cycle, but the steps are multiplied by 13 (13 and 91, or 91 and 13). The comparator is polled during the measurement interval and generates the interrupt during override, when the final downward ramp occurs.

11. This F8 routine takes 104 machine cycles and adds 78 counts to either the up or down counter. During the measurement interval, the routine loops 3280 times. All possible branches must take the same time for the program to function properly.
Accumulator instruction fixes the count time. So, the net count is 78 per duty cycle (91 - 13). This measurement routine is shown in the flow chart of Fig. 10, and as you can see, it is much like that in Fig. 2. The principal difference is that in Fig. 10 an up counter and a down counter replace the single counter that performs both addition and subtraction in Fig. 2. In the two-counter system, the up and down counts are subtracted at the end of each conversion (net count equals up minus down). For an F8 program that uses this measurement algorithm, see Fig. 11.

The errors go out fast

With this algorithm, a measurement interval lasts 3280 duty cycles (341,120 machine cycles) before the

Table: Dual slope vs quantized feedback for 5½-digit a/d converters with F8 µP control.

<table>
<thead>
<tr>
<th></th>
<th>Quantized Feedback</th>
<th>Dual Slope</th>
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</thead>
<tbody>
<tr>
<td>machine cycles</td>
<td>1 (increment instruction)</td>
<td>40¹</td>
</tr>
<tr>
<td>Count Time (µs/count)</td>
<td>2</td>
<td>80</td>
</tr>
<tr>
<td>Conversions length (counts)</td>
<td>200 k</td>
<td>200 k</td>
</tr>
<tr>
<td>Conversion time (s)</td>
<td>0.5</td>
<td>16</td>
</tr>
<tr>
<td>Program length (bytes, approx.)</td>
<td>500</td>
<td>100</td>
</tr>
<tr>
<td>Comparator Resolution</td>
<td>1 part in 78</td>
<td>1 part in 200 k</td>
</tr>
</tbody>
</table>

Note 1: Dual-slope counter-increment routine

Wait: LIOO
INC Set carry
LISL 2
Loop: CLR
LISU 2
AI 66
LNK
ASD C add to digits
LR E, C
BR 7, LOOP
BR WAIT wait for interrupt

override interval starts. The converter's maximum coarse-counting error is 156 counts (2×78). Therefore, the correction that occurs during the override interval is completed in less than 500 µs.

At the end of the override, the down count is subtracted from the up count. The result, the uncorrected count, is then adjusted by a number that represents the offset. The corrected count is then multiplexed out by a Digit Scan routine.

The single Digit Scan output is followed by the AZ interval. During AZ, the U/D line operates at a 50% duty cycle, the input buffer is grounded and the AZ switch closes. Also, the AZ capacitor stores a voltage representing the various amplifier offsets for nulling later. A second reference current is generated, which has the opposite polarity and half the magnitude of

ELECTRONIC DESIGN 6, March 15, 1978

(continued on page 116)
(continued from page 115)

The U/D current through $R_1$ when the U/D switch is connected to the reference, $V_{\text{ref}}$.

The U/D duty cycle during AZ is set at 52 machine cycles up and 52 down. Besides generating the negative reference voltage on the AZ capacitor, this duty cycle provides U/D switching transitions at the same rate as during the measurement. Fixing the transition rate, effectively nulls the effects of charge injection due to U/D switching or skew that exists between the U/D turn-on and turn-off delays.

Quantized-feedback can be used in other than precision DVMs. For instance, with minor modifications, the conversion systems for the 5 1/2 -digit DVMs in Figs. 5, 6 and 8 can provide a 700-µs 8-bit conversion, a 2.5-ms 12-bit conversion, or a 50-ms 4 1/2-digit conversion, respectively. In these conversion systems, the microprocessor can add digital linearization, data reduction and programmed limits. It can also automate ranging and function or multiplexer-addressing.

---

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*Or see Pages 405 to 408 in EEM

---

M0190=71 8E 0E 02 1F 91 6E 90
M019B=E7 6A 64 4C 65 5E 8F FB
M01A0=44 53 20 0F 55 90 D1 2B
M01A=A2 2B 2B 70 51 54 6A 20
M01B0=66 52 71 58 62 4C 18 63
M01BB=DC 1E C8 D2 64 5E 49 1E
M01CO=9E 21 02 12 58 8F EE 70
M01CB=8E 94 15 E1 94 12 6A 64
M01DO=4C 62 5C 63 70 5E 8F F8
M01DB=44 18 54 71 51 90 D0 1C
M01EO=6A 18 1E 64 1D 70 19 C2
M01E8=DC 1E 65 C2 DC 64 5E 49
M01F0=1E E9 21 02 59 8F ED 1C
M01F8=70 6A 54 62 5C 63 5E 8F
M0200=FA 29 01 7B 2A 73 20 2B
M020B=47 B0 A0 1F 91 24 6A 62
M0210=18 2B 46 B0 20 78 90 02
M021B=70 19 24 66 DC 5E 8F F9
M0220=20 F9 1F 94 FE A0 6C A0
M022B=71 8E 0E 02 1F 91 21 8F
M0230=DA 18 6A 63 20 78 90 02
M0238=70 19 24 66 DC 5E 8F F9
M0240=71 8E 0E 20 F9 1F 94 FE
M024B=2B 2B 6C 46 B0 8F DD 29
M0250=00 10 35 94 07 72 56 70
M0258=57 90 05 73 56 71 57 29
M0260=01 F8 B5 8A 11 7B DD 23
M026B=FD FC FB FD FB FB FB FB
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- SOFTWARE SYSTEMS DESIGN/ANALYSIS
- ELECTROMAGNETIC PULSE ANALYSIS
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CIRCLE NUMBER 55
Make your time generator versatile. You won’t have to redesign hardware to change system timing if you start out with a ‘universal’ timing generator.

Design your timing generator around a ROM and you can change system time sequences without any major redesign of logic or PC boards. Since a ROM can store the bit patterns that make up a timing sequence, it’s the only component you’ll have to change when your timing must be changed. But the other generator components—gates, counters, flip-flops—remain the same.

To make your timing generator even more flexible, use an electrically alterable ROM, or EPROM, as the memory device. Then you’ll only have to change programming to change timing. An EPROM timing generator can even serve as a system debugger, since it can be reprogrammed many times to emulate various time sequences.

Since a universal timing generator can emulate any timing sequence, you can compare operation of a ROM-based circuit with hardwired logic. The comparison, of course, should use the same timing sequence for each generator.

Back and forth with a ring counter

A hardwired timing generator with a reversible-time sequence is shown in Fig. 1a. This circuit uses a shift register such as the Fairchild 9300 as a twisted-ring counter, a configuration which allows for reversibility of the output pulse sequence. Also included is a dual four-input multiplexer (Fairchild 9309) and SN7400 output-decoding gates.

The decoding gates in Fig. 1a produce only four time pulses, A, B, C and D shown in Fig. 1b. However, you may want to design the generator for many more outputs, thereby increasing the complexity of the decode bus and circuitry. But, then, should timing changes be required, you would spend a lot of time redesigning the decode logic, not to mention cutting up the buses on your PC board.

The 9300 shift register in Fig. 1a is controlled by the state of the Count Forward line. With Count Forward at ONE (+5 V), Parallel Enable, PE, on the shift register is disabled, and the Clock line steps the output sequence, signals A through D in (b). And with a ring counter, the output sequence can be generated in either the forward direction (t₀ to t₁) or the reverse (t₁ to t₀).
To change the output sequence of a firmware timing generator, all you have to do is change the ROM since no decode bus or logic is required. However, if you use an EPROM, you can remove and reprogram it many times.

To reverse the output sequence, Count Forward must switch to a ZERO, and enable the PE input. Multiplexer inputs S0 and S1 are held low by Q2 and Q3, which allows ZB to go high. The register, now in its parallel-operation mode, transfers the contents of P0 through P3 to Q0 through Q3. The output sequence is generated in reverse, that is, from 0001, 0011 back to 0000. And pulses A through D in Fig. 1b will appear in reverse order via the bus and decode logic.

Of course, few applications require just the four timing signals generated by this simple hardwired scheme. A ROM-based generator, by contrast, can
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Typical Specifications

<table>
<thead>
<tr>
<th>L (±5% (uh))</th>
<th>Q Min</th>
<th>at Freq. (MHz)</th>
<th>Min SRF (MHz)</th>
<th>DIMENSIONS (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>L</td>
</tr>
<tr>
<td>0.05</td>
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<td>180</td>
<td>25</td>
<td>155</td>
<td>1.281</td>
</tr>
</tbody>
</table>

Intermediate values with similar specifications as well as custom designed units are also available.

JFD ELECTRONICS COMPONENTS CORPORATION
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Brooklyn, New York 11219
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produce the same timing sequence as its hardwired counterpart, and, in addition, can be easily changed or expanded to fit your needs.

Off the bus, onto the ROM

A 16-word ROM is the primary component of the firmware timing generator of Fig. 2. "Firmware" refers to the unique program stored in the ROM for generating a particular timing sequence. Except for the ROM, the ICs in this generator are universal, and the output sequence can be easily changed by inserting a new firmware package.

Notice, that this firmware generator has neither a decode bus nor associated logic. This is why it's more versatile than the hardwired version. The ROM and D flip-flops combine to replace the hardwired generator's bus and decoder.

A 4-bit binary counter, such as an SN7493, addresses the ROM by cycling through as many of its 16 states as is necessary to output the programmed locations in memory. Each ROM location contains a unique code, which is delivered to its output lines, DO through DO6, and then to the inputs of the D flip-flops. Timing pulses appear at the generator output, Q0 through Q6, when Clock transfers the logic levels on the D inputs to the output.

An SN7420 four-input NAND gate decodes the counter output when the last address count is reached. Any of the 7493's counts can be decoded by connecting its appropriate output lines to the NAND gate via a jumper board. This fires a retriggerable monostable, SN74123, thus resetting the counter to all ZEROS. Then the cycle for generating the timing pulses begins again.

To see how the ROM timing generator emulates the hardwired generator, look at the output sequence of Fig. 3a and the shaded portion of Fig. 2. Outputs Qo through Qs in Fig. 3a represent the program stored in the ROM. The Count Forward line is at ONE, and the clock steps the 7493 from 0000 to 0111. Two inverters and a NOR gate in the shaded portion of Fig. 2 hold input Aa of the ROM at ZERO. Therefore, ROM locations from 1000 to 1111 are not addressable, and the generator produces the output pulses shown in Fig. 3b. Notice that they make up the same time sequence as the one shown in Fig. 1b. But to emulate the hardwired generator completely, the ROM generator's time sequence must also be reversible.

At count 1000, the 7420 NAND gate is enabled, and the monostable fires, which resets the counter to all ZEROS. The Count Forward line then switches to ZERO, which makes Aa high. Now, locations 1000 through 1111 of the ROM can be addressed as the 7493 counts from 0000 to 0111. The program stored in this second group of locations is the exact opposite of the program in the first group. So the timing sequence is repeated, but in reverse order from the original. Thus the hardwired timing generator is emulated completely...
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CHAPTER TWO: MICROPROGRAMMED CONTROL.

At the heart of the microprogrammed machine is a memory and a sequencer.

At a minimum, the sequencer will increment through addresses and branch to other addresses in the memory.

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Settability of Bulk Metal® trimmers compared with wirewound and cermet

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CIRCLE NUMBER 60
Lee Wilson of Corning Speaks On Centralizing Engineering
In these days of worldwide markets, there’s a popular notion that the way to respond to those markets is to decentralize your engineering—to have your engineers in the local plants, right where the markets are—so you can respond quickly to changing market needs. A further advantage of such decentralization—so the theory holds—is that the engineers can respond to local manufacturing problems quickly and effectively instead of having to overcome communications barriers that geography, national and social differences conspire to create.

Well, we disagree, especially if your business is multinational. We tried that method for a long time, and found that centralization works a lot better. A few years ago our electronic-components business was organized as a domestic and an international business. We had two companies in Europe—Electrosil in Sunderland, England, and Sovcor in LeVesinet, France. Each had a managing director who reported to a general manager, who reported to the area manager just plant managers, also report to the manager of social differences conspire to create.

Well, we disagree, especially if your business is multinational. We tried that method for a long time, and found that centralization works a lot better. A few years ago our electronic-components business was organized as a domestic and an international business. We had two companies in Europe—Electrosil in Sunderland, England, and Sovcor in LeVesinet, France. Each had a managing director who reported to a general manager, who reported to the area manager for Europe, who reported to the vice-chairman of the company here in Corning, NY, who happened to be the president of our international operations. He reported to our chairman of the board.

So we had two homogeneous businesses, one in Europe and one here, both making components that were largely identical. But product planning, budgeting procedures and almost everything else were different, no matter how hard we tried to coordinate.

And that’s understandable, because the European companies had a different boss to satisfy, and he was looking at the components business as just a little piece of Corning’s total European business, which includes television bulbs, dinner plates, ophthalmic blanks, Pyrex beakers, and what have you. And that made it really difficult for us to coordinate two distinct sections into what should have been one worldwide business enterprise.

Then we changed the structure so that the European plants now report on a functional basis, rather than a geographical one, just as the plants in the States do. So the two European managing directors, while they have corporate responsibility and are more than just plant managers, also report to the manager of manufacturing of the Electronic Products Division here in New York, as do the U.S. plant managers.

Now we have worldwide programs, not just American or British or French programs. This means we can centralize our engineering here in Corning. This, in turn, means that we can standardize our manufacturing processes and technologies.

These all came from Corning in the United States originally. But after many years they began to drift apart, with changes being made locally in the equipment and with new designs being developed that were clearly local in character. So we would end up with different processes in Britain, France and the U.S. One plant might be using a vertical cut-off machine, another a horizontal. One might use one kind of laser for spiraling resistors, and another might use a different kind of laser.

Well...so what? What’s so terrible about having somewhat different processes or machinery in different locations? The answer is that invariably they perform differently. They impart somewhat different product characteristics. Or one set-up is faster than another, or provides higher yield.

Now this could mean that one plant chose equipment better than another did, for whatever historic reason. But without a central point for working on such matters, we might never find out. And that’s not merely a problem of operating worldwide. We can find the same problem in different plants in the United States. As a matter of fact, a machine in one plant might perform better or worse than an identical machine in another plant.

What’s more, if everybody’s using different machinery, nobody can develop improvements that can prove useful to everybody. If you have a decentralized organization, people in one place never know what’s been done someplace else that can raise the performance of similar equipment. If you have a central group, even a small one, you can bring all your machines up to the level of the very best one in the corporation. You can develop useful liaison between your division manufacturing engineering and your corporate engineering group.

And that’s what we did.

Here in Corning, New York, we established a new position, Division Manufacturing Engineer, and gave that position to a man with broad international experience. He pulls all our programs together, international and national, and decides which ones to focus on with both capital and manpower. By focusing on the best opportunities, we get best total impact.

Now this doesn’t mean we don’t do any engineering in the individual plants. We do a lot. But we centralize the direction, especially for major programs like cost reduction and product development. Of course we recognize that regional markets have different needs. And that’s why there’s still lots of engineering in the individual plants. But those regional differences are
Who is Lee Wilson?

Except for a stint in the Army from 1954 to 1956, Leroy Wilson has been a one-company man. He joined Corning Glass Works as a technical trainee after he got his BS in mechanical engineering from Purdue in 1950. Then he got an over-all view of the company by going through one department after another—manufacturing, then engineering, then sales—before he worked in a branch plant. Then he went into product engineering as a permanent assignment until he went into the Army. When he returned, Wilson went to the Electrical Products Div., where he was given product engineering responsibility for developing the 110-degree television bulb.

A year later, he was selling TV bulbs in Chicago, and three years after that he returned to Corning in New York as sales manager of the Communication Products Dept., where he remained for four years, till 1965.

Then on to Europe as general sales manager for five years, then back to New York as area manager for Latin America and Canada. In 1975 he became vice president and general manager of the Electronic Products Div.

Lee and his wife, Claudie, have two children away at college and three still at home. The couple travel a lot, particularly to Brittany in France. They both dabble in tennis, cross-country skiing and sailing on Keuka Lake, where they have a cottage. And both are avid readers.

But some problems that appear to be merely regional idiosyncrasies and very simple may not be at all.

For example, take a “simple” thing like lead diameter. Some customer wants lead diameters different from the standards you offer. But a difference in lead diameter could affect the way a component holds a lead bend and the way it is inserted into a PC board. So it’s wise, even on something apparently trivial, to have local representation on the central organization.

But it’s not wise to involve the central organization on matters that can be taken care of entirely locally. Product definition, for example, must be taken care of locally. We don’t have one catalog. We have different catalogs in different countries. But as much as we can, we try to standardize products. That’s to be expected because, as I said, many of our customers are multinational. A computer manufactured in Detroit is going to be very much the same as one manufactured by the same company in Scotland, so it’s going to need the same components. The people in both plants are going to want the same specifications, the same body color and the same markings. They want things to be the same and to look the same.

So we try very much to standardize—starting with the raw materials and manufacturing processes. I think, in the end, you get better quality. And once your standardized processes are tuned up and running well, you can maintain an even higher standard.

If a component is standardized, a multinational systems manufacturer will feel more assured that the one he buys in Europe will be the same as the one he buys in the States. And it’s much easier for an
individual customer to qualify different plants making that product.

A European purchaser will feel more confident about qualifying us. He knows, not only that we make the same product elsewhere, but that we make it the same way wherever we make it.

There's also a personal element. If the chief engineer of a major customer in the United States begins to manufacture in Europe, he faces the unwelcome task of finding new vendors in Europe.

We can relieve him of that burden to some extent by letting him know that the vendor he's using here is the same vendor in Europe. Life will be easier for him if he knows that the same people designed the processes for the European and American plants and that the same person has the line responsibility for the quality of engineering in both plants.

Still another advantage to standardization is that if a natural tragedy—say a flood or fire—or a strike shuts down one plant, we can deliver from another plant. Fortunately, we've never had a strike. But a strike by somebody else could also affect us.

There's another advantage to having the same component available from different factories. You can solve problems stemming from local social customs. In France, for example, it's almost impossible to lay off people. You can do it, but it's always very costly. So you have practically zero flexibility in adjusting the size of your work force. And that's becoming more prevalent everywhere.

With standardized components, we can go a long way toward keeping our work force stable. If, for example, the market for resistors suddenly expands in France, and we suspect that the expansion is temporary, we'd be nervous about adding to our French labor force since we couldn't reduce it later.

