Electronic Design®
FOR ENGINEERS AND ENGINEERING MANAGERS
VOL. 24 NO. 15
JULY 19, 1976

Custom LSI or microprocessor? Which way? Each has its place, but the choice depends on many factors. These include: leadtime, performance specs, reliability, software, production volume and, of course, price. There are a number of sign posts that can help guide the engineer. This special report starts on p. 26.

AMERICAN REVOLUTION BICENTENNIAL 1776-1976 ®
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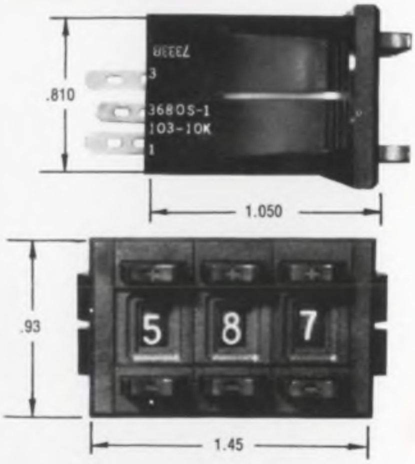

For more information,
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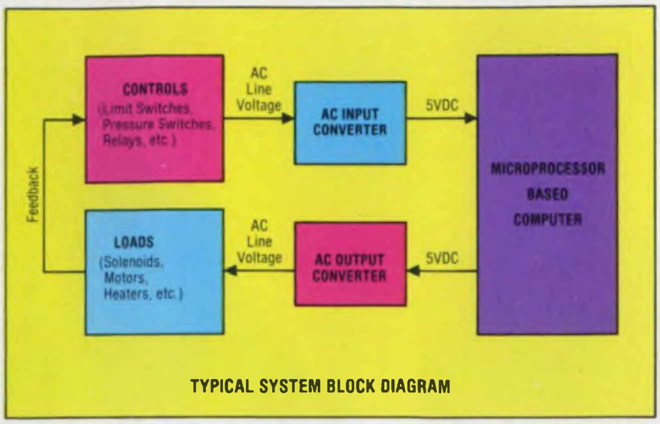
CIRCLE NUMBER 2

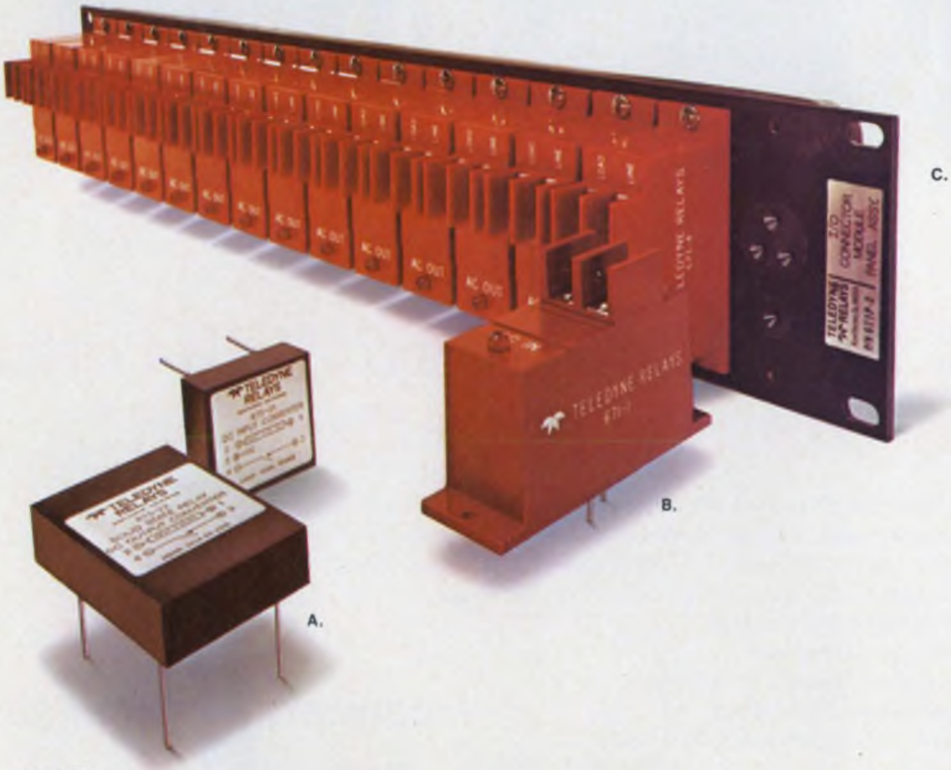
Microprocessors take control with Teledyne I/O converters



TYPICAL SYSTEM BLOCK DIAGRAM

Modular packaging of input/output interface circuitry. That's what Teledyne I/O Converter Modules provide microprocessor based industrial controls for maximum I/O flexibility and expandibility. This single circuit modular concept features all-solid-state circuitry, 1500V optical isolation, and high noise immunity. Our 671 Series modules plug directly into a low cost custom-designed mounting panel, which physically isolates service wiring from logic connections. For pc boards, we offer the same circuitry in our 675 Series low profile package. Both series include ac and dc input/output converters.

So for the best in I/O interface circuitry for microprocessor based industrial controls, contact the people who know the "ins and outs" of this business — Teledyne Relays.



A. 675 Series — Low profile I/O converter modules for pc board mounting

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Electronic Design®

VOL. 24 NO. 15

FOR ENGINEERS AND ENGINEERING MANAGERS

JULY 19, 1976

TECHNOLOGY

PRODUCTS

DEPARTMENTS

Cover: Design by Art Director Bill Kelly, photo courtesy of Fairchild Semiconductor.

