Microcomputer software costs can vary widely. Much depends on the design approach used. The hardware designer, drafted as a software expert, faces unfamiliar choices like type of language and whether to use in-house or outside development aids and services. For a detailed look at μP software, turn to page 20.
New Hybrid Potentiometer Combines the Best of Wirewound and Conductive Plastic—$5.33*

The new BOURNS® HYBRITRON™ resistance element brings you the best of both worlds...the long life and infinite resolution of conductive plastic...plus the tight linearity and low temperature coefficient of a wire-wound...at a new, low price.

You'll find this new element in BOURNS® Model 3541 ten-turn precision potentiometer...a new member of BOURNS popular 3540 family of compact (%" dia., ¾" deep), low-cost multi-turn potentiometers.

Significant specifications of the Model 3541: service life of 5,000,000 shaft revolutions; linearity 0.25%; temperature coefficient of ±100 ppm/°C maximum; reliable SILVERWELD® direct terminal-to-element bond; output smoothness of 0.015%; essentially infinite resolution; rugged, mechanically locked construction (no rear lid "pop-off"); special heat resistant insert around terminals to prevent damage during soldering.

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Write or phone the BOURNS PANEL POWER PEOPLE and tell us about your application. We'll send you the Model 3540/41 that best suits your needs.

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INFORMATION RETRIEVAL NUMBER 256

*1,000 pieces, same R.C., U.S. Dollars, F.O.B. Riverside, California
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art gallery.

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Cover: Photo by Patrick S. Tchrakian, courtesy of Intel Corp.
Meet the new 990 Computer Family from Texas Instruments

Introducing the 9900 Microprocessor and 990 Series Micro/Minicomputers
Upward Compatible Software and Downward Competitive Prices

At TI, we’ve started a new family tradition in micro/minicomputers with the 990 computer family...a new tradition built upon a heritage of semiconductor leadership.

The 990 computer family sets new price/performance standards because of an important milestone in MOS technology...

The TMS 9900 single-chip, 16-bit microprocessor.

Powerful enough to be the heart of a full minicomputer, the TMS 9900 is also the best microprocessor going for terminals, machine monitoring and control, and a host of OEM applications.

All in the Family

The same company...Texas Instruments...makes every member of the family, and makes every member software compatible, from the bottom up. The new Model 990/4 microcomputer and Model 990/10 minicomputer use the instruction set of the TMS 9900 microprocessor. This means that software developed for the low-end computers will be compatible with the higher performance models.

And, users can expand their systems with a minimum of interface and software adaptation.

The TMS 9900 Microprocessor

The TMS 9900 is a 16-bit, single-chip microprocessor using MOS N-channel silicon-gate technology. Its unique architecture permits data manipulation not easily achievable in earlier devices. With its repertoire of versatile instructions and high-speed interrupt capability, the TMS 9900 microprocessor provides computing power expected from a 16-bit TTL computer.

The Model 990/4 Microcomputer

It’s a complete computer on a single printed circuit board using the TMS 9900 as its central processor. The 990/4 is ideally suited for terminal control, central or peripheral device interface control, and as a CPU for OEM customers.

In addition to the TMS 9900 microprocessor, the 990/4 microcomputer contains up to 8K bytes of dynamic RAM, up to 2K bytes of static RAM and/or PROM, eight vectored interrupts, front panel interface, real-time clock input, two I/O buses for low- and high-speed devices, and optional ROM utilities.

With the 990/4, you can select a low-cost OEM package, a 7-inch or 12½-inch rack-mountable chassis, or a table-top enclosure... and memory expansion to 58K bytes.

Price: The Model 990/4 microcomputer with 512 bytes of memory is only $368* without chassis and power supply. This same model with 8K bytes of memory is only $512*.

A memory mapping feature providing memory protection and privileged instructions supports memory expansion to two million bytes. And TILINE**...an asynchronous high-speed I/O bus, supports both high-speed and slow-speed devices. Chassis options are the same as those for the 990/4.

Price: With 16K bytes of memory, chassis, power supply and programmer’s panel, the Model 990/10 minicomputer is only $1968*.

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Backed Better

In addition to the family of compatible hardware, Texas Instruments backs you with complete software and support.

Standard software packages include memory-resident and disc-based operating systems; FORTRAN, COBOL, and BASIC compilers; and program development packages with utilities. And, for you to develop application programs for the 990/9900 family, we offer cross support on timesharing networks and standalone software development systems. One is a low cost system using the 990/4... the other is a disc-based system using the 990/10. And, a prototyping system is offered for TMS 9900 users to develop custom software and firmware modules.

TI supports you with training and applications assistance, plus an installed nationwide service network backed by TI-CARE†, our automated remote diagnostic, service dispatching, and real-time field service management information system.

*To know our new family. Call your nearest TI office, or write Texas Instruments Incorporated, P. O. Box 1444, M/S 784, Houston, Texas 77001. Or, phone Computer Equipment Marketing at 512-258-5121.

Texas Instruments Incorporated

*OEM quantity 50, U.S. domestic prices.

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Electronic Design 26, December 20, 1975

INFORMATION RETRIEVAL NUMBER 4

Texas Instruments Incorporated
Cut package count ... Simplify board layout ... Reduce equipment size ... with

**DIP**

**MULTI-COMP® RESISTOR-CAPACITOR NETWORKS**

(Metanet® Film Resistors, Monolythic® Ceramic Capacitors)

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### STANDARDIZED DESIGNS* FOR BETTER AVAILABILITY, BETTER PRICES

<table>
<thead>
<tr>
<th>R (Ω)</th>
<th>C1</th>
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<tr>
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### BYPASSED PULL-UP AND R-C COUPLING NETWORKS

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### SPEED-UP NETWORKS

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</table>

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Sprague puts more passive component families into dual in-line packages than any other manufacturer:

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For more information on Sprague DIP components, write or call Ed Geissler, Manager, Specialty Components Marketing, Sprague Electric Co., 347 Marshall St., North Adams, Mass. 01247. Tel. 413/664-4411.

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How to turn an HP-45 into a stop watch

Readers of Electronic Design who are also the owners of Hewlett-Packard HP-45 calculators may be interested to know that they can use their machines as a digital stop watch and elapsed-time indicator, similar to the functions found on the HP-55 programmable version.

To gain access to the clock function, first clear the machine, using the gold alternate-function key. Then press the RCL key, and then simultaneously press the CHS key and the digits 7 & 8, or 4 & 5, or 1 & 2. The machine now displays the format:

```
 0.0 0.0
 0.0
```

To start the clock function, press the CHS key. Pressing the CHS key again will stop the clock without resetting the display to zero. (To reset the display to zero, press the CLx key.)

To save power during battery operation, you can turn off the last two digits (hundredths of seconds) by pressing the EEX key: depressing the EEX key will again turn on the last two digits.

The clock function can also be used as an elapsed-time indicator for timing and storing the elapsed-time measurements of up to nine separate events (assuming all events started from the same point in time). This function can be quite handy for measurement of physical phenomena, chemical reactions or even at a race track. While the clock is running, depressing any digit key (1 to 9) stores the displayed time up to that point in the respective register, the clock keeps running and is not otherwise affected.

After the clock is stopped by pressure on the CHS key, pressing any of the digit keys recalls to the display the time displayed in the respective register. Note that the STO key (while the clock is running) and the RCL key (after the clock is stopped) need not be pressed; the “store” and “recall” functions are automatically executed, depending on whether the clock is running or stopped. The CLx key should again be pressed after the last measurement is recalled, as the clock, when started again, will resume counting from the number on the display.

After the clock function is no longer needed, you can return the machine to normal operation by pressing the ENTER key (which returns the machine to fixed-point, 2-decimal operation) or by turning the machine OFF and then ON again. (The latter method is preferred, as the registers are cleared before the machine is used; however, the registers do not need to be cleared if the user wishes to store new elapsed-time data, as the registers are overwritten with new data any time the clock is running and one of the digit keys is depressed.)

While the clock function is operating, the only keys having any effect are the CHS, EEX, CLx, “+,” and the digit keys. All other keys, including the -, +, ×, and ÷, are nonoperating.

Accuracy? It seems the HP-45 was designed with the HP-55 in mind.

(continued on page 13)
Our AMI 6800 Kit is a big step forward in simplifying your design, evaluation and test programs. For example, our intelligent CRT is simple to operate with either resident or remote software. It really is smart, because it contains an S6800! And it's planned to have an in-circuit emulator added later.

Our dual disk is extremely useful for developing programs, and saves you hours of paper tape shuffling. And our Evaluation Board is loaded with all the parts you need to get your product on the market on time.

Now for the Caboodle. The dictionary calls it a "package." You'll call it the neatest set of instructions for any kit you've ever bought.

Now why don't you call your nearest AMI sales office or distributor, and ask them for the whole Kit and Caboodle. Or write AMI, 3800 Homestead Road, Santa Clara, CA 95051. What could be easier?

Here's where you pick up your Kit.

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Cleveland OH • (216) 837-6212
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Electronics Design 26. December 20, 1975
And Caboodle.

Software Brochure.
A rundown on AMI software products including assembler, loader and simulator.
(Avail. Now)

Evaluation Board Application Notes.
The why and wherefore of our Prototyping System, and how to make the most of it!
(Avail. Jan.)

Assembly Language Programming Manual.
Describes the instruction set and how to use the AMI Assembler and Simulator.
(Avail. Now)

AMI 6800 Brochure.
List of goodies. All you want to know about the AMI 6800 family.
(Avail. Now)

NCSS Users Manual.
All the magic necessary to work with National CSS time-sharing network.
(Avail. Now)

All the MOS you might need in addition to microprocessors.
(Avail. Now)

A detailed description of each component in the system, and how to make them work!
(Avail. Jan.)
When you put the Fluke 5200A Precision ac Calibrator and 5205A Precision Power Amplifier together, you'll be working with a fully programmable ac cal set-up offering outstanding range, superb stability and excellent accuracy.

Now you can calibrate ac devices up to 1200 volts rms over a frequency range of dc to 1.2 MHz. DC output of 1600 volts is available. Current levels range up to 200 milliamperes with a total output power of 220 watts.

Response is a fast 0.5 second. Both instruments are short-circuit proof. These Fluke instruments are the only ones on the market to meet the safety requirements of IEC 348. The field installable programming capability is offered in 8, 12, 16 or 52 bit formats so the system interfaces easily with almost any computer.

Midband accuracy is 0.02% overall and long term stability 200 ppm for six months. Instruments are fully guarded and interlocked. Phase lock and quadrature outputs are featured.

How much?
Cost of the 5200A and 5205A calibrator set-up in the U.S. is $8990. That's more than some other calibrators. But with Fluke, the short circuit feature alone will give you lower cost of ownership. Your Fluke sales engineer can point out other features that make our system your better buy.

Or use either unit alone
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Gain is 100 with a midband accuracy of 0.04%. Get dc to 120 KHz and get up to 1200 volts rms or 1600 volts dc at current levels up to 200 mA and 220 watts output power. Price of the 5205A alone is $3995 (U.S. price).

If you don't need the high voltage capability set-up, use the 5200A alone. Get outputs up to 50 mA from 100 microvolts to 120 volts with midband accuracies of 0.02%. The instrument offers isolated remote programming for all functions including frequency and amplitude. Price in the U.S. is $4995.

Learn more about using full ac measure power.
Call your nearby Fluke sales engineer listed in EEM and the Gold Book for a demonstration or complete literature. Or if more convenient, dial our toll-free hotline, 800-426-0361, for data out today.
O.K., you guys, back to the old drawing board.

It's a whole new ball game. And just when you'd made all your panel lamp decisions, right? But Monsanto's patented nitrogen doping process for GaAsP on GaP substrates has improved the light-emitting efficiencies of our LED lamps so dramatically that every good designer will want to take another look.

Monsanto has T-1 and T-1¾ replacement lamps in standard red color (improved significantly over last year's red LEDs) and new bright red which is unbelievably bright. Red. Plus green, yellow, and a dazzling new orange. In two lens choices and two lead lengths. And all improved, as you can see on the chart.

<table>
<thead>
<tr>
<th>Model Number</th>
<th>Color</th>
<th>Size</th>
<th>Luminous Intensity</th>
<th>Viewing Angle</th>
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<tr>
<td>5174B*</td>
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<td>T-1</td>
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<td>1.0 mcd</td>
<td>90°</td>
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<td>Yellow</td>
<td>T-1</td>
<td>4.0 mcd</td>
<td>90°</td>
</tr>
<tr>
<td>5774B*</td>
<td>Red</td>
<td>T-1</td>
<td>5.0 mcd</td>
<td>90°</td>
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<tr>
<td>5152**</td>
<td>Orange</td>
<td>T-1¾</td>
<td>40.0 mcd</td>
<td>28°</td>
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<tr>
<td>5252**</td>
<td>Green</td>
<td>T-1¾</td>
<td>15.0 mcd</td>
<td>28°</td>
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<tr>
<td>5752**</td>
<td>Red</td>
<td>T-1¾</td>
<td>40.0 mcd</td>
<td>28°</td>
</tr>
</tbody>
</table>

* Also available with 1" lead lengths, low profile (.138" high) lens, and 180° viewing angle.
** Also available with 24° and 65° viewing angles.

Last year there were some sockets that demanded filament lamps, despite their inherent failure-and-replacement problems. Bright was needed, and damn the torpedos.

This year you just might find the bright you need in a shake-rattle-and-roll-proof LED lamp. Come and see.

If you can take the time, you just might be able to add a lot of T to your MTBF.

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For product information, circle the service number or call your local Monsanto man. Or write Monsanto Electronics Division, 3400 Hillview Avenue, Palo Alto, CA 94304.

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They're good... no matter how bad

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OFFERS SWITCHING VERSATILITY OF
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EQUIPMENT.

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INCLUDING SOLID STATE, MIL SPEC
QUALITY (MIL-S-22885) AT COMM-
ERCIAL PRICES FOR CONTROL CONSOLES.

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4 LAMP DISPLAY. RFI ATTENUATION.
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DEPTH BEHIND PANEL. PX IS A
NATURAL CHOICE FOR MANPACK
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USE OF SPDT SNAP-ACTION SWITCHES
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REPLACEMENT, MAKE KS IDEAL
FOR RUGGEDIZED CONTROL PANEL
KEYBOARD APPLICATIONS.
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FREEPORT, ILLINOIS 61032
A DIVISION OF HONEYWELL

ACROSS THE DESK
(continued from page 7)

mind, and consequently it uses some of the circuitry of the HP-55. However, the HP-55’s internal oscillator is apparently “trimmed” for the required frequency, while that of the HP-45 is not. At any rate, the HP-45 should exhibit reasonable accuracy as is. (My own HP-45 measures about 5.3% slow when compared with a known time standard: I have used my machine on internal battery pack and on external power pack, and obtained similar accuracy results both ways.)

Owners of the HP-45 can compare their machines against a known time standard and use the resulting correction factor as required in future measurements. And although the absolute accuracy of the HP-45 may not equal that of the HP-55, the time function used during relative measurements—and particularly the storing of up to nine elapsed-time measurements—can be very, very useful indeed. 

Paul E. Miller
ENGINEERING TECHNICIAN
AMF ELECTRICAL PRODUCTS
DEVELOPMENT DIV.
1025 N. ROYAL ST.
ALEXANDRIA, VA 22314

Jobs, anyone?

In the April 1, 1975 issue we published an editorial in which we offered to try to match out-of-work engineers with potential employers. As one might expect, we received far more applications for jobs than announcements for job openings. We were successful in effecting a few matches but we’re still overstocked on resumes of engineers sprinkled around the country (and one in Germany who would like to come back to the U.S.). Some of the credentials look awfully impressive.

If you have some jobs available, get in touch with our Evelyn Morris (ELECTRONIC DESIGN, 50 Essex St., Rochelle Park, NJ 07662). Good engineers are going to be a lot tougher to find a few months from now.

CIRCLE 261 FOR DATA
CIRCLE 262 FOR SALESMAN CALL

Misplaced Caption Dept.

“We’ve got to clear out of the cafeteria for the next shift.”


Calculator errors and how some arise

In the Sept. 27 issue, a letter from Peter A. Stark discussed two types of alleged mistakes made by some calculators that employ algebraic notation with parentheses. I would like to point out that his second example actually gives the correct answer. It is his lack of understanding of the sequential operations of such calculators that causes the apparent error.

Algebraic calculators perform complex chain calculations in the order in which they are entered, rather than according to the standard mathematical hierarchy (in which exponentiation is done first, then multiplication and division, then addition and subtraction). For example, most users are aware that AB & CD must be entered as

\[ A \times B + (C \times D) =. \]

Entering it as

\[ A \times B + C \times D = \]

gives the erroneous answer \((AB + C)D\).

The calculation that tripped up Mr. Stark was of the general form \(A^3B^3\), for which he should have entered

\[ A \times \times 3 \times (B \times \times 3) =. \]

The incorrect answer was obtained by entering it as

\[ A \times \times 3 \times B \times \times 3 =, \]

which gives \((A^3B^3)\).

George Fergus

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MODEL 1248
For demo circle Reader Service #273
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DIGITAL IC TESTER
$1195.
Devices tested: TTL, DTL @ 5V, HTL @ 15V, CMOS @ 5V, 10V, 15V.
Tests performed: Same as 1248.
Remarks: Interfaces with manual and automatic handlers. Multiple voltages for CMOS.

MODEL 1249
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NEW!
East German computer proves better than expected

Tests and studies by Control Data Corp. show that East European data-processing machines are much more advanced than most U.S. experts have believed, while the peripheral equipment lags behind that produced in this country.

For example, the Robotron ES-1040 medium-to-large-scale computer, made in East Germany, is three to four times faster than the IBM 370/145 in processing scientific calculations, but in commercial applications the speed of the two machines is comparable, according to the CDC report.

However, when the memory speed of the German ES-1040 was tested along with that of the IBM 370/145 and the CDC Cyber 73, the ES-1040 took twice as long as the IBM machine and about six times longer than the Cyber 73.

Together, the two tests—that of arithmetic speed and memory speed—reveal that the ES-1040 is approximately twice as powerful as the IBM 370/145 in internal computing power.

Other findings by CDC:
The core memory of the ES-1040 is somewhat slow compared with the processor's speed—performance could be enhanced considerably with a faster memory.

- The ES-1040 executes the IBM 360 instruction set.
- The system could be improved through the use of more modern peripherals, chiefly in the mass storage area.
- In general, the East German machine is "very reliable."

The ES-1040 is constructed from ICs made in East Germany that are identical in logic to those produced in the U.S. by Texas Instruments, Motorola and Fairchild. The appearance of the ES-1040 prototype in late 1972 indicates a technology lag of three to four years in the IC area.

The logic design of the CPU is also very advanced, CDC says.

The processor employs microprogram control, a technique not too different from that used in the IBM 370 series. The processor includes a "lookahead" instruction feature, which allows various processor functions to be overlapped.

The memory is composed of 21-mil cores, has an access time of 450 ns and a system level cycle time of 1350 ns. The memory is composed of two to four independent modules, allowing memory interleaving. The path to memory is eight bytes wide. The theoretical memory transfer rate is about 142 million bps. CDC testing on a two-module memory showed that the memory speed was not well matched to the speed of the CPU.

The input/output channels operate under microprogram control and are compatible with the IBM multiplexer and selector channels. These channels are fast enough to allow connection of most modern U.S. peripherals, CDC says.

The two disc drives that came with the ES-1040 can store about seven million characters. The Control Data disc drives now connected to the ES-1040 have four times that capacity, and can also transfer data at twice the speed.

The tape drives that came with the East German machine were found to be equivalent in performance to U.S. units, but bulkier.

The East German printer offers a feature not provided by any U.S. manufacturer, CDC says. It allows different forms to be printed simultaneously. However, CDC points out that its printer outperforms the East German product in other ways: better print quality, slightly higher speed and an interchange-able character set.

Both the card reader and the punch were built in the Soviet Union and use standard 80-column cards.

Soft-recovery test cuts cost of diodes 30%

A new procedure for characterizing power diodes that removes ambiguities and costs by 30% is reported by General Electric, Schenectady, NY.

GE says it has achieved this by finding an easy way to test the soft-recovery characteristics of these devices. Until now, this characteristic has been hard to test, and even the results of the tests were open to many different interpretations, notes Ralph Locher, a product engineer for GE.

High-current diodes (over 100 A), when used in an antiparallel connection with SCRs in large switching supplies, prevent spikes caused by collapsing magnetic fields from destroying the SCRs. However, these diodes must have peak inverse voltages that are high enough to withstand the spikes.

By being able to measure the soft recovery time of the diodes accurately, Locher says, the more efficient units can be picked and thus diodes with lower PIVs can be used. And the lower the PIV, the lower the cost of the diode.

For example, GE says, where a 250-A, 1000-V device had to be used at a cost of $26 in 10- to 99-piece lots, a 250-A, 600-V diode can now be used at a cost of about $20 for similar quantities. Diodes are available with current ratings of 100 to 1000 A rms and with PIVs from 50 to 1500 V.

3-D radar improves target resolution

A monopulse tracking radar capable of providing three-dimensional target information and range resolution down to 1.5 ft is under development at the Naval Research Laboratory, Washington, DC.

Other features include the following:
- Ability to counteract enemy repeater-type countermeasures.
- Improved low-angle multipath tracking.
- Increased resolution of multiple targets.
- Improved target tracking in chaff and clutter.

The experimental radar uses a very narrow pulse width of 3 ns in conjunction with wideband monopulse processing to obtain azimuth and elevation information of each resolved part of the target.