But we could supply that surge demand from England or someplace else where we have idle capacity. And that can help avoid the old problems of double-ordering, followed by cancellations. This tends further to stabilize the work force, and it reduces capital investment. We're not yet at the stage where we can ship readily from alternative plants, mind you, but that's our direction. It would be impossible if each plant were working on its own.

And there's another point. It's a lot easier to increase the output from another plant to meet surge demand than it is to hire and train new workers.

For all those reasons, we try to standardize, while trying to recognize and accommodate regional differences. Even if these differences were much stronger, we'd still benefit overwhelmingly from our centralized organization—not only for product planning, but also for developing manufacturing equipment and processes.

Though all our plants got most of their equipment designs from Corning, there was no central group to make sure that each plant used its equipment most effectively. Each plant had its own cost-reduction program and its own process-development activity. The problem, of course, was the old one of everyone wanting to please his own boss. We found that it's much easier if everyone has the same boss.

We tackle this problem by having somebody from the division manufacturing engineering group visit all the plants. He focuses on a relatively small number of objectives. So he can get a great deal done.

If one plant improves a process, our manufacturing engineer can communicate that to all the other plants. He can bring them all up to the highest level.

Another very important advantage of a centrally directed engineering effort, especially for Corning, is access to the central corporate engineering group.

This large and very professional organization can accomplish engineering projects that no plant, or even division, engineering group could do on its own. And with a centralized division engineering group, major projects can be organized and undertaken with the corporate engineers much more easily.

For example, the central corporate engineering group can set up a whole line, get it working smoothly and optimally, then order the same equipment for all the other plants. If we tried to have each plant develop its own equipment, we would end up with an awful lot of duplicate effort.

In addition, our central corporate engineering group can concentrate on developing new equipment and processes without having to worry about keeping a plant running at the same time. Our people in the various plant locations can't do that because their engineers are busy running factories.

Finally, no local plant can bring to bear the level of engineering that we can offer from Corning. We have engineering manpower and resources that no individual plant can afford to carry. We have several hundred engineers in our central engineering group and they have an enormous range of disciplines.
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*CIRCLE NUMBER 72*

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TWX: 910-338-0254.
Constant-current feedback loop improves photodetector performance in optical sensors

Improve your beam-interrupt optical system with a constant-current feedback loop to bias the photodetector, and use both the dc and ac gain of a high-gain op amp in the feedback loop. The circuit (see figure) provides Class-A biasing for the phototransistor, a Motorola MRD 360 Darlington. Not only can you use the circuit for beam-breaking applications, but it's good enough for light-measuring.

A phototransistor is often called upon to distinguish between low-energy light pulses in the infrared region and ambient light, which may be strongly modulated by 60-Hz light sources. With Class-A biasing, the phototransistor's threshold is easily exceeded, which puts ambient light variations and fast rise time light pulses in the phototransistor's linear region. And ac coupling of the signal (via the specially selected $R_{12}C_s$ combination) helps attenuate 60-Hz components, but not the desired signals.

In the circuit, a dc reference voltage is established at $A_1$'s inverting input by voltage divider $R_8$ and $R_9$. Phototransistor $Q_3$, a Darlington arrangement, provides dc inverting to hold $A_1$'s noninverting input, through feedback, at a voltage which differs from the reference by a very small offset. Constant voltage drops across $R_8$ and $R_9$ provide constant Class-A current to the phototransistor. Photon overloading of the photosensitive base of $Q_3$ is minimized by $R_{10}$, a 10-MΩ resistor. And to control the op amp's dc output to a desired level of pulse clipping, $R_{18}$ can be a selected value. The photo-Darlington and op amp together produce a switching time of 25 µs.

In addition to the closed-loop circuit between $Q_3$ and $A_1$, the circuit contains a LED pulser, an inhibited trigger circuit and an alarm-horn driver. The pulser consists of $Q_4$, a 300-Hz unijunction relaxation oscillator feeding $Q_5$, the LED driver. Current pulses through the LED are about 1-A peak with a pulse width of 40 µs, giving a duty cycle of about 1%.

After a pulse is detected and amplified, the pulse is capacitively coupled (which rejects 60-Hz modulation) to pulse amplifier $Q_4$, and then fed to clamp transistor $Q_5$. Since $Q_5$ clamps the timing capacitor $C_6$ of the 100-Hz programmable-unijunction oscillator PUT $Q_6$, periodic pulses keep $C_6$ below the firing potential of the PUT. But if the infrared beam is broken for more than four pulse times (about 12 ms), $Q_5$ conducts, triggering horn-driver $Q_7$. A steady stream of pulses inhibits triggering, so the four-pulse feature provides false-signal immunity.

An interrupter-contact-type horn turns off $Q_7$ after initial triggering, if $R_{21}$ is large enough. A lower value of $R_{21}$ would allow $Q_7$ to latch, and the horn would sound continuously until the circuit is externally opened. A prototype system using a simple flashlight reflector behind the LED can respond at distances to 3.5 ft.

Al Pshoenich, Senior Application Engineer, Motorola Semiconductor Products, Inc., Phoenix, AZ 85008.

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CIRCLE NUMBER 65
Field-programmable logic array decodes keyboard without a debounce circuit

A field-programmable logic array (FPLA) can be programmed with hexadecimal code to load keyboard data into an 8-bit processor (Fig. 1). Not only that, but use of the FPLA and a one-shot makes key debounce-circuitry unnecessary.

Each of the FPLA's 16 inputs is assigned a unique key (Fig. 2). When a key is depressed, the FPLA immediately generates the 4-bit hex code (B₆ through B₉ in Fig. 2), and a fifth bit, B₄, which first passes through time delay R₁S, C₂, then fires one-shot U₂. Depending on the state of flip-flop U₆, the FPLA's contents are loaded into either buffer U₃ or U₁. The one-shot's trailing edge toggles U₆, which sets up the empty buffer to be loaded.

An 8-bit hex byte is available on the output lines, ready to input to the processor. Releasing a key presents an all-zeros input to the FPLA, which holds B₄ at ZERO. As a result, the buffers cannot be loaded on a key bounce.

John A. Glaab, Electronic Systems Engineer, National Aeronautics and Space Administration, Goddard Space Flight Center, Greenbelt, MD 20771.

CIRCLE NO. 312

1. An 82S100 field-programmable logic array is basic to this hex keyboard decoder. Hexadecimal code is programmed into the device; a single one-shot allows debounce circuits to be eliminated.

2. Hexadecimal coding of an FPLA provides a unique address to each key on a keyboard. The hex output code is stored in B₀ through B₃. A ONE on the B₄ line allows output buffers to be loaded.
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Improve double-balanced mixer response with an active-circuit design

With four 2N5109 CATV transistors in the active double-balanced mixer of fig. 1, you can use impedance-stabilized feedback in a transformer-coupled configuration. As a result, the mixer has lower intermodulation distortion than conventional field-effect or diode mixers at the same drive level, and a low-noise figure as well as stable gain. The circuit's 10-Ω emitter resistors reduce the amount of flicker noise. Furthermore, the circuit can achieve a 40-dBm intercept point with a local oscillator drive of 13 dBm. Even a reduced drive of 10 dBm still gives good circuit performance and low distortion.

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CIRCLE NUMBER 67
gether with their low-noise figure and improved gain-bandwidth product allow you to use the impedance-stabilized, current/voltage rf-feedback technique, where previous mixers were passive circuits that used hot-carrier diodes or grounded-gate silicon FETs.

An ordinary double-balanced mixer that uses just four hot-carrier diodes produces the response plot of Fig. 2a. A mixer constructed with a Siliconix quad FET (U 350) generates the plot of Fig. 2b. Note the significant improvement over Fig. 2a—third-order intermodulation distortion is suppressed by 35 dB. However, the circuit of Fig. 1, with CATV transistors, suppresses third-order distortion by 65 dB (Fig. 2c) for about the same component cost as a quad-FET circuit.

Ulrich L. Rohde, President, Rohde and Schwarz Sales Co., 14 Gloria Lane, Fairfield, NJ 07006.

CIRCLE NO. 313

IFD Winner of November 8, 1977

Raymond K. Ferris, Supervisor, Program Support, Actron, 700 Royal Oaks Dr., Monrovia, CA 91016. His idea “Constant Bandwidth PLL Tone Decoder Accepts Wide Range of Input Voltages” has been voted the Most Valuable of Issue Award.

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More than 12,871 state-of-the-art instruments ... off-the-shelf, throughout North America.

CIRCLE NUMBER 69
2,685 answers to power supply questions.

Answers to better power and thermal efficiency. Answers to size and weight reductions. Answers to available off-the-shelf covered/open frame power supplies and transformers. And price and delivery answers. These and many more answers can be found in our three product catalogs. And they're yours. Free. Just circle reader card number. Better yet, write or call Abbott. The Power Supply Specialist.

Power Supply Catalog — Comprehensive 60-pager describes our full line of 1,573 hi-efficiency, hermetically sealed, single and dual output power supplies and switcher modules. Inputs of 60 and 400Hz and DC are available with outputs from 3VDC to 740VDC, 1 to 250 Watts. Prices start as low as $174 for 2-4 units.

Industrial Power Supply Catalog — Some 279 of our low cost, high quality OEM power modules are detailed in this 16-pager. Includes covered/open frame, AC to DC single, dual and triple output versions, with outputs from 5 to 36VDC, 0.5 to 320 Watts. Plus DC to AC converters with 50 and 60Hz outputs. Priced as low as $35 for up to 24 units.

Transformer Catalog — A 20-pager for the do-it-yourself power supply designer with instructions on how to specify for your custom units. Also covers 833 of our standard military, industrial and miniature pcb power transformers. Included are 60 and 400Hz, single phase input units, with prices starting as low as $5.10 for up to 9 pieces.
GaAsFET may solve NMOS transistor memory problems

Silicon NMOS transistors, when used as nonvolatile-memory storage devices, are hampered three ways. Their data-storage lifetime leaves room for improvement; they are not radiation-hardened; and their access time is relatively slow. But these limitations may be overcome by a nonvolatile GaAsFET transistor, developed at the Dept. of Electrical and Electronic Engineering, University of Newcastle upon Tyne, England.

The new transistor uses a double-oxide gate-insulator structure consisting of aluminum oxide (Al$_2$O$_3$) and gallium arsenide anodic native oxide. The charge is stored at the interface between the two oxides (see Fig.).

The double-oxide structure is made by evaporating 450 Å of aluminum onto the gallium arsenide device and then anodizing through the aluminum layer. The final structure is 700 Å of Al$_2$O$_3$, with some 10 or 20 Å of GaAs underneath the aluminum oxide.

The interfaces between the oxides are charged by three-second pulses as high as 30 V. The ability of the structure to retain charge was measured with the gate disconnected after charging and with the gate grounded and the device operating. With the gate disconnected, saturation current of 5.2 mA decays at the rate of 0.17 mA per decade of time, measured over 2000 minutes.

Laser crystal produces high spectral purity

A new semiconductor laser element has almost ideal characteristics for fiber-optic communications systems. The laser, a neodymium aluminum-borate crystal between 10 and 100 µm long, emits a single spectral line of unusual purity, at 1.06-µm.

The key to the crystal's development is the process used for doping the aluminum compound. By varying the doping, the laser can be tuned to radiate at a wavelength where an optical fiber has minimum absorption loss. As a result, attenuations in the order of 1 dB/km or less are possible.

The doping process is, as yet, being kept secret. The crystal was excited by researchers at the Institute of Applied Physics, at Hamburg University in West Germany, using a krypton gas laser operating at 0.8 µm.
CIRCLE NUMBER 71

If you're into exporting, or about to take the plunge, this could be your market research department.

It's your guide to one of the most useful libraries in the world. And it's issued by the U.S. Commerce Department on a monthly basis. Inside, you'll find a list of reports containing a wealth of information for the overseas marketer. Spot news; timely surveys of industrial, commodity, commercial and economic conditions in more than 100 countries; in-depth market research performed by the Commerce Department or private research firms overseas; as well as reports sent to Washington by U.S. Foreign Service Officers. For a free sample, write Secretary of Commerce, U.S. Department of Commerce, BIC-10B, Washington, D.C. 20230.

Electronic Design 6, March 15, 1978
Input Voltage: 105-125 Vac, 47 to 420 Hz, single phase.

Output Voltage Setting: Single output models are factory preset to within ±2% of nominal output voltage, and may be more precisely trimmed to the nominal voltage rating with an external trim resistor. Dual models are set to within ±1% of their nominal ratings, and are not trimable.

Polarity: Either positive or negative terminal of a single output module may be grounded. Dual output modules have a positive/common/negative output terminal configuration.

Ambient Operating Temperature: -20 to +71°C. (Model SE150 and SEB150, 0 to +71°C.) No derating required.

Temperature Coefficient: 5-volt models, .03%/°C; dual output models, .015%/°C.

Impedance: 0.07 ohm at 1 kHz, 0.2 ohm at 10 kHz (approx.).

Optional 230 Volt Input: To order, add suffix "-230" to model number and $10.00 to price.

Case Sizes and Weight:
- EB-10: 3.5" x 2.5" x 1.375" (1 lb)
- EB-13: 3.5" x 2.5" x 1.625" (1 lb 5 oz)
- EL-10: 3.5" x 2.5" x 1" (15 oz)
- EL-13: 3.5" x 2.5" x 1.25" (1 lb 3 oz)
- EL-20: 3.5" x 2.5" x 2" (2 lb)
- ES-10: 2.3" x 1.8" x 1" (7 oz)

Other models available from 1 to 75 volts. Send for complete information.

**For Logic and Op Amps**

**With Screw Terminals**

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<thead>
<tr>
<th>Nominal Output Voltage</th>
<th>Output Current Amps</th>
<th>Regulation Load %</th>
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PCB Mounting

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Monolithic Memories announces:
a revolution in logic design!
**PAL™** will save you money, space and sweat.

A single PAL16R8 (package shown actual size) can be programmed to perform all the logic functions shown here. Other devices in the PAL family offer comparable efficiencies.

**Programmable PAL logic will reduce random logic chip count by 4-to-1.**

Monolithic Memories, Inc., the company that invented the modern bipolar PROM, soon will bring you PAL (Programmable Array Logic)—a family of monolithic LSI circuits which allows you to program your own logic on a chip, from random gates to arithmetic functions. We have samples now, with high-volume production scheduled to begin mid-year, and the entire family to be in full production by year’s-end.

The fifteen devices in the family will each contain a programming network which interconnects various types of gate arrays, consisting of AND/OR and AND/NOR gates, exclusive-OR gates, registers, optional three-state outputs and feedback connections.

The PAL family will replace 90% of 74005/LS Series functions.

When you use PAL, you'll be designing functions on-chip that are ordinarily performed by conventional TTL logic, and realizing tremendous efficiencies of time, space and cost. PAL replaces 9 out of 10 standard functions now provided by ordinary SSI/MSI TTL logic gates and flipflops.

Use PAL to interface your microprocessor—or maybe even replace it.

To the designer faced with implementing his logic with microprocessors, PAL will offer special blessings. It's ideal for interfacing peripheral devices to any microprocessor system, with minimum time and cost. And for those less complex logic system designs that don't really require a microprocessor, PAL will offer the ideal answer.

**Programmability simplifies design and saves dollars in production.**

PAL will let you structure your logic by programming fusible-link connections identical to those used in PROMs. All PAL programming will be handled by standard PROM programmers, simply, quickly and efficiently.

If your PC board layout should prove difficult or awkward, PAL can help. You can program the same logic functions into PAL a number of different ways, thereby eliminating jumper wires and crossed conductors, with substantial improvement in reliability, plus savings in space and power.

PAL's unit cost will be lower than that of microprocessors, custom logic and FPLAs. Compared with conventional TTL logic, you'll save in system cost, because PAL reduces parts inventory as well as parts on your board. It also simplifies production and saves in testing.

Every PAL will be packaged in a 20-pin "Skinny DIP," saving additional board space every time it replaces TTL, microprocessors, FLPAs or custom logic. Result: often you'll get your entire circuit on a single board, resulting in fewer boards per system. Ask for product details from Monolithic Memories, 1165 East Arques Ave., Sunnyvale, CA 94086, or call (408) 739-3535.

How they stack up. Only PAL offers across-the-board advantages over all other types of logic.

<table>
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<th>Package Count</th>
<th>Ancillary Cost</th>
<th>Flexibility</th>
<th>Space Savings</th>
<th>Power Savings</th>
<th>Speed</th>
<th>Reliability</th>
<th>Ease of Programming</th>
<th>Design Cycle Time</th>
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TM—Trademark, Monolithic Memories, Inc.
NEW! ICL Series
26% lower profile—.150". Ideal for high density, high volume configurations, provides maximum vibration resistance. Solder type, single leaf "side-wipe" contacts. 8 to 40 contacts.

ICN Series high reliability general-purpose sockets. Low insertion force allows automatic IC insertion. In solder or wire-wrap. 6 to 64 contacts. Dual leaf "side-wipe" contacts.

ICA Series high reliability pin socket contacts. Low profile in solder or wire-wrap. 8 to 40 contacts.

TS Series very long contact life. Very low insertion force. Ideal for incoming inspection. With 14 to 40 contacts. Also strip sockets up to 21 positions.

IC Series moderate cost, long life. Designed for general test and burn-in up to 350°C. With 14 to 40 contacts.

ICN/S2 Series lowest cost burn-in socket available. Designed to accept IC extraction tool. With 8 to 40 contacts, with strip sockets up to 25 positions.

WRITE TODAY for New RN “Product Selection Guide”...

and informative book “What to Look for in IC Interconnects.” Free from RN—the people who make more kinds of high reliability sockets than anyone.
A "Special" reminder.

We don't stock this one.

We put it together to demonstrate Cutler-Hammer's unique capability to produce custom—and even proprietary—switch "specials" to satisfy virtually any end-product requirement.

We offer "specials"... toggle, rocker, paddle, rotary, slide, key, lever-lock or pushbutton. Both illuminated and non-illuminated.

... ac or ac/dc. For one-hole, flush, sub-panel, snap-in or nest mounting. In all sizes. With special circuits that can be ampere or horsepower rated... or both.

... with screw, spade, pc, solder lug, wire wrap, wire lead and integrated wire terminations.

For "special" assistance on commercial, industrial and MIL-Spec applications, call your Cutler-Hammer sales office or distributor.

And for the many "non-specials" we do stock—write Milwaukee for your copy of our new 144-page catalog.
We’ve just terminated your flexcircuit connector cost problems... without sacrificing reliability.

Burndy Flexlok™ connectors combine high-reliability with low-cost design to slash installed costs 66%.