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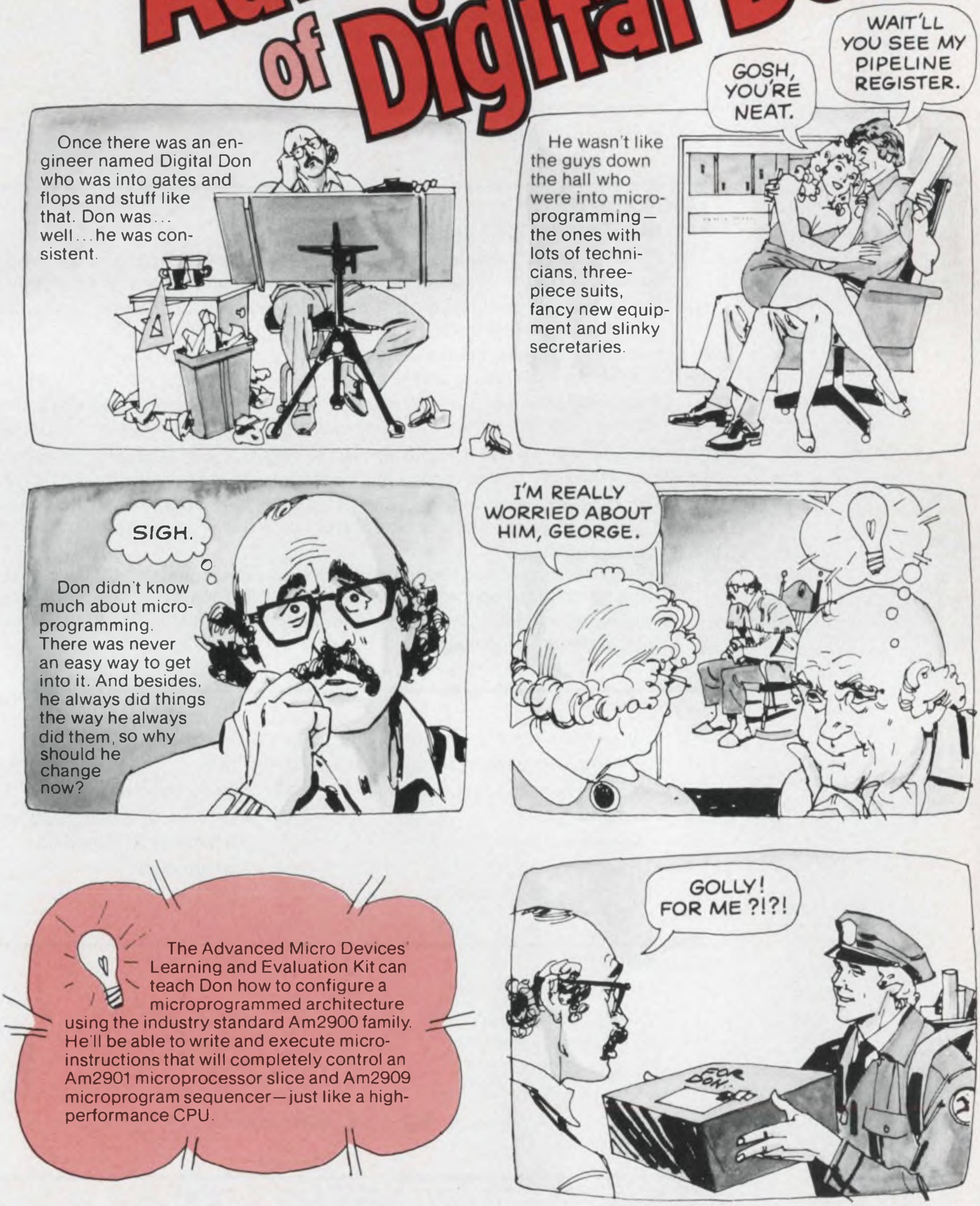
The Adventures of Digital Don.



Once there was an engineer named Digital Don who was into gates and flops and stuff like that. Don was... well... he was consistent.

He wasn't like the guys down the hall who were into microprogramming—the ones with lots of technicians, three-piece suits, fancy new equipment and slinky secretaries.

Don didn't know much about microprogramming. There was never an easy way to get into it. And besides, he always did things the way he always did them, so why should he change now?

The Advanced Micro Devices' Learning and Evaluation Kit can teach Don how to configure a microprogrammed architecture using the industry standard Am2900 family. He'll be able to write and execute microinstructions that will completely control an Am2901 microprocessor slice and Am2909 microprogram sequencer—just like a high-performance CPU.

The Am2900K1 Learning and Evaluation Kit.

It's terrific. For only $289.00 you can master the basic theory and application of microprogramming. Here's what you get:

A read/write memory storing up to 16 microinstructions driving a pipeline register. From the pipeline register, the microinstructions control: an Am2901; circuits for logical and arithmetic shift and rotation; and the Am2909 sequencer that selects the next microinstruction address. Sixteen sequence control functions are built in, including conditional branch, loop, jump to subroutine and return. Built-in display logic makes nearly every point in the system available at an LED display.

The Kit includes forty IC's, LED's, switches, resistors, decoupling capacitors, PC board and a really comprehensive manual covering assembly instructions, theory and experiments. The only thing you need to add is a 5-volt power supply.

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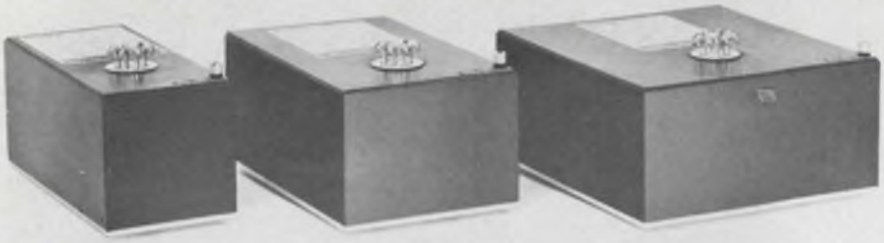

25 WATTS 50 WATTS 100 WATTS

Save 5 Ways with Abbott's New 77% Efficient Power Supplies!

Abbott has a Hi-Efficiency series of power modules that can save 5 ways in your system. The Model "VN" series converts 47-440 Hz AC lines to regulated DC power and uses a new approach in switching technology that provides a highly reliable line of sixty-three high efficiency power modules.

The Model "VN" series saves in the following 5 ways:

1 SAVES POWER – High frequency pulse width modulation and C/MOS digital IC control circuitry allow efficiencies of up to 77% in the Model "VN" series. This high efficiency realizes almost twice the output power per input watt than dissipative regulators.

2 SAVES SIZE – Off line techniques and IC technology combine for packages of 70% less volume compared to dissipative regulators.

3 SAVES WEIGHT – High efficiency means less power dissipated and less heat generated, thereby reducing or eliminating the need for bulky heat-sinking and forced air cooling. This translates into less total weight and smaller system size.

4 SAVES TIME – You can quickly get the power supply you need because we have an extensive line of models to choose from. Outputs of 25, 50 and 100 watts are available at any voltage between 4.7 and 50.0 VDC. With popular voltages in stock, chances are the unit you need is available immediately.

5 SAVES MONEY – At only $299 for 25w, $339 for 50w, and $359 for 110w in small quantities, the "VN's" are among the lowest priced Hi-efficiency units on the market.

Abbott also manufactures 3,500 other models of power supplies with output voltages from 2.7 to 740 VDC and output currents from 4 milliamps to 20 amps. They are all listed, with prices, in the new Abbott Catalog. Included are:

60 ~ to DC
400 ~ to DC
28 VDC to DC
28 VDC to 400 ~
12-38 VDC to 60 ~

Please see pages 1037-1056 Volume 1 of your 1975-76 EEM (ELECTRONIC ENGINEERS MASTER Catalog) or pages 612-620 Volume 2 of your 1975-76 GOLD BOOK for complete information on Abbott Modules.

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CIRCLE NUMBER 6

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Across the Desk

Home power usage is less than stated

In his generally excellent article on major solar-cell programs (ED No. 6, March 15, 1976, p. 24), Associate Editor Samuel Derman mentions that the average single family house is estimated to require 500 kWh/day. I think this figure must be incorrect.

My home here in New Jersey is all electric. Power consumption in the last three years has been as follows:

Year	Total Consumption	Daily Av.
1973	53,520 kWh	146.6 kWh
1974	43,374 kWh	118.8 kWh
1975	40,806 kWh	117.8 kWh

Since a very large part, say, 1/3 to 1/2 of the above energy is for heating, and since most homes use gas, or oil, I imagine, the correct figure for typical home electrical energy consumption must be more on the order of 50 kWh per day. At the time my house was built I was told that on a very cold day, 10 F, the heating load for my house would be about 20 kW. Thus, on an unusually cold day total power consumption might be about 500 kWh for an electrically heated house like mine.

John Pittman

3 Old Farm Rd.
Warren, NJ 07060

Ed Note: Yes, the published figures for electric usage should have been per month rather than per day. Consolidated Edison, New York City, provides the following data for average home use in New York City:

For a private home, approximately 500 kWh are used per month.

For each apartment in an apartment house, approximately 250 kWh are used per month.