Present high-range-resolution radars provide only one dimensional range-amplitude profiles. The 3-D radar, according to two of its developers, Dean Howard and David Cross, extends this capability, in that a target aircraft can be resolved into its major structural parts. Prominent features such as engines, tail surfaces, and wings can be located precisely in both range and angle. This is accomplished by processing the high-speed return pulses through special sampling and holding circuits, which convert the pulses to digital form for display, storage and analysis by computer pattern-recognition methods.

According to Cross, the next step in the program is to improve the radar performance and extend its range. This will be done by pulse-compression techniques to increase average transmitted power.

A similar radar, developed at Lincoln Laboratory, Lexington, MA, has been in use since 1968, primarily for long-range tracking. The Naval Research Laboratory radar differs in its method of processing and using target angular information.

### Speed of CCD memory is boosted tenfold

A tenfold increase in speed—from about 20 MHz to over 230 MHz—has been achieved for a CCD dual-speed, shift-register device. The development by Rockwell International's Autonetics Group in Anaheim, CA, is aimed at a transient recorder application.

According to Dr. Barry French, CCD research group leader: “The device can operate in two modes. In the first mode it accepts data at up to 234 Mb/s and transfers it out at up to 86 Mb/s. We call this the fast-slow mode. In the second mode it operates in a continuous way with up to 86 Mb/s data in and up to 86 Mb/s data out.”

This device has 130 cells and uses a two-phase overlapping gate approach—that is, there is a separate gate for transfer and a separate gate for storage associated with each cell. Charge transfer efficiency per cell is 99.9% at a 230 Mb/s transfer rate.

French notes that the device has a ion-implanted epitaxial n-channel that is deeply buried. It also has a gate length of 0.2 mil in the direction of charge propagation. Each cell has a 10-mil-wide channel that allows the full cell to contain about 0.76 picocoulombs of charge.

### Laser ‘thermometer’ to detect 80 million C

A laser “thermometer” to measure temperatures as high as 80 million degrees centigrade is being developed at the Massachusetts Institute of Technology, Cambridge, for thermonuclear fusion research.

The temperature-measuring system, being designed at MIT’s Francis Bitter National Magnet Laboratory, consists of a new high-power, methyl fluoride gas laser and an infrared detection system. The laser wavelength is 500 μm—in the far infrared.

The system, being developed under a $360,000 contract with the Federal Energy Research and Development Administration, will measure the temperature of deuterium ions in a plasma confined by strong magnetic fields inside a tokomak—a structure shaped like a hollow doughnut.

The thermal measurements will monitor the ion temperatures, according to Dr. Daniel R. Cohn, who is in charge of plasma physics research at the Magnet Laboratory.

“Measurements of ion temperatures are a crucial indicator of progress towards self-sustained thermonuclear fusion,” says Cohn. “The hotter the ions, the more often they will fuse into helium ions, giving off energy in the process.”

Fusion occurs at 80 million C, he notes.

Ion temperature is measured by use of a phenomenon called Thomson Scattering, Cohn explains. The laser beam is directed at the plasma, and as the beam hits and bounces off the ions, the laser frequency is shifted. By measurement of this shift, both ion temperature and concentration of impurities in the plasma can be determined.

### ROM capacity cut in voice synthesizer

A digital coding system used in a new electronic voice synthesizer reduces the required ROM capacity to only 2% of that needed in competitive voice systems, according to John E. Stork, president of Speech Technology, Inc., system developer.

“Conventional voice digitizing requires at least 50,000 bits/s to reproduce telephone-grade speech,” Stork points out. “With our coding method, we compress that down to 1000 bits/s.”

The Speech Technology synthesizer—the Model 200—uses a standard approach, Stork explains, in that it produces an electrical analog of the voice tract. It duplicates the resonances and other characteristics of speech.

“We take voice recordings—words or statements—and digitize them at 100,000 bits/s rate. But our trick is to extract from the recording features that can be stored in the digitizer and recalculated upon command.

“We do that by running the voice data through a computer analysis that compresses and transforms the data into unique code sequences that control the sound-generation portion of the synthesizer.

“To produce a particular sound, you send a 24-bit code to a control register in the synthesizer. The code—it is transferred in and out of the register in microseconds—programs the resonances, pitch frequencies and other sounds needed.

“For example, a sound like the vowel ‘aah’ in the word fox lasts for some 100 or 200 ms in normal speech. So the code directs the synthesizer to make that sound for 100 to 200 ms.

“Upon termination of that period, the code is replaced in the register by another code group, which is sent in for, say, 10 to 50 ms, until it is replaced by still another code, and so on.”
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Experts tell how to hold down high cost of processor programs

The hardware designer, enticed by ads for low-cost microprocessor boards, has several surprises in store when he embarks on his first micro-systems design.

First, he’ll learn that for a simple microprocessor control system, he’ll wind up with at least 25 additional chips surrounding the basic processor. For fairly complex systems, the number can rise substantially above 100.

But the big shock comes when the designer gets into microcomputer software. It can cost from hundreds of dollars to thousands for the finished system. For a $30 microprocessor, software has been known to cost $65,000 to $70,000.

Like it or not, the designer will have to become involved in programming to produce effective designs at minimum cost. And he’ll find himself in a design team that includes a specialized programmer.

A two-man team

You need at least two people on the microprocessor team,” says Gordon Gould, hardware designer for Advanced Electronics Development, Chester, CT, who has several successful micro-systems designs to his credit.

“You need the hardware man and the programmer. But the hardware man, to be effective, must have a good knowledge of programming language.

Software is more an integral part of microcomputer design than it is for a large computer, Gould notes, because much of the processing is related to the outside world rather than number crunching.

Jim McDermott
Eastern Editor
Costs of software development can vary widely, Gould points out, depending upon which of several approaches is taken and the skill of the programmer. A skillful programmer can reduce hardware costs by assigning hardware functions to software.

“Our initial discussions on a design,” says Tony Matthews, the programmer teamed with Gould, “are based on the assumption that software does everything. Then we back off from it when we find we can’t.

“We use this attack because once the software is completed, there is no more design work to do.”

Gould notes: “The more functions you can delegate to software, the better off you are, because you have more flexibility. For example, as changes come along, you can revise the software — on paper — and leave the hardware alone. Also, the less hardware, the lower the cost and the more reliable the system is.”

Decision-making in microprocessor hardware and software design can be a confusing experience. Some 60 or 70 vendors — semiconductor manufacturers, independent microprocessor hardware and software design houses and microprocessor hardware distributors — are marketing microprocessor design courses as well as software and development aids. The aids range from 4-bit microprocessor kits that are programmed by manual operation to extensive emulation systems, like Intel’s MDS or National’s IMP-16.

In addition time-sharing houses are available for running cross-assembler programs provided by the microchip manufacturer. And many of these programs can also be run on in-house computers.

**Kits and courses help**

For the hardware designer digging into microprocessor system design for the first time, the purchase of a kit or attendance at one of the many courses now given throughout the country can be of substantial advantage.

“Kits are extremely useful as a primary learning tool,” says Robert K. Lowry, executive vice president of Technology Marketing, Inc., a design house for computer based systems.

Just what microprocessor course to take depends upon how well the course presentation fits the designer’s approach to study. For example, Jerry Ogden, president of Microcomputer Technology, Inc., Reston, VA, who conducts seminars and is also responsible for the training at the 13 Cramer Microprocessor Design Centers, points out that “our courses are an intellectual exercise.

“We’re different from others,” he says, “in that we don’t teach

Once a microcomputer is in hand, the tendency is great for a user to develop his own instruction set. But this, according to Robert Richards, president of Megadata, Bohemia, NY, a microcomputer design house, “is the biggest mistake the designer can make.

“While instruction sets and documentation are getting better,” he says, “they’re still not as good as anything from a company like DEC or Data General.”

For minimum software costs,

Rahdigs advises the designer to follow Megadata’s procedure.

“We evolve our microprocessor technology about well-known minicomputer systems,” he notes. “For example, we’re using Intersil’s IM 6100 because it uses the DEC PDP-8/E instruction set.

“Software cost problems arise when you throw capable programmers into a new and totally unfamiliar instruction set. Finding programmers who can program by the pound — and that’s the way to look at it — is a lot easier for us, because there are so many available with experience on the DEC machine.”

A. Thampy Thomas, manager of microprocessor development at In-
tersil, Cupertino, CA, agrees with that philosophy.

"About two years ago we decided to build a microprocessor that emulated an existing instruction set, so we could use the software already developed for it," Thomas says.

The reason for that decision, he notes, is that "microprocessors usually take about two years to develop a resident assembler.

"For example," Thomas continues, "both Intel and National supported their microprocessors for two years on a Fortran processor before they wrote an assembler in the microprocessor language.

 Chuck Pedal, marketing director for microcomputers at MOS Technology, Norristown, PA, suggests that for a small program, such as debugging a printer or a piece of hardware, the use of a Teletype can be satisfactory.

For a larger program, on the order of 1 to 2 k, he recommends a resident assembler that has some kind of file structure.

"You can probably use a cassette and perhaps use a paper tape," Pedal says. But, in any event, a printout is mandatory, he notes.

For larger programs, Pedal says it's best to use the cross-assembler a microprocessor satisfactorily.

A complete microcomputer software-hardware development package is contained in Intel's MDS system. Its multiprocessor configuration permits design, development and debugging of systems based on the Intel 8080.

"In our case, the moment we came out, we had four or five self-assemblers available from DEC. We have compilers that recognize Fortran, Basic, Cobol and other high-level languages. And all this software was available without any development effort."

Minicomputer manufacturers are beginning to reduce microcomputer software costs by marketing new microprocessor boards and chip sets that are compatible with their own software.

One such manufacturer is General Automation. It is providing a one-board GA-16/110 and a two-board GA-16/220 microprocessor set. Both use the software developed over the last six years for the General Automation SPEC-16 minicomputer. In addition the micros are also compatible with the latest GA-16/330 and GA-16/440 minicomputer software.

Designers disagree on how much equipment is needed to program on a large computer, preferably in-house.

Richard Lee, manager of engineering development at Boonton Electronics, Boonton, NJ, has a different view. He says:

"There are only two reasonable approaches to software development. One is to go with a timesharing house to do your program development, and the other is to buy either a resident operating system device or a cross-assembler operating system with a minicomputer."

Needed: two capabilities

"You must have, in a productive system, file-handling and file-editing capability in order to get the job done in any reasonable length of time. It is possible to write programs in machine language, but your productivity is small. And even the little resident assemblers found in some of the development kits—the stand-alone processor, like the Intellec 8—is not a very productive machine because its editing capability is minimal.

"In particular, the data input-output program gets to be enormous. You read paper tape forever for one cycle of a program development. And when you find you made a mistake, you do it again and again.

"When you think of the time you're spending and of the value of the time, you have to realize that software is a substantial investment in any microprocessor-based system. I think Intel is on the right track with its MDS system, where you can use a floppy disc and put through program changes in a realistically small amount of time.

"We have a PDP-8/E system, which has a dual mag tape drive and a line printer. I've been looking at 8-bit processors, and so far I haven't found any instruction set that I can't trick the DEC PAL8 assembler into assembling for me.

"Another thing you need is a reasonable rate of creating hard copy. You can run with a Teletype, but to do a 4-k listing means that you walk away from it and let it run for the morning.

"So you have to size the development equipment to suit the job you're running. My own impression is that people sadly underestimate the amount of software they're going to wind up wanting to have. You usually wind up with three times the program you expected in terms of added functions. And that's liable to be five or six times as big in memory locations."

In-house development backed

George F. Martin, vice president of Advanced Electronics Development, favors an in-house development system for producing new designs.

"A company that's just designing one or two systems can't usually justify the cost of a full development system," he says.

"We started with just a microprocessor and a Teletype for editing, but it took a 12-hour day to edit and assemble one large program.

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## Microprocessor manufacturers and software support

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<td>6501/2/3 8-bit CPU</td>
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<tr>
<td><strong>Mostek</strong></td>
<td>F8 8-bit CPU</td>
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<tr>
<td><strong>Motorola</strong></td>
<td>M6800 8-bit CPU</td>
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</tr>
<tr>
<td><strong>National Semiconductor</strong></td>
<td>IMP 4/8/16 4-bit slices 1NS4004 4-bit CPU SCAMP-ISP500A 8-bit CPU PACE IPC 16 16-bit CPU</td>
<td>√</td>
<td>√</td>
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<tr>
<td><strong>NEC Microcomputers</strong></td>
<td>μPD8080A 8-bit CPU</td>
<td>√</td>
<td>√</td>
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</tr>
<tr>
<td><strong>Plessey</strong></td>
<td>MIPROC 16-bit CPU</td>
<td>√</td>
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<tr>
<td><strong>RCA</strong></td>
<td>CPD 1800 8-bit CPU</td>
<td>√</td>
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</tr>
<tr>
<td><strong>Rockwell</strong></td>
<td>PPS 4/2 4-bit CPU PPS 8 8-bit CPU</td>
<td>√</td>
<td>√</td>
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<tr>
<td><strong>Signetics</strong></td>
<td>2650 8-bit CPU</td>
<td>√</td>
<td>√</td>
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</tr>
<tr>
<td><strong>Texas Instruments</strong></td>
<td>TMS 1000/1200 Comp. TMS8080 8-bit CPU TMS 9900 16-bit CPU</td>
<td>—</td>
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<tr>
<td><strong>Western Digital</strong></td>
<td>MCP1600 9-bit CPU</td>
<td>√</td>
<td>—</td>
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</tr>
</tbody>
</table>
It's good to know that in low power dividers you don't have to be constantly comparing which is best, which is new, on and on.

Just look to Plessey Semiconductors if you're working on hand-held or mobile synthesizers, or high-speed instrumentation.

It makes sense. Plessey offers the most comprehensive line of dividers with frequencies of up to 1.2 GHz, and division ratios of 2, 4, 5, 10, 10/11, 16, 20 or 32. Three guaranteed temperature ranges are available: −40°C to +85°C, 0°C to +70°C, or −55°C to +125°C on MIL grades.

Most important, you get an incredibly low power drain. For example:

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
<th>Power Consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motorola MC12012</td>
<td>10/11 at 200 MHz</td>
<td>95 mA typical</td>
</tr>
<tr>
<td>Plessey SP8695</td>
<td>10/11 at 200 MHz</td>
<td>20 mA typical</td>
</tr>
<tr>
<td>Fairchild 95H90</td>
<td>10/11 at 200 MHz</td>
<td>70 mA typical</td>
</tr>
<tr>
<td>Plessey SP8690</td>
<td>10/11 at 200 MHz</td>
<td>14 mA typical</td>
</tr>
</tbody>
</table>

Other examples of Plessey's extremely low power devices with no competition:

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
<th>Power Consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>SP8667</td>
<td>+10 at 1.2 GHz</td>
<td>80 mA typical</td>
</tr>
<tr>
<td>SP8602</td>
<td>+2 at 500 MHz</td>
<td>12 mA typical</td>
</tr>
<tr>
<td>SP8685</td>
<td>+10/11 at 500 MHz</td>
<td>45 mA typical</td>
</tr>
<tr>
<td>SP8655</td>
<td>+32 at 200 MHz</td>
<td>10 mA typical</td>
</tr>
<tr>
<td>SP8660</td>
<td>+10 at 200 MHz</td>
<td>10 mA typical</td>
</tr>
<tr>
<td>SP8790</td>
<td>+4 at 200 MHz</td>
<td>10 mA typical</td>
</tr>
</tbody>
</table>

Still scratching your head, and saying, "Well, maybe...?" Then we've got something for you. Request copies of our data sheets with all the facts. The truth is there for all to see.

Compare Plessey's low power, high-speed dividers with the competition? Rubbish!
company and you want to automate your product, you can live with that, because in three months you'll have a system that you'll be selling for the next five years. So you don't want a lot of expensive prototyping equipment around.

"But in our business—designing microprocessor systems under contract—the initial $3000 for the prototype was a good investment."

In fact, each additional dollar invested, until we got up around $12,000, bought us more speed. For example, part of our system is an expensive high-speed card reader.

"But above $12,000 it takes considerably more dollars to get more programming output per hour. We believe that Intel has taken the right approach for our kind of need with its MDS system."

But Martin's advice is to go slowly and carefully before you make a large investment, "because once you start with a microcomputer that has its own unique software and development hardware, the investment in the software grows so rapidly that to convert to another system is usually a prohibitive expense."

The extent of development and software support provided by semiconductor manufacturers is very important in holding down software cost. A look at the table shows that for some microprocessors, across-the-board software support is provided.

The case for 16 bits

Another point that has been made is that in some cases software costs can be lower with use of a 16-bit processor, instead of an 8-bit device. The hardware price is usually about the same.

One reason for lower 16-bit software costs is that in some applications it may take more than 8 bits to define one instruction. In the 8-bit machine the machine must read in and fetch from two memory locations to get the instruction.

In one example, a system using a 16-bit processor took 1800 lines of coding in 1800 memory locations. Use of the 8-bit machine for the same job would have taken 5000 to 6000 memory locations. For, although the microprocessor is only 8 bits wide, the number of locations could have been divided by 2, but the software would still have come out with 2500 to 3000 lines of coding. And this would have required the debugging of 700 to 1200 lines more than necessary with the 16-bit machine.

High-level languages useful?

There has been much argument about the usefulness of high-level languages for microprocessor system development. So far four high-level languages for microprocessors have been offered.

The first entry, introduced two years ago, was Intel's PL/M. Motorola has just announced a new language: MPL. Plessey has a high-level language called PL-MIPROC, which is a super-set of Algol. And a "super-enhanced industrial Basic" has been generated by MITS, Inc., Albuquerque, NM, for the company's Altair 8800 microcomputer.

Phil Roybal, microprocessor marketing manager of National Semiconductor, Santa Clara, CA, feels that most high-level languages are not good for bit manipulation or I/O instructions.

"That is why," he says, "almost no minicomputers or large-scale machines use these languages for writing the operating systems and the drivers or anything normally done with microprocessors.

"If you can intermix high-level and assembly languages, it helps. Unfortunately, some are attracted to the high-level languages because it looks so easy to program. But they're wrong."

James Lally, manager of systems products for Intel, Santa Clara, CA, notes that "you use languages like Basic or Fortran or Cobol or Algol to do programming in which there is a lot of numerical analysis."

But Lally points out that the operating system itself is generally written in assembly language. Intel's PL/M language, he insists, is different from Fortran and the others, in that it is a systems-oriented, rather than an applications-oriented, language. The best indication of the effectiveness of a systems language is its use by the manufacturer, Lally says.

"We've used PL/M exclusively in the development of all of our software," he notes. "We've written our disc operating system, the ICE 80 executive, all of our assemblers and our text editors—everything—in PL/M."

Language merger

Robert Albrecht, a Basic language expert and an executive of the People's Computing Co., a non-profit organization in Menlo Park, CA, likes MITS' unique merger of Basic and machine language.

"The enhanced Altair Basic can load in octal machine-language instructions as part of data statements in Basic, and then position them in memory," he notes.

And Altair Basic has a potential for teaching machine-language programming. Albrecht points out.

The language can also be used to control output devices and perform bit manipulation, according to Paul Wasmund, programming specialist at MITS.

"You can directly address any I/O port with the IN and OUT instructions that correspond to the IN and OUT instructions of the machine itself," Wasmund says.

"It also has 'peek and poke' functions for recalling any memory location desired. In addition there's a WAIT function that gives you a bit mask. For example, if you use a bit mask for one, the computer waits for that one to go either high or low, depending upon what else you tell it in the WAIT statement.

"With this function you can wait on a port until it inputs, and as a result the computer can handle devices like a/d's."
Where other data terminal systems grow old, this one is designed to simply grow.

The Teletype® model 40 is the data terminal system to start with because it’s completely modular, and is designed to grow as your needs grow.

The display, operator console, printer and controller modules form the heart of the model 40 system and permit a variety of configurations to suit your application.

There’s a wide range of options, too, such as expandable memory with scrolling; half/full duplex modes; fixed and variable field transmission; protected formats; a variety of on-line controls; current loop and EIA (RS232) interfaces; and speeds from 110 to 4800 bps. Printer options include 80 column friction and adjustable tractor feed units.

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For complete information, please contact our Sales Headquarters at:

The Teletype model 40 system.
Nothing even comes close.
Sensor-minicomputer network tells when lightning will strike

Because Sandia Laboratories conducts many tests of military ordnance in the sands at Albuquerque, NM, atmospheric static discharges and lightning are a constant hazard. They might trigger explosions, with resulting damage to telemetering cables and instrumentation at the test sites. Sandia asked: Why not predict when static discharges and lightning strikes might occur?

The result has been a minicomputer-controlled network called the Lightning Early Warning System. It collects and processes atmospheric and potential-gradient data from 14 sensors placed from two to 30 miles from a main station, reports William W. Shurtleff, project leader. The data are interpreted at the main station and then retransmitted to test sites that store explosives.

The computer controlling the system—a Hewlett-Packard 2114B with a 20-k memory—also obtains weather data from four remote stations located in known paths of lightning and dust storms.

Although the Sandia application for the early-warning system is unique, Shurtleff sees the basic long-line acquisition and monitoring functions applied to other uses, such as in solar energy experiments and intruder detection.

He points out that the weather station acquisition system, in particular, is a general-purpose, long-distance system that can be adapted to other applications.

The potential-gradient sensors are laid out in a grid system. Data are fed to the main station, analyzed and retransmitted to users at the various test sites. If the potential gradient at any sensor reaches 2000 V/m, visual and audible alarms are sounded. The explosives are then stored until the danger is past.