Now, for less than 1¢ per contact, you can enjoy all of the design and production benefits of flexible circuitry and flat cable.* That’s a lot less than the 3¢ to 10¢ you’d normally expect to pay with other connectors.

But Flexlok not only costs less initially, it costs less to install. That’s because it comes fully assembled, inspected and ready for soldering and cable insertion. No separate handling. No loose contacts to assemble. No assembly machines or tools. No special operator training.

What’s more, these savings are all yours without sacrificing reliability. That’s because Flexlok connectors feature Burndy’s patented GT™ contact design that delivers gas-tight, high-pressure, good-as-gold contact even under adverse environment. Hard to believe? The proof is in the cost comparisons and performance data shown below.

*Flat-flat and flat-round types.
Here's proof!

**FLEXLOK COST COMPARISON**

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<th>GTH F/Flexlok</th>
<th>Clamp Type Pressure Tin</th>
<th>Insulation Displacement</th>
<th>Insulation Piercing</th>
<th>Solder Connections</th>
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*In Quantity

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**FLEXLOK DESIGN FEATURE COMPARISON**

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<td>Conductor Types Accommodated</td>
<td>Round Flat Flex P.C.</td>
<td>Flat Flex P.C.</td>
<td>Round Flat</td>
<td>Round Flat Flex P.C.</td>
<td></td>
</tr>
<tr>
<td>Top or Side Entry Available</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td></td>
</tr>
</tbody>
</table>

**FLEXLOK PERFORMANCE DATA**

<table>
<thead>
<tr>
<th>Contact Resistance Test Data</th>
<th>MILLIOHM MIN.</th>
<th>MILLIOHM MAX.</th>
<th>MILLIOHM AVG.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial Contact resistance</td>
<td>7.00</td>
<td>7.60</td>
<td>7.26</td>
</tr>
<tr>
<td>After thermal shock</td>
<td>7.10</td>
<td>7.50</td>
<td>7.26</td>
</tr>
<tr>
<td>After durability (5 cycles)</td>
<td>7.10</td>
<td>7.80</td>
<td>7.39</td>
</tr>
<tr>
<td>After moisture resistance (10 days)</td>
<td>7.20</td>
<td>8.70</td>
<td>7.68</td>
</tr>
<tr>
<td>After vibration</td>
<td>PASSED</td>
<td></td>
<td></td>
</tr>
<tr>
<td>After mechanical shock</td>
<td>8.20</td>
<td>25.20</td>
<td>12.30</td>
</tr>
<tr>
<td>Ammonium Sulfide exposure (3 min.)</td>
<td>7.20</td>
<td>8.00</td>
<td>7.59</td>
</tr>
<tr>
<td>Dielectric withstand voltage No breakdown @ 500V AC</td>
<td>002</td>
<td>9.50</td>
<td>5.26</td>
</tr>
<tr>
<td>Gas tightness</td>
<td>7.00</td>
<td>7.60</td>
<td>7.24</td>
</tr>
</tbody>
</table>


For details, call or write: Burndy Corporation, Norwalk, Connecticut 06856 (203-838-4444).
Get your hands on a CORTRON Solid State Keyboard, and you’ll soon find out why you can’t judge all keyboards on initial price alone.

It’s after installation that cost efficiency becomes most important. In life expectancy, ability to endure extreme environments, high speed operation without “misses,” accuracy, downtime caused by beverage spillages, reliability, serviceability and human engineered features. That’s where a CORTRON Solid State Keyboard really pays off.

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CIRCLE NUMBER 73
New products

True 12-bit CMOS multiplying d/a converter is low-priced

Analog Devices Semiconductor, 829 Woburn St., Wilmington, MA 01887. Jeff Riskin (617) 935-5565. P&A: Stock; see text for price.

Twelve bits for twelve bucks is now available in the first monolithic CMOS multiplying d/a converter to have linearity consistent with its 12-bit resolution. The AD7541 from Analog Devices features a low power consumption (below 32 mW) and nonlinearity error (±0.01% of full-scale range at 25°C). In a plastic DIP, and an operating temperature range of 0 to 70°C, the AD7541 goes for $12 each in quantities of 1000 or more.

The reference-voltage input to the converter may be steady dc of either polarity, or ac of either constant or varying amplitude. This versatility encourages such applications as digitally programmed power supplies, digital-to-synchro converters and digitally controlled attenuators.

The AD7541 contains a precision thin-film R-2R ladder network and CMOS switches. The network is connected—inverted—to generate binary-weighted currents. Each switch sends its current to one of two output current-summing buses; this provides a “push-pull” output. Having both of these outputs available, as well as a reference input that accepts either polarity, permits four-quadrant multiplication to be done with a relatively simple circuit that uses two external operational amplifiers.

To maintain the AD7541’s linearity, the voltages at the output terminals must be kept very close to ground. Op amps at the output(s) must be chosen for low bias current (less than 75 nA, or so) and low offset voltage (less than about 0.5 mV). The digital inputs, which are TTL and CMOS-compatible, are zener-protected, but still require typical CMOS design and handling precautions.

The AD7541 has no digital-input buffer register. Although this complicates microcomputer interfacing, it simplifies the converter, reduces its cost, and increases its versatility.

Two linearities are available: ±0.01% of full-scale as mentioned, and ±0.02% of full-scale, which costs less. Both are available in three temperature ranges: 0 to 70°C, −25 to +85°C, and −55 to +125°C. The first range is provided in a plastic DIP, while the latter two come in ceramic DIPs.

Linearity is affected slightly by temperature, and becomes ±0.012% and ±0.024% of full-scale over the rated temperature ranges.

Prices for the three temperature ranges, respectively, are $12, $16, and $49 for 0.01% linearity, and $11, $15 and $44 for 0.02%. In addition, the AD7541 is pin-compatible with its less-accurate predecessor, the AD7521, and all versions are in stock.

CIRCLE NO. 301

Hybrid IC audio amps deliver 25 and 90 W


The STK-075 hybrid IC audio amplifier delivers 15 W into 8Ω or 25 W into 4Ω at a cost of $4.80 (1000 quantity). The STK-086 delivers 70 W into 8Ω and 90 W into 4Ω at a cost of $16.00. The output has a specified, 0.3%, total harmonic distortion and a 20-Hz to 20-kHz frequency range. Since the device uses a dual power supply, it does not require a speaker coupling capacitor.

CIRCLE NO. 320

Multiprotocol chip formats data

Zilog, 10460 Bubb Rd., Cupertino, CA 95014. Jim Gibbons (408) 446-4666. $49 (plastic), $54 (ceramic); stock.

The single-chip Z80-SIO is a serial I/O controller that controls communications peripherals and formats data in data communication networks. The chip works with the interfaces of most 8 and 16-bit processors and supports the “daisy-chain” interrupt structure of the Z80 CPU. Each of the SIO’s full-duplex channels has four control lines for most commonly used modems. For systems with 2.5-MHz CPU clock rate, the SIO’s data rate goes up to 550 kbits/s, while in a 4-MHz system, it is up to 880 kbits.

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Westinghouse Semiconductor, Youngwood, PA 15697. (412) 925-7272. $200; 10 to 12 wks.

The D60T is a high-current, high-voltage and fast-switching transistor with turn-on and turn-off times of less than 0.5 \( \mu s \). Rated at 200 A peak, 450 V, the transistor has a gain of 10 at 50 A.

CIRCLE NO. 310

High-power SCRs operate at 150 C

International Rectifier, 233 Kansas St., El Segundo, CA 90245. (213) 322-3331. $44.85 to $87.65 (100 qty); stock to 4 wks.

The 325PAH series of high-power SCRs are for 150-C operation and have a nominal rms current rating of 510 A. The average current level is 325 A. Peak-reverse voltages are from 500 to 1200 V. The SCRs have a junction operating temperature range of -40 to +150 C and a maximum internal thermal resistance, junction to case, of 0.085 C/W. Packaged in a 1.6-in. diameter "hockey puck."

CIRCLE NO. 322

4-bit-slice processors operate at high speed

Texas Instruments, P.O. Box 5012, M/S 308 (Attn: S/81), Dallas, TX 75222. Rex Meek (713) 491-5115. $29.25; stock.

The S481 set of 4-bit-slice processors can select and operate on two operands, generate status and store results in a single 100-ns cycle. The chips provide built-in computational algorithms for automatically sequenced iterative, signed or unsigned multiplies and divides and cyclical-redundancy character calculations. The chip set consists of LS/481s, 54S/74S482 4-bit-slice controllers and either the 54S/74S330 or 331 field-programmable logic arrays.

CIRCLE NO. 323

A/d chip mixes linear and digital

Analog Devices, 829 Woburn St., Wilmington, MA 01887. Jeff Riskin (617) 935-5565. $24 to $60; stock.

The AD571 10-bit monolithic a/d converter combines linear and digital circuitry on a single IC chip. The device is a successive-approximation converter and includes a d/a, voltage reference, clock, comparator, successive-approximation register and output buffer on a 120 \( \times \) 150-mil chip. A complete conversion to 10-bit accuracy is executed in 25 \( \mu s \).
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CIRCLE NUMBER 76
ICs & SEMICONDUCTORS

HV rectifiers have 2-µs or 250-ns recovery

High Voltage Devices, 7485 Avenue 304, Visalia, CA 93277. Ken Corsetti (209) 733-3570. $6.90 to $23.93 (100 qty); 1 to 4 wks.

The KXS and KX Powerstack series of medium (2 µs) and fast (250 ns) recovery high-voltage, high-current silicon rectifiers are mini-sized. The body is 0.39 in. long with a max diameter of 0.515 in. Peak inverse voltages are 1.5 to 10 kV with average rectified currents at 50 C of 3, 2.2 and 1.5 A depending on PIV. Max reverse leakage is 1 µA at 25 C and 25 µA at 100 C. Forward surge current ratings are up to 200 A for 8.3 ms.

CIRCLE NO. 325

Controller gives memory transfer of 2 Mbytes/s

Advanced Micro Devices, 901 Thompson Pl., Sunnyvale, CA 94086. E. Sopkin (408) 732-2400. $18.25 (100 qty); stock.

The Am9517 controller has memory-transfer speeds up to 2 Mbytes/s. Four independent channels are available and these can be increased through cascading. Three transfer modes are provided: single word, demand and block. The device is available in molded and ceramic hermetic DIPs.

CIRCLE NO. 326

MOS memory is fully static

Motorola, 3501 Ed Bluestein Blvd., Austin, TX 78721. (512) 928-2600. (100 to 999 qty) from $12.25, stock.

The MCM2114 MOS memory is a 1024 x 4-bit static RAM that requires no clocks, no timing strobes, nor refreshing because of fully static operation. Data-out and data-in are of the same polarity and no address set-up time is required. Four speed ranges are offered: 200, 250, 300 and 450 ns. Two power versions are the MCM2114 at 550 mW and the MCM21L14 at 385 W. Two 18-pin packages are available; plastic and lid-seal ceramic.

CIRCLE NO. 327

Rectifiers supply up to 16 kV

Solid State Devices, 14830 Valley View Ave., La Mirada, CA 90638. Dee Peden (213) 921-9660. $0.66 to $7.29 (100 qty); stock to 4 wks.

Two types of high-voltage rectifiers combine high peak-reverse voltage and moderate current characteristics. An axial-lead series, 1N2372 through 1N2385, has PRVs from 420 V to 10 kV with average rectified currents from 250 mA to 70 mA. Forward voltage drops, at 100 mA, range from 3 V for the 420-V units to 39 V for the 10-kV units. Case dimensions are from 0.5 x 0.363-in. diameter up to 2 x 0.5 in. The ferrule series, 1N1133 through 1N1149, has PRVs from 1.5 kV at 100 mA to 16 kV at 45 mA. Forward drops are 7.5 to 60 V at rated current. The 0.625-in. diameter cases go from 1.813 to 6.025-in. long.

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*Texas Instruments, P.O. Box 84, M/S 812, Sherman, TX 75090, Lowell Chambers (214) 893-5166. $1.65 (100 qty); stock.*

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**Power transistors handle up to 10 A and 300 V**

*TRW Power Semiconductors, 14520 Aviation Blvd., Lawndale, CA 90260. John Power (213) 679-5561. $4.20 to $4.50 (100 qty); 4 to 8 wks.*

The SVT300-3, 300-5 and 300-10 are npn power-switching transistors that feature a minimum dc current gain of 15 at currents of 3, 5 and 10 A. Max collector voltage is 300 V. At 25 C, the SVT300-3 dissipates 116 W; the SVT300-5 and SVT300-10, 146 W. Operating and storage temperature is -65 to +200 C. The transistors are available in TO-3 or TO-61 isolated packages and can be made to meet JAN and JAN-TX military specs.

*TRW Power Semiconductors, 14520 Aviation Blvd., Lawndale, CA 90260. John Power (213) 679-5561. $4.20 to $4.50 (100 qty); 4 to 8 wks.*

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**Voltage regulator uses pulse-width modulation**

*Texas Instruments, P.O. Box 5012, M/S 308 (Attn: TL494), Dallas, TX 75222. Dale Pippenger (214) 238-5908. $2.88 (plastic), $3.31 (ceramic); stock.*

The TL494 is a switching voltage regulator IC that provides all the functions required for pulse-width modulation (PWM) control circuits. The chip contains a 5-V regulator, error amplifier, current-limit amplifier, adjustable oscillator, dead-time-control comparator, pulse-steering flip-flop and output-control circuitry. Uncommitted output transistors may be operated as common-collector or common-emitter. The trigger for the pulse-steering flip-flop is derived from the PWM circuit to prevent double pulsing of either output.

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With HP's newest distortion analyzer.

Automatic frequency nulling and auto set level features of the 339A Distortion Measurement Set speed your total harmonic distortion measurements (THD). And true-rms detection means accurate measurements as low as 0.0018% (-95 dB) from 10 Hz to 110 kHz. Whether you're testing signal sources or amplifiers, here's how the 339A, priced at $1,900*, can help you make quick and precise measurements.

**Speed your set-up.** Just select the frequency of the built-in oscillator and the 339A's "tum signal" indicators show you how to make the proper input range setting. This means you have a low-distortion source for testing high-performance amplifiers and you tune one instrument instead of two. If you're using an external source, "tum signal" indicators show you which direction to turn frequency controls for quick manual nulling.

**Save test time.** The 339A's auto set level feature automatically sets the 100% reference level, within a 10 dB capture range, every time you change frequency or level. Again, visual indicators show you which way to turn the input range switch if your signal is outside of the capture range. You not only save time, you also minimize operator errors.

Standard features even make the 339A suitable for checking broadcast equipment for FCC compliance. And for measuring frequency response, you can quickly read relative measurements in either percentage or dB.

Contact your local HP field engineer for further details.

* Domestic U.S.A. price only.
Darlplings can sustain 400 V when switching

A series of monolithic Darlington transistors, for motor controls and switching power supplies can sustain 400 V. With a rise time of 0.4 μs and a fall time of 1 μs, the devices are suited for high-speed switching circuits (10 kHz). Three transistors, SVT 6060, 6061 and 6062, have a dc current gain of 30 at 15 A and a peak collector current of 25 A. Junction-temperature range is -50 to +150 C.

Dynamic RAM suits low-cost uses

Motorola, 3501 Ed Bluestein Blvd., Austin, TX 78721 (512) 928-2600. From $5.75 (100 qty); stock.

The MCM4096 is a 4 k × 1-bit dynamic RAM. All inputs are TTL compatible and the output is three-state TTL compatible. Each of the 64 row addresses requires a memory cycle every 2 ms to refresh the RAM. Max power dissipation is 445 mW in the active mode and 19 mW for standby. Three speeds are available: 250, 300 and 350 ns (max access time). Package types are 16-pin ceramic or frit-seal ceramic.

32-k ROM for M6800 bus is fully static

Motorola, 3501 Ed Bluestein Blvd., Austin, TX 78721 (512) 928-2600. $13.10 (plastic, 250 qty).

The MCM68A332 is a 32,768-bit programmable ROM that is fully static and can be used with bus-oriented systems such as the M6800 or other 8-bit microprocessors. The memory uses a single 5-V supply, dissipates less than 440 mW with an access time and cycle time of 360 ns. The 24-pin package is available in either plastic (P suffix) or ceramic (L suffix).

SCRs have grounded cathodes

Texas Instruments, P.O. Box 5012, M/S 308 (Attn: TIC101/102), Dallas, TX 75222. Keith Renard (214) 238-3041. $0.26 to $0.57 (1000 qty); stock.

The TIC101/TIC102 series of grounded-cathode SCRs are pnpn silicon reverse-blocking triode thyristors with the cathode in electrical contact with the mounting tab. Electrical insulation of the SCR tab is thereby eliminated. Repetitive peak off-state voltages and repetitive peak reverse voltages range from 30 to 600 V. Surge on-state current is to 30 A with up to 600-V capability. Continuous on-state current at or below 80-C case temperature is 5 A dc.
BergLance™ Wire-Wrapping Posts give a classic performance on the Lowrey Organ.

The BergLance System assures rapid staking of miniature thru-lugs for solid or stranded wire terminations. It's an approach that offers high quality and reliability... and is economical, too.

Lowrey likes it, and has used millions of BergLance posts throughout the past decade. Lowrey has found it can rely on Berg Electronics... to supply the product and the application machines that precisely meet its interconnection needs.

Berg is experienced. We read interconnection needs like Lowrey reads music. We have the products, the background and the back-up to do the job. Your job. Let's work on it, together. Berg Electronics, Division, E. I. du Pont de Nemours & Co., New Cumberland, Pa. 17070—Phone (717) 938-6711.

We serve special interests—yours!
Some of these components will probably never
The others will just come close.

Snap-action V3, SM and SX switches offer
a wide variety of actuators, electrical capacity and
termination.

Mercury switches offer hermetic sealing, a
variety of electrical capacity and broad temperature
ranges at a low cost.

The SR, XL, XK and AV are solid state position
sensors featuring almost infinite life. All offer zero
speed operation with some up to 100 Khz. ES current
sensor utilizes Hall-effect IC and protects against
damage from short circuits or overcurrent conditions.

AML manual devices for
low installed cost,
electrical flexibility and attrac-
tive panel appearance. Series 8
miniature manual switches provide small size and
wide variety of operators. DM offers inexpensive
snap-in panel mount design.

Solid state keyboards provide high reliability no mechanical keyboard can offer. Panel sealed
versions also available.
Video monitor takes the lead in resolution and distortion

Tektronix, Inc., P.O. Box 500, Beaverton, OR 97077. Bob Down. (503) 644-0161. P&A: See text.