According to the Edison Electric Institute, a national electric-utility organization, the average residential use of electricity in 1975, nationally, was 8176 kWh for the year, or 681.3 kWh per month.

Solar-cell inventor was unappreciated

As I scanned Samuel Derman's fine article on "Major Solar-Cell Programs" (ED No. 6, March 15, 1976, p. 24), I was constantly reminded that the inventor of the solar cell lives just six miles south of here: Anthony H. Lamb, 726 S. Fowler Ave., Newbury Park, CA 91320. (805) 498-5860.

I've seen the original prototype. It still works.

Back in 1931 he was threatened with dismissal if he persisted in promoting it. So he turned it into the Weston light meter.

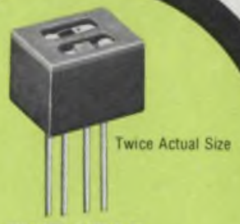
When retired he was in charge of 1400 creative engineers. He holds Federal citations in such arts as night flying, and guided missiles, and at 72 he took out his 200th patent.

All through the years, Tony has bucked the interests. Today when we need his ideas more than ever, nobody seems to give him a tumble. Now he's 73, and naturally frustrated, but active in other fields.

Maybe his name should appear in your closing list, titled "Need More Information?" Personally I

(continued on page 11)

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



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The hermetically sealed glass-metal-ceramic package offers extremely high reliability and stable performance at a cost competitive with that of plastic encapsulated devices. And, the OPB 704 has a usable continuous operating life of more than five years when operated at an average LED device current of 20 mA.

The OPB 704's phototransistor senses radiation from the LED only when a reflective object is within its field of view. With an LED input current of 50 mA, the output of the phototransistor is typically 0.5 mA when the unit is positioned 0.100 inch from a 90% reflective surface. With no reflective surface within the phototransistor's field of view, maximum output is 10μA with a LED input of 50 mA and V_{CE} of 5 volts.

Ideal applications for the OPB 704 reflective transducer include EOT/BOT sensing, mark sensing, detection of edge of paper or cards and proximity detection.

The OPB 704 and other low cost, high reliability OPTRON reflective transducers are immediately available. Custom designed versions for special applications are available on request.

Detailed information on the OPB 704 reflective transducer and other OPTRON optoelectronic products . . . chips, discrete components, limit switches, isolators and interrupter assemblies . . . is available from your nearest OPTRON sales representative or the factory direct.

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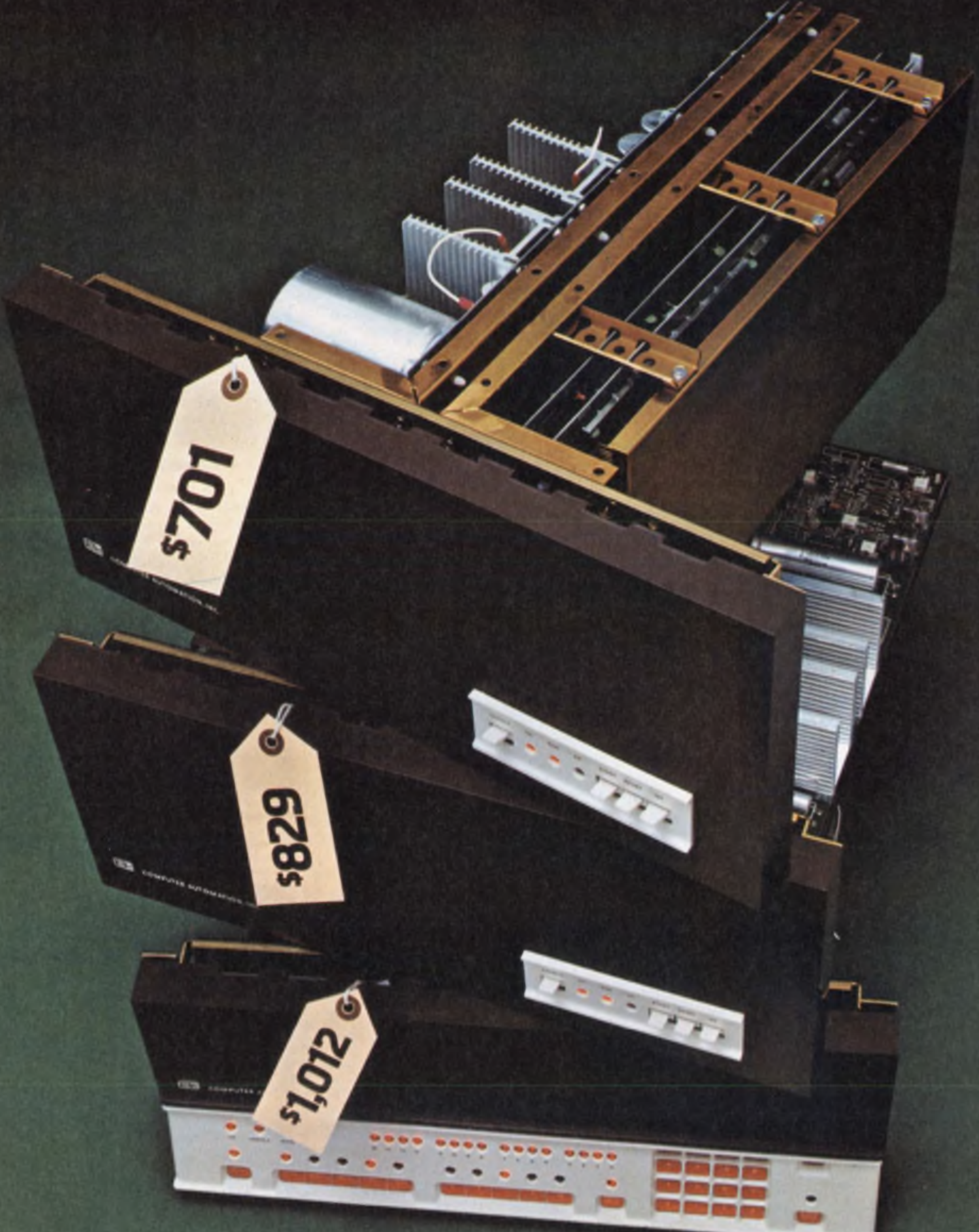
CIRCLE NUMBER 7

What our bottom-of-the-line



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ComputerAutomation's low-cost line of 16-bit, full-scale,
fully compatible computers.

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Stack the ALPHA LSI-3/05 millicomputer up against any other low-end computer.

Preferably while you're sitting down, because on price alone, you're bound to be astounded.

Ready? $701 total packaged price. And that's complete with 256 words of MOS RAM, and a CPU that offers a really powerful instruction set, Power Fail Restart, Real-Time Clock and Autoload capability.

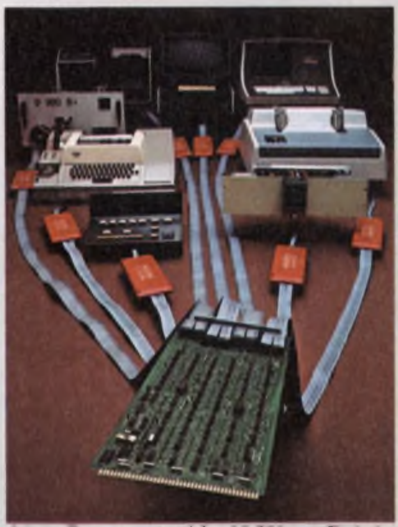
Try to buy an equivalent computer at twice the price.