The user, or test site operator, can adjust the potential level at which an alarm sounds. He may, says Shurtleff, reduce the level to as low as 500 V/m when he is monitoring tests that employ particularly sensitive explosives.

The test-site equipment has, as part of its display, a potential-gradient map with 2000 V/m warning lights. The observer can follow the path of a storm by watching the sequence in which the lights go on and off (see photo).

Sensors are radioactive

The key element of the system, Shurtleff explains, is the potential-

Display panel of on-site early-warning system equipment has a map with sensors pinpointed by warning lights. Storms can be traced by watching the lights go on. The system is installed at Sandia Laboratories test sites.
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Amphenol trimmers.
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When you can connect it and forget it...that’s quality.

**AMPHENOL**
NEWS

(continued from page 28)

gradient sensor. Eleven of these probes are linked to the central station by telephone wires and three by an rf telemetering system. Designed by Sweeney Manufacturing, Denver, each sensor contains a small amount of radioactive tritium, which ionizes the air surrounding the probe. The output ionization signal, which is detected by an electrometer FET amplifier, increases with an ambient, positive potential and decreases with a negative.

The FET output is detected, amplified and converted to a frequency by a Sandia-designed voltage-controlled oscillator. With a zero ambient atmospheric potential at the probe, the VCO output is 1000 cycles. For a positive 2000 V/m gradient, the frequency increases to 1500 Hz; for a negative 2000 V/m voltage, the frequency decreases to 500 Hz.

The probe signal is sent over phone lines or an rf transmitter. The transceiver is powered by a solar-energy panel.

As Shurtleff explains the rf-probe operation, the main station, under computer control, sends out a tone that is unique to a field station. Upon receiving the tone, the field unit switches from standby to full power, takes a reading and sends back a tone frequency that is proportional to the gradient measured. The field transceiver unit then returns to standby power status to wait for the next interrogation signal.

At the main station, the rf signal is received, detected, amplified and filtered to produce a pure af tone. The tone is multiplexed into a frequency-to-voltage converter, which translates it to a dc voltage that is proportional to the measured potential gradient.

The dc voltage is fed to an a/d converter having 11 bits plus a sign bit. The a/d output is computer-compatible.

System needs maintenance

Experience with the rf system has shown that the batteries must be recharged once every six months, despite the constant charge from the solar panel.

Shurtleff points out that recalibration and maintenance are performed at the same time and that the system has worked well through snow, rain and dust storms.

Signals received at the main station via remote-probe telephone lines are converted, in the same way as the rf signals, to digital data that can be fed into the computer.

In addition to the probes, the four remote weather stations transmit, over phone lines and upon computer command, wind speed, wind direction and temperature. The weather system has 16 channels at each station, thus providing 13 spares that can be used for additional meteorological data or weather-related experiments.

The computer requests a weather station to transmit data by sending a 360-Hz tone over its telephone line. The tone resets an a/d converter at that station to the first channel, and a reading is taken locally. The reading is converted to a series of digitally encoded FSK tones that contain the station and channel numbers, and 10 bits of data that are sent back down the line to the computer.

In like fashion, the readings of the other weather channels are converted, encoded and transmitted to the computer, until all active channels are interrogated and have replied. The system is then automatically reset and ready to start over again.

At the main station, the data tones are converted to digital levels, checked for errors and presented to the computer. Once the computer request has been satisfied, the 360-Hz tone is turned off and the process stops.

The remote stations have their own self-test features, Shurtleff points out, including test points, LED displays of critical levels and manual cycling capability.

After a weather station was struck by lightning, destroying a wind-direction sensor and translator circuitry, lightning surge arrestors were placed at all stations.

At the main station, the programming support consists of a high speed paper-tape reader and punch and a Texas Instruments operator terminal. Twin cassette tapes are available for recording data and programs. ■
The biggest thing to ever hit the OEM market, gets even bigger.

The four slot version of the Nova 3 gets pretty big. Up to 32K words of memory. But Nova 3 doesn't stop there. If you want to go further, consider the 12 slot Nova 3.

It can take on up to 128K words of memory. And our optional Memory Management Unit makes efficient use of all that memory, without a lot of systems overhead.

If you're going to need more I/O than the 12 slot Nova 3 can give you, there's an optional 12 slot expansion chassis.

And if one fully expanded Nova 3 still isn't big enough to handle the problem, you can add more Nova 3's and make multiprocessor systems. And they come with standard off-the-shelf software.

Why do we go to the trouble of offering such a wide range of configurations?

So you can meet any number of different systems requirements with the same processor. Without buying a lot of different spares. Without training your people in a lot of different test and maintenance procedures.

And so you can take your smallest product and make it a lot bigger. Without systems redesign. Without rebuilding your interfaces. Without rewriting your software.

And, no matter how small a Nova 3 you start out with, you get big performance. Nova 3 executes instructions in only 700 nanoseconds. Or more than twice as fast as the computers you're apt to compare it with.

Yet for all its bigness, there is one small feature in the Nova 3. Price. You can get a 64K word MOS memory Nova 3 with Memory Management Unit, Automatic Program Load and Power Fail Protection for just $16,800.* (Or a smaller Nova 3 for an even smaller price. A 4K MOS system for $2,600.*)

Write for the brochure.

You may discover that bigger is better.

DataGeneral

Nova 3: The biggest thing to ever hit the OEM market.

*Single unit price before OEM and quantity discounts get figured in.

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Sears Roebuck, look out.
Compiler for 6800 offers a high-level language to speed \( \mu C \) programming

No longer does Intel have the only high-level language, and associated compiler, for microprocessors. Motorola now offers a compiler for its language, called MPL, that works with systems based on the company’s 6800 \( \mu P \).

Thus 6800 users have many of the benefits hitherto available only to users of the 8080 and 8008. But in addition the MPL (short for Microprocessor Programming Language) compiler contains such features as the ability to accept assembly-language statements, to manipulate bits, and to handle and reference data structures—collections of different kinds of data.

Both Intel’s PL/M and Motorola’s MPL languages are based on IBM’s PL/1. The Intel compiler has been the sole microprocessor-compatible entry for the past two years or so.

Similar compilers are expected next year from Fairchild and National Semiconductor among others, though at least one manufacturer—Texas Instruments—plans to introduce Cobol, Fortran and Basic for its new \( \mu P \) (see “Processor Family Debuts,” Electronic Design 22, Oct. 25, 1975, p. 137).

Like Intel’s PL/M, the MPL compiler from Motorola (Phoenix, AZ 85036. 602-244-3466) can be used to reduce programming costs, increase software reliability and simplify program maintenance and documentation when compared with an assembly-language approach. But a program written in assembly language typically requires less memory space than one written in a high-level language.

(continued on page 34)

Floppy-disc systems speed program development

The most time-consuming part of a microcomputer design—program development—can be slashed by a factor of 10 or more by the use of the floppy-disc operating system, or FDOS, from Icom (6741 Variel St., Canoga Park, CA 91303. 213-348-1391). With FDOS, a typical edit and assembly sequence takes 5 to 10 minutes, compared with 3 hours for a teletypewriter and 45 minutes with a high-speed paper-tape reader.

FDOS works in conjunction with the company’s FD360 floppy-disc. Versions of the combined hardware/software system are offered for use with Intel’s MDS-800 development tool and the Micropac 80A design aid from Process Computer Systems (Flint, MI). However, the basic FDOS/FD360 system can be applied to most microprocessors with the aid of standard interface circuitry.

Contained in FDOS are such single-command operations as disc-to-disc program editing and assembling, disc-to-memory program loading, and file transferring between paper tape and disc or between discs. Also, the operating system allows variable-length named files. The storage area on each diskette is available for any number of files of any length from a single sector of 128 bytes up to an entire diskette, or 256-k bytes. The files may contain program source data, program object data or user-generated data.

Prices for the MDS-compatible version start at $2650 for a single-drive system, including all software and an MDS-interface card. The corresponding price for the Micropac-compatible unit is $2400. Delivery is 2 to 4 weeks.

CIRCLE NO. 501

Electronic Design 26, December 20, 1975
MICROPROCESSOR DESIGN

(continued from page 33)

An important difference, however, between PL/M and MPL is that the Motorola compiler produces assembly language as an output, rather than going directly to machine code as PL/M does. MPL works in conjunction with the 6800's assembler. Thus MPL takes slightly longer for compilations because of the additional step.

But this provides several direct benefits. First, assembly-language statements can be embedded in a compiler-language program. Thus, you can optimize portions of a program by writing them in assembly language, without the entire program written that way. Another benefit is that assembly-language subroutines from, say, a user's library can be applied directly within a program otherwise written in the compiler language.

In addition, program debugging can be greatly simplified. You can more easily see what the computer is doing. If necessary you can use Motorola's Exorciser development system to insert breakpoints in the program, follow the processor's execution step-by-step and actually see the instructions in the assembly-language output as they are to be executed.

Further, portions of the program already written in the compiler language can be shortened somewhat if, say, available memory space is slightly less than that called for by the program. Motorola's MPL allows programs that occupy memory space as large as 65-k bytes, as does the latest PL/M versions.

In another difference, MPL permits data structures, like those found in Cobol. A particular data structure can include 8-bit and 16-bit integers, as well as, alphanumeric characters such as might exist in an inventory system or anywhere that data isn’t homogeneous. Data structures contrast with the more common data arrays—like those of Fortran—in which data must be of the same type.

The types of data that can be handled by MPL include bit, binary (1 or 2 bytes long), decimal, and label. The compiler’s ability to manipulate individual bits overcomes one of the major drawbacks of existing high-level languages. Micros spend much of their time talking to the “outside world” in terms of bits, but earlier languages don’t permit bit manipulation.

Another feature of MPL is that it can perform an automatic conversion of two binary numbers of different length or a binary and decimal number for arithmetic operations. And it allows three-dimensional arrays of data. Thus three levels of data can be stored and indexed.

Other improvements include signed integer arithmetic—the language allows the representation of negative numbers. Also subroutine arguments may be passed in internal registers, thereby saving program steps and memory space for subroutine calls.

Presently the MPL compiler is available on GE time-share services. Beginning during the first quarter of next year, versions priced at $1250 will be available in Fortran on standard cards or magnetic tapes. Portable versions will run on any computer that has a word length of 16 bits or more. Thus many popular minis as well as large computers will be able to run the compiler. For more information

CIRCLE NO. 502 MOTOROLA, 503 INTEL.

(continued on page 36)

QUICK...
What number is this?

If you have to read your microcomputer the old-fashioned way — bit by bit, from rows of lights — the computer’s making you do its work!

• Don’t toggle in a program on a bank of switches — key it in.
• Don’t read data and addresses bit by bit — read a series of fully decoded digits (octal or hex).
• Don’t debug by single-stepping through a program — set breakpoints.

The modular micros from Martin Research. A 20 pad keyboard; six bright digits; and a Monitor program in a PROM make program entry easy. And, even the smallest system comes with enough RAM to get started! The MIKE 2 system, with the 8008 and the 8080 based MIKE 3 use the same bus structure. Accessories — like our 4K RAM — work with these and other 8-bit CPU's. And systems start at under $400.


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INFORMATION RETRIEVAL NUMBER 23

Electronic Design 26. December 20, 1975
Hot-molded resistors provide low temperature coefficient and unmatched reliability.

The Resistance Temperature Coefficient of Allen-Bradley hot-molded fixed resistors is typically less than 200 PPM over the entire resistor range shown in the normal equipment operating temperature of +15°C to +75°C. Excellent RTC ratings have always been an Allen-Bradley benefit. And consistency of Allen-Bradley resistors means repeatable results and tight performance patterns. Allen-Bradley resistors offer the lowest cost—on the board—where it counts!

Reliability is unsurpassed. Over 700 million unit test hours without a single failure.

No coatings. Insulation and resistance element integrally molded into one solid structure.

Pulse handling characteristics offer outstanding protection against surges and transients.

Quality in the best tradition.

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Electronics Division
Milwaukee, Wisconsin 53204
Next in kits: do-it-yourself gas-discharge displays

Look for Burroughs to enter the rapidly growing microcomputer design-aid field with a display kit that will make it easier to monitor and check a developing micro system. The Plainfield, NJ, manufacturer is rumored to be working on a kit to be used with do-it-yourself processor systems to be offered by Intel, Motorola and others. The Burroughs’ entry will have a single-line Self-Scan display with 16 or 32 characters, and it will contain a dc-to-dc converter to translate the low $\mu$P voltage levels to the 180 V or so needed for the gas-discharge displays.

16-bit microcomputer system cycles in 350 $\mu$s

Plessey Microsystems, Inc. (1674 McGaw Ave., Santa Ana, CA 92705. 714-540-9945) has introduced the Miproc 16, a high-speed 16-bit microcomputer with a cycle time of 350 ns. The computer has 82 instructions, which include multiply and divide. It is a complete processor on a card and is configured for parallel fetch and execution.

Included in the Miproc 16 are two separate program memory and data memory architectures, so most instructions take a single cycle. Conditional branches take 700 ns, and multiply or divide times are 5.6 and 11.2 $\mu$s, respectively. The system is supported by a versatile prototype development system and a Fortran IV cross-assembler simulator for use on the Tymshare and GE Mark III networks.

The price of the CPU board is between $700 to $800 for large quantities, and delivery is 30 days.

Security field turns to micros for monitoring and control

The security electronics field, long dominated by the relay and battery, is taking on new sophistication with the introduction of microprocessor-controlled monitoring and scanning equipment. The microprocessor is starting to do a good portion of the job once done exclusively by either hard-wired logic or manual control.

For years, large apartment complexes and office buildings have used guards, sitting at panels of video monitors, to detect trouble. Today these monitors are still used, but added to their effectiveness are $\mu$P-controlled scanners that can monitor alarms in up to 1000 locations. In addition card readers controlled by microprocessors are permitting selective access to restricted areas.

Whether the system application is scanning or selective access, microprocessors are ideal as control elements because of their inherent flexibility, says Victor White, vice president of Receptors, Inc., Torrance, CA. “We presently use the Digital Equipment Corp. LSI-11 microcomputer to handle the data from our Model 300 multiplex monitoring and control system,” he notes. The LSI-11 is built around a custom microprocessor.

Microprocessor systems developed by Keltron, Waltham, MA, are based on the Intel 8080. These systems can monitor up to 1000 points and provide visual and audible alarms. Two basic systems are being offered by Keltron: the DM-600, a 100-zone system, and the DM-700, a 1000-zone system. The smaller system, complete with all zone circuits, costs about $5500 and can connect to an optional printer, if hard-copy printout of conditions is needed. The larger system costs about $6000 when equipped with 100 zone circuits and a printer, but it is expandable to 1000 zones.

(continued on page 38)
The real test for a display's readability is direct sunlight. Most of them are washouts.

By comparison, Beckman displays stand out. With wider viewing angles and more brightness by the foot. Important factors when you're looking at critical readouts in the air or on the ground.

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Reliability is part of the Beckman Neoptic display picture. Assured by extensive in-process testing and 100% burn-in. As a result, we can give you a warranty that's good for 1 year. (Or you may qualify for our Warranty Plus Option.)

To top it all, Beckman Neoptic displays can give you a visible edge in your market—a simple case of product differentiation.

This is how Beckman displays beat the daylights out of all others. Paint for point, digit by digit. Clearly and decisively. And if you're not convinced, just plug in one of ours. Then compare it to theirs. The difference will show up day or night.

For complete details, write: Beckman Instruments, Inc., Information Displays Operations, P.O. Box 3579, Scottsdale, Arizona 85257, or call: (602) 947-8371.

Beckman®
INFORMATION DISPLAYS OPERATIONS
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Beckman beats the daylights out of all other displays.

Beckman displays.
The visible edge.

This photo of our model SP-101 was taken in actual daylight.
Selective entrance or exit in large company stock rooms, data-processing centers and vaults can be critical. To keep track of who enters and leaves, microprocessors and other dedicated processors are being used to control the opening and closing of doors and gates. Encoded pass cards, about the size of plastic credit cards, contain data that are keyed back to a central controller or used by a "smart lock" to open doors. The controllers can usually check the code against a list of stolen and defunct cards and either generate an alarm if an illegal card turns up or open the door if the card holder is authorized.

On large processor-controlled systems entry codes can be changed at the flick of a switch. Smart locks, on the other hand, must either be rewired or all the pass cards must be changed. Processor-controlled system prices start at $10,000 for a system that can handle 1000 remote readers and 20,000 individuals. Smart readers cost about $650 each.

PC-board PROM permits easy word changes

The Plug-Prom ROM uses small, 0.5 x 1-in. plug-in printed-circuit boards to program half an 8-bit word. Two plugs are needed for each memory word. Each plug is labeled with a hexadecimal value (0 to 9, A to F) that programs a diode matrix.

The Plug-Prom connects easily to any system using a short cable with a 24-pin plug on the end and is electrically equivalent to a type 1702 PROM. A LED option, a helpful tool, lights a LED in every word position when that word is selected. If the execution time is slowed or single-cycled, the LED indicators will visually show every fetch, jump, jump-to-subroutine and return-to-subroutine in the program.

Brent Olson (1950 Colony St., Mountain View, CA 94043. 415-326-2000) offers eight models, with dimensions ranging from 15 x 8 to 15 x 30 in. Organizations of 8 x 32 to 8 x 256 are available, and prices range from $250 to $1995. The plugs cost extra. Delivery of standard units is from stock to 60 days.

16-bit processor system has multiple-sourced software

Execution times of less than 1 µs and multiple-sourced software are offered by the Micromini System 300, a 16-bit microprocessor from Monolithic Memories (1165 E. Arques Ave., Sunnyvale, CA 94086. 408-739-3535). The µP system is based on the company's Model 6701 bipolar bit-slice processor.

The system comes in a variety of forms. It is available as a fully tested kit of components, as a set of PC cards, as a stand-alone six or 12-slot card file, or as a chassis-mounted computer with power supply and programmer's front panel.

The System 300 is software compatible with Data General's NOVA series. Compatible mass-storage operating systems with full software-development support are available from both Xebec Systems (Sunnyvale, CA) and Educational Data Systems (Newport Beach, CA).

Versions of the System 300 come in two performance ranges, as well as, in a militarized
The Am2905/6/7 Bus Transceivers:
High-speed I/O for your microprocessor any way you want it. Three versions of the same superb low-power Schottky LSI slice. Yours. Off the shelf. Now.
Single or dual driver input ports. With or without parity checking and generation. With or without three-state receiver outputs.
The Am2905/6/7 have open collector outputs that drive 50-ohm loads on terminated long lines. They store driver and receiver data for pipeline operation. And, with a bus-to-receiver delay of just 17 nanoseconds, they're ideal for any microprocessor, bipolar or MOS.

Bye bye, MSI.
Say bye bye to your complicated, costly MSI systems. The Am2900 family is here!
We started with the world's fastest, most powerful LSI microprocessor, the Am2901.
And went on from there until now we have eleven large scale, low-power Schottky circuits that combine the architectural simplicity and functional flexibility of MSI with the performance and cost advantages of LSI. Check the block diagram of a typical high-speed microcomputer, and you'll find everything you'll ever need for computation, control, communications and storage in any high-speed microprogrammed application.
If you like the picture, you'll love the book.
Send for the Am2900 story, and wave bye bye.
Bye bye, MSI!
Portable analyzers design and test μP systems

Both the program and hardware for systems using popular 4-bit and 8-bit μPs can be designed and tested with a new series of portable analyzers from Pro-Log (852 Airport Rd., Monterey, CA 93940. 408-372-4593). The new instruments eliminate the need for control panels, diagnostic routines or other data-processing tools for testing microprocessor-based systems.

The series consists of units that test systems based on 4004, 4040, 8008, 8080 and 6800 μPs. Used in conjunction with standard oscilloscopes, they can test program and hardware either together or individually. The analyzers display all data related to a selected instruction cycle and generate a scope sync pulse. They interface to the system under test through use of a DIP connector that clips onto the microprocessor.

Prices range from $550 to $750, and all analyzers are available from stock.

CIRCLE NO. 507

16-bit μP chip set includes DMA chip

The latest microprocessor entry is a 16-bit, three-chip set from Panafacom (P.O. Box 4637, Mountain View, CA 94040). It features a CPU IC that can perform 16-bit parallel operations in 3 μs or less. The two other chips—the Subchannel Adapter (SCA) and Direct Memory Access Controller (DMAC)—provide the I/O functions for the new PFL-16A chip set and permit data-transfer rates up to 1 Mbit per second.

The CPU chip responds to 33 basic instructions, allows six addressing modes and has five 16-bit registers. Like other processor chips, it contains control logic, arithmetic and index registers and stack pointer. But in addition the new CPU has three levels of program-maskable interrupt control and a type of software interrupt called program-status-word switching. And its auto-start feature ensures startup from a specified address whenever power is turned on.

The SCA chip operates in a program-control mode if used alone and in a DMA mode when used with the DMAC. Up to eight DMA channels, each with four subchannels, can be accommodated by the PFL-16A. The total subchannel capacity is 32, and up to 256 input and 256 output device addresses can be connected. Further, the chip set operates with either 8 or 16-bit data; external systems using either can be interfaced directly.

Each of the three chips in the set is a silicon-gate NMOS circuit requiring 12, 5 and −3-V supplies. Each chip features TTL compatibility and comes in a 40-pin DIP.

The PFL-16A system is available on preassembled, standard-sized cards. Thirteen cards are offered, and their use simplifies hardware development. For software development, Panafacom provides three complete debugging and program-maintenance systems. Other software support includes resident and cross-assemblers, editors and loaders.