Need high resolution, low distortion and uniform brightness in a video display? You can get the best of all three in the Tektronix 634, a 10 × 12-cm, flat-screen monitor. Resolution is guaranteed to be 1100 lines minimum at a brightness of 100 candelas/m² (30 footlamberts). Distortion stays under ±0.5%—without calibration—over a 9-cm circle at the center of the screen, and it remains below 1% elsewhere. And brightness doesn't vary more than 20% over the entire screen.

The best resolution until now was about 800 lines with the Conrac VF-02, a popular 10 × 12-cm display. But even that resolution isn't guaranteed, nor is the VF-02’s brightness variation specified. However, the VF-02’s distortion is adjustable to 0.5 to 1%. The maximum brightness of both competing displays is over 150 ft-L.

Tektronix measures the 634’s worst-case resolution of 1100 lines—the nominal value is 1400 lines—with the shrinking-raster method at a 60% modulation index. At a 90% index, resolution falls to 840 lines, nominal, and 660 lines, worst case. Distortion is measured with a superimposed, transparent linearity chart, and brightness is read at the center and four corners of the chart by Tek’s J-16 photometer.

With the 634’s improved performance, the black-and-white range is so wide, you get better gray-scale images than ever before. Moreover, you don’t need any calibration time for accurate on-screen image measurements. Also, you get more uniform reproduction of equivalent gray shades over the screen area.

With the Tek unit’s modular construction, the various controls for contrast, focus and brightness can be connected at the 634’s top or side, or elsewhere in your equipment arrangement. Or functions can be controlled remotely via an optional connector.

The 634 operates from a standard 110 or 220-V line, but unregulated dc operation (21 to 25 V, −21 to −25 V, 8 to 10 V) is available optionally. The 634 goes for $1125 (just about a buck a line). If resolution isn’t important, you can get a 650-line unit for $900. Either way, delivery takes 12 weeks.

Tektronix
Conrac

CIRCLE NO. 302
CIRCLE NO. 303
NOW

4 Watts Linear
1 to 1000 MHz
Only $2700

Model 4W1000
ULTRA-WIDEBAND AMPLIFIER

It's fact! Model 4W1000 is the only ultra-wideband, solid-state power amplifier that supplies a minimum of 4 watts of RF power from 1 to 1000 MHz. It's probably all the bandwidth and power you'll ever need.

You can use this versatile, unconditionally stable amplifier with frequency synthesizers or swept signal sources to provide high-level outputs. Applications include RFI susceptibility testing, NMR spectroscopy, antenna and component testing as well as general lab use.

Very likely, the 4W1000 will satisfy all your ultra-wideband power amplifier needs. However, if the 4W1000 offers more power than you need, consider the more economical 1W1000, priced at only $1,250. For complete information, write or call:
Amplifier Research
160 School House Road
Souderton, Pa. 18964
215/723-8181

CIRCLE NUMBER 83

INSTRUMENTATION

Pulse generator has true/complement outputs

Dytech, 2725 Lafayette St., Santa Clara, CA 95050. (408) 241-4333. $385; stock to 4 wks.

The Model 801 pulse generator provides true and complementary outputs with amplitude control from 0 to +10 V. Rise and fall times are 5 ns or less while delays of from 50 ns to 1 s are available. The unit accepts external triggering as well as internal automatic and manual modes and produces pulse-pair bursts over the entire delay range. A single-cycle switch also generates any fixed number of pulses of any pulse width for any duration within the min-max ranges of the generator. The unit accepts DTL, TTL or ac input at both the external and gate inputs.

CIRCLE NO. 337

Tester locates shorts in multilayer PC boards

Idlewild Associates, Box 41, McMinnville, OR 97128. Larry Lockwood (503) 472-0005. $275; stock to 2 wks.

A fault finder, called Model 911 Short Sniffer, locates shorted runs buried in multilayer circuit boards. The instrument enables technicians to locate and patch around defective runs and acts as a diagnostic tool to aid in circuit-board failure analysis. The device indicates the direction of shorted conductors as well as pinpointing the location of the short. Indication is by audible clicks that increase in frequency as the short is approached. Meter indication is also provided.

CIRCLE NO. 338

Thrifty function gen spans 0.1 Hz to 1 MHz

B&K Precision, 6460 W. Cortland Ave., Chicago, IL 60635. (312) 889-9087. $175; stock.

Model 3010 function generator spans 0.1 Hz to 1 MHz in six ranges, with each range providing linear 100:1 frequency control. The unit generates sine, square, TTL square and triangle waveforms. Frequency generation is by a stable voltage-controlled oscillator (VCO) that can be varied on each range by a front-panel control or the VCO external input. If a 0-to-5.5-V ramp is applied to the VCO, the unit will provide a 100:1 output frequency change. With an audio signal in place of the ramp, the unit will produce a direct FM output. Variable-output, square-wave rise or fall time is 100 ns; TTL square-wave rise/fall time is 25 ns.

CIRCLE NO. 339

Word generator delivers up to 50 MHz

Taku Tron, 11 Esquire Rd., North Billerica, MA 01862. Jim Hanley (617) 667-3874. $4400; 6 to 8 wks.

Model MG-3 programmable word generator module has speeds up to 50 MHz. The device contains 1024 bits of RAM, programmable from front-panel controls or via an optional remote bus. The bits are arranged in a matrix of 128 words by 8 bits. An auxiliary ninth channel is used as an additional data channel or auxiliary sync channel. Data outputs may be in either 8-bit parallel or serial, RZ or NRZ-selectable. The output word or bit length in either mode is controllable in integer steps.

CIRCLE NO. 340
that speaks your language!

It's incredible but... the Datalogger 2000 can measure 4 parameters that you've chosen... offer 2000 internal alarms... manage your data collection and report it in your language... and still remain 'pushbutton-simple to operate.'

The Digitec DATA INFORMATION CENTER features:

• Multi-Parameter capability
  Combine up to 4 of the 38 field interchangeable signal conditioning modules for measuring:
  - Temperature (Thermocouple, Thermistor, RTD)
  - DC Voltage, DC Auto-ranging
  - AC Voltage, True RMS
  - Transmitter output

• Up to 20 channels internal—expandable to 1000.
• ±25,000 count display (4½ digits) of measured data.
• Alphanumeric printout.
• Exclusive skip-channel capability.
• 24-hour clock and Julian date.
• Internal microprocessor.
• Pushbutton programming.

And these options can make your DATA INFORMATION CENTER even more versatile!

• Internal alarms
  Up to 2000 individual set-points.
  4-level limits assignable per channel.

• English messages
  6-character message assignable to each limit which eliminates the need for translation codes and look-up tables.

• Data outputs
  Isolated BCD, Isolated RS-232-C, TTY compatible, with selectable baud rates from 110 to 9600.

From the leaders in data acquisition, the Datalogger 2000 delivers all the traditional Digitec qualities—premium components, designer styling and reliable performance.

For a free brochure that explains how your measuring and collecting of data can be made simple, write or call:
Don Gerdeman, our Datalogger Specialist.

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Precision measurements to count on.

FOR DEMONSTRATION ONLY CIRCLE 85
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Single-Turn Film
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Tired of broken delivery promises and poor quality? Deal with the trimmer capacitor specialist, for quality products delivered on schedule! Call on us for custom designs too, we deliver!

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A "LIGHT" TOUCH

The optically encoded Series 5000.
A fully custom keyboard priced for low volume users.
And it's as reliable as a light beam.

You define the key codes, functions, interface, key locations and cap markings. If you can make do with a choice of only 2048 different codes, 360 keys or less, n-key lockout, 2-key rollover and logical or non-logical pairing, we'll make it up to you with fast delivery and no NRE or tooling charges.

Series 5000. The most sensible keyboard technology available today. Affordable in any quantity.

INSTRUMENTATION

IC thermal resistance checked in 7 seconds

Sage Enterprises, 1080 Linda Vista Ave., Mountain View, CA 94043. B. Siegal (415) 969-5111. $5000; 8 weeks.

The thermal resistance of ICs can be measured quickly (in accordance with MIL-STD-883A Method 1012) with the THETA 400. Using the forward-biased substrate-isolation-diode junction voltage as the temperature-sensitive parameter, the instrument applies a repetitive pulse that heats the test device. Sensing the change in isolation junction voltage, the device automatically divides the change by the applied heating power to produce a direct full-scale reading of 199.9 C/W. Accuracy of 6% max is made possible by the use of multiwire Kelvin contacts.

CIRCLE NO. 341

8-digit freq counter sells for $135

Continental Specialties, 44 Kendall St., New Haven, CT 06509. (203) 624-3103. $134.95.

The MAX-100 frequency counter operates from 20 Hz to 100 MHz and reads out on an 8-digit display. The crystal-controlled time base offers 3-ppm accuracy and the counter updates every second. The input is preamplified to work with 30 mV of signal and is diode protected up to 200 V. The display has a 0.6-in. digit height. No range switch is necessary since the least significant digit always represents 1 Hz. The unit can be operated on internal rechargeable batteries or from wall power using a charger.

CIRCLE NO. 342

Electronic Design 6, March 15, 1978
How fast can you accurately measure period or frequency of this wave form?

The old way.

(About 5 minutes)
1. Find a scope and voltmeter.
2. Connect signal to scope.
3. Determine proper trigger points.
4. Connect signal to counter.
5. Select period or frequency function.
6. Select time base.
7. Set input voltage range.
8. Set input coupling to DC.
9. Connect voltmeter to trigger level output—if counter has output. (If not, good luck.)
10. Set desired trigger level.

The easy way.

(About 5 seconds)
1. Connect signal to Racal-Dana 9000 counter.
2. Push \( P \) or \( F \) button.
3. Push \( TL \) button.
4. Push \( AU \) button.
The rest is automatic.

Now it's up to you.

You can continue to struggle along the old way. Or you can find out about the Racal-Dana 9000 Microprocessing Timer/Counter. The patented Auto-Trigger capability makes it the fastest and most accurate instrument in the world for the precision measurement of wave forms. Give us a call and we'll tell you how Racal-Dana systems technology can solve all your measurement problems the easy way.

RACAL-DANA
Others measure by us.

Racal-Dana Instruments, Inc., 18912 Von Karman Avenue, Irvine, CA 92715, Phone: 714/833-1234.
Opens new horizons for PCB design.

70%-90% Reduction in Mating and Unmating Forces
- simpler board support systems
- fewer damaged boards

Extended Circuit Count Potential
- up to 400 Bristle Brush per connector

Extensive Product Line
- mother board, daughter board, input/output, PC receptacle body styles
- 2-, 3-, and 4-row configurations
- 90° and straight PC, solderless wrap, crimp removable, willowy tail terminations

For complete information, contact The Bendix Corporation, Electrical Components Division, Sidney, New York 13838.
Featherweight Miniature Panel Mount Thermal Printer

Datel's new model DPP-7 Digital Panel Printer uses only 2 moving parts for OEM reliability. At only 2.3 Lbs. (1.1Kg) it is one of the lightest panel-mounting recording instruments available.

Includes all electronics.
The $475* single quantity price includes everything required for full parallel BCD/TTL data inputs plus an input storage register for multiplexed bus applications plus an AC power supply! There are no extra boards to design or bulky cables and power supplies needed. The DPP-7 is ready to use.

Thermal printing means no messy inks, banging hammers or twirling print-wheels. Nothing to jam or run out of ink.

Use the miniature DPP-7 for simple data logging systems, automatic test fixtures or with a digital panel meter for accurate unattended data measurement.

The small size of the DPP-7 makes it ideal for panel-mounting in analytical instruments and compact data systems. Up to six digits and sign may be printed to identify channel number and data.

The DPP-7 uses +5VDC power in a very short 6.2" (158mm) deep version or 100, 115 or 230 VAC power in an 8.7" (221mm) deep version.

*U.S.A. domestic price only

Datel Systems, Inc.
1020 Turnpike St., Canton, MA 02021
TEL: (617) 828-8000 / TWX: 710-348-0135

Send for your FREE Brochure
CIRCLE NUMBER 247
Data acquisition system measures time intervals


The Model 5391A is a compact data acquisition system capable of high-speed, high-volume measurements of time interval and frequency. Measurements of successive pulse widths or periods as short as 2 ns can be made at rates over 50,000/s. The system measures frequency from 50 µHz to 500 MHz or intervals from 2 ns to 20,000 s in either of two input channels. Up to 8 kbytes of measurement data can be acquired and temporarily stored in the plug-in memory per run. By pressing a single key on the Computing Controller keyboard, all of the specified measurements are automatically made and stored. Pressing another key causes previously-specified statistical analyses to be performed.

CIRCLE NO. 343

Triggered scope has 20-MHz bandwidth

Leader Instruments, 151 Dupont St., Plainview, NY 11803. Pat Redko (516) 822-9300. $500.

The LBO-507 oscilloscope has automatic-triggered circuitry and a 20-MHz bandwidth. Pushbutton switches select all functions. Vertical sensitivity is 10 mV/cm, and calibration is in 11 steps, up to 50 V/cm, with variable control. Rise time is 17.5 ns. Sweep speed ranges from 0.5 µs/cm to 500 ms/cm in 18 steps. Magnification of X5 delivers 100 ns/cm maximum speed. The unit has a 5-in. CRT with an 8 x 10 effective area.

CIRCLE NO. 344

Transient detector holds spikes

Industrionics, 115 Pleasant St., Millis, MA 02054. Joe Hersey (617) 376-8147. $125; stock.

The Zap-Trap is a portable battery-operated transient voltage detector that senses and holds voltage spikes for up to 30 minutes with only 10% decay. If necessary, the unit can be operated unattended, with connection made to any dc meter on the 10-V scale. Pulse widths ranging from 2 µs to 1.1 ms in both positive and negative directions can be sensed. Voltage range is from 10 to 1000 V, but a special adaptor allows you to detect pulses up to 10 kV. The instrument mounts directly on two 12-V #1463 batteries, or can be powered by 16 C-cells mounted in an optional carrier.

CIRCLE NO. 345

Freq synthesizer spans 20 to 160 MHz

Syntest, 169 Millham St., Marlboro, MA 01752. (617) 481-7827. $699; stock to 4 wks.

The SI-160 is a 5-digit frequency synthesizer that provides ECL signals into a 50-Ω load over the range of 20 to 160 MHz with a resolution of 1 kHz. Temperature stability is ±1 ppm from 0 to 50 C. Options include external BCD programming with latching for computer control, sine-wave output at 13 dBm into a 50-Ω load and a standard RETMA 19-in. rack-mounting adapter.

CIRCLE NO. 346

Audio gen and monitor checks received signals

International Data Sciences, 100 Nashua St., Providence, RI 02904. (401) 274-5100. $810; 4 wks.

The Model 8508 audio generator and monitor allows the operator to listen to and measure received analog signals appearing at a modem-telephone line interface. The instrument generates a 1-kHz tone, variable from 0 to -16 dBm, patched into a telephone line. The monitor portion has an audio speaker and a dBm meter to monitor and measure line signals from -20 to +3 dBm. The input signals may be amplified to a level up to 50 dB.

CIRCLE NO. 347

Logic tester checks general-purpose ICs

E.I.S., 1617 E. 17 St., Santa Ana, CA 92701. Hal Horrocks (714) 541-0415. $249; 4 wks.

The Model 500 Functional Logic Tester is a general-purpose IC logic tester that can be used by non-technical personnel. The instrument can be operated manually, testing one device at a time, or can be connected to an automatic handler since it contains built-in interface and control circuitry. Three internal test frequencies are 100 Hz, 250 kHz and 500 kHz. Also available is one external test frequency ranging from 50 kHz to 6 MHz. There is a selection switch for either TTL or CMOS devices. IC packages of 6, 8, 14, 16 and 18 pins can be handled.

CIRCLE NO. 348
New, 16 Bit Microcircuit D/A Converter

Datel has it...

Two versions to choose from:

**DAC-HP16BMC**
- 16 Bit Binary Resolution
- 15 ppm/°C Max. Tempco
- ± 0.003% Linearity
- 0 to +10V, ±5V Output
- 35 µsec. Settling Time

**DAC-HP16DMC**
- 4 Digit BCD Resolution
- 15 ppm/°C Max. Tempco
- ± 0.005% Linearity
- 0 to +10V Output
- 15 µsec. Settling Time

When high resolution and stability are demanded, Datel's DAC-HP series provides the performance—applications such as precision signal reconstruction, automatic test systems, and ultra-linear ramp generation. DAC-HP's excellent performance results from special low tempco nichrome thin-film resistors, laser trimmed for optimum linearity, and a low tempco zener reference circuit. Operating temperature range is 0 to 70°C, with models available for -25 to +85 and -55 to +125°C operation.

$77 50* (100's)

Price, both versions: $119.00* (1-24)

*U.S.A. domestic prices only

1020 Turnpike Street, Canton, MA 02021
TEL: (617) 828-8000 TWX: 710-348-0135
INSTRUMENTATION

Lab rf amplifier yields preset constant level

Logan (516) 694-1414. $4910; 4 wks.

The Model 2600 rf amplifier is for use where a load may be damaged by excessive power. Either the power or voltage delivered to the load can be maintained at a preset constant level, regardless of impedance changes in the load. In addition, the unit turns itself off if power or voltage reaches a predetermined level. Two meters monitor forward and reflected power. The amplifier covers 0.5 to 35 MHz and is rated at 130 W output. The unit is solid state and operates into any load impedance from a short to an open circuit.

CIRCLE NO. 349

General-purpose scope handles 15 MHz

Philips Test & Measuring Instruments, Mahwah, NJ 07430. (800) 631-7172. $875; stock.

Model PM3211 portable, 15-MHz/2-mV oscilloscope features comprehensive triggering facilities. The unit has an 8 X 10-cm screen in a 300 X 135 X 445-mm case. Its weight is 7.5 kg. Triggering can be in “Auto” or level-set modes and multisourced. Channel B can be used as an X input to facilitate X-Y displays, with calibrated attenuation of both X and Y inputs. Channel B can be inverted, and with the ADD function, can display A ± B.

CIRCLE NO. 350

Current probe measures peaks up to 500 A

Tektronix, P.O. Box 500, Beaverton, OR 97077. (503) 644-0161. $665.

The P6303 probe measures peak pulse currents to 500 A and steady-state currents to 100 A within the frequency range of dc to 15 MHz. A 1 X 0.83-in. jaw accommodates large conductors. Because inductive coupling is used, no electrical contact or circuit break is required. The probe operates as a part of a system with the AM503 current probe amplifier, any TM500 power module and an oscilloscope.