Have it your way.

You also get the capability to configure your computer pretty well the way you want it. A choice of packaging, of course, that includes either the Operator's or the Programmer's Console, power supplies and so on.

A choice of two standard I/O options.

And a choice of optional memory configurations that include RAM/ROM, RAM/EPROM and RAM-only in sizes from 256 words all the way up to 32K words. Totally addressable.



Maxi-Bus compatible ALPHA LSI-3/05 achieves unprecedented cost-effectiveness with ComputerAutomation's new Distributed I/O System.

Family connections save you still more money.

So far, what we've been talking about could easily add another five or six figures to the bottom line of your ledger.

But there's more. Really big savings on off-the-shelf software, peripheral controllers and I/O interfaces.

The reason is that the ALPHA LSI-3/05 millicomputer is a full-fledged member of ComputerAutomation's LSI Family... Maxi-Bus compatibility and the whole works. So, every piece of Family hardware we've ever developed will work like it was made for the ALPHA LSI-3/05. Including ComputerAutomation's exclusive new Distributed I/O System... just like you see it in the picture.

With this versatile interface system, you can interface virtually any kind or combination of peripherals. Parallel or serial. Just by plugging them in.

Your cost? Probably less than $200 per interface.

The pros know.

Computer-wise OEM's will tell you that product requirements sooner or later get ahead of the hardware. For instance, the computer you buy today may not have enough I/O or memory capacity for tomorrow's Mark II Super Widget.

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You lose.

Of course, with our LSI Family of compatible computers you don't.

You can switch to a different CPU or a different memory anytime. Faster, slower, bigger, smaller. The electrical interface will still be the same; the original programming will still work.

You win.

From the people who brought you the NAKED MINI.®

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And the PICOPROCESSOR.

And now the ALPHA LSI-3/05 millicomputer.

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Or call (714) 549-5701.

Hughes Connecting Devices

CIRCLE NUMBER 9

(continued from page 7)

am convinced there are few men in the nation who could be more likely to steer us to simpler, less costly solar collectors.

A.S. Eves
Business Consultant
1668 Regent St.
Camarillo, CA 93010

Photovoltaic studies gain increased support

Thank you very much for your recent correspondence and the article by ELECTRONIC DESIGN on solar-cell technology. I have referred this material to my Subcommittee for further review.

I would like to point out that the Subcommittee has actually increased funding for photovoltaic research and development, over ERDA's FY1977 request, bringing the total to $37,800,000—an increase of $5 million. Additionally, the Materials Sciences portion of the ERDA budget will provide substantial funds for photovoltaic studies.

Thank you again for sharing with me your ideas on the development of solar cell technology as a potential large-scale source of electricity.

Mike McCormack, Chairman
Subcommittee on Energy
U.S. House of Representatives
Suite 2321 Rayburn House Office Bldg.
Washington, DC 20515

New squelch circuit has multiple functions

Let me tell you about the new IC I have designed, which may be useful in implementing your latest "Thou shalt not sin . . . except in the interests of business."

It's a new squelch circuit that disables the transmitter whenever an audio signal occurs, and permits only the broadcasting of silence. It can also be used to implement the old dictum, "No news is good news," when applied to communications circuits. Best yet, this IC can be used in receivers as well as in transmitters, so as to excise any sounds that unenlightened souls may foolishly broadcast. Bob Dobkin says this is the best invention since the Darkness-Emitting (Arsenide) Diode. Oughta sell millions . . . Keep up the good work.

Robert Pease
Staff Scientist
National Semiconductor Corp.
2900 Semiconductor Dr.
Santa Clara, CA 95051

What is this? Why, it's the Fruit of the Loom

No human ever painted this self-portrait.

The loom in the background is the "artist." It wove the picture in silk according to instructions on punched cards. Each of the ten million thread intersections was coded by hand on graph paper; the cards were then produced from the graph.

The year, by the way, was 1844—50 years before Herman Hollerith "invented" the punched card. Designer of the loom was the Frenchman, Joseph Marie Jacquard.

Short HP-25 program does combinations faster

I read with interest Mr. Schaffer's letter (ED No. 7, March 29, 1976, p. 7) about an improved HP-25 program for computing factorials. I also wrote programs for computing such important functions as permutations and combinations (binomial coefficients) which are much shorter than the

(continued on page 15)

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Call Hughes (714) 548-0671

1,021-channel Digital Frequency Synthesizer. 5V supply, 5 MHz input. (HCTR 0320)

Decade Counter/Latch/Decoder/Driver. Up/down, 2 MHz, 5V operation, 7-segment output (HCTR 0200)
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Custom MOS designs. Use our experience in MOS/LSI circuits to meet unusual requirements like wide supply variations, high speed, ultra low power, differential amplifier input, RC oscillator and crystal oscillator. (Ask for custom MOS brochure).

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Solid State Products Division

New ideas from a new source for flat cable and connectors

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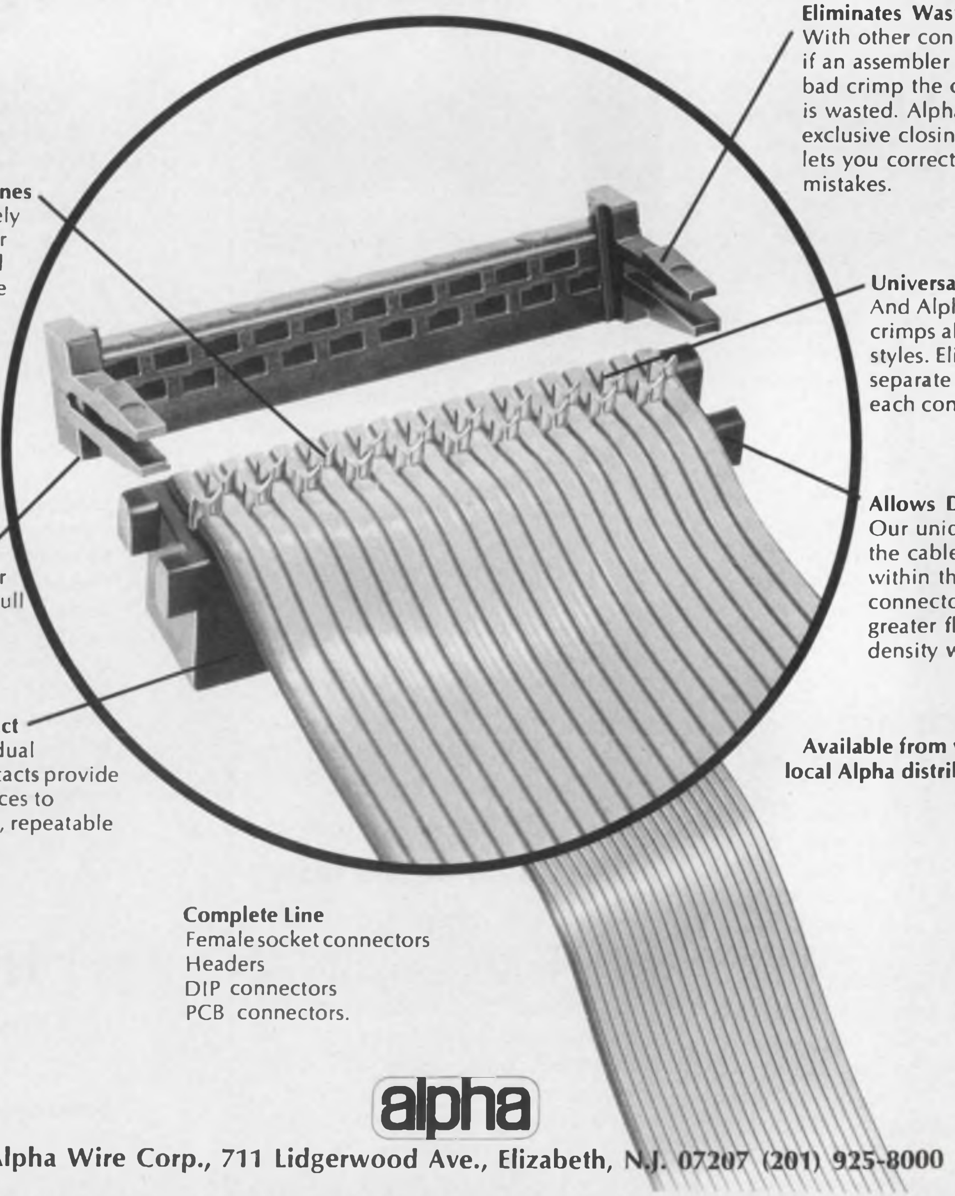
Let's start with our cable. It's compatible. Matches all flat-cable connectors designed for 0.050 in. (1.27mm) conductor spacing. Excellent teardown characteristics make it easy to cleanly separate the conductors—essential when cable has to be routed to more than one location. It can be folded back on itself without damage to conductors or insulation—ideal for intricate cable routing. Another bright idea: an exclusive footage indicator on the reel shows how much cable is left. And it's UL listed (style 2651). Complies with requirements of FR-1 flame test.