CIRCLE NO. 508
What's new in solid state...

RCA announces a no-nonsense price for the no-nonsense μP.

Has high cost kept you away from microprocessors? RCA just demolished that reason. Even in small quantities you can buy our versatile CDP1801 8-bit CPUs at only $40 for the 4-6-volt version, $56 for the 3-12-volt version.

This, of course, is the RCA 1800 no-nonsense microprocessor family. Simple, easy to program, flexible. COSMAC architecture was designed with one no-nonsense objective: maximum flexibility with minimum cost. COSMAC cost-effective features include: single power supply; single phase clock; compact programs and strong I/O to reduce memory and I/O circuit requirements. Plus the CMOS benefits of low power and high tolerance of temperature extremes, supply variations and noise.

Compare support systems, too. The RCA Software Development Package is available two ways: in Fortran IV and on GE Timeshare. Our Microkit gives you low-cost systems breadboarding. And for low-budget programming we offer a Resident Software Package. A listing of memory and logic (I/O) parts, Microkit cards and other literature available to you is in the RCA 1800 brochure 2M1135.

**Microprocessors (CPU), 1-99 quantities**
- CDP1801D (3-12 volts).......................... $56.00
- CDP1801CD (4-6 volts).......................... $40.00

**Hardware support**
- CDP18S001 Microkit (basic).................... $2250.00
- CDP18S002 Microkit (Stand-alone).............. $3000.00
  (Includes resident Assembler & Editor)

**Software support**
- CDP18S900 Software Development Pkg............ $2000.00
- CDP18S902 Batch Assembler...................... $750.00
- MPM-101 RCA 1800 User Manual.................. $5.00
- MPM-102 Program Development Guide................ $10.00

For more information, contact your local RCA Solid State distributor. Or RCA.

Write: RCA Solid State. Box 3200, Somerville, New Jersey 08876; Ste. Anne de Bellevue 810, Canada; Sunbury-on-Thames, U.K.; Fuji Bldg., Tokyo, Japan.

RCA 1800. Low-cost approach to microprocessing.
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Free Demos Arranged!

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Competition sought in common-carrier communications

An inquiry by the House Subcommittee on Communications into regulations affecting domestic common-carrier communications is setting the stage for regulatory reforms that could shake up the communications industry.

The White House policy on the communications industry emerged loud and clear in testimony: Market competition should be the rule and regulated monopolies the exception.

One beneficiary of competition would be the Federal Government, the nation's largest customer of telecommunications, with a current investment of $50 billion and an annual expenditure of $10 billion. Government procurement has largely been sole-source from monopoly common carriers, and a competitive market would ostensibly result in savings.

"We still have today a kind of presumption in favor of regulated monopoly," says John Eger, acting director of the Office of Telecommunications Policy in the White House. "This means, in practice, that any would-be provider of a new or improved service must bear the onus of justifying his entry into the market and must undergo the accompanying burden of regulatory delays—and must usually accept the added cost of some kind of regulations."

The Ford Administration contends that the burden of proof should be shifted in favor of competition and that those opposing it should be obliged to show concretely that the detriments outweigh the benefits.

Rise in defense budget spending planned in '77 budget

The Ford Administration's tentative budget estimate for fiscal 1977 calls for $11.5 billion more for defense than was authorized for 1976. Defense budget authority would increase from the current $103 billion to $114.2 billion, and outlays from $91.5 billion this fiscal year to $103 billion in fiscal 1977.

Procurement of defense items again takes a back seat to personnel costs, which would account for over $6 billion of the increase. Budget authority for procurement would rise from the current $22.2 billion to $24.4-billion. Actual outlays would increase from this year's $16.2 billion to $18.3 billion.

The Defense Dept.'s research and development budget authority would increase to $10.6 billion from $9.7 billion, and outlays are expected to be $10 billion, compared with $9.3 billion this year.

Almost no change is projected for general science and technology, which includes the National Aeronautics and Space Administration budget. That
category will climb $300 million to a total of $4.6 billion, and all of the hike is for manned space flight in connection with the space-shuttle program.

The President will officially transmit the 1977 budget to Congress early next month.

**FAA landing and beacon programs pushed**

The Federal Aviation Administration has a green light from Congress to move ahead with three systems: microwave landing, discrete-address beacon and aeronautical satellite. This approval came with passage of the Dept. of Transportation money bill for fiscal 1976, in which $67.5 million was earmarked for FAA’s research, engineering and development.

Congress didn’t specifically break out the allocations for the programs, leaving that to the agency, but it did say that the funds were intended to provide sufficient capital to ensure essential progress in the microwave landing and beacon systems. In restoring funds for Aerosat, Congress said it expected the FAA to test both L-band and vhf capabilities and to present findings to the Congress to acceptance of either frequency.

**Minimum altitude control sought by military**

In the near future air controllers and military control centers are going to be alerted instantly when aircraft are below minimum safe flying altitude. This capability will come from a programmable indicator data processor system now under development by the Air Force, which plans to buy 91 units under a contract to be awarded in the spring of 1976. Navy flying fields will also get the units.

The heart of the new system is a programmable digital minicomputer which will generate alphanumerics to indicate flight density, ground speed and message data. Radar scopes will either have to be modified or replaced to accommodate this more detailed presentation of flight information.

**Capital Capsules:** The Dept. of Transportation has authority in its budget to begin deployment of a Loran C navigation network in the Gulf of Mexico and along the Atlantic Coast. . . . The Air Force is testing a new electronic security system in a variety of terrains. Tests have been made at sandy Eglin AFB in Florida, and Fort Drum in northern New York State is to be the next site. The transducers under development are said to be so sensitive that they can detect ground vibration caused by air waves from a helicopter flying overhead. The object of the tests is to program the system’s logic so it can tell the difference between a man crossing a field of sensors and, for example, a rabbit. . . . The Air Force Systems Command wants a source to develop a low-cost high-performance integrated circuit capable of amplifying photodiode signals at data rates to 10 Mbits s. The Directorate of R&D Procurement (ASD/PPM-1) at Wright-Patterson Air Force Base also is looking for low-cost fiber-optic transmitter and receiver modules for those data rates. . . . Congressional pressure is reportedly one reason why the Energy Research and Development Administration has deferred to next month or later that issuance of guidelines for submission of proposals for the Solar Energy Research Institute. Southwestern states are on record as saying their area would be ideal for such a facility.
Go SDVM*

*Systron-Donner "smart" DVM

Meet Model 7115, the industry’s first microprocessor-based digital multimeter. It does what no conventional DVM could hope to do:

**Automatic zero/self calibration.** Using its computing power and built-in memory, Model 7115 continually calibrates itself against drift and component aging. Similarly, it detects and corrects for zero drift and offset error. Result: accurate readings all the time!

**Self-diagnosis.** Microprocessor power again. Out-of-limit conditions or failures are signalled on the front panel; internal LED's direct the operator to their location inside.

**High-speed autoranging.** A rapid new S-D autoranging technique finds the correct range, goes there immediately and reads. It's not only a big improvement for bench use, but systems users can now use autoranging.

**Command performances.** An optional keyboard for programming the Model 7115 allows it to linearize and normalize, run comparison programs for checking out-of-tolerance conditions, multiply by a constant, average readings... and much more.

**These features, too.** Up to 100 readings/sec. • DC accuracy of ±0.002% rdg. • Parallel programming or ASCII option • True RMS AC volts option • High accuracy resistance measuring option.

Get the full story on the first SDVM from Scientific Devices, or contact us at 10 Systron Drive, Concord, California 94518. Phone (415) 676-5000. Overseas, contact Systron-Donner in Munich; Leamington Spa, U.K.; Paris (Le Port Marly); Melbourne.
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For less than you're willing to pay.

Unitrode Corporation, 580 Pleasant Street, Watertown, Mass. 02172.

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*TO-202 ** TO-202 OR TO-92
Delegating authority

Joe's a great manager. If you don't believe it, ask him. He's read just about every book anybody has ever written on management and he subscribes to all the management publications. He has probably read everything Peter Drucker has written 16 times.

One of the cornerstones of his success, he confides, is that he knows how to delegate authority. Just about everybody working for him is authorized to do something. But if you ask his people, they offer a different view.

"Sure he delegates authority," Stan will tell you, "but he gives it to you with one hand and takes it away with the other." If one of Stan's engineers screws up, Joe will be in there chewing him out. And if one of Stan's engineers does a sensational job, Joe will promise him a raise—often forgetting to mention this to Stan.

So Stan has all the authority he wants and needs to do his job properly, but Joe frequently takes it away without telling him. Under pressure of a deadline, Stan gives one of his engineers a time-sensitive assignment, only to discover later that Joe has stopped by to chat and asked the engineer to run through some tests on a different project. The engineer, unfortunately, hadn't read all the management books so when his boss' boss asks him to do something, he does it.

I'm particularly sensitive to this problem because, eleven years ago, I lost a fine editor, who resigned one day because he never got the fantastic raise promised him by my boss, who never bothered to tell me about it.

It's unfortunate that our industry has bred so many hundreds of well-intentioned Joes for whom thousands of Stans must bear a double burden. It might make a major contribution to improving the way we operate if they could teach themselves, when speaking to their subordinates' subordinates, to restrict their conversations to: "Good morning," "How are things going?" "Did you hear about these two guys in a saloon who. . .?"

GEORGE ROSTKY
Editor-in-Chief
THIS YEAR...
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ENTER OUR JAN. 5, 1976 TOP TEN CONTEST

WIN THE POPULAR CARIBBEAN WINDJAMMER CRUISE FOR TWO Once again, by reader demand, a week's Windjammer Cruise for two in the fabulous blue Caribbean is waiting for the lucky winner of Electronic Design's annual TOP TEN CONTEST. Think of it... a complete vacation absolutely FREE! Spend easy carefree days sailing among the Bahama Out Islands, the U.S. and British Virgin Islands, or the exotic Windwards and Leewards. Shop in the free ports, sun, swim, snorkel, help sail the ship or just relax by the rail. It's truly the cruise of a lifetime.

PLUS A COOL $1,000 CASH AND PRE-PAID AIR TRANSPORTATION FOR TWO In addition to the cruise, the first prize winner gets $1,000 cash, plus air transportation for two to and from the cruise ship's point of departure.

PLUS FREE AD RERUNS FOR YOUR COMPANY If your company has an ad in Electronic Design's Jan. 5, 1976 issue, and you are one of the top three reader or advertiser winners, you earn a free ad rerun* that can be worth up to several thousand dollars for your firm.

100 PRIZES IN ALL

READER PRIZES
1st Prize: Caribbean Windjammer Cruise for two, $1,000 cash, air transportation for two, free ad rerun*.
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6th through 100th Prizes: Technical books.

SEPARATE CONTEST FOR ADVERTISERS AND THEIR AGENCIES
Advertisers, marketing men, and advertising agencies can enter too. Duplicate awards are given to the top three winners (cruise, cash, air transportation, free ad rerun*, color TV and digital watch). Remind your advertising people it's the issue of the year to build business for your company and win valuable prizes at the same time.

HERE'S ALL YOU HAVE TO DO TO ENTER
Examine the January 5, 1976 issue of Electronic Design with extra care. Read the Rules. Then:
(1) Select the ten ads you think will be best seen and read
(2) List the ten ads by company name and inquiry number on the contest entry card.
(3) Fill in your name and address and mail before midnight Feb. 15, 1976.

COMPLETE RULES AND ENTRY BLANKS IN JAN. 5 ISSUE
Employ \( \mu \)P software tools properly, and you’ll shorten development time and reduce errors. Get to know the three types of design aids offered by vendors.

Software provided by microprocessor vendors is an invaluable tool for the digital system designer. Properly used, it can greatly speed the development and reduce the errors in a program design. For these reasons, logic designers ought to be aware of what software packages are available and how they can be used effectively.

There are three types of computer software: operating, program-development and diagnostic (Fig. 1). This is true for microprocessors as well as for minicomputers and large mainframe computers.

Operating software is the group of programs that runs on the computer under normal use. In a dedicated computer system, the programs are in the read-only memories (ROMs) that come with the machine. For example, in a microprocessor-controlled automatic weighing system, the operating software is the program that calculates and displays the weight. Usually operating software combines user-written and vendor-supplied programs.

Program-development software refers to design tools that help in the creation of operating software. It is a computer-aided-design package, and the tools range from simple assemblers to complex high-level-language compilers.

Diagnostic programs test the computer hardware and verify that the system is operating properly. Typical programs test the central processing unit, memory and selected I/O devices. There are also software diagnostic programs, such as simulators and debuggers. These test for proper program sequencing and functioning.

Who does what in software?

The user must write his own operating software, since this represents the logic design of the system or product being built. The computer vendor can supply some prepackaged items, such as binary loaders and mathematical subroutine packages, but the rest is created by the user for his application. On the other hand, diagnostic software is a fixed package of programs supplied by the \( \mu \)P vendor.

Program-development software represents the largest investment on the part of the computer supplier. It is this type of software that is usually referred to when one speaks of a vendor’s software support, and the degree of support can vary markedly from one vendor to another.

If you are a logic designer using microprocessors for the first time, you may ask: “What does all this software do for me?” You have to answer this question to know what you need for your design and how to evaluate what the microprocessor vendor is supplying. The three types of software may be needed even for very simple systems.

A computer system design for, say, an automatic meat scale typically goes through the following steps:

1. State the problem. (Create an automatic meat-weighing scale with digital readout.)
2. Analyze the problem into a sequence of operations that will perform the function.
3. Arrange the sequences in a list or flow chart that will show how they are to be performed.
4. Write the program from the flow chart of operations. If the definition of the operations is detailed enough, this should be a simple conversion. Each operation will be performed typically by a few instructions.
5. Enter the instructions into the computer-system memory. Let us assume that we enter it manually through the computer front panel.
6. Test the program. This will probably be done first by stepping the computer through the program, instruction by instruction, and then at full speed. This corresponds exactly to testing a hard-wired logic system, clock-step by clock-step, and then at full speed. When the program and system have passed these tests, the program design is complete.

Small systems can be designed easily

For a simple program of, say, 20 words, the design is straightforward. Instructions, address-
es and data can be generated as binary bit patterns. These bit patterns are entered through the front panel, and the program is then tested. Programs of 100 words or larger, however, create the following problems:

1. Instructions are hard to remember as binary numbers.
2. Addresses are difficult to remember as binary numbers. Also, addresses change when the program changes. It is often hard to remember what the address locations are being used for.
3. It is difficult to follow the program flow with binary addresses and data during debugging.
4. The program must be entered into the computer memory. Programs of over 100 words are impractical to enter manually through the front panel.
5. If you have a system failure during debug-

<table>
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<tr>
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<th>Sample Program</th>
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<tbody>
<tr>
<td>Start: DIA 0, 15</td>
<td>First Word to Location 2</td>
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<tr>
<td>LDA 1, X</td>
<td>Load Reg 1 From Location X</td>
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<tr>
<td>ADD 1, 0</td>
<td>Add Reg 1 to Reg 0</td>
</tr>
<tr>
<td>STA 0, Y</td>
<td>Save Result in Location Y</td>
</tr>
<tr>
<td>DOB 0, 15</td>
<td>Output Result To Device 15, Reg B</td>
</tr>
<tr>
<td>JMP Start</td>
<td>Loop Back To Start</td>
</tr>
<tr>
<td>X: 30</td>
<td>Octal Data</td>
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<tr>
<td>Y: 0</td>
<td>Result: Initial Value = 0</td>
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<td>LOC 2</td>
<td>First Word To Location 2</td>
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<tr>
<td>DIA 0, 15</td>
<td>Load Reg 0 From Device 15, Reg A</td>
</tr>
<tr>
<td>LDA 1, X</td>
<td>Load Reg 1 From Location X</td>
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<tr>
<td>ADD 1, 0</td>
<td>Add Reg 1 To Reg 0</td>
</tr>
<tr>
<td>STA 0, Y</td>
<td>Save Result In Location Y</td>
</tr>
<tr>
<td>DOB 0, 15</td>
<td>Output Result To Device 15, Reg B</td>
</tr>
<tr>
<td>JMP Start</td>
<td>Loop Back To Start</td>
</tr>
<tr>
<td>X: 30</td>
<td>Octal Data</td>
</tr>
<tr>
<td>Y: 0</td>
<td>Result: Initial Value = 0</td>
</tr>
<tr>
<td>. END</td>
<td></td>
</tr>
</tbody>
</table>

| Binary Tape Contents: | 000002 060415 024010 123000 040011 062015 000002 000030 000000 |

1. Three types of software—operating, program-development and diagnostic—exist for all computers, from micros to large mainframes.

2. An assembler generates this sample program. Each line of the source-tape listing contains one or more symbols that define a binary word.

Operating software:
- Customer application programs
- Binary loaders
- Relocatable binary loaders
- Operating systems
- Miscellaneous utility programs:
  - Math subroutines
  - I/O control subroutines
  - Paper tape copy and list programs
  - Etc.

Program development software:
- Assemblers
- Relocatable assemblers
- Paper tape editors
- Macroassemblers
- Compilers
- General-purpose microassemblers

Diagnostic software:
- CPU diagnostics
- Memory diagnostics
- I/O device diagnostics
- Software diagnostics:
  - Debuggers
  - Simulators

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A paper-tape editor employs various commands to read alphanumeric characters into a buffer area in memory, modify the buffer's contents and punch a new tape from the modified buffer. Modifications are performed on lines of text, and each line consists of a string of characters terminated by a carriage return.

Assemblers: Simple, but powerful

Assembler programs represent the lowest level of program-development software. But though an assembler provides but a few basic bookkeeping functions, it allows a programmer to design programs of up to several thousand words.

An assembler provides three functions to the programmer: It allows him to specify instructions by name, to specify addresses by name, and to specify data in several forms other than binary. Instead of writing down a list of binary numbers for instructions, addresses, and data words, the programmer lists shorthand symbols for the instruction words and names for the address words, and he specifies data constants in more convenient decimal, octal, or hexadecimal data formats. The assembler program then processes this list to create a corresponding list of binary numbers.

The list of symbols that an assembler processes to create the binary program is called the source program. Each line of the list contains one or several symbols to define one binary word. A line in the source program may also provide information to the assembler program, such as indicating the start and the end of the source program, as well as where the binary program is to be placed in memory. A small assembly-language program illustrates these features (Fig. 2).

Each assembler has its own list of shorthand symbols or mnemonics for instructions. This list may be either fixed or expandable, depending on the design of the assembler. It is possible to write a general-purpose assembler in which all of the instruction mnemonics are defined by the user. These mnemonics are usually three to five characters long.
Memory locations are named by writing the name, followed by a colon, before a line that specifies an instruction, a data constant or another address. The assembler associates the address value for that location with that name. Names are usually restricted to five or fewer characters. There may be other restrictions about numbers and nonalphanumeric characters in the names.

Once a location has been named, it can be referred to by that name throughout the rest of the program. This is very convenient, because if the program is changed and the named location becomes a different address, the assembler will automatically use the new number. The programmer does not have to perform any calculations to determine the new address. Likewise he does not have to scan the program to find all of the places where that address may be used and then update them.

The ability to specify data in other than binary form is also a useful feature. It is very time-consuming for a programmer to convert decimal data to binary if he needs to specify a decimal constant. And manual conversion is prone to error.

Microprocessors and small minicomputer systems use paper-tape assemblers. These programs accept the source data on paper tape and also produce the binary program output on paper tape. In the source paper tape, one line of teletypewriter data is interpreted as one line of source code. A paper-tape assembler assumes the existence of a small operating program called a binary loader. The binary loader reads the binary paper-tape output from the assembler and generates the corresponding binary words in the memory of the computer.

The binary loader program, although small, may itself be too long to be loaded into the computer by hand. A second, smaller paper-tape loader program, called a bootstrap loader, is used to load the binary loader into memory. This bootstrap loader is designed for minimum size and easy entry from the front panel.

A paper-tape assembler package usually includes a program called a paper-tape editor whose primary purpose is to overcome a problem that occurs when source tapes are generated. It is difficult to add or delete characters or a line of characters in the middle of a paper tape. The editor overcomes this problem by reading the source tape into a buffer area in memory. It allows the user to add and delete lines and characters to and from this buffer. It punches out the new source tape when additions, deletions and modifications are complete.

Diagnostic programs determine whether a system failure is caused by hardware or software. Hardware diagnostic programs are usually supplied with each machine. Typically one diagnostic program is supplied for the CPU, memory and each I/O device. When a user designs a custom I/O interface, he must also write the corresponding diagnostics. Software diagnostics are called debugger programs. These tend to be loosely classified under the heading of program development software, although, in fact, they are a type of operating software. Obviously, debugger software is considered a marketing tool by the computer vendor in the same category as program development software.

The software debugger program is a collection of useful functions. A simple, teletypewriter-based debugger program will include the ability to load memory from paper tape, dump a section of memory to paper tape, and dump a section of memory to the teletypewriter printer in readable format. It will also include the ability to examine and modify memory locations and to execute a program starting at a specified address.

**Debugger permits breakpoints**

A debugger has another important feature, called breakpoint. This allows the programmer to stop the program when it reaches a specified point. To use the feature, the programmer inserts a breakpoint at an address in the program. The debugger program then goes to that address, removes and saves the instruction and inserts an instruction that causes the computer to jump back to the debugger program. After returning to the debugger, the original instruction is replaced. Thus the program can be executed up to a point and then stopped. The programmer can then examine the memory to see if failures have occurred.