CIRCLE NO. 356

New technique measures power for fiber optics


The 84801A thermistor sensor, when used with any HP 432 power meter, measures optical power from 1 µW (-30 dBm) to 10 mW (+10 dBm) over the wavelength range of 600 to 1200 nm, with an absolute accuracy as low as 7%. Using an optical fiber as its input, the system is a high-efficiency design for single-fiber power measurement. Absolute calibration is provided by the calibration factor adjustment on the 432. The power sensor is a thermistor bead that is attached to one meter of fiber-optic “waveguide.” The fiber diameter is 200 microns, maximizing the amount of light detected by the sensor and assuring high accuracy of measurement.

CIRCLE NO. 357

Equations & Diagrams

87% efficiency in a compact 200 watt 400Hz to DC power supply

High wattage power supplies needn't be hot, heavy or bulky. Tecnetics' new 4200 Series packs 200 watts of power in 60 cubic inches of space, and delivers it with up to 87% efficiency. It's accomplished through pulse width modulation techniques, a technology pioneered by Tecnetics.

What did we give up to achieve these impressive specs? Nothing. Just look at the state of the art features: remote error sensing, full encapsulation, MTBF up to 30,000 hrs. on single output units, EMI filter, overload and short circuit protection, excellent regulation, and environmental specs that meet the requirements of MIL-E-5400.

This impressive power supply series is now available with single and triple outputs to meet a wide variety of military and aerospace power conversion needs. Get full specs on this and over 1000 other AC-DC and DC-DC power supplies by sending for our catalog.

CIRCLE NUMBER 93

Electronic Design 6, March 15, 1978
Datel's Digital Voltage Calibrator, DVC-8500 comes in a mini-benchtop package, at a mini-price ($450 in singles*), but provides very big performance. DVC-8500 offers 4½-digit resolution and a ±19.999 volt full scale output range with ±1 millivolt accuracy (±0.005% of full scale.)

Use your DVC-8500 to calibrate A/D and D/A converters, DPM's, DVM's, Op Amps, V/F converters, and Data Acquisition Systems. A short-proof, buffered output gives up to ±25mA output current with an LED overload warning signal. The ±1.5 millivolt front panel vernier allows fine tuning of A/D and D/A bit steps.

Included are rear PC sense terminals and a choice of 100, 115, or 230 VAC inputs. A panel mounting kit is optional.

Contact Datel, or your nearest Datel Representative listed in Gold Book or EEM.

*S.A. Domestic Price only.

**Electronic Design** 6, March 15, 1978
Where can I get an AC-DC or DC-DC switching power supply in a modular, open frame or P.C.B. design, with a 5 year warranty at reasonable cost?

**ETATECH**

85-135 VAC INPUT, 60 WATT 5 OUTPUT SWITCHING POWER SUPPLY.

187-M W. ORANGETHORPE, PLACENTIA, CA 92670  (714) 996-0981

CIRCLE NUMBER 95

---

Double Balanced Mixers

10-1500 MHz

- 6 dB Midband Conversion Loss (typ.)
- 40 dB Midband LO-RF, LO-ISOLATION (typ.)
- 0 dBm RF Input for 1 dB Compression
- DC Offset 10 mV (typ.)

Either Flatpack or TO-8 version provides high performance for applications with RF signals in the 1000 to 1500 MHz range (e.g., TACAN).

Both Model MD-149 and Model MD-152 are $39 (1-49 quantity). IMMEDIATELY AVAILABLE FROM STOCK.

---

**MICRO/MINI COMPUTING**

16-bit µP outperforms most 8-bit CPUs

National Semiconductor, 2900 Semiconductor Dr., Santa Clara, CA 95051. Howard Raphael (408) 737-5956. $10; stock.

The INS8900, a 40-pin, 16-bit microprocessor, sports an interrupt structure, addressing modes and logical capabilities associated with minicomputers. Instruction execution times for most commonly used routines are equivalent to those on advanced 8-bit designs and 10 to 30% faster than on present generation designs, such as the 2-µs 8080. The 8900 is a true 16-bit CPU. It uses 16-bit instruction words and 16-bit data words and has a flexible set of 45 instruction types. The chip contains status and control circuitry, conditioned branch-sense circuitry, interrupt logic and a portion of the clock generation circuitry. By adding a ROM and one to four RAMs, a complete microprocessor system can be implemented.

CIRCLE NO. 358

Single-chip µP has four 8-digit RAMs

Western Digital, 3128 Red Hill Ave., Newport Beach, CA 92663. (714) 557-3550.

The WD/40 microprocessor, for dedicated control uses, has four 8-digit RAM data storage registers and 400 or 512 10-bit words of ROM. The chip directly drives seven-segment displays through a ROM programmable decoder.

CIRCLE NO. 359
One Mallory THF capacitor can replace up to four CSR types in a switching power supply.

These small, solid-tantalum capacitors give you a per-unit substitution factor as high as one for four and can by-pass 4.5 amp rms at 100kHz. So by using these high ripple performance capacitors you save in space, weight and cost.

Specially designed for low equivalent series resistance, at frequencies from 1 kHz through 1 MHz. They’re ideal for high frequency power supply switching, for regulator switching, or for bypassing or filtering unwanted ripple currents.

Because ESR is low, power losses are low. With the solid electrolyte and hermetic seal, long life is inherent. Electrical characteristics are very stable over a temperature range of -80°C through 125°C. Two case sizes: .29 x .69 and .35 x .79 inches.

Mallory THF capacitors are available in a wide range of ratings: 5.6 to 330µF, 6 to 50VDC.

They’re the result of Mallory’s engineering program that’s finding ways to produce high performance type capacitors at less cost to you.

Just ask your Mallory representative. Available direct, or through authorized Mallory Distributors in U.S. or overseas. Or call Help-Force Headquarters at (317) 856-3731. Mallory Capacitor Company, a division of P. R. Mallory & Co. Inc., Box 1284, Indianapolis, IN 46206.
**CRT terminal handles 9600-baud data**

North Star Computers, 2547 Ninth St., Berkeley, CA 94710. (415) 549-0858. $995.

Soroc Model IQ 120 is a CRT terminal that can be connected to North Star's Horizon computer and handle data rates up to 9600 baud. The terminal displays 24 lines x 80 characters and has an addressable cursor, upper and lower-case ASCII character set and a numeric key pad.

**µC chip includes 4032 x 8 bytes of ROM**

Mostek, 1215 W. Crosby Rd., Carrolton, TX 75006. Jim Vittera (214) 242-0444. See text; 8 to 10 weeks.

The 3872 single-chip microcomputer includes 4032 x 8 bytes of mask programmable ROM, 64 bytes of scratchpad RAM and an additional 64 bytes of executable RAM. Supporting the executable RAM is a stand-by power mode for battery backup. The chip requires just a 5 V supply, and includes 32 bits (four ports) of bidirectional I/O; a programmable binary timer and external interrupt capability. The 3872 costs $25 in 1000-unit quantities with a refundable masking charge of $3000.

**Data-acquisition system is programmable**

Signal Lab, 202 N. State College Blvd., Orange, CA 92668. Bill Chidester (714) 634-1533. $3495; 4 weeks.

UPDAS (user programmable data acquisition system) includes a microcomputer, analog and digital I/O, and the integrating software in a single chassis. The system provides real-time computation in multiple process and control loops. The unit accepts analog and digital inputs; performs real-time computation; outputs in analog and digital form; displays, prints and accepts commands from the front panel. All functions can be programmed by the user.

---

**Time Delay Relays**

More design options with delays of 0.1 seconds to a year... and more.

Widest choice of timing modes, voltages, mountings, enclosures and contact arrangements. Save design time by selecting a standard P&B time delay relay. Or, we'll make a special for you if your application demands it. All built to P&B's high standards of quality and performance. Potter & Brumfield Division AMF Incorporated, 200 Richland Creek Dr., Princeton, IN 47671. 812/386-1000.
Data coupler delivers date, time or messages


Series 70,000 digital clock/calendars interface with the communications port of a computer, CRT terminal or recording device and deliver date, time and messages with up to 31 ASCII-coded characters. Up to 31 ASCII-coded characters. Up to 16 of these characters can come from variable sources such as digital time and front-panel thumb-switches. The remainder are fixed and stored in a PROM. Each character can include 7 or 8 data bits. Speed can be selected from 75 to 9600 baud.

CIRCLE NO. 363

Cross-assemblers mate with PDP-8 systems

Sierra Digital Systems, 13905 Rancheros Dr., Reno NV 89511. (702) 329-9548. $400; stock.

Four microprocessor cross-assemblers have been added to the X8 Series for the DEC PDP-8 minicomputer. The series covers the Z80, 1802, SC/MP and 8048 µPs in addition to the previous 6502, 6800, 8080, F8 and 2650 versions. The cross-assemblers run in 8 kwords of memory under the OS/8 system and are written in PDP-8 assembly language. Pseudo-ops and run-time options provide for conditional assembly and extensive listing control. Generated object code may be output in the µPs standard loader format, or BNPF for ROM generation. The cross-assemblers are distributed in PDP-8 binary format on paper tape, Dectape or DEC floppy diskettes.

CIRCLE NO. 364

Single-board computer ups its ROM capacity

Intel, 3065 Bowers Ave., Santa Clara, CA 95051. Don Schare (408) 987-7253. $495.

The iSBC 80/10A single-board computer is an enhanced version of the 80/10 and gives up to twice the ROM capability of the older 80/10. With the 80/10A, the user can store the program in either a type 2716, 2048-byte EPROM or smaller 8708 or 2758, 1024-byte EPROM. With the 80/10, the user could only use the 8708.

CIRCLE NO. 365

...and other solutions to your tough design problems are found in P&B's growing product line.
Now... the next generation of bench DMMs!

Two New Keithley Models offer uncompromising performance and outstanding value.

- Accuracy: 3½'s can't match: 0.04% + 1 digit on dc volts and ohms.
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- Convenient bench size that won't get "lost" yet doesn't crowd.
- Exceptional reliability.

Model 178 offers functions and ranges for most measurements: 100µV to 1200V dc, 100µV to 1000V ac, 0.1Ω to 20MΩ. At $199* it is a remarkable value!

Model 179 is a full-function, multi-feature model offering the same advantages as the 178. Plus TRMS AC; 10µV Sensitivity; Hi and Lo Ohms; AC and DC Current. Yet it's still half the price you'd expect. Only $289*!

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For complete specifications and immediate delivery on the 178 and 179, call your local Keithley representative (see adjoining list). Or, call or write: Keithley Instruments, Inc., 28775 Aurora Road, Cleveland, Ohio 44139. (216) 248-0400. In Europe: D-800 München 70, Heiglhostrasse 5, West Germany. (089) 7144065.

*U.S. domestic price only.
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San Diego, (714) 226-0305

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**DELAWARE:** (302) 242-5920

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**MAINE:** (207) 773-9888

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**NEW HAMPSHIRE:** Nashua, (603) 929-9446

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CIRCLE NO. 358

To order Keithley's Toll Free DMM Hot Line (800) 321-0560

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**MICRO/MINI COMPUTING**

**High-speed RAM is nonvolatile**

ElectriCom, P.O. Box 1235, Hawthorne, CA 90250. Pat Patterson (213) 676-6576. 8287.

Model 4020 nonvolatile high-speed semiconductor RAMs have size and word widths of 2 k × 8/9 or 1 k × 16/18, which are jumper selectable. Data is maintained for a minimum of three months (six months is typical) after the primary board power is removed. Constructed on a 5 × 10-in. card, the memory has a 450-ns access time, bank selectable by DIP switches within 64 k, phase-programmable operating controls, separate data inputs and outputs that can be bussed together, S100 bus compatibility, on-board address registers for A0 through A9 and LS-type TTL interfacing. On-board NiCd batteries, battery charger and power-state monitors are also included.

CIRCLE NO. 366

**Disc storage unit adds 10 Mbytes to computer**

Diablo Systems, 2500 Industrial Blvd., Hayward, CA 94545. (415) 783-8910. See text: 8 wks.

Disc-storage capacity of Model 3200 small business computer systems has been increased to 10 Mbytes with the addition of a fixed/removable disc drive. The Model 3200-14 disc system has a 5-Mbyte fixed disc and an additional removable 5-Mbyte disc cartridge that can be used in place of, or in addition to, the 630,784-byte diskette drives currently available on the computer. The disc subsystem achieves a data transfer rate of 312,000 bytes/s with an average access time of 50 ms. A typical 3200 system with the 1-Mbyte disc drive is priced at $29,000.

CIRCLE NO. 367

**Data cartridges use 1/4-in. tape**

TAB Products, 2690 Hanover St., Palo Alto, CA 94304. Jim Snyder (415) 493-5790.

The Model 1040 quarter-inch magnetic-tape cartridge is compatible with the ANSI, ECMA, ISO and IBM standards. Features include ceramic edge guides for extended cartridge life, interchangeability with IBM 5100 and 3M DC300A units, manually operable internal file protection, endless drive belt, roller and hub retaining system that reduces skew and bit-to-bit jitter, a polycarbonate cover and precision-machined metal base.

CIRCLE NO. 368

**64-k RAM mates with SBC 80/10**

GSI Systems, 223 Crescent St., Waltham, MA 02154. Ed Letscher (617) 899-6688. 8179: stock.

The Model 10046, 64-k RAM board is a direct replacement for four SBC 80/10, 16-k RAM boards. Providing 475-ns access and 650-ns refresh times, the board is compatible with a standard SBC 80/10 backplane. The memory can be driven by any 80/10 CPU board, and its 64-k address starts at 0000, page selectable.

CIRCLE NO. 369
Unit allows computer to control ac outlets

Mountain Hardware, P.O. Box 1133, Ben Lomand, CA 95005. (408) 336-2495. $189 (controller), $149 (remote); stock to 4 wks.

The Introl controls ac devices remotely from any S-100 bus over existing 110-V-ac wiring. The system impresses a code-modulated 50-kHz control on the ac wiring and then decodes the signal at any outlet to switch appliances on and off. A single ac-controller board plugs into the computer bus and connects to the ac interface adapter, which, in turn, is plugged into any 110-V-ac outlet. The controller can address as many as 64 channels remotely. When polled, the remote unit sends a signal back indicating the status of each device.

CIRCLE NO. 370

ROM/RAM simulator tests software

Electro-Design, 7364 Convoy Court, San Diego, CA 92111. (714) 277-2471. $495.

To test software when developing µP systems, the ED5000 simulator can be plugged into any standard ROM or RAM socket to verify new programs under actual operating conditions. Programs entered into its standard 2-k x 8, 45-ns memory can then be edited. Also, programs already stored in PROMs can be loaded into the system. The display serves as a memory map.

CIRCLE NO. 371

16 k × 16 core memory plugs into LSI-11 micro

Micro Memory, 9438 Ironside Ave., Chatsworth, CA 91311. (213) 998-0770. $1181; 3 wks.

The MM-1103/16, 16 k × 16 core memory system plugs directly into the DEC LSI-11 microcomputer. Access time is 400 ns. The memory is plug-compatible with the DEC MMV-11A and may be installed in any location in the LSI-11 chassis. By using slot four of the chassis, two spare slots are provided. The memory has byte control and has module selection in 4-k increments up to 32 kwords.

CIRCLE NO. 372

An 8½ inch Microprocessor Controlled Impact Printer for just $345*

Now that's what we call Practical!

Laugh all the way to the bank, OEM's. With both matrix impact print head and built-in microprocessor controller, our DMTP-8uP is a budget printer in price only. In practice, it's one of the greats.

You can print 80-96 columns of both data and text at a fast 110 cps. Turn out up to four copies at once on regular 8½-inch roll paper, even on fan-fold forms and labels. Not only are all needle drivers and diagnostic routines included with the microprocessor, but you can choose the interface function you want — parallel ASCII, RS-232C/T-Loop, or switch-selectable baud rates from 110 to 1200. You even get the economy of easily-replaceable ink rollers and a self-reversing 10-million character life ribbon.

All that for $345?? It's phenomenal... and it's also very Practical.

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A magnetic circuit breaker that proves LESS is MORE!

The Airpax T11 is a single pole, single throw, series trip magnetic circuit breaker that combines power switching and accurate, reliable protection in one aesthetically pleasing package. It features a patented snap-action that assures immediate and positive opening or closing of the contacts. This snap-action results in an increase in operational life of up to 5 times that previously available. It also eliminates possible operator "teasing" of the contacts and minimizes arcing.

Airpax T11 Snap-Action Magnetic Circuit Breaker.

LESS COST. The T11 costs less than any other magnetic circuit breaker on the market today... under $5.00 in small quantities. Even less as the quantity increases. And the traditional Airpax Five-year warranty. Result: MORE protection for your money.

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LESS INSTALLATION COST. The T11 does the job of a power switch, fuse and fuse holder—all in one easy-to-mount unit. This means only one item to be installed instead of three, less assembly time, and one-third the inventory. Result: MORE Productivity... and profit... for you.

LESS SERVICE REQUIRED. The T11 is immediately resetable to complete specifications, and a handy how-to-order chart. Result: MORE information for you. To get your bulletin, call your local Airpax representative or contact Airpax Electronics, Cambridge Division, Cambridge, MD 21613. Phone: (301) 228-4600. Telex: 8-7715. TWX: 665-9655. Other factories in Europe and Japan.

LESS GUESSWORK. Airpax has a bulletin fully describing the T11 snap-action magnetic circuit breaker, including rating, delays, complete specifications, and a handy how-to-order chart.

CIRCLE NUMBER 101
Board expands memory and I/O for TI µC

Digital Interface Systems, P.O. Box 1436, Benton Harbor, MI 49022. Mahesh Seth (616) 926-2148. See text; 8 to 12 wks.

The Model 990-110 memory and I/O expansion board is compatible with the Texas Instrument TM990/100M microcomputer. The board provides 2-k, 16-bit words of EPROM (expandable to 4 k), (1-k and 16-bit words of static RAM. Memory addresses are selectable on 1-k boundaries for RAM and 4-k boundaries for EPROM. Also, three TMS 9901 chips for input, output and interrupt lines are provided. Prices range from $395, for a board with unbuffered inputs and outputs and no memory, to $635, for a buffered and fully populated board.

CIRCLE NO. 373

8-kbyte static RAM mates with S-100 bus

Pacific Digital, 2555 E. Chapman Ave., Fullerton, CA 92631. (714) 992-5540. See text.