The connectors, (57 of them) are an integral part of our flat cable connection system. They also offer some bright new ideas as you can see:



Microetched Offset Tines
Grip conductor securely and prevent conductor damage. (All burrs and knife-sharp edges have been removed.)

Built-In Strain Relief
And self-latching cover means cable will not pull out of connector.

Positive Contact
Self-cleaning dual cantilever contacts provide 2 wiping surfaces to insure reliable, repeatable terminations.

Eliminates Waste
With other connectors, if an assembler makes a bad crimp the connector is wasted. Alpha's exclusive closing action lets you correct your mistakes.

Universal Adapter
And Alpha's bench press crimps all connector styles. Eliminates need for separate adapter plates for each connector type.

Allows Denser Wiring
Our unique design allows the cable to remain within the profile of the connector, affording greater flexibility in high density wiring.

Available from your local Alpha distributor.

Complete Line
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CIRCLE NUMBER 10

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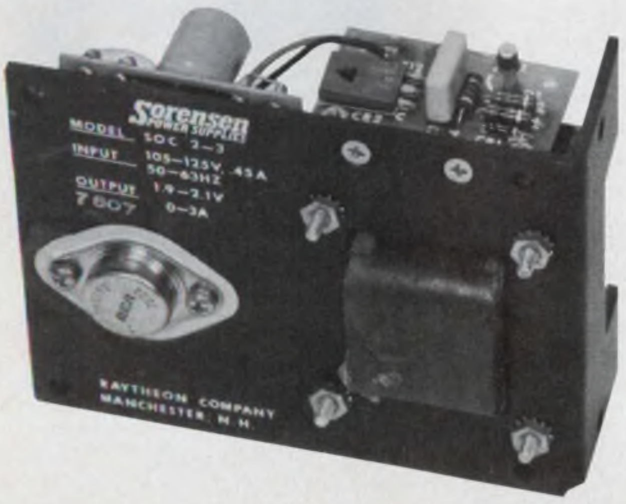
- Conservatively designed and rated
- Low heat dissipation, high temperature stability
- One-year warranty, backed by a worldwide service organization

Model No.	Series	Voltage**	Output Current (Adc)* @ 40°C	@ 50°C	@ 60°C	Price
SOC 2-3	A	2V	3.0	2.4	1.8	$32
SOC 2-6	B	2V	6.0	4.9	3.8	54
SOC 2-10	C	2V	10.0	8.0	6.5	67
SOC 5-3	A	5V	3.0	2.4	1.8	32
SOC 5-6	B	5V	6.0	4.9	3.8	54
SOC 5-10	C	5V	10.0	8.0	6.5	67
SOC 12-1.6	A	12V	1.6	1.3	1.0	32
SOC 12-4.0	B	12V	4.0	3.0	2.5	54
SOC 12-6.0	C	12V	6.0	5.0	4.2	67
SOC 15-1.5	A	15V	1.5	1.2	1.0	32
SOC 15-3.0	B	15V	3.0	2.6	2.2	54
SOC 15-5.0	C	15V	5.0	4.2	3.5	67
SOC 24-1.0	A	24V	1.0	.75	.55	32
SOC 24-2.2	B	24V	2.2	1.9	1.6	54
SOC 24-3.5	C	24V	3.5	2.9	2.4	67
SOC 28-0.8	A	28V	0.8	.64	.45	32
SOC 28-2.0	B	28V	2.0	1.7	1.4	54
SOC 28-3.1	C	28V	3.1	2.6	2.0	67

* Free-air rating — no external heatsink. ** ±5% adjustable.

Common Specifications:
AC Input Power: Vac 105-125 (190-226). (210 to 250 available by using taps on transformer.)
Frequency 50 to 63Hz. (Derate 10% at 50Hz.)
Voltage Regulation (comb. line and load): ±0.15% + 6mV for 105 to 125 Vac and 100% load change.
Voltage Ripple and Noise: 1.5mVrms, 5mVpp.
Temperature Coefficient: 0.03%/°C.
Drift (24 hours): 0.2% after 1-hour warm-up.
Remote Sensing: 100mV maximum drop in each leg.
Operating Temperature: 0°C to 60°C.
Storage Temperature: −20°C to +85°C.
Overvoltage Protection: Available on all models except 2 volt. Specify by adding "VP" suffix to model number and add $8 to unit price.
Current Foldback: Automatic, factory-set to 140% of rated (40°C) output current.
Cooling: Convection.
Finish: Black anodize.