The debugger program duplicates many of the functions of the computer front panel. But while the computer front panel directly controls computer hardware and is useful for debugging hardware problems, the debugger program focuses on software problems. Its use assumes that the hardware is working well enough for the debugger program itself to run.

**More powerful tools**

The amount of support software required by the logic system designer depends on the size of the program he intends to write. If the program is less than 200 words, support software may not be required. It may be practical to create the program directly in binary or hexadecimal form, enter it through the front panel and debug it manually through the front panel.

For common programs of approximately 200 to 4000 words, a paper-tape assembler and debugger package are sufficient. But for larger programs,
systems of programs and programs of a high degree of complexity, more extensive software support packages have been developed. These include (in order of increasing sophistication) relocatable assemblers and loaders, macroassemblers and high-level-language compilers.

A relocatable assembler is the same as a simple assembler, except that it produces its binary tape in a format that is compatible with a relocatable loader. This loader allows the programmer to load several programs at the same time and to stack them automatically in memory. It also provides any necessary communication between programs, such as in a program that calls several common mathematical subroutines. The relocatable loader must modify all addresses used by a given program, since these addresses depend on where the program finally ends up in memory. Thus a relocatable loader is considerably larger and more complex than a simple binary loader.

A macroassembler allows the programmer to create and specify blocks of instructions. Suppose a programmer uses a three-instruction sequence for any call to an I/O device. A macroassembler allows the programmer to define this three-instruction sequence and to assign a special mnemonic to it. When this mnemonic is encountered by the macroassembler during processing of a source program, it will create the corresponding three binary words. These user-defined multiple-word instructions are called macroinstructions.

High-level-language compilers, such as those for Fortran and PL 1, are somewhat like macroassemblers. A high-level language provides these four features:

1. The ability to specify mathematical operations in algebraic form and have them converted to a series of instructions.

2. A convenient method of handling real numbers in floating-point notation. This is the same as adding a floating-point feature to a fixed-point calculator, since most computers are binary fixed-point machines in operation.

3. The ability to specify data in a matrix or subscript form. Data can be identified by row and column location within a matrix. This is convenient for handling large amounts of data and data arranged in matrix or table form.

4. Indexing macros for a loop sequence. Program loops are very common and typically require several instructions in the beginning and end of each loop.

**Programming vs debugging time**

These sophisticated software packages have a disadvantage, though. Because of their size and sophistication, they create a distance between the source code and the binary object code. This is inherent in any program-development tool, from a simple assembler up to the most complex compiler, and it’s easy to understand why this is so. The more a program does for you automatically, the less aware you are of what it is doing in the resulting binary code. A programmer using the simple paper-tape assembler creates a source program that is very close to the resulting binary code. The symbols used are one-for-one representations of the binary code.

A programmer writing in a high-level language like Fortran may never see the binary code except when he is debugging the program. This distance from the machine code is significant only during program debugging, which requires dealing with the binary instructions being exe-

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>An</td>
<td>Examine/modify accumulator register (n)</td>
</tr>
<tr>
<td>En</td>
<td>Examine/modify memory location (n)</td>
</tr>
<tr>
<td>Gn</td>
<td>Go to location (n) and execute program</td>
</tr>
<tr>
<td>Il,m,n</td>
<td>Initialize: load (n) into all memory locations between (l) and (m)</td>
</tr>
<tr>
<td>Dm,n</td>
<td>Dump memory to teletypewriter printer, locations (m) through (n)</td>
</tr>
<tr>
<td>R</td>
<td>Read in program from teletypewriter paper tape reader (binary loader function)</td>
</tr>
<tr>
<td>Om,n</td>
<td>Punch out memory contents from locations (m) through (n) in binary loader format on teletypewriter paper tape punch</td>
</tr>
<tr>
<td>B</td>
<td>Breakpoint examine/set</td>
</tr>
<tr>
<td>C</td>
<td>Continue from last breakpoint</td>
</tr>
</tbody>
</table>

**Commands for a debugger program** allow the isolation of software errors. The debugger has a breakpoint capability that permits the program to be stopped when it reaches a specified point.
then know or learn how the Fortran compiler generates the resulting binary code from its source-statement input.

The use of program-development software tends to result in fewer program errors, because these tools do many things automatically and provide many design-checking features. But if the program doesn't work, sophisticated debugging techniques may be needed.

**Special techniques for special problems**

Several other program packages commonly available represent solutions to special problems. One of these is the "microassembler," which is actually a misnomer. A microassembler is really a general-purpose assembler that allows the program to define the word size of the machine, the instruction mnemonics, and their corresponding binary bit patterns. A microassembler can therefore be used to generate an assembler for a specific machine.

Operating systems are similar to debuggers. They can load and run programs and dump the contents of the memory to a printer or other output device. Often they provide software-diagnostic features. Unlike a debugger, the operating system contains a relocatable loader and can load programs from different sources, such as paper tape, magnetic tape and disc.

An operating system is typically used in conjunction with a disc file or other storage medium and provides a library function as well. This means that the user can specify a program by name, load it, and execute it. The operating system includes facilities for program filing on the storage units. These facilities include program loading, dumping, copying, renaming and deleting.

The operating system also provides a standard set of I/O control subroutines. These allow all programs to use the same method of calling I/O devices. The system can then provide various I/O utility features, such as stopping the program to add paper to the printer.

Simulators are diagnostic tools for the debugging of software. A simulator creates a software model of a hardware computer. Each step of the internal operation of the simulated CPU is visible to the programmer. Complex problems of hardware and software interaction can often be solved with this tool, but it runs 10 to 1000 times slower than the hardware it simulates. This means you cannot use it to solve timing-related problems.

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Wyland, David C., "Increase Microcomputer Efficiency," *Electronic Design* No. 23, Nov. 8, 1975, pp. 70-75.
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ELECTRONIC DESIGN'S GOLD BOOK IS WORKING...IT'S WORKING FOR READERS...AND IT'S WORKING FOR ADVERTISERS, TOO.
Assembly language for μPs: Mnemonic programming isn't hard once you learn the coding. Here's how to organize and write a program.

Learning assembly language programming isn't hard. All an assembly language program consists of is a list of mnemonic commands that tell the microprocessor what to shift, pull from memory, which registers to clear, where to store data, etc. To do any work with microprocessor systems, programming is a necessity.

All μP manufacturers use a form of mnemonics, but unfortunately they are different from one vendor to the next. Therefore, to learn the basics of assembly-language programming, we will use the Motorola M6800 μP and its software as an example, since its structure is fairly generic and since it is now available from more than one source.

A μP can be viewed as a group of registers that, upon command, extract data from a memory bank, perform the programmed operations and then return the data to the memory or to an output device. To do all these operations, the μP-based system must contain these main sections (Fig. 1):

- MPU—the main processing unit. This houses the registers, control gating and counters needed to manipulate and keep track of the data.
- ROM—the read-only memory. It usually contains the binary equivalent of the assembly-language program that gives the MPU all of its instructions.
- RAM—the random-access memory. This can be used to hold the active part of the program and any other data that are being inputted or generated. It usually is very volatile and is only for temporary storage.
- PIA—the peripheral interface adapter. This lets the MPU and memories talk to external devices, such as terminals, printers and tape drives in parallel data words.

Communication between the various sections of the μP system is done over a multi-line communications bus. One part of this bus is unidirectional—from the ROM to the MPU and contains mainly instructions and perhaps key constants. The rest of the bus is bidirectional—the MPU can communicate with the RAM and PIA, and the PIA can talk to the RAM directly as if all of these were simply read/write memory.

In large systems the computer words are usually long enough to obtain the entire data word or instruction at once. In the smaller μP systems the words are only about half the size, and in some cases two or more words (of 8 bits each) must be used to supply data or give instructions. One prime example of this is when the data needed for the MPU to complete an instruction is external to the MPU.

When this happens, the MPU must reach out to successive locations where the data are stored and bring them to the registers within the MPU. To do this, address words must be issued to direct the data into the register.

Since all the MPU consists of is a bunch of registers connected by a complex gating arrangement and a controlling set of counters, let's examine these sections a little closer. The MPU

---

2. Inside the MPU are the different counters and registers that let you separately keep track of both the program and data. And, correspondingly, the programmer treats memory as if it were composed of two parts — a data or variable section and a command or instruction section. Also included are the logic circuits and control gates needed to do all the arithmetic operations.

Separate the commands and data

The first steps of the processing cycle depend on the data within the program counter of the MPU. These data determine which operation the computer is to perform. Subsequent cycles may generate read or write commands to the data or variable section of the memory in order for the processor to manipulate the data.

As a rule, the clocked program counter (PC) generates sequentially increasing addresses to pull control words from the ROM or other control block. The PC controls the entire operation of the processor, unless commands are encountered in the program flow that cause the counter to depart from sequential operation. The next value of the PC may then depend upon commands for conditional branching (similar to Fortran IF statements) or direct branching (like GO TO in Fortran). The PC value may also be forced to a specific location by the presence of an external interrupt.

Data addresses depend on the type of command and can be modified by the value stored in the index register. The read write control line of the MPU tells it whether it should fetch or store data.

Although the MPU operates under binary control, the chance for an error, should the program or data be entered manually, is enormous.

Assembly language is a shorthand way of writing the binary instructions that can be converted into binary form by an assembler. And, as a rule, a single statement generates a single storable command. These shorthand statements are grouped into fields and are designated by the following four names: Label, Operator, Operand, Comments.

The four elements when combined on a single line are separated from one another by some form of delimiter, such as one or more blank spaces, a slash or a comma. The Comments field is used only to help others understand what the programmer intends; it will not generate any instructions for the computer.

A sample working instruction for the M6800 might appear as follows:

```
UPDATILDA A  | NB | BEGIN THE LOOP
Label | Mnemonic | Operand | Comment
```

Labels help the programmer use branching commands, since he can then write the equivalent of a GO TO statement just by associating it with the label. The mnemonic command LDA A instructs the μP to load the accumulator known as A with the data that will come from the location described by the operand. The operand, NB, instructs the μP to fetch data from the location called NB. This pseudo English tells the MPU that the binary data in the byte following the LDA instruction names or points to the address from which the MPU is to fetch the desired data (Fig. 3).

Assign values to the symbols

Once an assembly language program is written, you must systematically determine the locations in which the program is stored in ROM or RAM. First, concentrate on the commands and store each command in sequentially ascending order of memory locations.

Whenever a label is noted, write the address of the memory location presently associated with that label. Since the mnemonic operation codes have unique binary descriptions assigned by the manufacturer, there is no difficulty in storing them. This process is usually done in most larger systems by the assembler, which converts the
3. When the op code LDA A is given, the byte of binary data following the instruction is added to the index register information to supply the address of the data needed by the op-code instruction.

mnemonic into binary and assigns numbers to all labels.

After the commands are all located, you must provide unique locations for storing the operands or data. These locations don't have to be in any particular sequence, except that arrays usually receive consecutive assignments. Once fixed, these addresses provide the data to fill in some of the missing command words when the assembler assigns location and sequence numbers.

Returning to the sample instruction given earlier, we could have chosen the location FFF (hexadecimal notation) for NB. Assemblers let the user specify the origin or starting address for his commands and the locations for his data.

These addresses are referred to as directives (to the assembler), and while they influence the final values selected for the numerical data other than operation codes, they do not result in any extra instructions. But they can be confusing, since the format of the directives often resembles the actual assembly code. Similarly directives to insert constant values at certain locations in ROM resemble MPU commands. Fortunately most assemblers sort them out and arrange them in columns.

Address the data properly

When you specify the address of data, use the most direct way—too long an address and the computer slows down, too short and you have a limited amount of memory available. This can break a system if you're not careful.

The M6800 provides a wide variety of different addressing modes (see Table 1):

- Inherent—Operations are performed on or between registers within the MPU chip.
- Accumulator—Operations affect only the data in the accumulator such as clear, complement, shift, etc.
- Relative—The memory address to which the MPU refers depends on the value of the program counter.
- Immediate—The instruction contains the value of the operand to be used in the computation.
- Direct—The instruction provides the necessary address (up to 8 bits for the M6800).
- Extended—This form of direct mode can address 64 k words of memory (16-bit address).
- Indexed—Memory reference depends upon the data stored in the command word plus the contents of the index register.

Another form of addressing used on almost all minicomputers and large machines is called indirect. This is a two-step process: First, the CPU fetches data from an address. Then it uses the data word as the address of the operand.

The M6800 uses commands that range from one to three bytes long: Inherent and accumulator modes use one byte; relative, immediate, direct and indexed modes use two; and extended uses three.

Motorola has developed a program that accepts symbols and mnemonics to assemble a program. The symbols that indicate the address mode include the asterisk, period, pound and single alphabetic characters. These are used in the operand field.

The asterisk indicates that the relative address mode is to be used, and it has been accepted as the de facto standard for this mode by many companies. Another way of looking at this symbol is to think of it as the present value of the program counter.

The pound character, #, designates the use of the immediate addressing mode. An alphabetic character (X for Motorola) indicates that indexed addressing is to be used. Each of the symbols is, of course, mutually exclusive—only one addressing mode can be used at a time. The Motorola assembler will select either extended or direct addressing by default if the other modes are not specified. If the numerical address lies within the range 0 to 255, default is to direct addressing, while if the address specifies a location out of that range, extended addressing is used.

The relative addressing mode, though, is restricted to branching instructions, such as BSR (branch to subroutine).

Electronic Design 26. December 20, 1975
Table 1. Explanation of various addressing modes

<table>
<thead>
<tr>
<th>Addressing mode</th>
<th>Processing required to load address into internal address register</th>
<th>Byte appearance of instruction</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Immediate</td>
<td>Current value of PC indicates the op code and the digital information represented by PC + 1 is the data the op code is to perform its operation on.</td>
<td>op code ( K )</td>
<td>Only one data byte is used except for mnemonic instructions CPX, LDS and LDX which use a second byte.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>data ( x+1 )</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>see ( x+2 )</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>bit 0 ........................</td>
<td></td>
</tr>
<tr>
<td>Direct</td>
<td>The current value of the PC indicates the op code. Increment the PC and then move the data from the location specified by PC + 1 to the address register.</td>
<td>op code ( K )</td>
<td>Two data bytes are used.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>address ( K+1 )</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0 ........................</td>
<td></td>
</tr>
<tr>
<td>Extended</td>
<td>The current value of the PC indicates the op code. Increment the PC by 1 and transfer the data from the location specified by PC + 1 to the address register. Increment the PC again to PC + 2 and transfer the data from the location specified by PC + 2 to the address register.</td>
<td>op code ( K )</td>
<td>Two data bytes are used.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>address ( K+1 )</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>address ( K+2 )</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>16 bits</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0 ........................</td>
<td></td>
</tr>
<tr>
<td>Relative</td>
<td>The current value of the PC indicates the op code. Increment the PC by 1 and add the contents of the location specified by PC + 1 to the value of the PC after it is incremented again (PC + 2)</td>
<td>op code ( K )</td>
<td>One data byte used. This applies only for branch instructions.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>displacement ( K+1 )</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0 ........................</td>
<td></td>
</tr>
<tr>
<td>Indexed</td>
<td>The current value of the PC indicates the op code. Increment the PC by 1 and add the contents of the location specified by PC + 1 to the index register.</td>
<td>op code ( K )</td>
<td>One data byte used.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>data from ( K+1 )</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>memory location ( K+1 )</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0 ........................</td>
<td></td>
</tr>
</tbody>
</table>

When you write programs for the M6800, they can be done in modular form and then strung together. To do this, though, you must make use of the stack pointer (SP) within the \( \mu \)P chip. The SP register provides an address that is used for subroutine jumps, or if the program is interrupted, it holds data from some of the other registers.

The stack is a set of memory locations that are addressed and sometimes modified when interrupts or subroutine jumps are invoked. A jump-to-subroutine (JSR) command orders the \( \mu \)P to increment and store the program counter value in the next empty stack location and then jump to the new (subroutine) location. The stack pointer is also set to the next empty location, just in case another subroutine or interrupt command is given.

The return-from-subroutine (RTS) instruction decrements the stack pointer and places the contents of the register specified by the pointer back into the program counter. Two additional instructions—mnemonics PSH (push data) and PUL (pull data) allow transfer of accumulator data to and from the stack.

An interrupt command causes the \( \mu \)P to react as if indirect addressing is in effect. After the MPU completes its current instruction, it initiates the following sequence of operations:

- Stores the contents of the program counter, accumulators and condition code registers into the interrupt stack registers.
- Generates a 16-bit address that points to locations n-2 and n-3.
- Follows instructions starting at a location prestored by the user in locations n-2 and n-3.

The last eight memory locations of the stack should be reserved for interrupt vectoring (another name for such indirect addressing). This allows for four 16-bit words to redirect the MPU. For instance, beginning with location FFF8 (hex), you could have:

- FFF8 MS | Hardware interrupt
- FFF9 LS |
- FFFA MS | Software interrupt
- FFFB LS |
- FFFC MS | Nonmaskable interrupt
- FFFD LS |
- FFFE MS |
- FFFF LS | Restart

The software interrupt lets you develop an over-all systems executive or monitor. Thus if a program module has some data to send through the asynchronous communications interface adapter (serial data port)—ACIA—it could execute a software interrupt and vector the MPU to the appropriate input/output routine.

Let's look at a sample program

To write a program without the aid of an assembler, start with a list of the commands you
Table 2. Program to clear 10 registers

<table>
<thead>
<tr>
<th>ROM Location (decimal)</th>
<th>ROM Content</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>000</td>
<td>7F</td>
<td>op code</td>
</tr>
<tr>
<td>001</td>
<td>8 bits/</td>
<td>address of</td>
</tr>
<tr>
<td>002</td>
<td>8 bits/</td>
<td>buffer (1)</td>
</tr>
<tr>
<td>003</td>
<td>7F</td>
<td>in binary</td>
</tr>
<tr>
<td>004</td>
<td>8 bits/</td>
<td>address of</td>
</tr>
<tr>
<td>005</td>
<td>8 bits/</td>
<td>buffer (2)</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>027</td>
<td>7F</td>
<td>address of</td>
</tr>
<tr>
<td>028</td>
<td></td>
<td>buffer (10)</td>
</tr>
<tr>
<td>029</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3. Rewritten clearing program

<table>
<thead>
<tr>
<th>Label</th>
<th>Op code</th>
<th>Operand or location</th>
</tr>
</thead>
<tbody>
<tr>
<td>BEGIN</td>
<td>LDX</td>
<td>#BUFFR*</td>
</tr>
<tr>
<td></td>
<td>LDA A</td>
<td># 1</td>
</tr>
<tr>
<td></td>
<td>CMP</td>
<td>A # 11</td>
</tr>
<tr>
<td></td>
<td>BEQ</td>
<td>PROC</td>
</tr>
<tr>
<td></td>
<td>CLR</td>
<td>O, X</td>
</tr>
<tr>
<td></td>
<td>INC</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>INX</td>
<td>BEGIN</td>
</tr>
<tr>
<td></td>
<td>BRA</td>
<td>New program section</td>
</tr>
</tbody>
</table>

*The pound sign shows that immediate addressing is to be used for the first three commands.

Table 4. Assembled clearing program

<table>
<thead>
<tr>
<th>Label</th>
<th>ROM location (decimal)</th>
<th>Op-code (hexadecimal)</th>
<th>Description or name of op code</th>
</tr>
</thead>
<tbody>
<tr>
<td>BEGIN</td>
<td>000</td>
<td>FE</td>
<td>LDX extended address to first location of data-symbol BUFFR</td>
</tr>
<tr>
<td></td>
<td>001</td>
<td>2E</td>
<td>LDA A with literal 1</td>
</tr>
<tr>
<td></td>
<td>002</td>
<td>86</td>
<td>CMP A with literal 11</td>
</tr>
<tr>
<td></td>
<td>003</td>
<td>08</td>
<td>BEQ relative address to location 015</td>
</tr>
<tr>
<td></td>
<td>004</td>
<td>0B</td>
<td>CLR (see note 2) indexed by 0</td>
</tr>
<tr>
<td></td>
<td>005</td>
<td>06</td>
<td></td>
</tr>
<tr>
<td></td>
<td>006</td>
<td>6F</td>
<td></td>
</tr>
<tr>
<td></td>
<td>007</td>
<td>00</td>
<td></td>
</tr>
<tr>
<td></td>
<td>008</td>
<td>4C</td>
<td></td>
</tr>
<tr>
<td></td>
<td>009</td>
<td>08</td>
<td></td>
</tr>
<tr>
<td></td>
<td>010</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td></td>
<td>011</td>
<td>0F</td>
<td></td>
</tr>
<tr>
<td></td>
<td>012</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td></td>
<td>013</td>
<td>FF</td>
<td></td>
</tr>
<tr>
<td></td>
<td>014</td>
<td>XX</td>
<td></td>
</tr>
<tr>
<td></td>
<td>015</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes:
1. Use hex equivalent of -10 in location 14 to get a relative branch back to location 005 which continues the loop.
2. This is an indexed address command with 0 shift that refers to one of the locations in the array BUFFR.

4. The interface program has an executive portion (a) with only a few steps and an interrupt subroutine (b) with many steps.

The interface program will use to process the data. Remember, the program will reside in the ROM until needed, and the RAM will be used to hold the active part of the program.