The 8KRS is an 8-kbyte static RAM for use on an S-100 bus. The memory is organized as two independently addressable 4-k blocks with address selection by jumper and plug, which can be changed while the board is plugged in. Write protection for the entire board is provided by an on-board toggle switch, and memory disable is via a phantom line. Also, 0, 1 or 2 wait states are plug and jumper selectable. All bus lines are buffered with one LS-type TTL load per line. Prices are $199.95 for 450-ns-speed units and $219.95 for 250 ns.

CIRCLE NO. 375

Memory/disc controller meets Euro standards

Zilog, 10460 Bubb Rd., Cupertino, CA 95014. Vince Schlezes (408) 446-4666. $895.

The Z80-MDC/E is a memory and disc-controller board that meets the standard specs commonly adopted in West Germany, United Kingdom, France and Switzerland. The board provides 12 kbytes of dynamic RAM plus a floppy-disc controller capable of handling up to eight floppy-disc drives. The MDC/E has a strapping option for setting the start address of each 4-kbyte memory page. Also, disc read/write accuracy is ensured by 16-bit cyclic-redundancy-check-code circuitry.

CIRCLE NO. 374

Single-board computer is disc based

Altos Computer Systems, 4340 Stevens Creek Blvd., San Jose, CA 95129. (408) 244-5766. $8394.

The Z8000 is a full-sized disc-based business system with all electronics on one plug-in 8 X 12-in. board. The desktop package contains two Shugart floppy discs for IBM compatibility. The system uses the Z80 CPU and the CP/M random access disc operating software together with extended commercial basic.

CIRCLE NO. 376

Data cassettes handle short tape lengths

Avdex, 2280 Grand Ave., Baldwin, NY 11510. (516) 546-2272. $4.95 to $6.35.

The CDC line of data cassettes are loaded with only 1 to 5 min of tape. These cassettes use computer shells, polyolefin slip sheets, machined guide rollers, stainless steel pins, oversized pressure pads and oversized hubs for smooth, uniform tape transport. Extra-short leaders do not come in contact with the recording head, which allows instant-start operation, eliminating lost data.

CIRCLE NO. 379

Flexible-disc drives store 6.4 Mbits


The FD410, 5X0, 511A and 514 are flexible-disc drives that boast a maximum storage capacity of 6.4 Mbits (unformatted). These drives are floppy read/write heads that are IBM compatible. The disc's positioner uses a three-step track-to-track movement for track-positioning accuracy, and a retractable-head system contacts the recording media only when reading or writing data. The different models offer a selection of interfaces.

CIRCLE NO. 377

Talk to a computer and it talks back

Digital Group, P.O. Box 6528, Denver, CO 80206. (303) 777-7133. $595.

With a Votrax voice synthesizer card, you can verbally command your Z80 microcomputer and it will answer. The card plugs into any I/O slot of a Digital Group microcomputer system. Other computers require some extra hardware and software programming. The developed software assumes a Z80 system with at least 18 k of memory, a 1024-character TV and cassette interface card. A high-impedance microphone is required for voice input and an external 8-Ω speaker for voice output.

CIRCLE NO. 378

Electronic Design 6, March 15, 1978
Same great name. Same great color.
And now a neat new way to definitive display performance.

**DOT MATRIX**

Consider the new Noritake-Ise dot-matrix line-up—9, 10, 16, 20 and 40-character line displays. Variety aimed at giving you more design potential. Or consider our unique 400-dot graphics display with 17m/m depth and low 35V drive rating. It's aimed at helping you think low voltage, portability and economy all at the same time.

In short, consider Noritake-Ise period for dot matrix (or segmental) displays. Itrons always help you design more competitively.

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**Variety aimed at giving you more design potential.**

**Or consider our unique 400-dot graphics display with 17m/m depth and low 35V drive rating.**

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**Consider the new Noritake-Ise dot-matrix line-up—9, 10, 16, 20 and 40-character line displays.**

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CIRCLE NUMBER 103

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CIRCLE NUMBER 104

Cherry Electrical Prod., 3600 Sunset Ave., Waukegan, IL 60085. Frank Amendola (312) 689-7702. $88.00 (100 qty); 2 wks.

The PRO keyboard, for users who don’t want to work around a totally dedicated unit, features an alpha-lock key that changes outputs from typewriter keyboard to teletypewriter code, and also five unassigned keys whose legends you can change. The keyboards daughter-board circuit can be easily piggy-backed. Alterable options that permit rapid customizing of the unit include negative logic, which can be derived by substituting SN7400N ICs for SN7408Ns and three-state positive logic, which can be obtained by using two SN74126Ns. Additional options include CMOS-compatible output, encoded or nonencoded outputs, an automatic repeat function, optional parity bit, varied strobe pulse width, output latch and shift-control mode.

CIRCLE NO. 380

Rocker switches are sealed

Cutler-Hammer, P.O. Box 463, Milwaukee, WI 53201. (414) 442-7800.

Commercial environmentally sealed rocker switches resist dust, dirt and liquid contaminants found in harsh environments. The switches are available in either snap-in bezel, flush or sub-panel mounting; in 1, 2 and 4-pole configurations. The switches have flame-retardant mineral-filled melamine bases, die-cast frames, high-impact nylon rockers and screw-type terminals. The units have a seal around the bushing and a seal between the base and frame.

CIRCLE NO. 381

CIRCLE NUMBER 103

COMPONENTS

Keyboard allows many uses
Anyone who buys a 1978 Continental Mark V has come a long way. And this year, a new option lets him know exactly how much further he can go without running out of gas.

A unique "miles-to-empty" display is controlled by a single 3600-transistor microcircuit, designed specially for Ford by AMI. It processes data from sensors in the car's gas tank and transmission, correlating speed and fuel level to estimate the miles remaining.

For the driver, this means an end to that nervous "can-we-make-it-to-the-next-town" syndrome, and helps him gauge his mpg. Ford, of course, adds another touch of class to a superb automobile—and another selling point to win customers in a highly competitive market.

If you want to get more mileage from your new product, the place to start is AMI. Since 1966, we've developed a variety of ways, using standard or custom circuits, to solve our customers' MOS needs. We have 4, 8 and 16-bit microprocessors ready to program. (The 4-bit S2000 even has a customized I/O.) We can also design a custom circuit for you. Or produce one that you design.

To find out which way is best for you, write to AMI Marketing, 3800 Homestead Road, Santa Clara CA 95051. Or call (408) 246-0330. We'll show you how little it takes to make big ideas work.
COMPONENTS

Audible alarms blast 70 to 86-dB sound alerts

Cybersonic, P.O. Box 151, Glenside, PA 19038. F. Coller (215) 885-2244. $6.50; stock.

Models of the Bleeptone audible signalling device provide a compelling 70- to 86-dB audible alerting signal at 1 meter. All models come with either a 2.5 or 1-kHz (nominal) frequency. Driving voltages are 3, 6 or 24 V dc ± 30%, compatible with DTL, TTL or HTL logic.

CIRCLE NO. 382

Double-balanced mixers use Schottky diodes

Vari-L, 3888 Monaco Pkwy, Dewer, CO 80207. Carol Kiser (303) 321-1511. $15.95 to $35.00; stock.

A series of high-level doubly-balanced mixers cover 0.5 MHz to 1 GHz and are designed around beam-lead Schottky diodes. Model CM-1H4 and CM-1H8 cover 0.5 to 500 MHz and are rated at +13 and +17 dBm (LO) respectively. Models CM-2H4 and CM-2H8 cover 5 MHz to 1 GHz and are also rated at +13 and +17 dBm. Typical conversion loss is 6 dB and typical isolation is 40 dB. The 1-dB signal compression point for models CM-1H4 and CM-2H4 is +7 dBm. For CM-1H8 and CM-2H8 the compression point is +12 dBm.

CIRCLE NO. 383

Illuminated switch has multiple legends

Industrial Electronic Engineers, 7740 Lemona Ave., Van Nuys, CA 91405. Helen Sands (213) 787-0311. $29; 6 to 8 wks.

The Proswitch is a multi-legend, illuminated pushbutton switch with 12 different selectable messages. Up to three lamps can be energized at one time to yield a maximum of 64 possible compound legends. The switch contains 12 lamps, an optical system, a 12-legend film chip, viewing screen and switch. The viewing screen is pivot mounted and doubles as the pushbutton to operate a snap-action switch.

CIRCLE NO. 384
From Crydom... A totally new design in microprocessor interface switches!

AC and DC Solid-State Input Switches and companion Output Switches that deliver 4 Amps at 40°C, 2.75 Amps at 70°C Ambient... without added heat sinks.

Very simply, Crydom's new family of solid-state Input-Output switches give you the highest current capability and highest transient immunity in the industry, with all of the advantages of photo isolation and zero voltage switching. Electrically clean, isolated and noise-free interface switching between logic-level "smart" circuitry and the brassy power level equipment it controls.

But there is much more to the Series 4 design, including models available to NEMA Part ICS-2-230 specifications. These all-new switches include such quality features as: gold plated logic-level PC board pin terminals: screw-type, color coded power level terminals; and a LED status indicator, all environmentally sealed by solid encapsulation.

Most important, the output devices have their own highly efficient heat radiators, plus a unique and proprietary thermo/mechanical output power construction designed to provide unequalled current handling capability. That's why the Series 4 output models can handle 4 amps at 40°C and 2.75 amps at 70°C with an extra margin of safety.

And there are other space-saving advantages. Like internal transient suppression in the DC models and internal snubber networks in the AC models. It's all there!

These single-package devices offer you a better and cost-competitive way to switch from logic-level to power levels... and vice versa. They're bound to simplify your designs and increase your reliability.

Contact your local Crydom distributor or representative for immediate response to your product and/or technical data needs.

And, find out why it will pay you to switch to — and with — Crydom Series 4 Input/Output devices.

International Rectifier Crydom, 1521 E. Grand Ave., El Segundo, CA 90245. (213) 322-4987. TWX 910-348-6283.

International Rectifier
1521 E. Grand Ave., El Segundo, CA 90245 (213) 322-4987

CIRCLE NUMBER 108
COMPONENTS

Resistor network meets MIL-R-83401

TRW/IRC Resistors, 4222 S. Staples St., Corpus Christi, TX 78411. Bill Wagner (512) 854-4872. $7.70 to $8.40 (1000 qty).

TRW's 14-lead flat-pack precision resistor networks now qualify under MIL-R-83401, Style RZ030. Package density is either 7 or 13 resistors in 0.07-in.² ceramic sandwich packages. Standard resistance range is 150Ω to 51 kΩ, with 0.1 to 2% tolerance. Four tempcos are offered: ±25 ppm/°C, ±50 ppm/°C and -50 to -150 ppm/°C. TCR tracking is ±5 ppm for most values and current noise is less than -25 dB. Individual resistor elements are rated at 0.1 W and package dissipation is 0.5 W at 70°C, 1 W at 25°C ambient.

PC relays allow immersion cleaning

Potter & Brumfield, 200 Richland Creek Dr., Princeton, IN 47671. Roy Stewart (812) 386-1000. $1.74 up; stock.

Immersion-cleanable PC-board relays, Type R50, are rated to 5 A and accept full immersion in cleaning solvents for 2 min. The low-profile relays are available as 1 and 2 A versions for 28 V dc or 120 V ac in SPDT and DPDT models, and as 5-A SPDT model. Standard and sensitive-coil ratings range from 5 to 48 V dc. Sensitivity coils can be driven by ICs capable of sinking 80 mA (TTL) and 40 mA (MOS at 12 V dc). The smallest model is 0.46 X 0.595 X 1.09 in.

DIPs switch 2 to 10 circuits

Waldom Electronics, 4301 W. 69 St., Chicago, IL 60629. (312) 685-1212. See text; stock.

Rocker or lever actuated multiposition DIP switches feature SPDT, SPST or DPST switching for 2 through 10 circuits. The switches handle 30 V dc at 50 mA. Contact resistance is 100 mΩ max at 10 mA and voltage breakdown is 500 V dc. The terminals, on 0.1-in. centers, are tin plated for ease of soldering. A typical price for an 8-circuit SPST switch (type DSL-8) is $5.55.

Sealed RC networks have 0.05% tolerances

PF C, 100 Community Dr., Great Neck, NY 11022. Tom Cary (516) 487-9320. $20 up; 8 to 10 wks.

RC networks with tolerances as close as ±0.05% for the RC product come hermetically sealed in metal containers. The accuracy is guaranteed for one year. Variation of the RC product from -55 to 85°C is maintained within ±10 ppm/°C. Several packaging styles are available, including a flat-pack for PC mounting. Two or more networks can be supplied in a single package, with tracking to within 5 ppm/°C.

Keyboard allows typing with one hand

New O, Palo Alto, CA 94303. Sid Owen (415) 321-7979. $98; stock to 2 wks.

Writehander is a keyboard on which you can type all 128 ASCII characters with one hand. The typist places four fingers on four press switches and the thumb on one of eight press switches. The four finger-operated switches actuate the four least-significant bits of a seven-bit ASCII code. The thumb then selects a desired character from a choice of eight groups. The keyboard's hemispherical shape comfortably accommodates the hand, and the fingers naturally locate themselves on the switches.
Without the waiting.

The newest thing you ought to know about our MP-7570 A/D Converter circuit is its immediate availability. That means you can get it—now!

The circuit itself isn’t new. It’s been around for a couple of years, initially as an Analog Devices part. Its popularity is well-established, which means demand occasionally exceeds supply.

Micro Power’s recently expanded production capabilities now provide a volume second-source supply for the 7570. You can design in its unique characteristics and depend on us for the delivery you need.

Functionally, the 7570 is a CMOS 10-bit A/D converter on a single chip. It uses the successive approximation principle and requires only an external comparator, reference and passive clocking components. Ratiometric operation is inherent in the design, since an extremely accurate multiplying DAC is incorporated in the feedback loop. The 7570 has appropriate control inputs and status outputs for convenient interface with most 8-bit or 10-bit microprocessors.

Micro Power’s proprietary High-Density CMOS is employed in producing the 7570. This low-power process features an on-chip network of thin-film resistors and silicon nitride passivation to enhance reliability and long-term stability.

Listed in the table are some of the key specs and prices for the 7570 and related CMOS converters. To get more information on these and other linear CMOS products, use the coupon below.

### LOW-POWER CMOS CONVERTERS

<table>
<thead>
<tr>
<th>Type</th>
<th>Resolution</th>
<th>Non-linearity</th>
<th>Conversion Time</th>
<th>Price (100+)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7570 JD (A/D)</td>
<td>8-bits</td>
<td>N/A</td>
<td>20µsec</td>
<td>$19.90</td>
</tr>
<tr>
<td>7570 LD (A/D)</td>
<td>10-bits</td>
<td>N/A</td>
<td>20µsec</td>
<td>$42.00</td>
</tr>
<tr>
<td>7550 BD (A/D)</td>
<td>13-bits</td>
<td>N/A</td>
<td>40msec</td>
<td>$24.90</td>
</tr>
<tr>
<td>7522 JN (D/A)</td>
<td>10-bits</td>
<td>8-bit</td>
<td>500nsec</td>
<td>$13.90</td>
</tr>
<tr>
<td>7522 KN (D/A)</td>
<td>10-bits</td>
<td>9-bit</td>
<td>current</td>
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</tr>
<tr>
<td>7522 LN (D/A)</td>
<td>10-bits</td>
<td>10-bit</td>
<td>settling time</td>
<td>$26.10</td>
</tr>
</tbody>
</table>
General Scannings thermal writing Strip Chart Recorders are available in a wide range of configurations and performance characteristics to meet virtually every recorder need. You can select open-loop, velocity feedback or closed-loop operation; continuous roll or fan-feed paper; one to eight channels in channel widths of 20, 40, 50, 80 or 100mm; a variety of chart speeds; and either AC or DC operation. Recorders can be furnished as modules for use by OEM's or fully packaged.

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COMPONENTS

**LEDs illuminate pushbutton switches**

Dialight, 293 Harrison Pl., Brooklyn, NY 11237. (212) 497-7600. $1.96 (1000 qty); stock.

Switches and indicator lights in the 554 Series use a 5/8-in.-square, Series 332 caps in which rectangular LEDs are flush-mounted as integral components. The caps can replace incandescent-lamp caps on existing 554 Series units. Seven cap colors and three LED color options give a choice of 21 color combinations. In addition, caps can have hot-stamped or engraved legends. Current-limiting resistors are built into the caps for operation at 5 V dc, 15 mA.

*CIRCLE NO. 397*

**μP crystal line covers 1 to 48 MHz**

Bulova Electronics, 61-20 Woodside Ave., Woodside, NY 11377. Bob McComb (212) 335-6000. $6.00 to $11.75; stock to 6 wks.

Type BU quartz crystals cover from 1 to 48 MHz. The crystals are AT cuts and packaged in hermetically sealed HC-18 holders. Low-frequency units are available also in the HC-33 holders. Frequency tolerance is ±0.0005% at 25 C and stability from −20 to 75 C is ±0.003%.

*CIRCLE NO. 398*

**Pushbutton switches sealed in rubber boots**

Standard Grigsby, 920 Rathbone Ave., Aurora, IL 60507. (312) 844-4300. $0.25.

TL360 miniature pushbutton switches are completely sealed in silicone-rubber boots that prevent contact contamination by water, oil and dust and fluids during cleaning. Just 0.16 × 0.36-in diameter, the switches mount easily on PC boards.

*CIRCLE NO. 399*

---

**PUSHBUTTON SWITCHES**

Our Mustang Series features a 15/32" bushing size, a SNAP action and a variety of large colored caps. Offered in a choice of Push On/Off or Momentary in one through 4 poles – 6A @ 125V or 3A @ 250V capability in a miniature size. Molded-In terminals, DAP case & PC types.

Please call or write today for other technical data and prices.

*CIRCLE NUMBER 112*

**LOCKING TOGGLE**

Miniature switches with a fool proof Pull-to-Unlock feature for critical or dangerous operation. Attractive anodized aluminum finish toggle. Available in one through 4 pole style. Has all the premium features at no added cost, including Molded-In terminals, gold finished contacts and terminals, etc.

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*CIRCLE NUMBER 113*
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Over 1500 styles, sizes, ranges. If it's a special, we'll make it for you.
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Our DB relays offer exceptional reliability at extremely low cost ($1.35 in 10,000 quantities). Self-healing contacts in welded steel package give more than 2 billion bounce-free operations between failures. Contact resistance is stable to 0.015 ohm with loads from nanowatts to 20 watts.

Operation is unaffected by mounting position.

Terminal pin options are available to match most dry reed and mercury wetted relay foot prints.