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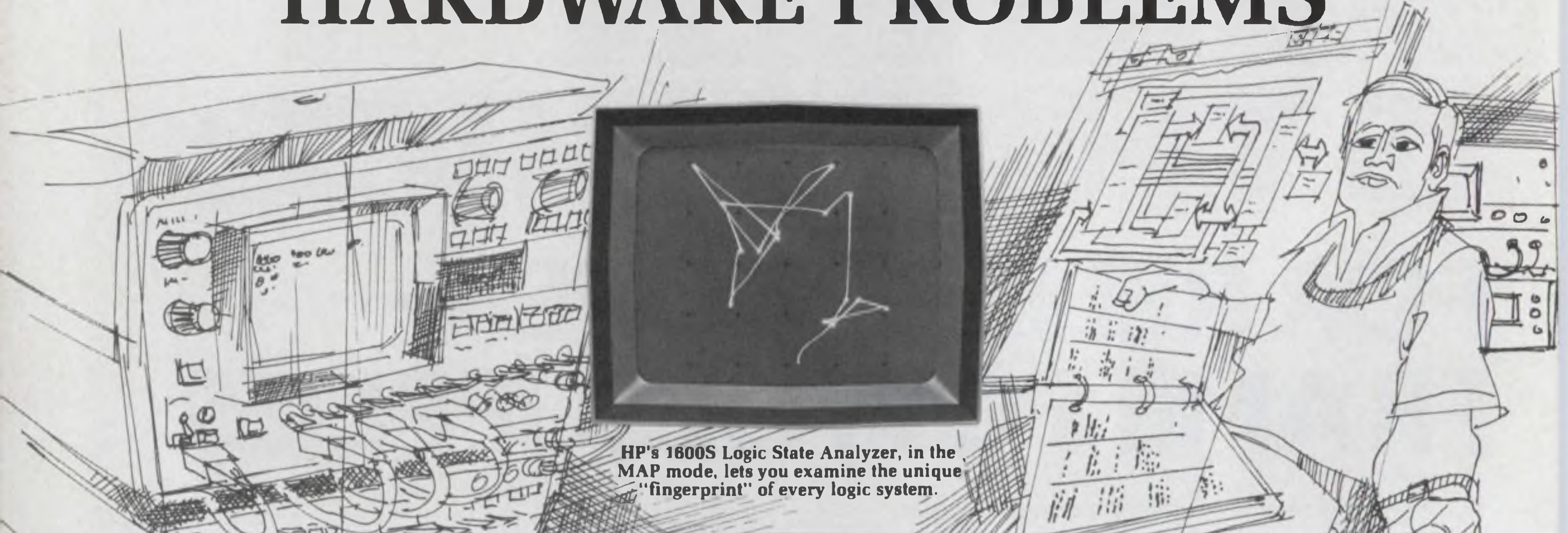
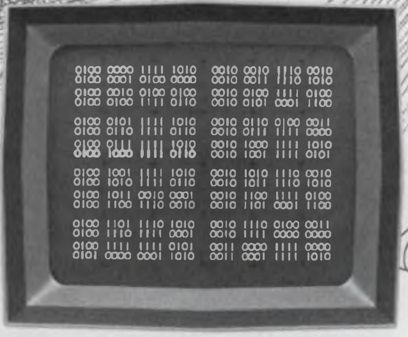
CIRCLE NUMBER 11

Let's talk about the easy way for you to spot microprocessor
HARDWARE PROBLEMS



HP's 1600S Logic State Analyzer, in the MAP mode, lets you examine the unique "fingerprint" of every logic system.



```
0100 0000 1111 1010   0010 0010 1110 0010
0100 0001 0100 0000   0010 0011 1110 1010
0100 0010 0100 0100   0010 0100 1111 0100
0100 0100 1111 0110   0010 0101 0001 1100

0100 0101 1111 1010   0010 0110 0100 0011
0100 0110 1111 0110   0010 0111 1111 0000
0100 0111 1111 1010   0010 1000 1111 1010
0100 1000 1111 0110   0010 1001 1111 0101

0100 1001 1111 1010   0010 1010 1110 0010
0100 1010 1111 0110   0010 1011 1110 1010
0100 1011 0010 0001   0010 1100 1111 0100
0100 1100 1110 0010   0010 1101 0001 1100

0100 1101 1110 1010   0010 1110 0100 0011
0100 1110 1111 0001   0010 1111 0000 0000
0100 1111 1111 0101   0011 0000 1111 0000
0101 0000 0001 1010   0011 0001 1111 1010
```

In the TABLE mode, the 1600S displays up to 16 32-bit words. These words could be combinations of addresses, instructions or states of the control lines.

We've probably both spent hours at the simulator to prove we had good software and then discovered the hardware won't play—what do we do? You know the traditional answer. Dig out the scope, get out the program printout, and brace yourself for hours of grinding, point-by-point checks. But I can tell you that doesn't have to be the case. Especially now that HP has introduced some new tools that can really cut down your troubleshooting time.

HP's Logic State Analyzers can really take a lot of pain out of your troubleshooting procedures. You'll find wiring errors, defective components, and even solder splashes; and you'll find them a lot more quickly than ever before.

Let me give you an example. We had an eight-bit microprocessor system with start-up problems. The clocks were running and phased right, and the address lines toggled, but the machine didn't function. So, we set up an HP 1600S Logic State Analyzer to look at both the Address and Data buses. It was then we noticed that only "zeros" were being fetched from memory. Knowing the ROM was good, we then added several control lines to the display and the problem showed up immediately. The "Enable" line never went high. A quick look at the "Enable" driver showed the input was ok, but no output. Obviously, the gate was defective.

I don't know how long it would have taken to find that one without HP's Logic State Analyzers, but I *know* it would have taken us a lot longer.

Call your local HP field engineer. He'll give you all the details on the 1600S (priced at $7100*) including spec sheets and application notes detailing the use of mapping for troubleshooting minicomputer and microprocessor systems. He'll tell you about the seminars that HP has arranged around the country and tell you when one will be held in your area and how you can attend. You ought to go to one, because you'll discover an exciting new concept in digital troubleshooting.

*Domestic U.S.A. price only.

088/5

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CIRCLE NUMBER 12

ACROSS THE DESK

(continued from page 11)

programs provided by HP. My programs require only 19 steps for P(m,n) and 17 steps for C(m,n) as compared to 42 and 30 steps, respectively, in the HP-25 application manual.

Being able to squeeze these functions into fewer steps allows writing many statistical programs within the pocket calculator capacity than would otherwise be possible. To keep the story short, I am presenting here only the binomial coefficient program:

```
STO 2
CLX
1
STO 3
+
STO 1
RCL 1
RCL         17 steps
X = 0
GTO 17
÷
1
STO - 2
—
STO × 3
—
GTO 07
RCL 3
```

To compute C(m,n), initial m↑n, f PRGM, R/S

Cass R. Lewart
System Development Corp.
185 Monmouth Pkwy.
West Long Branch, NJ 07764

Misplaced Caption Dept.

Another over-40 engineer thrown to the lions.

Sorry. That's Henri Rousseau's "The Sleeping Gypsy," which hangs in the Modern Museum of Art in New York City.

Our Micro-J® capacitors exceeded even our own expectations.

Not long after we introduced our sub-miniature ceramic disc trimmers, some customers began calling our attention to an error we made. It seems our Micro-J Capacitors actually perform better than we said they would.

The Quality Factor is typically greater than 1000 at 1 MHz. And the temperature coefficient of capacitance is typically better than ±150 PPM/°C over the entire operating range from —55° to 125°C. This has prompted a number of people to call our Micro-J the best ceramic disc trimmer available at any price. And one customer even suggested that we could probably start charging more for it.

We must admit we were tempted. But we decided to continue selling Micro-J's at the original price.