Let's start with a simple program that will clear a set of data locations named BUFFR. We will assume that BUFFR consists of 10 consecutive locations and exists in the RAM data space. The program could then consist of the clear command (CLR) given 10 times, with the location in the operand field:

CLR BUFFR(1)
CLR BUFFR(2)
CLR BUFFR(3)
CLR BUFFR(4)
CLR BUFFR(5)
CLR BUFFR(6)
CLR BUFFR(7)
CLR BUFFR(8)
CLR BUFFR(9)
CLR BUFFR(10)

The location of BUFFR was chosen so that extended addressing is used. The resulting hex characters appear in ROM as shown in Table 2. The contents of the op-code byte—in this case, 7F—informs the MPU that extended addressing is to be used. Use of an index register, though, can replace the repetition of the same command with a short program loop. The same program to clear 10 locations can be rewritten as shown in Table 3.

The program operates as follows: Before the main program loop begins, the program loads the
The address of BUFFR(1) into the index register and sets location A to 1. At the command labeled BEGIN, the program compares A to 11 (decimal notation) and if A ≠ 11, the program performs the next instruction, CLR. As the program continues in the loop, A will increase to 11, and when the program reaches the BEQ command it breaks out of the loop into the next program.

The entire program that must either be put on paper tape or into ROM is shown in Table 4. This type of programming is fine for small programs where you can keep track of variable locations, but for larger programs some sort of assembler is needed. Assemblers can refer to unnamed locations as a numeric expression that involves a label name. Thus BRA = BEGIN + 1 would refer to location 5 that of the next instruction.

Commercial assemblers let you locate the origin of programs anywhere in ROM through the ORG directive. For example, ORG 100 states that the given program segment is to start at ROM location 100. The EQU directive equates a symbol with a numerical value, another symbol or an expression. The RMB command reserves memory bytes. These and other directives assign values and addresses in data memory.

Interface instruments with software

To interface anything to the μP, you must make connections through a form of PIA or ACIA. The PIA handles parallel data, while the ACIA handles serial. Let’s look at the complex problem of interfacing an instrument to the μP.

As a starting point, assume the instrument delivers a parallel digital data word. The PIA would then be used to interface the instrument. Inside the PIA are enough interface circuits to handle two peripherals. The PIA is internally divided into two symmetrical (noted as A and B), but independent, circuits that consist of three registers each. Each half contains a data direction register, a control register and an output register.

The registers are eight bits wide and are externally controllable. To define the operation of the PIA A or B side, an 8-bit word is loaded into the control register, and to define the data lines as inputs or outputs, an 8-bit word is loaded into the data direction register. Finally the actual data to be transferred goes into the output register.

The instrument we want to interface has data and a data ready line that can be used to signal an interrupt of the processor. Both halves of the PIA must be used to move the data from the instrument to the memory. The B side of the PIA holds the data word, and the A side identifies that word.

Basically the PIA and μP operate together as follows: When the interrupt occurs, the B side of the PIA is read into the B accumulator of the μP. Then the A side of the PIA is read to define the memory location of where the data stored in accumulator B should be placed. Next the data are transferred from the accumulator to the memory location, and then the μP goes back to waiting for another interrupt.

The MSB of the A side data word specifies the first location, the next bit the next location, and so on. If a ONE is not present in any of the four MSBs, the data are to be stored in the fifth location. These data locations are contiguous, with the first at an address we’ll call DATLOC and all others in increasing sequence. When any of these locations receives a data word, the new data wipe out the old.

The CA1 terminal of the PIA can accept the interrupt signal generated by the rising edge of a waveform. This configures all the data ports as inputs, while the other interrupt lines CA2, CB1 and CB2 are not used. The flowcharts for the system program to pull in data are shown in Fig. 4.

When started, the program configures the PIA, sets the stack pointer and clears the interrupt line and can proceed to do any program it has in memory. When an interrupt comes, present values of the last instruction and program counter and registers are stored in the stack, and the interrupt program is set in the program counter. When the interrupt routine is finished, the μP registers are reset to their values just before the interrupt and the main program continues along.

Table 5 shows the complete instrument interface program developed by Motorola Semiconductor Products to do the job.
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All 5 on the FG-512A1.
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A Linear-Analog Itron. And a Digital Clock Itron. Five ways to be heartless if you put a little heart into it.

All 17 of the segments on the 17-digit Itron.
All 5 on the FG-512A1.

FG209M2
ef = 10V
ec = eb = 40Vp-p
ic = 10mA
ib = 0 mA
Wd. 205 mm
Lg. 40 mm
Segment 9 mm

FG179F2
ef = 7V
ec = eb = 35Vp-p
ic = 7mA
ib = 5.5mA
Wd. 170 mm
Lg. 40 mm
Segment 9.5 mm

FG512A1
ef = 3.5V
ec = eb = 24Vp-p
ic = 4mA
ib = 0.2mA
Wd. 100 mm
Lg. 40 mm
Segment 12 mm

FG625A1
ef = 5.5V
ec = eb = 35Vp-p
ic = 8mA
ib = 6.5mA
Wd. 140 mm
Lg. 59 mm
Segment 25 mm

FG128S1
ef = 5.5V
ec = eb = 35Vp-p
ic = 4mA
ib = 0.2mA
Wd. 140 mm
Lg. 40 mm
Segment 8 mm

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The monitor can interface to a main control system or operate as a stand-alone system. And, if necessary, a large number of parameters—with certain restrictions—can be monitored. These restrictions stem from the finite scan frequency, which is inversely proportional to the number of parameters.

Also, the scan frequency affects the type of parameter to be monitored since, for reliable conversion, the sensed quantity should not vary appreciably between conversion periods. Usually, though, physical quantities like temperature and pressure vary so slowly that a single a/d converter can monitor a large number of sensors.

In addition to the basic CPU, the system uses a peripheral interface adapter (PIA), such as the MC6820, and memory for the control program. Fig. 1 shows the allocation of the PIA register and control lines. To interface all the required operations of the display board through one PIA, the BCD inputs to the display decoder/drivers are multiplexed.

Also, the ramp control lines for the a/d subsystems are tied to a single line in the register that interfaces the comparator outputs of the a/d to the CPU. This configuration allows up to seven a/d subsystems per PIA register to be interfaced to the CPU.

Higher voltage improves S/N

Hardware external to the CPU mounts on the display board. Included are the display select switch, the a/d subsystem chips (MC1405), dis-
play latch/decoder drivers (MC14511), and seven-segment LED displays (Fig. 2). The a/d chips are powered by a 12-V supply, permitting a higher integrator-capacitor peak voltage than would a 5-V excitation. This improves the signal-to-noise ratio. The other parts on the display board are powered by a 5-V source.

After it initializes the system, the control program reads the control switch, performs the necessary a/d conversions, does any required calculations and displays the result. Since the object is to represent an analog voltage digitally, the main segment of the program is the routine that controls the MC1405s and performs the analog-to-digital conversion (Fig. 3). The assembly-language coding for the conversion is listed in Fig. 4.

The a/d routine is entered with (1) the addresses of the appropriate limits in the X register; and (2) a bit set in the B accumulator corresponding to the PIA register line that carries the comparator input signal.

The routine first stores the limit addresses and loads the X register with the address of that PIA register interfacing with the MC1405. After the routine loads the A accumulator with 99—one less than the value of 100 required as a base count for a 2.1/2-digit conversion—it checks to

Table. Display-select switch settings

<table>
<thead>
<tr>
<th>Position</th>
<th>Display</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$V_1$</td>
</tr>
<tr>
<td>2</td>
<td>$V_2$</td>
</tr>
<tr>
<td>3</td>
<td>$V_3$</td>
</tr>
<tr>
<td>4</td>
<td>$V_4$</td>
</tr>
<tr>
<td>5</td>
<td>$V_1 + V_2$</td>
</tr>
<tr>
<td>6</td>
<td>$V_1 - V_2$</td>
</tr>
<tr>
<td>7</td>
<td>$V_1 \cdot V_2$</td>
</tr>
<tr>
<td>8</td>
<td></td>
</tr>
</tbody>
</table>

2. The a/d-converter subsystem and all hardware external to the μP mount on one board. Included are the display and its drivers, plus the required switching.
3. Flow chart shows the section of the program that controls the converter chips and performs the analog-to-digital conversion routine.

4. Assembly-language coding for the analog-to-digital conversion. The routine takes about 4.6 ms.

see if the comparator output is low. If it isn’t low the routine waits until it is. Otherwise, a false conversion value would be obtained. When a low occurs, the routine sets the ramp control high and waits until the comparator output goes high.

When the high appears, the routine begins its base count: It decrements the A accumulator in a loop from 99 to 0 to produce the basic a-d-conversion time interval. The BIT B O,X and NOP instructions act as “filler” in the base-count loop so the time per decrement equals the time per increment in the conversion-count loop.

Carry bit serves as overrange

The hundredth count time required for the 2-1 2-digit conversion is provided by the COM O,X instruction, which sets the ramp control high
5. In a typical application, the $\mu$P controlled system monitors physical parameters, such as pressure, and provides a digital readout of a desired value.

and the CLR A and NOP instructions immediately preceding. In this way, the ramp control goes high at the end of the base count and the conversion count immediately begins.

To perform the conversion count, 1 is added to the A accumulator. The carry bit acts as an over-range detector for the BCS OVRRNG instruction since the bit is set if the count reaches 256. When this happens, the program exits from the conversion-count loop and goes to the voltage-overrange display routine.

Continuing in the conversion count loop, the program next checks the comparator output. To do this, the routine loops back up and adds 1 to the A accumulator if the comparator output is still high. When the output goes low, the program exits from the conversion-count loop and corrects the conversion value by subtraction of 10 as the MC1405 requires.

The value now in the A accumulator is the digital representation of the analog input voltage. Since the conversion-count loop requires 15 CPU clock cycles per count, at a CPU clock frequency of 1 MHz for a full scale conversion, the a/d routine requires 15 $\mu$s count $\times (100 + 199 + 10)$ counts = 4.64 ms plus the comparator check time.

For use in a parameter sensing system, the outlined routine can be easily converted to a subroutine independent of the PIA address. Just put the first two instructions before the subroutine call and begin the subroutine with the LDA A #99 instruction. No other modifications are required since the routine is already independent of the PIA data register line on which the comparator signal appears.

If you do convert to a subroutine you can retain the overrange-detect feature by setting a flag before returning from the subroutine and after the conversion has gone to overrange. A check of the conversion value against preprogrammed limits can also be included in the subroutine. In this way, you can apply the subroutine to a $\mu$P controlled, parameter-sensing system (Fig. 5).
Keyboard circuit saves time, needs no microprocessor scanning software

As much as 20 to 30 ms of valuable microprocessor time wasted in scanning keyboard inputs can be saved with a circuit that does not need any software and uses only a few TTL ICs.

Though the example in the figure is an 8 x 4 matrix, the circuit can easily be expanded to 8 x 8 or any other suitable configuration. Decimal-decoded outputs of a 74142 BCD counter drive the columns of the matrix. The counter's input signal is derived from the microprocessor's SYNC clock and the circuit's KEYN signal. The KEYN signal is derived from the matrix rows, via a NOR gate, whenever any key is closed. The KEYN signal also clocks a D flip-flop to provide an interrupt signal for the microprocessor.

Three-state output 74173 TTL latch ICs serve as the input port of the system. The interrupt signal, when it goes HIGH, clocks the data into the 74173s. An RC time constant of 2 to 3 ms on the KEYN signal, before it's used to clock the D flip-flop, takes care of switch bounce. An interrupt-acknowledge signal from the microprocessor then resets the 74173s and the D flip-flop, after the input ports are read.

A second interrupt signal will not be generated unless the first key is released. Thus the circuit automatically provides a two-key lockout. Further, the microprocessor should be programmed to provide an error signal if it detects more than one HIGH bit at any one time in the input port latches.

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The circuit is divided into three main blocks—an oscillator, reference-voltage supply and comparator (Fig. 1). Only a change in the reference voltage, B, changes the comparison point and thus the duty cycle (Fig. 2). The duty cycle is independent of the frequency as long as the voltage output of the oscillator remains constant.

Pull-down resistors to pins 3 and 6 help keep the power-supply currents balanced to minimize interaction between the function blocks. Positive feedback in the comparator between pins 7 and 10 reduces the rise and fall times of the output pulses and also minimizes narrow-pulse jitter. The 47-Ω resistor, in series with the output terminal, ensures a 50-Ω output-impedance match to a coaxial cable.

William A. Palm, Principal Engineer, Control Data Corp., 7801 Computer Ave., Minneapolis, MN 55435.  
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INFORMATION RETRIEVAL NUMBER 40

Electronic Design 26. December 20, 1975
Current sinks increase the range of IC function generators

When a current sink is substituted for the external control resistors in IC function generators, the range of adjustment is greatly expanded. For example, the XR-2206, with the factory recommended resistor hookup shown in dashed lines, has a frequency range of 2000:1, but with a current sink, a tuning range of 8000:1 is attainable (Fig. 1).

The XR-2206 can also be used as a variable duty cycle pulse generator if a second current sink is arranged to track the first (Fig. 2). However performance of the factory-recommended hookup with two fixed resistors is limited to a single frequency and duty cycle. The current-sink circuit gives just over a 100:1 duty-cycle range controlled by variable-resistor R. The output frequency can still be controlled over about the same range as with the circuit of Fig. 1, but the duty cycle varies at the extremes of the frequency range.

The major parameter that affects performance of the circuit is the threshold current of the tuning inputs. In particular, differences between the thresholds of terminals 7 and 8 limit the performance of the circuit in Fig. 2. Tuning becomes somewhat nonlinear as control currents approach the threshold levels.

The frequency can be controlled if the input amplifier is driven by a current-output DAC (Fig. 3). The value of R, must match the DAC output capability, and the R, /R, ratio must then be chosen to give the required current range. Threshold current limits allow the use of a 10-bit DAC in a Fig. 1 configuration, but only a 7-bit DAC for the Fig. 2 configuration with constant duty-cycle operation.²

Reference

Ralph Tenny, Senior Research Assistant, Texas Instruments, Inc., P.O. Box 5936, Dallas, TX 75222. CIRCLE NO. 313

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Hayden Book Company, Inc., 50 Essex St., Rochelle Park, N. J. 07662
New Products

FET-input hybrid op amps match modules for performance at low cost

By combining a matched FET pair with a wideband amplifier, Analog Devices has come up with a hybrid op amp that rivals the high performance of modules and the low cost of ICs. The 515 series of electrometer op amps has input bias currents as low as 75 fA, maximum, and small-signal bandwidths of over 350 kHz. And they cost about half as much as competing modules and about 20% less than competing monolithic ICs.

The Model 515 amplifiers use a separate matched FET chip and laser trimming to minimize input offset to 1 mV, maximum, and drift to only 15 µV/°C. Noise has also been kept low—only 4 µV, pk-pk, 'over a 0.1-to-10-Hz bandwidth. The op amp has internal compensation, is free of latch-up and is short-circuit-protected on the output. A case guard connection in the hermetic TO-99 metal package minimizes stray leakage to the case and shields the input circuitry from external noise and transients.

Quiescent current drawn by the op amp is claimed to be around the lowest available—only 1.5 mA, max, for ±15-V supplies. With ±5-V supplies, the quiescent drain drops to 0.5 mA. The op amp has a 0-to-70-C operating temperature range and comes in three performance versions.

The 515J, K and L have maximum input-bias currents of 300, 150 and 75 fA, respectively, when measured after warmup on ±15-V supplies. Maximum input offset voltages are 3, 1 and 1 mV, respectively, and offset voltage drifts are 50, 15 and 25 µV/°C, respectively. All amplifiers have a differential input of 10^13 Ω and a common-mode input impedance of 10^15 Ω.

Prices for the Analog Devices 515 series amplifiers are $16, $21 and $27 for the J, K and L models, respectively, in 1 to 24 pieces. In 100 unit lots the prices drop to $9.90, $14 and $18, respectively.

Delivery of all three versions is from stock.

Competitive modules, such as the 102901 from Teledyne-Philbrick (Dedham, MA) or the A-127 from Intech (Santa Clara, CA), are about double the cost of the 515. They are also many times the size, with both the 102901 and the A-127 modules at least 1.5 x 1.5 in.

There are, though, some IC op amps that can meet some of the 515's specs—such as the 3523 series from Burr-Brown (Tucson, AZ) or the 142902 from Teledyne-Philbrick—but they tend to cost more.

Analog Devices CIRCLE NO. 302
Burr-Brown CIRCLE NO. 303
Intech CIRCLE NO. 304
Teledyne-Philbrick CIRCLE NO. 305

130-bit CCD register delays up to 25 ns

Fairchild, 464 Ellis St., Mountain View, CA 94042. (415) 962-3816. $49 (100-999); factory stock.

A charge-coupled analog shift register, the CCD311, functions as a wide-range analog delay line. The device can be operated either as a single 130-bit device, or a 260-bit device using multiplexing techniques. It can operate over frequencies extending from 10 kHz to video rates up to 15 MHz. A range of delay times from 20 µs to 25 ms can be obtained simply by varying the rate of an external clock signal. The device comes in an 18-pin DIP, and features a signal-to-noise ratio of more than 50 dB and an input bandwidth of greater than 4 MHz.

CIRCLE NO. 308
INTEGRATED CIRCUITS

Quad amp boosts specs for 741-type units

Teledyne Semiconductor, 1300 Terra Bella Ave., Mountain View, CA 94041. (415) 968-9241. $3.40 to $11.50 (100-999).

The 836 quad op amp—an improved 741-type amplifier—has a typical slew rate of 1.2 V/μs, small signal bandwidth (unit-gain frequency) of 1.5 MHz and power bandwidth to 20 kHz. The internally compensated amplifier permits class AB output operation. At maximum output voltage, an 836 output remains symmetrical about ground and typically swings within 1 V of either supply. Input common-mode voltage range is −15 to 13.5 V. Typical supply current at ±15 V is only 700 μA per amplifier resulting in a total dissipation per package of 84 mW, or only 21 mW per amplifier.

CIRCLE NO. 320

1-k bipolar PROMs start at $5.95

Monolithic Memories, 1165 E. Arques Ave., Sunnyvale, CA 94086. (408) 739-3535.

A series of low-cost 1024-bit bipolar PROMs, with 256 × 4-bit organizations, are offered in both commercial and MIL temperature versions. The 6300-1 (open collector) and 6301-1 (three-state) commercial parts are priced at $5.95 in quantities of a hundred. The 5300-1 (open collector) and 5301-1 (three-state) military parts are priced at $11.95 (100-999). All units are said to have the lowest power dissipation available. At least 95% of all units will program to completion in two seconds or less.

CIRCLE NO. 321

CMOS family simplifies counting and timing

Intersil, 10900 N. Tantau Ave., Cupertino, CA 95014. (408) 257-5450. $1.50 to $17.00 (1000).

Seven CMOS devices complete the company's line of timing microcircuits for industrial control and instrumentation applications. The new devices consist of the 7045 and 7205 low-power counter-timers; the 7208 counter; and the 7038A, 7207, 7209 and 7213 crystal frequency generators. The 7045, which times intervals from 0.01 s to 24 h, typically dissipates 0.9 mW. The 7205 times from 0.01 s to 1 h and dissipates 2.5 mW typical. The 7208 is a 7-digit unit counter, requiring a LED display, two resistors, a capacitor and control switches for operation.

The 7038A is a CMOS oscillator, frequency divider and driver. It accepts crystals with frequencies from 200 kHz to 15 MHz, and provides outputs at the crystal frequency and at ±20 and ±26 frequency-divider stages. The 7207 is a complete frequency counter time base that dissipates less than 5 mW at 5 V. The 7207 accepts crystals from 1 to 10 MHz, and it provides outputs at the crystal frequency, and at ±20, ±26 and ±1026 divider stages. The 7209, a high-frequency clock generator for 5-V systems, accommodates crystals from 10 kHz to 10 MHz and provides outputs at crystal frequency and ±26 divider stage. The 7213 is an oscillator, divider and waveshaping circuit using crystals from 1 to 6 MHz. Outputs are at crystal frequency, ±26 frequency, and one-second and one-minute pulses.

CIRCLE NO. 322

$10 circuit provides 10-V reference

Analog Devices, Route 1 Industrial Park, P.O. Box 280, Norwood, MA 02062. (617) 329-4700.

The AD2700/L, a 10,000 ±0.001-V reference, costs just $10 in hundred quantities. The thin-film circuit has ±0.03% maximum output error at 70 °C and 50-ppm/year long-term stability. The unit comes in a 14-pin DIP, and it is available from stock.

CIRCLE NO. 323

All wrapped up in a neat little package, our Model 510L is an ultra-wideband RF power amplifier whose wide range of frequency coverage and power output provide the user with the ultimate in flexibility and versatility in a laboratory instrument. Easily mated with any signal generator, this completely solid state unit amplifies AM, FM, SSB, TV, pulse and other complex modulations with a minimum of distortion.

Constant forward power is continuously available regardless of the output load impedance matching making the 510L ideal for driving highly reactive loads. Unconditional stability and instantaneous fail-safe provisions in the unit provide absolute protection from damage due to transients and overloads.

This outstanding unit covers the frequency range of 1.7 to 500 MHz with a linear power output of more than 9.5 watts and there is no tuning.

For further information or a demonstration, contact ENI, 3000 Winton Road South, Rochester, New York 14623. Call 716-473-6900 or TELEX 97-8283 E N I ROC
COMPONENTS

Pushbutton switches withstand PC processes

Grayhill Inc., 561 Hillgrove Ave., La Grange, IL 60525. (312) 354-1040. $0.98 (100 up); stock to 7 wks.