DB relays are well suited to applications in telephone, modem, data acquisition, and industrial control circuits.

The DB relay offers lower price than mercury relays, and superior performance to dry reeds.

For further information, write or call Fifth Dimension, Inc., 707 Alexander Road, Princeton, NJ 08540; phone (609) 452-1200; TWX 510-685-2387.

Fifth Dimension Inc.
Princeton, New Jersey

CIRCLE NUMBER 117

COMPONENTS

Linear solenoids use 1.7 to 14.5 W

Canon USA, 10 Nevada Dr., Lake Success, NY 11040. Phil Specter (516) 488-6700. $8.67 to $5.00; stock to 10 sets.

A line of 20 models of linear solenoids with maximum continuous power ratings from 1.7 to 14.5 W are available in push, pull or push-pull versions. Both C and D frames are included. Max force ratings at rated power range from 0.30 kg to 7 kg and up to about 13 kg at 10 times rated power for intermittent duty. Stroke length in the largest standard unit is 1.25 in.

CIRCLE NO. 403

Time-delay relay has delayed-on mode

Master Electronic Controls, P.O. Box 25662, Los Angeles, CA 90025, Shirley Wilkerson (213) 393-3177. $25.40 (100 qty); stock.

The D10 and D11 solid-state time-delay relays provide a delayed-on mode of operation with fixed, local and remote-adjustable time ranges from 100 ms to 1800 s. Available input voltage ratings are 24, 48, 115, 230 V ac and 12, 24, 48, 110 V dc. Voltages may vary ±10%. The timers feature polarity and false-output transfer protection. Repeat accuracy is as high as ±1%.

CIRCLE NO. 404

Low-pass audio filters allow choice of specs


Series JW33-4000 low-pass audio filters are available in a choice of attenuation characteristics (Cauer or Chebyshev), cut-off frequencies (1 to 50 kHz), and operating impedances (250 to 10,000 Ω). The filters mount on PC boards on 0.2-in. centers. The max seated height is 0.562 in. Hermetically sealed cases prevent crosstalk and unwanted pickup, and allow operation under extreme environmental conditions.

CIRCLE NO. 405

Large LED display readable at 33 ft

Hewlett-Packard, 1507 Page Mill Rd., Palo Alto, CA 94304. (415) 493-1501. $1.80 (1000 qty); stock.

HDSP-3400 series, 0.8-in. numeric displays are readable in bright light at distances to 33 ft. Made from GaAs phosphide, these LED displays come in standard 0.6-in. DIPs that mount on PC boards or plug into standard IC sockets. Models in the series include the 3400 with a common-anode left-hand decimal; the 3401 with a common-anode right-hand decimal; the 3403 with a common-cathode right-hand decimal; and the 3406 with a universal overflow (±1) right-hand decimal.

CIRCLE NO. 406

Solid-state relay boasts 10¹² operations


The Model SSR-1285-5050 solid-state relay has no moving parts and is capable of over 10¹² operations. “Contact” rating is 50 V, 50 mA; actuation time is 2 μs and dropout time is 5 μs. Actuation frequency can be as high as 50 kHz. The relay is epoxy encapsulated and operates from -55 to 125 C.

CIRCLE NO. 407
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Transformer designs a la Stackpole toroids Contain no air gaps or efficiency voids.

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We'll get back to you and we're sure you'll be pleased with our Ceramag Bulletin 59-103.

Stackpole Carbon Co.
Electronic Components Div.
St. Marys, Pa. 15857

CIRCLE NUMBER 118

Ceramag. The right ferrite. 

STACKPOLE
COMPONENTS

Rotary switches qualify under MIL-S-3786

Cole Instrument, 2034 Placentia Ave., Costa Mesa, CA 92627. Phil Hanson (714) 642-8080.

Type 3600 1-in. enclosed rotary switches are fully qualified under MIL-S-3786. Up to twelve decks of switching are available. Each deck can have one to six poles per deck with 30, 36 or 45-degree steps and 8, 10 or 12 positions. Both shorting and nonshorting contacts that handle 6 A can be combined in the same deck.

CIRCLE NO. 408

Surge shunts protect solid-state devices

Morel International, 21583 Castleton St., Cupertino, CA 95014. (408) 257-2414, 80.39 to 80.42 (OEM).

Carbon-film surge-shunt protectors have a discharge lag of less than 0.1 \( \mu s \) when installed across ac input lines. They protect solid-state devices from damage by lightening or high-voltage surges. The protectors can be supplied for high-voltage surges from 180 to 3000 V. For 120-V-ac operation, the shunts are made to arc over at 205 V. They withstand 2000-A impulse currents. Their glass capsules, filled with inert gas, are 5.5-mm diameter by 2-mm long.

CIRCLE NO. 409

Heat sinks fit plastic SCRs and transistors

Aavid Engineering, 30 Cook Court, Laconia, NH 03246. (603) 524-4443. Free samples; stock.

A series of low-profile heat sinks for cooling plastic power SCRs and transistors is adaptable for use on PC boards with 0.5-in. spacing between boards. Part numbers 5070 and 5072 have a total height of 0.375 in. Part number 5071 is for high-power use and can be used with either the 5070 or 5072 heat sinks as a cap to provide doublesided cooling of TO-220 devices.

CIRCLE NO. 410

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CIRCLE NUMBER 121

Electronic Design 5, March 15, 1978
COMPONENTS

Mini power relay switches 15 A

Ownon Electronics, 233 S. Wacker Dr., Chicago, IL 60606. Don Nelson (312) 876-0800. $8.30 to $9.90; stock.

Model O2H miniaturized power relays meet UL and CSA standards for switching high-capacity ac loads. Rated at 240 V ac with resistive loads of 15 A or inductive loads of 10 A, the relays have DPDT contacts. The units are enclosed in transparent polycarbonate-resin cases and are equipped with an arc barrier that provides a dielectric strength of 2000 V at 50/60 Hz for 1 min.

YELLOW LED arrays readable in sunlight

Plessey Optoelectronics & Microwave, 1641 Kaiser Ave., Irvine, CA 92714. R.G. Millett (714) 540-9934.

The GPD 420 family of GaP solid-state LED arrays are legible in 100,000-lux (lm/m²) light levels (equivalent to illumination from direct sunlight above clouds). The displays consist of four, seven-segment digits, each 4-mm high, mounted in a hermetically sealed package. Typical LED intensity is better than 2 mcd at a current of 20 mA/segment.

MINI TOGGLE SWITCH MOUNTS ON PC BOARDS

Alco Electronic Products, 1551 Osgood St., North Andover, MA 01845. Clem Czapinski (617) 685-4371. $1.20 (100 qty).

A family of miniature toggle switches for use on PC boards can withstand flow-soldering temperatures. Four types are available: upright PC with silver or gold contacts; right-angle PC with side toggle motion; and vertical right-angle types with up-down action. Ratings are 5 A at 125 V ac (silver) or 0.4 VA at 20 V ac or dc max.

PHOTO SCANNER DETECTS MATERIAL AT A DISTANCE

MEKontrol, 56 Hudson St., Northboro, MA 01532. Dean Percival (617) 393-2451. $124 (qty discount); stock.

LED proximity scanner, MEK-55-SCS5, doesn't need a reflector, but still detects any material at a distance. Its small size—only 3.25 × 3.8 × 1 in.—makes it easily mountable. The sensor is immune to electrical noise and ambient-light and uses a phase-locked-loop circuit built into the amplifier. A choice of plug-in output and timing modules is available.

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Carter Mfg., Sugar Rd., Bolton, MA 01740. (617) 779-5501. $10 up; stock.

Series ST477 single and dual-element plug-in wirewound potentiometers are side-actuated and housed in polycarbonate cases. They can be stacked on 1-in. centers and are supplied with matching receptacle boards. The pots have 3-in.-stroke slider action. Resistance values to 100 kΩ are available in a 0.5-W rating, with or without switch and pilot lamp. Basic size is 1 × 0.875 and 6.25 or 4.5 in. long. A pilot lamp provides lighting for the strip.
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The GO 781.400 (Controller)

CIRCLE NUMBER 124

Electronic Design 5, March 15, 1978
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plug-compatible reader/punch

Desktop combination reader/punch with serial asynchronous RS-232C compatible interface. Designed to operate with a terminal device on the same serial data lines or alone on a dedicated serial line. Reader will generate data at all standard baud rates up to 2400 baud. Punch accepts data at all standard baud rates up to 600 baud continuous or 4800 baud batch, utilizing a 32 character buffer.

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**DATA PROCESSING**

Floppy-disc system uses IBM 3740-type diskettes

Sykes Datatronics, 375 Orchard St., Rochester, NY 14606. Bruce Paton (716) 458-8000. See text.

Comm-Stor II is a communications floppy-disc system that uses IBM 3740-compatible diskettes and interfaces with all RS-232 communications devices. The system is μP-based, enabling the user to store and retrieve files by file source. Variable length files give increased file storage capacity and maximum usage of the diskette. Merging files provide the capability of merging and creating new files composed of existing files. The system provides buffering at the terminal and/or modem port to allow commands and data to be stacked. A single drive system lists at about $3000 and a dual system at about $4000.

**MINI-CONTROLLER EXPANDS FROM 1 TO 8 DISPLAYS**

Triplex, 3180 Red Hill Ave., Costa Mesa, CA 92626. R.J. Martin (714) 546-7781. 83950; 6 to 8 weeks.

The Model 0712M is a minicontroller that is expandable from one to eight displays and is plug-compatible with IBM's 3271 remote controller. The system operates up to 19.2 kbaud at switch-selectable speeds. The Model 0772M display, used to expand the 0712M cluster, features self-test, OCR wand, light pen, prompting line, cursor position indicator, local display to print, upper and lower case, character indicators in unprotected fields and a 10-key numeric pad.
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Now DIG this: for more information and prices on our new Miniswitches with optional LED lighting, call our new toll-free number 800-528-6050 (residents of Arizona phone 800-352-0452), Ext. 924, for address and phone number of your nearest representative or distributor.
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For PM-350 Circle Number 47

CIRCLE NO. 129

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Multiuser computer has 1-Mbyte memory

Data General, Route 4, Westboro, MA 01581. Howard Steiner (617) 366-8911. $160,000 to $285,000.
The M/600 computers contain semiconductor memory capacity up to 1 Mbyte and a demand paging facility to optimize memory use in large on-line applications. A three-level I/O management system features an independent I/O processor with 64 kbytes of local memory, a standard data channel and a burst multiplexer channel with a 10-Mbyte/s transfer rate. The I/O management system provides hierarchical control for low, medium and high-speed peripherals. A typical system would include 512 kbytes of main memory, 4 Mbytes of fixed-head disc storage, 760 Mbytes of disc file storage, two 8-track 1600-bits/in magnetic tape drives, a 600-line/min printer, a 600-card/min card reader, synchronous communications and 32 terminals.

CIRCLE NO. 418

Modem originates and auto answers

U.S. Robotics, P.O. Box 5502, Chicago, IL 60680. (312) 528-9045. $160 to $195; stock.
The USR-300 series of originate and auto-answer modems operate asynchronously, full or half duplex at data rates up to 300 baud. The stand-alone modems are compatible with the Bell 103 and 113 lines. Connection to the public telephone network requires a CBS-100IF data-access arrangement (DAA).

CIRCLE NO. 419

CIRCLE NUMBER 128
Specifier's QPL Shopping List.

Shop the Weston Mil-Qualified Trimmer Supermarket for great selection and quality!

<table>
<thead>
<tr>
<th>WESTON MIL-QUALIFIED TRIMMERS</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
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<tr>
<td>M39015/1 L.P.Y</td>
<td>1¼&quot; Rectangular, Wirewound</td>
</tr>
<tr>
<td>M39015/2 L.P.W.X</td>
<td>½&quot; Square, Wirewound</td>
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<tr>
<td>M39015/3 L.P.W.X</td>
<td>¾&quot; Square, Wirewound</td>
</tr>
<tr>
<td>M39035/2 P.W.X</td>
<td>¾&quot; Square, Cermet</td>
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<td>M39035/5 P</td>
<td>½&quot; Rectangular, Cermet</td>
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<tr>
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<tr>
<td>Mil-R-27208/10 P.W.X</td>
<td>¼&quot; Square, Wirewound</td>
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<td>½&quot; Square, Cermet</td>
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<tr>
<td>Mil-R-22097/6 P</td>
<td>¼&quot; Round, Cermet</td>
</tr>
</tbody>
</table>

Weston Mil-Qualified Trimmers will meet all your most demanding applications because they're designed and manufactured to the highest government standards for consistently superb performance. For model specifications, check our chart. With 12 Mil-Qualified Trimmers to choose from, we're sure you'll find just what your shopping list calls for. And on the way home, don't forget to stop for that milk!
If your application requires only moderate power, ENI's new Model A150 will do the job. All it takes is a laboratory signal generator and you've got a perfect match for RFI/EMI testing, NMR/ENDOR, RF transmission, ultrasonics and more. Capable of supplying more than 150 watts of RF power into any load impedance, the A150 covers the frequency range of .3 to 35 MHz. We could mention unconditional stability, instantaneous failsafe provisions and absolute protection from overloads and transients, but that's what you expect from any ENI power amplifier, and the A150 is no exception!

For additional specifications, a demonstration, or a copy of our new, full-line catalog, contact ENI, 3000 Winton Road South, Rochester, New York 14623. Call 716-473-6900 or Telex 97-8283 ENI ROC.  

CIRCLE NUMBER 149

DATA PROCESSING

Modems operate in satellite FM systems


The Model 1260 QPSK data-over-voice or group-band modems are for use in terrestrial microwave links and satellite FM systems. The modems interface directly with the baseband input of the FM above the highest voice frequency or at any place within the operating FM baseband. Data services can be provided from 1.2 kbaud to 10 Mbaud. The equipment has interchangeable interface options for the use of RS-232, Bell 303 or V35 devices. Operating modes are full duplex, half-duplex or simplex. The transmit and receive frequency ranges are 60 kHz to 50 MHz with a minimum carrier-to-noise ratio of 14 dB.

CIRCLE NO. 420

Journal printer yields 3 lines/s on 40 columns


The Model 512 serial-entry dot-matrix printer prints 3 lines/s on 40 columns. The character set is 64 ASCII. The print-out is 3.5-in. wide friction-fed fan-folded or rolled paper, inked by ribbon or impact. The size is 6 x 7 x 9.6 in.

CIRCLE NO. 421

Modem mounts directly into teletypewriter

Omnitec Data, 2405 S. 20th St., Phoenix, AZ 85034. (602) 258-8244. $925; stock.

The Model 4500 data modem mounts directly into a teletypewriter and replaces the Bell Model 101C data set. The modem operates over the DDD telephone network at a rate of 110 baud. The principal mode of operation is two-wire, half-duplex over the dial network. The unit interfaces to the telephone line via a DAA type CBT and provides full auto/answer capability for unattended operation.

CIRCLE NO. 422

Interactive software creates business reports

Control-Data, Box O, Minneapolis, MN 55440. Ken Thompson (612) 853-3053.

IPS Report Writer is an interactive software package that allows simple reports to be generated quickly using only a few basic terminal commands. More sophisticated reports can be created with minimum effort. Features include command file processing, “what if” and “look up” commands and virtual field and scroll report-writer processing functions.

CIRCLE NO. 423

Software lets OS/8 talk to remote computers


CMU, a software product, permits communications between two OS/8 systems and provides a method for the system to reduce time-sharing service charges. CMU provides full duplex bidirectional terminal communications as well as real-time reception and transmission of OS/8 files with a time-sharing mainframe or another mini-computer. It operates with all PDP-8 systems as well as the PDP-12 and the DECatation-78. All that is required is a minimal OS/8 operating system and an interruptible device handler. The software allows an OS/8 system to perform like a remote terminal with local storage and editing capabilities. The single-system binary license costs $350, and the binary and source license costs $700.

CIRCLE NO. 424

Electronic Design 6, March 15, 1978
There's a Hoffman enclosure for almost every electronic application you can think of.

One company uses our NEMA 12 enclosures to house water-testing instrumentation. Whatever your electronic application, Hoffman probably offers an enclosure to match it, whether it's for servo controls or sensitive instruments.

Hoffman electronic rack enclosures, consoles, instrument boxes, and a full range of NEMA types are just some of the components in a broad-spectrum 1700-product line. All are quality-built in the materials, finishes, and sizes your application requires.

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Division of Federal Cartridge Corporation
DEPT. ED675, ANOKA, MN 55303

THE RMP-116 INTRODUCES
A NEW DIMENSION TO SOLID STATE SOFTWARE
FOR THE PDP-11

For the first time you can have
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Price
RMP-116 $895* in quantities 1–9
Remote Unit $250

*Does not include EPROMs

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Don't gamble on chancy electromechanical contacts. Murata's new solid-state Posistors provide highly reliable stepless temperature control and heating functions in a single, compact package. What's more, they are virtually immune to shock, vibration and dirt. Standard units are designed for 120 or 12 volt operation at up to 300 watts each and may be used in a variety of consumer personal care and industrial products. Write for complete technical information to: Murata Corporation of America, 1148 Franklin Road, S.E., Marietta, Georgia 30067. Phone: 404-952-9777.

CIRCLE NUMBER 135
sealed high density miniature switching

for 12 to 60 poles with MIL-R-5757 protection against
humidity ... sand ... dust ... moisture ... corrosion ... splash ... explosion ... built to withstand shock/vibration!

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RELAYS

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All contacts epoxy sealed in backfilled metal enclosure for
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environments. Pulse operated magnetic latching available. Simple
crimp snap-in contacts fit into single block connectors for easy
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CIRCLE NUMBER 136

POWER SOURCES

Switchers yield four independent outputs

Gould, 3601 N. Arden Dr., El Monte,
CA 91731. (213) 442-7755. $695.

The Model MGQ-300 offers switching-regulated isolated outputs of +5 V
at 30 A, −5 V at 5 A and ±15 V at 2 A. Overvoltage and current protection
are provided on all outputs. All outputs remain within voltage regulation at
full load for 28 ms after the removal of nominal line voltage. The size is
12.25 × 3.9 × 7.5 in.

CIRCLE NO. 427

Regulated supplies work over wide temperatures

Tecnetics, P.O. Box 910, Boulder, CO
80302. Vern Garrison (303) 442-8837.
$200 to $365.

The Type 400 compact, low-power,
encapsulated, ac to dc regulated power
supplies operate at a baseplate-temperature range of −55 to 100 C. In-
cluded in the line are units with 3, 6, 10, 15 and 20-W outputs, each with
single, dual or triple outputs. Input
voltage is 115 V, 400 Hz, single phase
per MIL-STD-704A. Regulation is 30
mV, line plus load. The use of military-
type parts yields 70,000-h MTBF.