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☐ I desire test samples. Please call me at ____________.
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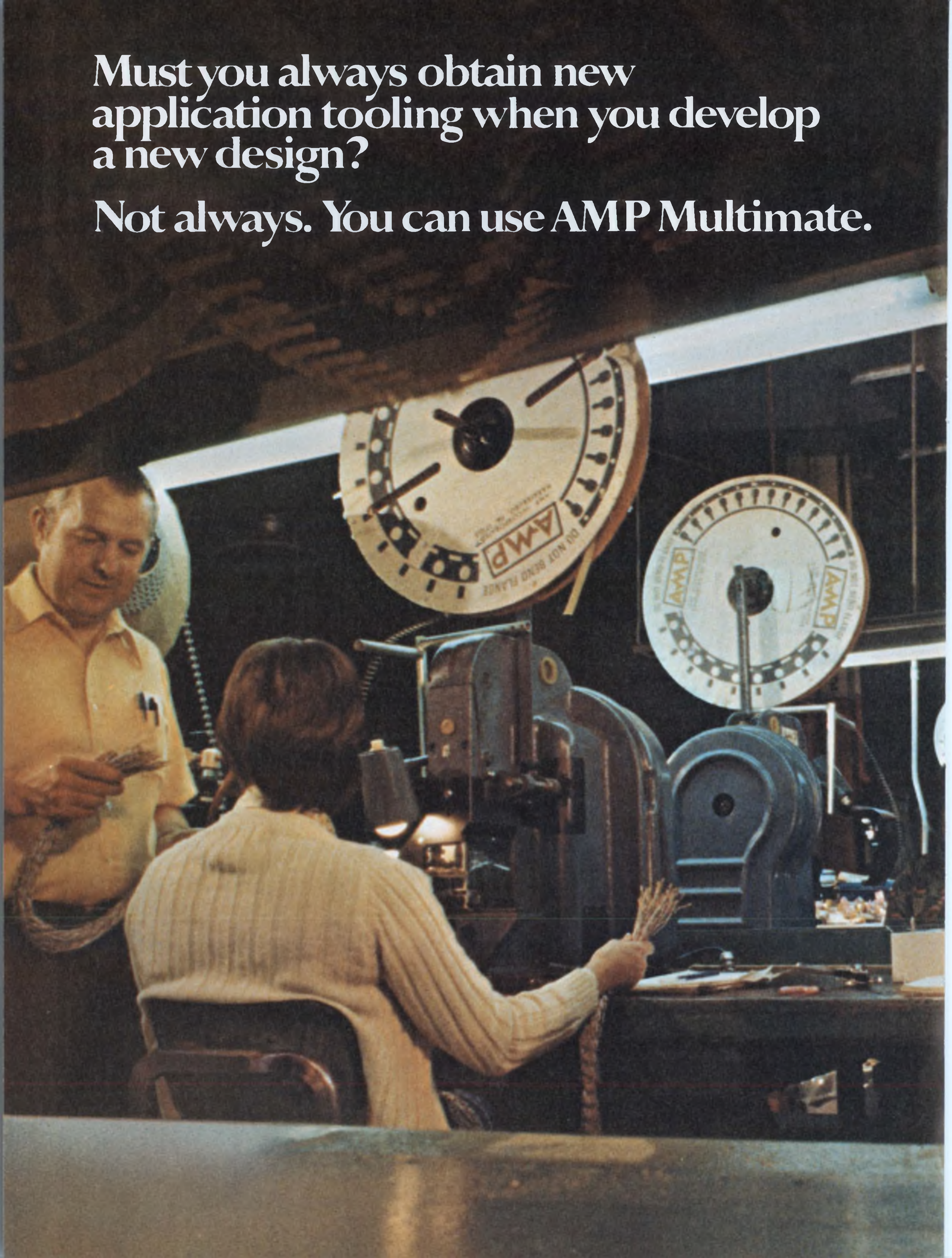
CIRCLE NUMBER 13

Must you always obtain new application tooling when you develop a new design?

Not always. You can use AMP Multimate.



You asked for a way to produce new I/O cable or internal harness designs without always having to obtain new connector application tooling.

AMP answers with the Multimate concept.

For example.

A choice of three, size 16 contacts. A screw machine contact, and 1 or 2-piece precision formed contacts. All interchangeable and intermateable plus AMP Subminiature Coaxial contacts fit in the same cavities when needed.

Then specify AMP Connector housings from many proven styles and sizes.

The rugged, economical Circular Plastic Connector, or those versatile M Series connectors widely used for commercial and military applications; or the AMP MI Connectors, designed to international standards. Additionally there is a cast shell rack and panel range as well as metal-shelled modular connectors.

If you have AMP application tooling for the Multimate contacts, you can produce these connector assemblies. And that can save inventory and allows for larger piece part volume purchases. Further savings can be made in the field because fewer service tools are needed.

Here at AMP, answering your problems is our business.

So when you work with Multimate, you can expect the kind of service and backup for which AMP is famous.

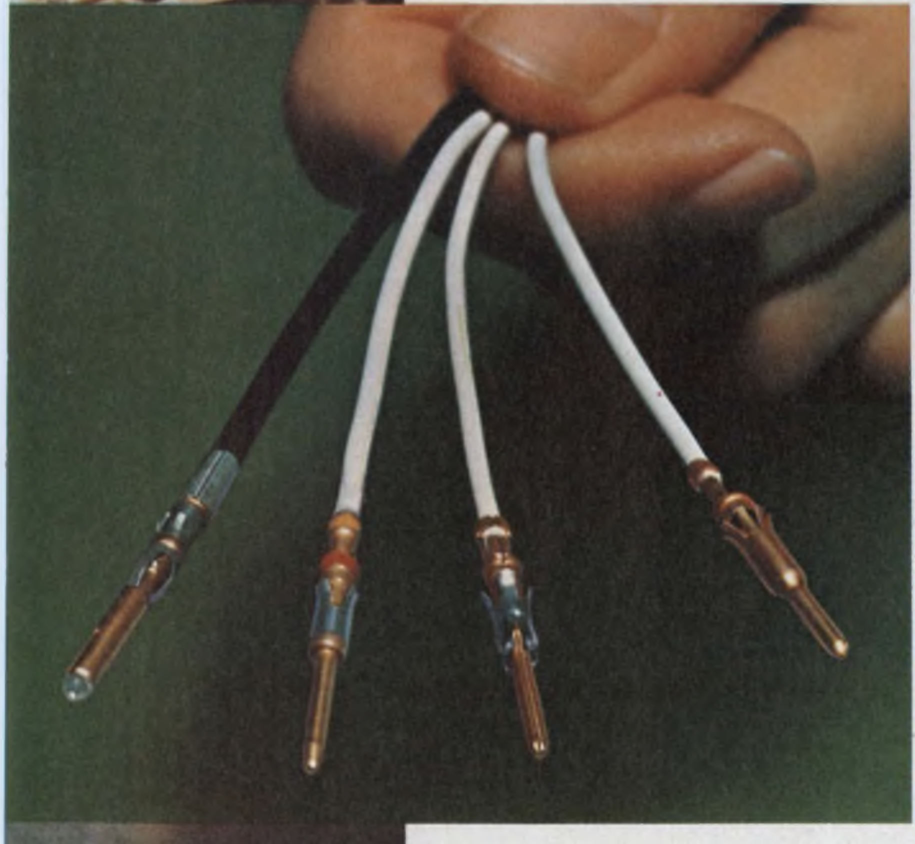
We have district sales offices around the country; they are there for one purpose only. To serve you.

With Multimate, you not only get real contact-connector flexibility, you have AMP behind your design innovations.

For information on Multimate, write or call AMP Incorporated, Harrisburg, PA 17105. (717) 564-0100.

AMP
INCORPORATED

CIRCLE NUMBER 16



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Design with the complete flat cable/connector system.

Assembly-cost savings are built in when you design a package with "Scotchflex" flat cable and connectors. But more important, 3M Company offers you the full reliability of a one-source system: cable *plus* connectors *plus* the inexpensive assembly aids that crimp the connections quickly and securely (with no special operator training required).

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With cable, connectors and assembly tools from one design and manufacturing source, you have added assurance the connection will be made surely, with no shorts or "opens."