New PC-board mounted pushbutton switches, Series 39-251, withstand wave soldering and related cleaning processes. The switches have the terminals ultrasonically welded to the switch body, and the top and bottom halves of the cases are molded from high-temperature polyester, also ultrasonically welded. An optional semirigid boot is available to fit over the plunger. The switch can provide SPDT, SPST-NO or SPST-NC contact action. Gold-plated contacts can handle logic-level loads to 1/4 A for a minimum of 250,000 operations.

Toggle switches added to line

Oak Industries Inc., Crystal Lake, IL 60014. (800) 435-6106. Stock.

Oak's lines of switches now include miniature toggles with either SPDT, DPDT, 3PDT or 4PDT switching action. The new lines are Series 31, with standard toggles, Series 32, with long toggles and Series 33, with decorative flat plastic caps. Each consists of 20 basic switch models, with either solder or PC terminals. Several momentary-action types are also available. Contacts are rated at 6 A, 125 V ac. Mechanical life is 100,000 cycles and electrical life is 25,000 to 50,000 cycles.

Electronic buzzer generates no rf


New Li'l Ear splitter miniature solid-state electronic buzzers, less than 1-in. long, 5/8-in. wide and 5/16-in. high, give off a big, rich sound. There are no mechanical points to arc and require maintenance, and no rf noise is generated. They are available with 3, 6, 9, 12 and 24-V ratings.

CIRCLE NO. 326

THE NEW 3403A.
OUTPERFORMS
ALL QUAD OP AMPS.
FASTER SLEW RATE.
DISTORTION FREE.

Raytheon Semiconductor's new 3403A Quad Op Amp gives you a faster slew rate and absolutely no output distortion, plus other improved AC and DC characteristics. The 3403A is significantly better than either the standard MC3403 or LM324. And it's pin compatible too. Our 3403A is simply the best quad op amp from the leader in linear quads.

For complete details and your own Quad/Dual brochure, contact Raytheon Semiconductor or your local distributor. For your free sample, write Raytheon Semiconductor on your company letterhead.
INSTRUMENTATION

It looks like a logic analyzer; it's also a word generator

Moxon Inc., SRC Div., 2222 Michelle Dr., Irvine, CA 92664. (714) 833-2000. See text.

One quick glance at the timing-diagram display on Moxon's Model 777 Digitester, and you get the feeling that you're looking at yet another logic analyzer. But peer closer. Panel legends such as "generate" and "receive," along with a calculator-like numerical keyboard, tell you that there's more here than meets the eye. The 777 not only receives data; it generates words. And that, no other logic analyzer can do.

Thus with the 777 you can "tickle," say, a microprocessor with any desired bit pattern, and use the same piece of equipment to watch the \( \mu P \) respond. The pattern can consist of up to 1024 bits of serial data at rates up to 20 MHz. Or if parallel bits are what you need, you've got them: up to 64 sixteen-bit words. What the 777 dishes out, it can take right back—in either serial or parallel modes.

It costs $11,950, to be sure. But you can spend more than that for a logic analyzer alone.

Five internal memories in the Moxon unit let you do all kinds of good things. You can generate only, receive only or do both simultaneously. With one memory used as a scratch pad, you can direct the integral CRT to display the program as you formulate it. When you're satisfied with the pattern, you can then load it into a transmit memory for delivery to the circuit under test.

How fast do the data come out? As fast as you'd like, up to the maximum 20 MHz. Just dial in the crystal-controlled bit rate or let your system clock replace the internal oscillator for synchronous operation. And data can be delivered continuously or in bursts. Another parameter you can dial in is the logic ONE output level—it can be set to anywhere from 1.5 to 3.5 V.

With the 12-key numeric pad, entry of individual bits or strings of ONEs and ZERos couldn't be simpler. Hit a number and then the LOGIC ONE or LOGIC ZERO button. For instance, the sequence, 1, 5, 6, LOGIC ONE, programs 156 consecutive ONEs.

In the serial mode, the bits appear horizontally along each line, from left to right, on the CRT. In parallel, the bits appear vertically for each word, from top to bottom, on the CRT. With the aid of a displayed cursor and a toggle switch, you can invert any bit without reprogramming or reloading memory. Thus you can examine the response to parity errors or the effects of single-bit changes. Other alphanumeric displays help even more.

As a receiver, the 777 gives you all the features you'd expect in a logic analyzer and more: You can store results, adjust the input threshold (-10 to 10 V), set a 16-bit combinatorial trigger and look forward or backward in time.

You can juggle and transfer data between memories, take a snapshot and display just a portion of a data stream, or compare the contents of various memories. One memory can be the response, the other the preloaded, expected response or the transmitted data. If the contents of the two memories disagree, you'll know it right off by the flashing bits on the CRT.

These aren't all the tricks in the Moxon 777 repertoire. There are lots more. If you can wait 90 days to get one, you can check the unit out in your own lab.

CIRCLE NO. 301

Function generator sells for just $245

Exact Electronics, 455 S.E. 2nd Ave., Hillsboro, OR 97123. (503) 648-8661. $245.

Model 119 vcf function generator offers a dynamic frequency range from 0.02 Hz to 2.2 MHz with sine, square, triangle and variable time symmetry of all waveforms for ramp and pulse operation. A vcf input allows the generator frequency to be varied either up or down over a range of 1000:1. The HI output delivers 20 V pk-pk open circuit, 10 V pk-pk into 50 \( \Omega \). The LO output delivers 632 mV pk-pk open circuit, 316 mV pk-pk into 50 \( \Omega \).

CIRCLE NO. 327
Test system handles μPs and other LSI

Sentry II is a computer-controlled semiconductor test system that uses multiprocessor techniques. The system is said to accommodate the most intricate semiconductor circuitry used or produced today, including microprocessors and equivalent memory components in which cells must be individually verified. It can test each device at its individual operational speed. Key feature of the Sentry II is its use of two special purpose processors, a Sequence Processor and a Pattern Processor.

CIRCLE NO. 328

Probe converts rms to dc output signal

Model RMS-10 is a portable, battery powered probe for measurement of true rms. The unit has three ranges—2, 20 or 200 V fs. A dc output signal of 0 to 2 V represents the rms value of the input, whether dc, ac or a combination of both. Accuracy of the conversion is ±1%. Input impedance is 1 MΩ and response is -3 dB at 10 kHz. NiCd batteries and a charger unit are included. Size is only 1.4-in. dia. and 7-in. long.

CIRCLE NO. 329
A/d converters with accuracies to 0.0015% drop prices sharply

Analogic, Audubon Rd., Wakefield, MA 01880. (617) 246-0300. See text.

High-precision analog-to-digital converters have been available, but at prices not all users could afford. Analogic, with its 8000 series of 14-bit through 16-bit converters, does the job without putting the customer into hock—prices start at $480. Heretofore the going price for this precision was about $1000.

There are three units in the series: the 8014, a 14-bit; the 8015, a 15-bit; and the 8016, a 16-bit a/d converter. All converters can be short-cycled if shorter word lengths are needed. Accuracies, based on measurements traceable to NBS standards, are 0.006%, 0.003% and 0.0015%, FSR, for the 14, 15 and 16-bit converters, respectively.

Absolute accuracy is ±0.006% for the 14 and 15-bit models and 0.003% for the 16-bit model. Noise produced by the converters is less than 1 LSB—at 300 μV, pk-pk, for a 3 σ measurement. Power-supply sensitivity for all three models per 1% change in supply voltage is 0.0005%. Warmup time to full-rated accuracy is only 10 minutes, and the recommended recalibration interval is six months.

The converters won’t drift out of spec either—the differential linearity tempco is a low 1 ppm/°C max, the gain tempco less than 2 ppm/°C and the offset tempco less than 1.5 ppm/°C.

All converters have a built-in buffer amplifier that provides an input impedance of 1000 MΩ. The converters can handle input voltages of 0 to 10 V or −10 to 10 V, and they deliver either offset binary, ONEs complement or TWOs complement binary outputs.

All units have a conversion speed that is externally adjustable from fixed times of 1.5, 2 and 2.5 μs per bit to a minimum of 0.6 μs per bit. And the internal clock has a stability of 0.1%/°C.

Competitive converters are few. Analog Devices (Norwood, MA) has several models that provide 14 or 16-bit outputs, but they tend to be slower or much more expensive. For instance, that company’s ADC-141 and 171, which are 14 and 16-bit converters, have conversion times of 10 ms and cost $272—almost 100 times slower than the Analogic converter, but at half the cost. The ADC-16Q, on the other hand, converts in 400 μs but costs $1418—still slower but almost
double the cost of an equivalent unit from Analogic.

Prices for the Analogic converters start at $480 for the 14-bit unit, $560 for the 15-bit unit and $640 for the 16-bit. All units are available from stock.

Analogic CIRCLE NO. 306
Analog Devices CIRCLE NO. 307

**High accuracy modulator is linear to ±0.1%**

*Computer Conversions, 6 Dunton Ct., East Northport, NY 11731. (516) 261-3300. Under $100 (large qty.); stock to 4 wk.*

The MOD 503 series of high-accuracy modulators with up to ±0.1% full-scale linearity converts dc-input signals to linearly proportional ac-output signals. The modulators accept ±10-V-dc or ±100-V-dc inputs and produce an ac output of 0 to 7 V rms. These modulators have an output impedance of only 1 Ω, maximum, and are insensitive to ±10% reference line changes. Any ac output voltage can be provided via internal or external transformers, and the output is short-circuit protected.

Gain and zero adjustments are also standard. The units have a reference input of 26 V, 400 Hz ±5% (60-Hz units available); input impedances of 100 kΩ minimum; operating temperature ranges of 0 to 70 C (MOD 503-1) or -55 to 70 C (MOD 503-2); and measure 2.6 × 3.1 × 0.625 in. The modulators require ±15 V at 50-mA supplies.

CIRCLE NO. 330

**Solid-state flasher handles 10-A surges**

*SSAC Precision Products, P.O. Box 395, Liverpool, NY 13088. (315) 457-9810. From $1.95.*

The Mini-Flasher, a solid-state on/off blinker, can handle 10-A surges. It will operate 120-W resistive, incandescent or inductive loads. The flasher has a 1-A, 115-V-ac steady-state rating; with a 50% duty cycle. The flash rate is 75 fpm and the unit operates over a 0-to-135-F range. A cylindrical case that measures 1.5 in. long and has a diameter of 15/16 in. houses the flasher.

CIRCLE NO. 331

*American made. Competitively priced. Airpax miniature switches are the product of years of experience in the design and manufacture of electromechanical devices. Single and two pole models. Maintaining or momentary switching actions. A wide range of options for appliances, industrial, military, and consumer applications. You can choose the exact combination required from the selection of basic switching functions, contact ratings, terminations, handle types, and hardware. Airpax miniature switches assure you of the superior quality, performance, and service that has been synonymous with Airpax products throughout the years.*

Send for catalog.
Ultraviolet lamp has intensity of 72 mW/cm²

American Ultraviolet, Commerce St., Chatham, NJ 07928. (201) 635-8355. $180, $200 (tripod): stock.

The Porta-Cure 1/100 ultraviolet irradiator has a typical intensity at 12 in. from light source of 72 mW/cm². This power is in the spectral range of 325 to 382 nm. The lamp requires 120 V ac at 2.1 A, measures 8 x 6.125 x 8.5 in. and has an optional tripod stand.

CIRCLE NO. 332

Reinforced nylon has high tensile strength

Fiberfil Div., Dart Industries, 1701 N. Heidelbach Ave., Evansville, IN 47711. (812) 424-3831. $1.28/lb ($32,000 lb and up): stock.

Type 66 fiberglass reinforced nylon with silicone additive, Hilube Nylasil J-1/30/3/3, has an increased service life under load bearing conditions. This is due to the silicone additive that reduces the coefficient of friction. Property test values include tensile strength of 22,000 psi, flexural strength of 30,000 psi, elongation of 2%, coefficient of linear thermal expansion of 2.1 x 10⁻⁵ and a deflection temperature under load at 264 psi of 485°F.

CIRCLE NO. 333

Conductive adhesive has R of only 0.0005 Ω-cm

Aremco Products, P.O. Box 429, Osning, NY 10562. (914) 762-0685. From $21.50 (50 grams).

Aremco-Bond 556, a two-component silver filled epoxy, has a volume resistivity as low as 0.0005 Ω-cm. Its shear strength after bonding to metals, ceramics, glass or epoxy ranges from 3000 to 4000 psi. The material has a pot life of 30 m and a shelf life (unmixed) of 6 mo. It can be cured at room temperature in 12 h, or there are several optional heat cure cycles such as 105°C for 3/4 h, or 65°C for 3 h. After curing the material has an operating temperature range of −60 to +200°C.

CIRCLE NO. 334
Switcher weighs 4 lb, yet delivers 50 W
Nippon Electronics Memory Industry Co., Ltd., Park Avenue Bldg., 1-20-1 Sendagaya Shibuya-ku, Tokyo, 151, Japan. Start at $87 (50-W unit).
HR series of switching power supplies delivers various voltages from 5 to 48 V at 50, 100 and 150 W. Size of the 50-W unit is 2.68 × 7.65 × 7.09 in., and weight is 4.19 lb. Efficiencies range from 70 to 80%. The MTBF is listed as 120,000 h. Features include remote control and sensing, overvoltage and overload protection.

CIRCLE NO. 338

Solid-state supply provides 60 kV
Spellman High-Voltage Electronics, 1930 Adee Ave., Bronx, NY 10463. (212) 671-0300. $550; 4-6 wks.
Model UHP60P5, zero-to-60-kV dc power supply operates from an input voltage of 115 V rms, 60 Hz. Output current is 75 μA at 60 kV and increases to 250 μA below 20 kV. The output is positive with respect to ground and the unit features ripple of less than 0.5% rms. A ±2% meter reads the output voltage directly through a high-voltage multiplier resistor.

CIRCLE NO. 339

Supply maintains power on RAMs when line fails
Scarpa Laboratories, Inc., 48 Liberty St., Brainy Boro Station, Metuchen, NJ 08840. (201) 559-4260. $150; 2-4 wks.
"This 5-V, 6-A open-frame supply features an auxiliary battery back-up which can automatically keep permanent power on a 4-k by 8-bit RAM memory bank of 2102s. The stand-by battery pack is continuously trickle charged as long as line voltage is present. Power outages can range from between one week and one month without loss of data. The modules feature short-circuit-proof operation and overvoltage-crowbar protection.

CIRCLE NO. 340

We’ll go to any lengths
Whether you need one terminal or 35, Kulka can provide them. Ours come in all lengths, widths and hardware configurations. Along with one of the most comprehensive sales and distribution networks in the industry. Rest assured, whatever type of terminal board, block or strip you order, they will have the durability and workmanship that has made Kulka a benchmark for quality for over thirty years. Which is why we feel no competitor can ever measure up.
DISCRETE SEMICONDUCTORS

12 and 24-A rectifiers housed in TO-3 cases

Solitron Devices, Inc., 1177 Blue Heron Blvd., Riviera Beach, FL 33404. (305) 848-4311. From $2.10 (100-up); stock.

Two series of fast switching silicon planar integrated power rectifiers are available in hermetic TO-3 cases. The SPDA 6205, 10, 20, 30 are 12-A devices (6 A per chip) and the SPDA 12205, 10, 20, 30 are 24-A units (12 A per chip). Each series is available with common-cathode, common-anode or doubler construction. Both the SPDA 6205 through 6230 and the SPDA 12205 through 12230 offer lead-spaced voltages from 50 to 300 V. The units have reverse breakdown voltages of less than 200 V and storage temperature ranges from −65 to +200 °C. The TO-3 copper case dissipates 1.25 C/W.

CIRCLE NO. 341

High power triac comes in TO-65 package

International Rectifier, Semiconductor Div., 233 Kansas St., El Segundo, CA 90245. (213) 678-6281. From $15.40 (25-up); stock.

The 50 AC series of triacs is rated for operation at 50 A, with voltage ratings up to 1200 V. The company believes these units to be the first rated for such high power operation that are available in standard TO-65 packages. The line offers a choice of gate drive currents—a standard 500-mA gate and a sensitive 200-mA gate. Triacs in the series are available with blocking voltage ratings of 400, 600, 800, 1000 and 1200 V and a surge current of 1200 A, maximum. Commutation dV/dt is 10 V/μs at rated voltage and 125°C junction temperature.

CIRCLE NO. 342

Impedance converter also houses IR detector

Eltec Instruments Inc., Central Industrial Park, Daytona Beach, FL 32114. (904) 252-0411. $45 (10 up); 2 wks.

Model 320 impedance converter is designed for IR radiation detectors that need high-impedance, low-capacitance and low-noise coupling. This package allows selection of detector and window material, load resistor and mounting for the detector without interfering with the impedance converter performance. The converter circuit is hermetically sealed in a TO-99 housing and detectors up to 3-mm dia can be used. The circuit uses an n-channel JFET, a selection of three load resistors and one output resistor. The entire circuit floats.

The single-digit “light-pipe” series 1720R/1723R are 1-in-high LED numeric displays. They are available with either a common-anode (1720R) or common-cathode (1723R) and are housed in an electrically nonconductive, plastic-compound base that measures 1.3 × 0.886 × 0.334 in. Typical luminous intensity is 250 μcd at 20 mA and 3.3 V per segment. The maximum dissipation is 760 mW per digit.

CIRCLE NO. 343

LED displays use light pipes for 1-in. height

IEE, 7740 Lemona Ave., Van Nuys, CA 91405. (213) 787-0311. $4.35 (100 up); 60 day.

CIRCLE NO. 344
DATA PROCESSING

Cursor enters data from maps and graphs

A keyboard cursor facilitates the entering of numerical data while digitizing maps and charts. A keyboard is built right into the new cursor. A Gradicon digitizer then senses the cursor position and converts the coordinate data into digital form for computer processing.

Sound-sensor system digitizes 3 dimensions

A new three-dimensional Graf/Pen sonic digitizer, Model GP-3/3-D, is used to convert descriptions of three-dimensional objects into digital form suitable as inputs to data-processing systems. Slant-range distances are converted to orthogonal coordinate sets by the software of the data system. The operator traces an object with a stylus that generates supersonic pulses. The time for the sound wave to reach three linear microphones is a measure of the distance. Outputs are in English or metric units. Resolution of English units is 0.01 in. and sensor lengths are up to 24 in. Standard size is the cube enclosed by 14-in. sensors.

Disc memory system handles to 4500 Mbytes

The MSM-10 disc systems for HP-2100 and 21MX computers consist of an Ampex, CDC or Century Data disc drive, Microcomputer System microprogrammed controller and host adapter. Expandable up to 15 drives and multiported up to eight computers, the system can provide 4500 Megabytes of disc storage with a single controller.

Announcing new frontiers in transistor chips.

We're into new technology areas where other companies have never been: a UHF amplifier with 8dB gain at 1.6GHz; a 30W, TO-5 Darlington with BVCEO 120V at 5A, gain 10,000 at 5A, and ft 100MHz; an RF amplifier at 1.0GHz, <$1.00 in quantity; or a 200W, 100A, 120V, 40MHz switching transistor. If this kind of technology interests you, call us and find out what's new today.

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DATA
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Phoenix Data’s new 8000 Series

Phoenix Data’s floating point 8000 Series data acquisition system features adaptability to virtually any analog input signal currently in use—offering automatic or programmed gain selection with 11 binary ranges from ±10 millivolts to ±10.24 volts full scale. The data word (12 binary bits) is combined with the range data (4 binary bits) for a 16 bit output word in the automatic ranging mode. The system will resolve input changes of 5 microvolts on the ±10 milli- volt range for an overall analog dynamic range of 132 db.

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• ADC resolution of 12 binary bits
• 11 binary gain ranges.
• ±10 mv to ±10.24v input ranges.
• Solid state MOSFET multiplexing.
• Thruput rates from 1 to 20 KHz
• Auto or programmable gains.
• Up to 128 channels per chassis
• System accuracy of 0.05% of reading
• System T.C.: 0.001%FSR±1μv volt RTI/°C.

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PHOENIX DATA, INC.
3384 W. OSBORN RD. PHOENIX, AZ 85017
Ph. (602) 278-6528, TWX 910-951-1364

INFORMATION RETRIEVAL NUMBER 58

Application Notes

Curve tracer
A “Testing Opto-isolators” bulletin deals with using a standard curve tracer to check the most important opto-isolator device specifications. Tektronix, Beaverton, OR

CIRCLE NO. 350

Dc clocks
Simplified dc circuitry for driving the company’s SP-151, SP-152 and SP-552 planar gas discharge displays is presented in a four-page bulletin. Beckman Instruments, Helipot Div., Fullerton, CA

CIRCLE NO. 351

Impatt diodes
Advantages of double-drift Impatt diodes for high-power cw microwave applications are given in a 12-page brochure. Information about circuits and operating characteristics are included. Hewlett-Packard, Palo Alto, CA

CIRCLE NO. 352

Impedance measurement
An application note is intended as an introduction to mechanical-impedance testing. Described are some of the terms used, problems encountered and techniques employed in mechanical-impedance testing. EMR Telemetry, Sarasota, FL

CIRCLE NO. 353

RFI suppression
Among the topics discussed in the illustrated eight-page “Radio Frequency Interference Suppression in Switched-Mode Power Supplies” applications note are interference specifications; effects of circuit design and construction on RFI; RFI produced by heat-sink current, interwinding capacitance and currents in the transformer core; wiring layout; RFI generated by diodes; and RFI at the output. Ferroxcube, Saugerties, CA

CIRCLE NO. 354

Design Aids

Microwave materials
Typical properties of 3M microwave materials are highlighted in a six-page foldout. 3M

CIRCLE NO. 355

Copper-clad laminates
An easy-to-read six-page foldout chart lists applications and specifications for copper-clad laminates for PC boards. Westinghouse Electric, Micarta Div.