CIRCLE NO. 428

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TAPE DATA PRESERVERS

Protect your magnetic tapes from degradation and physical
damage. Designed for storage, shipment and hand carrying. A wide choice of
models and capacities available for standard reels, discs,
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TP-5 CATALOG

CIRCLE NUMBER 137
Now industrial users of transformers who need the space/performance of a high grade well tested product can choose from the I-DOT and I-DIT line of audio, signal, pulse or power transformers and inductors.

You see, we relaxed some of the environmental specifications of our prominent line of Mil spec DOT and DIT transformers, but kept the identical excellent electrical performance. Only the cost was reduced.

And the nice part, this industrial counterpart to the world renowned military line is a stock product available now at your authorized TRW/UTC distributor.

The I-DOT family has a frequency response of ± 3 db, 300 hertz to 20K hertz. The I-DIT has a ± 3 db, 400 hertz to 100K hertz, and is available both with flexible leads and with uninsulated dumet wire leads for printed circuit board mounting.

Check your authorized TRW/UTC local distributor for immediate off-the-shelf delivery or contact TRW/UTC Transformers, an Operation of TRW Electronic Components, 150 Varick Street, New York, N.Y. 10013. Area code: 212-255-3500.
MODULES & SUBASSEMBLIES

A/d converter delivers high accuracy


The Model ADC 1215L analog-to-digital converter has an accuracy of ±0.004%, a 5.5-μs conversion time, 15-bit binary output resolution and ±0.002% linearity. The a/d converter requires no external reference voltage. Power consumed is 2.2 W. The size is 5 x 4.5 x 0.92 in.

CIRCLE NO. 429

Data acquisition units come in matched pairs

ILC Data Device, Airport International Plaza, Bohemia, NY 11716. (516) 567-5600. $255 (amplifier), $310 (converter); stock to 8 wks.

A matched pair of 8-bit data-acquisition components consists of a hybrid video sample-and-hold amplifier, SH-8518, and a hybrid a/d converter, ADH-8512. The pair is capable of word rates up to 900 kHz. The SH-8518 has a 25-ns acquisition time, a 60-ps aperture uncertainty and a 20-MHz sampling rate. Linearity error is 0.05% and droop rate is 1 mV/μs. The ADB-8512 employs successive approximation with linearity of ±0.2% and a conversion time of 1 μs.

CIRCLE NO. 430

Op amp in DIP has low offset

Precision Monolithics, 1500 Space Park Dr., Santa Clara, CA 95050. Don Soderquist (408) 246-9222. $3.25 (100 qty); stock.

The OP-07CP op amp, housed in a plastic DIP, maintains an input-offset voltage below 250 μV over an ambient range of 0 to 70 C. Max long-term input-voltage drift is 2 μV. Input noise voltage is 0.65 μV from 0.1 to 10 Hz.

CIRCLE NO. 431
For expensive business and commercial computers, talk to DEC®, IBM® or Data General®

for value-priced home or business computers,

H8 Kit $375.00

H11 Kit $1295.00

talk to Heath!

If you work with computers, you know how much of an asset they are to your business. Fast, accurate data handling, instant retrieval of important information and storage of vital records and statistics are all part of the computer revolution. Computers mean better business, but there’s another side to them as well.

Computers can work for, educate and entertain you right in your own home. Because they are true “open-end” machines, the number of ways you can use a computer at home is limited only by your imagination and programming prowess. Computers can also be an important adjunct to your children’s education and an introduction to the modern technological world.

Best of all, computers happen to be FUN! There are hundreds of fascinating and challenging games that can stimulate your brain and provide hours of relaxation and recreation. And because the computer can make its own decisions, you can “compete” at any level you program into it.

Heathkit computers are designed to fit right into your home. No matter what your computer application, we have the unit for you. Our H8 is an 8080A-based machine with an “intelligent” front panel that is ideal as a programming trainer and instruction tool. The powerful H11 is based on the most successful commercial computer in the world, the Digital Equipment Corporation PDP-11. These two computers, along with a complete line of peripherals and I/O devices, make Heath your home computing system headquarters.

Heathkit computer systems provide the documentation you need to get up and running right—complete step-by-step assembly manuals, comprehensive operating procedures and complete and thorough rundowns of software programs. What’s more, Heathkit computer systems include the systems software you need to start programming right away. The H8 includes a front panel monitor program, Benton Harbor BASIC, assembly language, text editor and console debugger. The H11 includes editor, relocatable assembler, link editor, absolute loader; debug, executive and dump programs plus BASIC and FOCAL.

Heathkit computer systems are designed to give you home computing at its very best. And since they’re backed by Heath’s 54-year reputation for honesty, reliability and quality, you know that a Heathkit computer system is one of the best investments you can make!

Prices are mail order net F.O.B., Benton Harbor, Michigan. Prices and specifications subject to change without notice.

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I am not on your mailing list.

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Address
City State
CP-141 Zip

CIRCLE NUMBER 141
**PACKAGING & MATERIALS**

**Large-area boards take DIPs and irregular pins**

Vector Electronic, 12460 Gladstone Ave., Sylmar, CA 91342. Floyd Hill (213) 763-9661. $9.96 to $19.95; stock.

A family of large-area “pad-per-hole” plugboards permit breadboarding of either custom circuits or S-100 bus-compatible boards. All boards have an isolated array of square solder pads surrounding 0.1-in. spaced holes. Two are made without card-edge connectors and may be cut to any desired shape. The 45P80-1 is 4.5 x 8.08 in.; the 106P106-1 is 10.6 x 10.6 in. Model 8801 is compatible with the S-100 bus system, accommodates DIP devices, modules and discrete components. All boards accept DIP packages from 8 to 64 leads as well as special modules with leads spaced on irregular multiples of 0.1 in.

**CIRCLE NO. 432**

**Epoxy bonds optic fibers, has thermal stability**

Epoxy Technology, 14 Fortune Dr., Billerica, MA 01821. (617) 667-3805. $16.60 (1-lb kit); stock.

Epo-Tek 330 is a two-part epoxy formulated for bundling optic fibers. Thermal stability results in less than 5% weight loss at 300 C. At 2.65 microns, spectral transmission is 84.9% with a 0.0015-in. sample thickness. Pot life is 8 h and the curing cycle is 5 min. Curing is indicated by a change in color from clear amber to bright red.

**CIRCLE NO. 433**

**Edge connector allows removal of contacts**

Methode Electronics, 1700 Hicks Rd., Rolling Meadows, IL 60008. (312) 392-3500.

Term-Aeon Series 1500 card-edge connectors provide 0.1-in. centers cable-to-board interconnects and allow field contact removal or replacement. The connectors’ crimp contacts are rated at 3.5 A and accept board thicknesses of 0.062 in. Connector housing material is 94V-2 or 94V-0. Polarizing features, with or without strengthening flanges for extended PC boards, are available.

**CIRCLE NO. 434**

**Fiber-optic cable uses single large core**

Valtec, West Boylston, MA 01583. Rick Cerny (617) 835-6082. $1/meter; stock.

The general-purpose fiber-optic communication cable, PC10, consists of a single, large-core silica fiber clad in a rugged plastic dielectric jacket. The cable can be used for high-bandwidth optical transmission over distances ranging from a few centimeters to 2 km. The maximum cable attenuation is 20 dB/km at 800 nm. Pulse spreading is 40 ns/km. Over-all diameter is 4 mm.

**CIRCLE NO. 435**

**Kit mounts TO-220 devices**

Thermalloy, 2021 W. Valley View Lane, Dallas, TX 75234. (214) 243-4321. $0.098 (10,000 qty); stock.

Type 4880 mounting kit for TO-220 devices provides fast, uniform mounting and maximizes thermal performance. Mounting hardware includes a stainless steel 4-40 nut, flat washer, flat washer and 4-40 x 1/2-in. screw. In addition, a polyphenylene-sulphide shoulder washer is provided to fit inside the device tab to electrically insulate the device from the mounting screw. A plastic film provides electrical insulation as well as low thermal resistivity (2.25 C/W).

**CIRCLE NO. 436**

**Desolder connections with vacuumized wick**


A vacuumized wick for desoldering has improved capillarity and shelf-life. The vacuumization technique deoxidizes the copper braid while applying a smooth, adhering coating of noncorrosive flux. To use, place the wick on the connection and apply the soldering iron to the wick. The solder is absorbed almost instantly. Wicks are available in 1/16, 3/32, and 1/8-in. widths, on plastic dispenser spools each 66 in. long.

**CIRCLE NO. 309**

**Circular connector mates blindly**


The KJL miniature circular connector has a “scoop-proof” feature that eliminates the possibility of contact damage in blind mating use. The connector meets MIL-C-38999 and operates from −65 to 200 C. As many as 58 crimp snap-in contact arrangements take from 3 to 128 contacts in wire sizes 16 through 28. Contacts are of high-conductivity copper alloy with a gold-plated finish. The price of a mated pair (type OF shell) 5-contact plug and receptacle is $45.54 in lots of 50.

**CIRCLE NO. 437**
Silicon-iron alloys, for instance. Magnetics offers you fast delivery on silicon-iron alloy coils in 1- to 7-mil thicknesses, either coated or uncoated. And we're the only source for 5- and 7-mil nonoriented types. You can count on them for uniformity in magnetic properties—in fact, we make and use them for our own magnetic devices, so they have to be right. In widths to 15".

Our Magnesil catalog tells more. For a copy, write Magnetics, Metals Division, Butler PA 16001.

Very special specialists in specialty alloys.

Tape cores, for instance. When it comes to tape wound cores, we offer thousands of choices—900 sizes, eight materials, seven gauges. Our Supermalloy tape cores feature high permeability and low loss for such applications as precision current and ratio transformers, high-perm inductors, bridge lifters, etc.

We also make bobbin cores from Permalloy 80 and Orthonol® ultra-thin tape. These cores are wound on nonmagnetic stainless steel bobbins, with core diameters down to 0.050".

For more information on tape or bobbin cores, write Magnetics, Components Division, Butler PA 16001.

Very special specialists in tape wound cores.

WE KNOW A LOT ABOUT A LITTLE.

WE KNOW A LOT ABOUT A LITTLE.

DMM Sensitivity:
Never Have We Packed So Much Of It Into Such a Small Package
$345 Complete

No other 1½-digit portable multimeter gives you 10µV DC and AC sensitivity, True RMS AC voltage and current measurement along with unsurpassed ±0.05% basic DC accuracy, guaranteed for one year—in a truly portable, easy-to-read instrument.

Model 248 measures:
Resistance 100mΩ to 20MΩ
DC Volts ±10µV to ±1KV,
True RMS AC Volts 10µV to 500V, both DC Current and True RMS AC Current 10 nanoAmps to 2A.

Small, Light, Easy-to-Read
Just 1¾" x 5½" x 3½" (4.45 x 13.97 x 8.89 cm) and only 1.3 pounds, the 248 has only 2 controls—Function and Range—and a bright 0.3 LED display for easy viewing.

Extras Included
You also get these standard accessories: a rechargeable NiCd battery module, a pair of test leads, line cord with charger, carrying case, and full instruction manual and test data. A full range of optional accessories is also available.

Price: $295* complete.
For complete information or a demonstration, contact your local Data Precision representative or Data Precision Corporation, Audubon Road, Wakefield, MA 01880, (617) 246-1600. TELEX (0650) 949341.

*price USA

Shown with optional bench stand.
New literature

Test instruments
A 20-page catalog features test instruments, including frequency counters, universal counter-timers, digital volt/multimeters, sweep generators, spectrum analyzers, microwave components and a new instrumentation controller for IEEE bus applications. Systron-Donner, Concord, MA
CIRCLE NO. 441

PROM matrix
A compact, space-saving, programmable-read-only-memory matrix for switching, testing and programming applications is described in a catalog from the Programming Devices Division. Sealectro, Mamaroneck, NY
CIRCLE NO. 439

Microwave components
A storehouse of standard and custom components for microwave and electronics engineers, designers and specifiers is detailed in a revised and updated 40-page handbook. Premier Microwave, Port Chester, NY
CIRCLE NO. 440

Snap-action switches
Operating and dimensional data on hermetically and resiliently sealed snap-action switches are given in a 16-page catalog. Haydon Switch & Instrument, Waterbury, CT
CIRCLE NO. 438

Indicator lamps and LEDs
Descriptions of LEDs, lamps, lamp-holders and indicators are included in an 88-page catalog as well as the company's complete line of products. Mouser Electronics, Lakeside, CA
CIRCLE NO. 442

Centrifugal blowers
An 84-page catalog describes an extensive range of centrifugal blowers. The catalog also contains sections on technical notes and standard connection diagrams. IMC Magnetics, Westbury, NY
CIRCLE NO. 443

Rectifiers
Over 1600 rectifiers, rectifier assemblies, zener voltage regulators, high-voltage rectifiers, Klipvoit surge suppressors and selenium rectifiers are covered in a 20-page catalog. ST-Semicon, Bloomington, IN
CIRCLE NO. 444

7-1/2 digit DVM
A 7-1/2 digit precision digital voltmeter that is the only DVM with a displayed scale length of 14-million counts is the feature of an 18-page catalog, whose full-color photos highlight each function and control. Guildline Instruments, Elmsford, NY
CIRCLE NO. 445

Open-frame switchers
Photos, dimensional drawings, features, and specifications on open-frame switchers are included in a catalog. LH Research, Irvine, CA
CIRCLE NO. 446

Connectors
A 40-page catalog describes miniature PC-card and cable-to-cable connectors. Featuring a graphic-selector chart, the catalog offers designers photos of actual application-board mountings as well as line drawings, dimensional and specification charts. Methode Electronics, Rolling Meadows, IL
CIRCLE NO. 447

Assembled instruments
An entire line of electronic test instrumentation is covered and displayed in a 32-page catalog, which carries complete listings of oscilloscopes, laboratory-grade strip and X-Y recorders, power supplies, various signal and function generators, counters, a full line of multimeters (analog and digital), and a complete selection of associated accessories such as probes and interconnecting cables. Heath, Benton Harbor, MI
CIRCLE NO. 448

Power FETs
The VMOS Power FET brochure covers general VMOS power FET benefits, markets and new design possibilities previously not achievable with bipolar transistors. It works in conjunction with the VMOS Power FET Design Catalog consisting of a device/application selector, data sheets, geometry characteristics, application notes and design aids. Siliconix, Santa Clara, CA
CIRCLE NO. 449

Transistors
More than 1000 types of transistors are covered in a 28-page catalog. Kertron, Riviera Beach, FL
CIRCLE NO. 450

Electronic kits
Nearly 400 electronic kits and products are featured in a 104-page catalog. Heath, Benton Harbor, MI
CIRCLE NO. 451

12-bit data acquisition
Two complete 12-bit data-acquisition systems, one with eight differential-input channels and one with 16 single-ended input channels, are presented in an eight-page brochure. Datel Systems, Canton, MA
CIRCLE NO. 452

Automatic testing
A 12-page brochure describes computerized automatic test equipment for functional testing of loaded printed-circuit boards, electronic assemblies, and electromechanical devices. S.I.R. Atlanta, Atlanta, GA
CIRCLE NO. 453

Electronic Design 6, March 15, 1978
QUALITY FABRICATION

Zenamic
(Metal Oxide Varistor)

This varistor is fabricated from Metal Oxide and mainly use for absorption of lightning surge, protection of all varieties of semi-conductors, suppression of switching surges and contactor protection. Following types are available.

<table>
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<th>Type No</th>
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<th>Z15L</th>
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**Z 10 L 221**

**Zenamic voltage**

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<td>8-20  S</td>
<td>2000A</td>
</tr>
</tbody>
</table>

ISHIZUKA'S ABSORBERS

Sic Varistor
V.R.D. (Bipolarity Zener Diode)
Gas Tube Arrester
and Thermistor

ISHIZUKA ELECTRONICS CORP.
3-16-7, Higashi-Kowai, Edogawa-ku, Tokyo 133, Japan
Phone: TOKYO(03)658-5111

CIRCLE NUMBER 146

**TYPE OF**
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Selected companies with recent reports are listed here with their main electronic products or services. For a copy, circle the indicated number.

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**Dataram.** Core memories.

**Cubic Corp.** Defense electronics, mass transit, elevator industry/electronic controls, two-way radio communications and medical/industrial equipment.

**Youngwood Electronic Metals.** High-precision metal stampings for semiconductor components.

**Penril.** Data-communications equipment, digital panel meters, test instruments and power supplies.

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A comprehensive magnetic-media-compatibility guide for digital cassettes, disc packs, disc cartridges, diskettes and MCST magnetic cards gives an instant cross-reference to hundreds of products by dozens of manufacturers. Wabash Tape Corp.

**Frequency spectra**

Using the acoustic noise and vibration of an electric fan as illustrations, an eight-page application note shows how to interpret frequency spectra with the company’s Model 444A FFT computing spectrum analyzer. Nicolet Instruments.

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Advertising Sales Staff
Susan G. Apolant
Sales Coordinator
Rochelle Park, NJ 07662
Robert W. Gascoigne
Thomas P. Barth
Stan Tessier
Constance McKinley
50 Essex St. (201) 843-0550
TWX: 710-990-5071
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Philadelphia
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**ELECTRONIC DESIGN** 6, March 15, 1978
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<th>MN1402 28-Pin Plastic DIP</th>
<th>MN1498 46-Pin Plastic DIP</th>
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<td>Power Supply</td>
<td>+5V</td>
<td>+5V</td>
<td>+5V</td>
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<tr>
<td>Instr. Cycle Time</td>
<td>10.0 ns</td>
<td>10.0 ns</td>
<td>10.0 ns</td>
<td>10.0 ns</td>
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<tr>
<td>Instruction Set</td>
<td>75</td>
<td>57</td>
<td>65</td>
<td>75</td>
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<tr>
<td>Instruction Memory ROM</td>
<td>Internal 624 x 8 bits (8192 bits)</td>
<td>Internal 164 x 8 bits (6144 bits)</td>
<td>External 1024 x 8 bits (8192 bits)</td>
<td>External 2656 x 8 bits (16284 bits)</td>
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<tr>
<td>Total on Chip RAM</td>
<td>64 x 4 bits (256 bits)</td>
<td>32 x 4 bits (128 bits)</td>
<td>64 x 4 bits (256 bits)</td>
<td>64 x 4 bits (256 bits)</td>
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