CIRCLE NO. 356

Metric conversion
“Conversion Factors,” a 24-page booklet, provides multiplication fac- tors for literally hundreds of industrial and scientific measurement units. They run the gamut from A to Y (amperes to years) and from common to esoteric terms (bushels to parsecs). Engelhard Minerals & Chemicals.

CIRCLE NO. 357

Data code conversion chart
A Universal Code Chart provides a cross-index of ALPHA-NUMERIC, HEX and OCTAL for fast, easy reference. Codes listed are ASCII-8, ASCII-7, EBCDIC, EBCD, FIELD DATA, 6-BIT TRANS-CODE, ELECTRIC and BAUDOT. The Hex-to-Character Code Chart provides reference from Hex to character in the same codes as the aforementioned. Atlantic Research.

CIRCLE NO. 358

LED cross-reference
A four-page folder matches all widely used LEDs primarily on the basis of size, shape, input and output characteristics. Actual part numbers are listed on side-by-side charts to show which LEDs are interchangeable with the company’s products, and an alphabetical code is used to indicate specific differences in cross-referenced pairs. Chicago Miniature Lamp.

CIRCLE NO. 359
Freq control components

Forty types and series of quartz crystals, crystal oscillators, crystal filters and solid ultrasonic delay lines are covered in a 12-page catalog. Frequency ranges and tolerances, temperature ranges, drive levels and other application data are included. Bliley Electric, Erie, PA

CIRCLE NO. 360

Switches

Toggle, rocker and lever-handle miniature switches are illustrated in an eight-page catalog. Data include basic switching functions, contact ratings, terminations, handle types and hardware options. Airpax Electronics, Cambridge Div., Cambridge, MD

CIRCLE NO. 361

Power transistors

An updated and expanded 44-page edition of the power transistor directory lists power transistors and power hybrid circuits. Applications information, a list of transistors which may be used as complementary pairs and charts are included. RCA Solid State Div., Somerville, NJ

CIRCLE NO. 362

Bridges

Impedance, capacitance, resistance, and inductance bridges are covered in four sections of a 40-page catalog. Specifications are included for 25 instruments, and each major section is introduced by a brief description of measurement techniques and theory related to that section. General Radio, Concord, MA

CIRCLE NO. 363

Thermistor thermometers

A four-page brochure features the DigiTec HT Series (High Technology) portable thermistor thermometers. United Systems, Dayton, OH

CIRCLE NO. 364

SEaled Contact Key Switch Applications

WE'VE COVERED THE BOARD*

NOW IT'S YOUR MOVE

Our flexible tube, mercury contact has proven long life, reliable performance, and it provides you sealed switching at a price competitive with mechanical contacts. We offer a large variety of keytop styles and contact configurations including front panel relamping lighted models, single and double pole versions, and alternate action type. All of our keytop switches are designed for easy and secure P.C. board mounting without requiring any sheet metal structures.

Other features of our sealed contact switches are: • Doubleshot molded keytops for 3/4" or 5/8" mounting • Easy change legend system • 0.170 plunger travel for good tactile response

Also consider our complete line of standard small encoded and non-encoded keyboards — they may be just what will put you a move ahead.

YOUR LETTERHEAD REQUEST OR PHONE CALL WILL BRING A FREE SAMPLE SWITCH WITH KEYTOP.

*Particularly P.C. boards.
**NEW LITERATURE**

**Amplifiers**

The application, theory and selection of single and multichannel isolation amplifiers and instrumentation amplifiers are covered in a 16-page brochure. Specifications and definitions are included. Analog Devices, Norwood, MA  
CIRCLE NO. 371

**Switches**

Photos, line drawings and specifications of switches are contained in a 16-page catalog. Molex, Lisle, IL  
CIRCLE NO. 372

**Terminal blocks**

More than a dozen different types of modular rail mounted blocks are featured in a 36-page catalog. All are described with ratings, dimensions, AWG wire sizes, material specifications and tables of accessories. Technical and application data are included. Electrovert, Mount Vernon, NY  
CIRCLE NO. 373

**Microelectronic technologies**

"Microelectronics Interconnections and Packaging," a 16-page booklet, is devoted to ceramic packaging and to microinterconnect systems and their primary application: beam tape technology. 3M, St. Paul, MN  
CIRCLE NO. 374

**Circuits, interconnections**

Custom, high-reliability flexible circuits and interconnections are illustrated in a 16-page brochure. It includes several charts outlining properties of conductors and insulators, as well as round-to-flat conductor conversions and a cable-material selection guide. Hughes Connecting Devices Div., Irvine, CA  
CIRCLE NO. 375

**Conductive silvers**

Applications of conductive silvers in semiconductor work, thick-film hybrid and thin-film microelectronic circuits, as well as capacitor terminations, are covered in a 10-page catalog. Transene, Rowley, MA  
CIRCLE NO. 376

**Crystal impedance meter**

Features and specifications of a crystal impedance meter are covered in a four-page brochure. RFL Industries, Boonton, NJ  
CIRCLE NO. 377
### Power supplies

Power supplies for integrated-circuit logic and op amps are described in a four-page brochure. Acopian, Easton, PA  
**CIRCLE NO. 378**

### Relays

Dimensional drawings, specifications, ordering data and prices on hundreds of relays, stepping relays (steppers), solenoids and solid-state controls are included in a 16-page catalog. Guardian Electric, Chicago, IL  
**CIRCLE NO. 379**

### Process controller

A 60-page bulletin describes the operation and applications of the Bristol UCS 3000 process controller. Included are a sample flow diagram, a wiring drawing of the control and reporting system, module coding sheets used to enter the system configuration and system documentation automatically prepared by the Accol compiler. Acco, Bridgeport, CT  
**CIRCLE NO. 380**

### Pluggable gp relay

A general-purpose pluggable relay available in 6 to 230 V ac or 6 to 110 V dc operation is described in a four-page bulletin. Included are specifications, selection procedures, mounting dimensions and life charts. North American Philips Controls, Cheshire, CT  
**CIRCLE NO. 381**

### Microwave, rf components

A 96-page loose-leaf data booklet covers microwave and rf components. Complete specifications are given on all products, and curves, block diagrams and outline drawings are included. Trak Microwave, Tampa, FL  
**CIRCLE NO. 382**

### Accelerometers

Features and characteristics of semiconductor strain gauge accelerometers are described in a 28-page manual. Entran Devices, Little Falls, NJ  
**CIRCLE NO. 383**

### Wirewound trimmers

Three-quarter-inch rectangular wirewound trimming potentiometers are featured in a data sheet. Data on special options, a chart of standard resistance specifications and ordering information are included. Amphenol Connector Div., Broadview, IL  
**CIRCLE NO. 384**

### Modular microcomputers

A 16-page catalog describes modular microcomputers. The company's book on designing with microprocessors, "Microcomputer Design," is included in the catalog. Martin Research, Northbrook, IL  
**CIRCLE NO. 385**

### Audio ICs

The "Audio IC Selection Guide" indicates the operating supply voltage range and the package used for each audio IC manufactured by the company. SGS-ATES Semiconductor, Newtonville, MA  
**CIRCLE NO. 386**

---

**Breakthrough.**

**Switch 7 amps for under $3.85.***

Sigma's new Series 226 miniature Solid State Relay gives you better price/performance than any other SSR on the market.  
It will switch up to 7 amps, yet has a quantity price far under the $7 to $10 you would pay for competitive devices.  
The 226 is a designer's delight. It measures only 1.5" x .73" x .66" overall, including heat-sink flange and termination pins. When inserted in a PC board, it stands less than 0.5 inches high. Or unit can be chassis-mounted via standard slip-on connectors.  
The 226 is completely solid state and opto-isolated with TTL compatible LED input. Output is a triac, with versions rated at both 120 VAC and 240 VAC. Units are ultrasonically sealed and potted internally to resist moisture and vibration.  
All standard input voltages are available.  
The low price, current handling capability and convenient packaging of this unit make it ideal for switching AC loads with low level logic signals.  
Contact your distributor or Sigma to learn how the Series 226 can help cut your costs.  
*1,000 quantity price.  
SIGMA INSTRUMENTS, INC., 170 Pearl Street, Braintree, MA 02184, (617) 843-5000  
CANADA: Sigma Instruments (Canada) Ltd., 55 Six Point Road, Toronto, Ont. M1Z 2X3, (416) 239-8161  
EUROPE: Sigma Instruments GmbH, Burgsteinstrasse 14 D-817 Bad Toelz, West Germany, (08041) 9127
NEW LITERATURE

Electronic components

Electronic components, test equipment and production tools are covered in a 48-page catalog. Prices are included. Mouser Electronics, Lakeside, CA

CIRCLE NO. 366

Thermal printers

Specifications and application data on the Model DPP-7 miniature seven-column panel-mounting printer are covered in a 12-page catalog. Block and wiring diagrams are included. Datel Systems, Canton, MA

CIRCLE NO. 365

Rf inductors

A 16-page catalog highlights rf inductors. Special and nonstandard coil capabilities are shown in diagrams and photos. Airco Electronics, Nogales, AZ

CIRCLE NO. 367

Transducers

Subminiature pressure transducers for industrial and aerospace testing are featured in a six-page catalog. Sensotec, Columbus, OH

CIRCLE NO. 368

Gas discharge displays

Technical and application data for Plasma-Lux gas discharge display panels are contained in a literature kit. Included are individual sheets containing dimensional drawings and electrical specifications. Cherry Electrical Products, Waukegan, IL

CIRCLE NO. 369

Instrumentation

"News from Rohde & Schwarz" presents equipment shown by R&S at the 1975 Hanover Fair. Detailed articles cover the uhf-vhf receiving system ET 001, the motor-vehicle sound-level meter ELMOT and the tone-sequence generator SSN/SSNZ. An article shows how to combine the automatic radio-telephone test assembly SMPU with Tektronix' desktop calculator TEK 31. Rohde & Schwarz, 8000 Munchen 80, Muhldorfstrasse 15, West Germany

CIRCLE NO. 370
Monolithic Memories is second-sourcing National Semiconductor's 18-pin Model MM5270 and 22-pin Model MM5280 4096-bit RAMs.

CIRCLE NO. 387

Signetics has introduced 19 more 74LS-TTL elements. Twelve devices are MSI functions and seven are SSI.

CIRCLE NO. 388

Systems Engineering Laboratories has announced a program translator that converts SEL 800 series computer programs to SEL 32 series computer programs.

CIRCLE NO. 389

General Semiconductor Industries has completed qualification of its 2N3418/19/20/21 npn transistors to MIL-S-19500/393 (USAF).

CIRCLE NO. 390

Facsimile, word-processing and time-sharing terminals can now file Western Union's Mailgrams.

CIRCLE NO. 391

Fairchild and Mostek have jointly announced that Mostek will second source Fairchild's F8 microprocessor.

CIRCLE NO. 392

Digital Equipment has introduced Fortran/RT-11 extensions that add extensive software support for PDP-11 laboratory peripherals to the RT-11 disc operating system.

CIRCLE NO. 393

Exar Integrated Systems is offering custom integrated injection logic (I1L) in volume quantities.

CIRCLE NO. 394

Significant steps in a program to standardize and improve specifications and performance for COS/MOS ICs have been announced by RCA Solid State Div.

CIRCLE NO. 395

Weil-McLain. Heating and air conditioning, fluid systems and air handling systems.

CIRCLE NO. 396

Tracor. Components, instruments, and research and development.

CIRCLE NO. 397

AMP. Electrical connection, switching and programming devices and application machines and tools, and power units.

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Superior Electric. Industrial products for voltage and motion control.

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Philip Morris Industrial. Electro-sensitive paper, packaging adhesives and materials, and coatings.

CIRCLE NO. 400

Reynolds Metals. Aluminum.

CIRCLE NO. 401

The International Nickel Co. of Canada. Metals and batteries.

CIRCLE NO. 402

Pfizer. Chemicals, materials-science products and pharmaceuticals.

CIRCLE NO. 403

Conrac. Communications, control products, information displays and automated assembly.

CIRCLE NO. 404

THE INSIDE STORY
OF CHIP CAPACITORS

Annual and interim reports can provide much more than financial-position information. They often include the first public disclosure of new products, new techniques and new directions of our vendors and customers. Further, they often contain superb analyses of segments of industry that a company serves.

Selected companies with recent reports are listed here with their main electronic products or services. For a copy, circle the indicated number.

Weil-McLain. Heating and air conditioning, fluid systems and air handling systems.

CIRCLE NO. 396

Tracor. Components, instruments, and research and development.

CIRCLE NO. 397

AMP. Electrical connection, switching and programming devices and application machines and tools, and power units.

CIRCLE NO. 398

Superior Electric. Industrial products for voltage and motion control.

CIRCLE NO. 399

Philip Morris Industrial. Electro-sensitive paper, packaging adhesives and materials, and coatings.

CIRCLE NO. 400

Reynolds Metals. Aluminum.

CIRCLE NO. 401

The International Nickel Co. of Canada. Metals and batteries.

CIRCLE NO. 402

Pfizer. Chemicals, materials-science products and pharmaceuticals.

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Conrac. Communications, control products, information displays and automated assembly.

CIRCLE NO. 404

NOW HEAR THIS...
If you're interested in the basics of monolithic chip capacitor construction, circle the reader service number below for your copy of "The Inside Story" and a sectioned ATC 100 chip capacitor.

If you'd like samples of any other ATC UHF/Microwave Capacitors, call Ralph Wood at (516) 271-9600.
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- To promote communication among members of the electronics engineering community.

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Editor
Electronic Design
50 Essex Street
Rochelle Park, N.J. 07662

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Electronic Design 26, December 20, 1975
We're on the move... 
with a 15-ns deglitcher.

Computer Labs introduces a new line of modular deglitchers with the DGM-1040 & DGM-1080. Used to eliminate the non-linear effects of glitches in the output of D/A Converters, these miniature modules generate an output signal with extremely high spectral purity, required for TV signal reproduction, CRT displays, and waveform generation. Acquisition times as low as 15 ns and linearity of 0.01% make these the highest speed and most versatile deglitchers available commercially.

INFORMATION RETRIEVAL NUMBER 60

OUR PROTO-CLIP™ CAN PAY FOR ITSELF THE 1ST TIME YOU USE IT.

The reason's as simple as the time you'll save testing, signal tracing or wiring in DIP's. Not to mention the cost of IC's ruined by accidental shorts. A Proto-Clip is the foolproof, short proof way to bring up leads from crowded circuit boards. Its patented, molded design and unique gripping teeth free hands for other work. Built to withstand tough day-to-day use, CSC clips are available with or without cable for 14-, 16-, and 24-pin DIP's, starting at $4.50. For more information, see your dealer or write for our full-line catalog and distributor list.

INFORMATION RETRIEVAL NUMBER 61
HIGH Q MULTILAYER CAPACITORS feature very high quality factors at micro-wave frequencies. Offered in three standard sizes: 0.050 x 0.040, 0.080 x 0.050, 0.125 x 0.095. Capacitance values from 0.1 pf to 1000 pf with close tolerance and voltages to 1000 VDCW. Johanson/Monolithic Di-electrics Div., Box 6456, Burbank, Ca. 91510, (213) 848-4465.

MULTILAYER CHIP CAPACITORS

Transconductance Power Driver for $33.50. The ERG 303D drives high-power audio amplifiers; accurately controls servo motors. With +50V supply and output transistor pair, the ERG 303D produces 100-300+ Watts R.M.S., 0.02% T.H.D. Bandwidth 80kHz-200kHz. $29.95 in quantity. Electronics Research Group, Inc., 134 Mt. Auburn St., Cambridge, MA 02138 (617) 661-9383.

ERG 303D

ASCII DISC DATA SYSTEM: BRD D-474 Floppy Disc System, RS-232 plug compatible for any serial ASCII central processor or other ASCII I/O device. Features: 277,504 alphanumeric character storage; only 8 basic ASCII instruction characters; Fully buffered I/O memories; Selectable 110-9600 baud rates; Average 200 millisecond access time per sector. BRD inc., Box 12237, Bainbridge Island, Wash. 98110 (206) 842-4777.

DISC SYSTEM

EASIER ECL VOLTAGE AND GROUND DISTRIBUTION SYSTEMS—Reduced system noise, high packaging density and less design time for PC boards with ECL circuits are yours with Mini/Bus®, the Rogers way to eliminate the cost of multilayer boards by off-board voltage and ground distribution. Rogers Corp., Chandler, AZ 85224 (602) 963-4584.

MINI/BUS

DIGITAL SIGNAL ANALYSIS, S. Stearns. Contains the most recent advances, brand new design material, and a comparison between continuous and digital systems, making it an ideal master reference to today’s signal processing techniques and systems. 5828-4, 288 pages, $18.95. Circle the Info Retrieval Number to order 15-day exam copy. When billed, remit or return book with no obligation. Hayden Book Co., 50 Essex Street, Rochelle Park, N.J. 07662.

DIGITAL SIGNAL ANALYSIS


POLYAMIDE SPACER-BUSHING

Low Cost Image Sensing Module contains a 1024 element (32-by-32) image sensor and all support circuitry on a single pc board. Digital video output may be displayed directly on an oscilloscope. Complete module (SE1024W) is $150. Kit (SE1024K) is $90. Cromemco, 26655 Laurel, Los Altos, CA 94022.

MODULE

48 HOUR TRANSFORMER SERVICE FOR $49.00. 115 volts Input with any one voltage you specify as the output voltage. Up to 100 watts 60HZ, 600 watts 400HZ. Don’t settle for a stock item, get what you need. Call 516-654-1166 or Write MAGNETICO, INC., Holtsville, N.Y. 11742.

TRANSFORMER SERVICE


TRAINING TEXT
ALL 8080As DON'T COME FROM THE SAME PLACE.

Meet the μPD8080A. From NEC Microcomputers, Inc. The microprocessor that's both fully software and pin compatible with Intel's new 8080A. And it's backed by all the chips, support systems, software, and service you need to make it into a complete microcomputer system — the μCOM-8.

THE CHIPS.
We start with not one, but four 8080-type microprocessors.

At the top of the line is the μPD8080A. It gives you everything their 8080A does, plus extras like full BCD capability for both addition and subtraction. For low-cost applications, we also have a 1.25 MHz option — the 8080A-E. Plus there are two other models, featuring improved I/O.

In addition, we can give you the best in RAMs, ROMs, and PROMs, including the only Electrically Alterable PROM with the speed to match the processor.

THE SUPPORT SYSTEMS.
We offer both a full-scale microcomputer — the PDA-80 — for software development and hardware emulation; and a microcomputer-on-a-board — the EVAKIT — for evaluation purposes.

THE SOFTWARE.
For the PDA-80 we have a full line of resident software. Or, we can give you a full line of cross software, available on national timesharing services or installed on your own computer system. This includes our unique Macro Maintenance Program (MMP) for storing common macros and sub-routines for use with our Macro Assembler.

AND THE SERVICE.
The μCOM-8 package also includes complete documentation, an ever-expanding library of Applications Notes, and a responsive, in-depth applications engineering service, available nationwide.

SO...
Whatever your application or your needs — first source or second source, large volume or small, chips or complete systems — take a look at everything our 8080A gives you.

You really can't afford not to.

WHERE TO BUY IT.

New England:
- Circuit Sales Company
  - Lexington, MA
  - 617/861-0367

Mid-Atlantic:
- Trionic Associates, Inc.
  - Great Neck, NY
  - 516/466-2300
- C.H. Newson & Associates
  - Philadelphia, PA
  - 215/248-3377
- C.H. Newson & Associates
  - Hershey, PA
  - 717/223-8576 (Harrisburg)
  - 301/825-0001 (Baltimore)

Southeast:
- Perrott Associates, Inc.
  - Orlando, FL
  - 305/275-1132
- Perrott Associates, Inc.
  - Clearwater, FL
  - 813/726-1549

Midwest:
- MCDaden Sales, Inc.
  - Columbus, OH
  - 614/221-3363
- Bitronics Sales Company
  - Minneapolis, MN
  - 612/835-7744
- RF Specialists
  - Park Ridge, IL
  - 312/698-2044

Southwest:
- Merino Sales Company
  - Dallas, TX
  - 214/233-6002
- Tri-Tronix
  - Albuquerque, NM 87110
  - 505/265-8400
- Summit Sales
  - Scottsdale, AZ 85251
  - 602/994-4587

Northwest:
- Tri-Tronix
  - Bellevue, WA
  - 206/454-0940

So. California:
- Electronic Component Marketing
  - Woodland Hills, CA
  - 213/340-1745
- Electronic Component Marketing
  - El Toro, CA
  - 714/830-9939
- Electronic Component Marketing
  - San Diego, CA
  - 714/295-6122

No. California:
- Trident Associates
  - Mountain View, CA
  - 415/967-7031

Canada:
- R.F.Q., Ltd.
  - Toronto, ON
  - 416/826-5874
- R.F.Q., Ltd.
  - Montreal, QUE.
  - 514/626-8324

NEC microcomputers, INC.

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**Cost effectiveness**

Our revolutionary low introductory price of $17.76 is only part of the cost story. When all factors are considered —

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including capability, power and parts-count savings — overall system savings can turn out to be even more dramatic. Since it's static, the 5001 saves on parts by requiring no memory refreshing, no clock, no pulsing. And it has a 3-state output, which allows power savings from common busing.

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