And "Scotchflex" now offers you more design freedom than ever. From stock you can choose shielded and non-shielded 24-30 AWG cable with 10 to 50 conductors, and an ever-increasing variety of more than 100 connectors to interface with standard DIP sockets, wrap posts on standard grid patterns, printed circuit boards, or headers for de-pluggable applications. 3M's DELTA "D" type pin and socket connectors are now also available. For full information, write
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3M
COMPANY

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See our catalog in EEM 2•1034.

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CIRCLE NUMBER 14

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Low Cost and **High Density Configuration** are only two of the features of Sprague Type 216C Metanet® Resistor Networks. Now, you can also enjoy the benefits of improved power dissipation, better temperature coefficient of resistance, and closer standard resistance tolerance.

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Better TCR. Typical temperature coefficient of resistance is within ±200 ppm/°C, cutting previous allowable limit almost in half.

Up-graded Power Dissipation. Individual terminating, pull-up/pull-down, and interface networks are capable of dissipating 250 mW per resistor at 70°C, an increase of 100% over previous designs.

Closer Resistance Tolerance. Standard resistance tolerance for each resistor is ±2%, with other tolerances between ±1% and ±5% available on special order.

Proven Product Line. Sprague has more than fifteen years of experience in the development and manufacture of precision thick-film resistor networks, which include individual terminating, pull-up/pull-down, interface, and dual terminating designs.

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CIRCLE NUMBER 15

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REI stocks over 8,000 fully checked-out test instruments. And they're ready whenever you are. For the full story on renting as well as our low prices, send in the coupon for prompt delivery of our free illustrated catalog. Or call us now for your immediate requirements.

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CIRCLE NUMBER 17

Consumer electronics show highlights television games

Semiconductor manufacturers are pursuing the latest consumer electronics market—video games—with the same zeal that accompanied the introduction of calculators and digital watches in previous years.

This was evident at the recent Consumer Electronics Show in Chicago, where no less than 30 manufacturers displayed the latest video games. Their products ranged from low-cost, single-chip games without sound or color, to single or multiple-chip games with both sound and color.

At the most expensive end, interactive entertainment, and education centers using microprocessor systems under local program control were unveiled.

Of the 30 or so games, some 20 used General Instrument's single-chip game IC, the AY-3-8500. The chip was designed with n-channel devices, and uses dedicated microprocessor logic.

Both black-and-white and color games in single-chip form are programmed on the chip. These games include tennis, hockey or soccer, squash, practice skeet and random-target rifle shooting. Discrete supporting circuits are required for interfacing with the TV.

National Semiconductor is marketing its own "Adversary" game, which is a full-color system that has three game options: tennis, hockey and handball. The National system has one game chip and two supporting interface chips.

Other manufacturers producing game chips include Texas Instruments, American Microsystems and MOS Technology. More firms are expected to join the video-game bandwagon.

The arrival of the long-heralded home computer terminal may be hastened by the development of microprocessor systems with programs that can be interchanged by the user. One such system is Videospond by Rockwell International. The Videospond uses the Rockwell PPS-8, a programmed tape cassette, keyboard, and a color TV for display.

Programs demonstrated included those for math calculations, interactive child or adult teaching programs, and a variety of games. The system is not being marketed as yet.

Universal Research (Des Plaines, IL) demonstrated an interactive game and educational system using a video-tape cartridge to provide question-and-answer formats as well as to display recipes and perform other interactive chores.

Universal already has several cartridges available and is working with software houses and book publishers to develop a library of information.

Fairchild's "Video Entertainment System" was also introduced at the show. The system incorporates the F-8 microprocessor, and allows the user to plug in a plastic cartridge that contains 8-k-bit programmed ROMs. Use of the ROM—rather than tape—to contain the programs prevents the software from being copied, such as can easily be done with magnetic-tape cassettes.

National Semiconductor is also using semiconductor-memory cartridges, rather than cassettes or other tape media in programmable systems now under development.

Marines test ground-unit concept before buying

The Pentagon's practice of flying an aircraft before deciding whether to buy it or not, has now been extended to ground equipment.

A command-and-control system is being built for the Marines that the Corps will evaluate, not only for its performance but also for the feasibility of the initial concept: did they ask for more automation than they need? too little? in what specific areas?

Called the Marine Tactical Command-and-Control Systems, the test version for the program will serve as the basis for a family of closely-related systems. They will all use. integrated data-processing equipment to automatically receive, process, display and distribute the tactical information that Marines need to plan and control both amphibious landings and the ground operations that follow.

The system—which is being built by the Ground Systems Div. of Hughes Aircraft, Fullerton, CA—is designed around a Control Data CDC-3500 computer with 20 megabytes of memory. It also contains both graphic and text-only CRT displays. The text-only displays. are controlled by a Digital Equipment PDP-8 minicomputer.

"With the computers, displays and communications equipment available in this test-bed, the Marines can evaluate various approaches to automating their future command-and-control needs," says Robert Sandell, project manager at Hughes.

All of the equipment used on the test-bed is commercially available and off-the-shelf, rather than custom-designed to MIL specs.

Three μPs share memory and drive machine tools

For the first time, three microprocessors are working together to control the various functions of a numerically-controlled machine tool.

The system, developed by Actron of Monrovia, CA, assigns the functions of input/output controller, path calculator and servo control to individual μPs and provides a single memory that they all share.

Custom-designed 16-bit NMOS μPs were designed for Actron by Nitron, Cupertino, CA. Both Actron and Nitron are divisions of McDonnell Douglas Corp.

The most important advantage presented by the μP system is the increased reliability that it offers compared to other systems now available, according to S. G. Froyd, engineering manager at Actron. "The projected MTBF (mean-time-between-failures) of the Actron systems is 2500 hours as compared to 536 hours for a hard-wired NC system and 984 hours for a mini-computer-controlled NC system," he says.

He also notes that: "The majority of NC workpiece rejections result from servo problems. To overcome these problems, one of the microcomputers has resources available to compare the NC output (velocity reference) to actual machine speed (from the position feedback transducer).

"Further, it can take into account gain, transport lag, etc., and continuously monitor the performance of the machine axes—providing warning and fault signals before the part is miscut. This function is analogous to having an NC maintenance technician permanently installed on each axis, continuously rechecking the following error."

If the equipment fails, pushbutton-actuated, board-level self-test circuits are resident in the system. LEDs are used as readouts of self-test results.

The controller can be used with any NC machine tool.

Everest climbers to carry medical data sensors

An expedition to scale Mount Everest next spring is expected to provide new medical data on the operation of the heart and lungs under conditions of limited oxygen and extreme stress.

Such conditions are similar to those that exist in advanced coronary and pulmonary cases, where the lungs fail to oxygenate the blood properly and the oxygen level in the arteries falls to low levels.

Ten experienced mountain climbers will carry with them an array of electronic physiological monitoring equipment designed to measure heart and respiratory functions under the severe temperature and atmosphere conditions found atop the world's highest peak.

The lightweight equipment will be strapped to the climbers' bodies. It includes a four-channel tape recorder with sensing attachments, to record electrocardiograms (ECG), respiratory frequency, and respiratory volume. A fourth channel on the recorder is used for timing.

Studying the results on a round-the-clock basis will be an international team of medical experts led by Dr. Michael Ward of the University of London, who was a member of the 1953 expedition—the first group to reach the summit of the 29,000-ft peak.

The medical team will climb to a camp at the 20,000-ft level, with the professional climbers continuing to the summit.

The recording and monitoring equipment built by Ambulatory Monitoring Co., Inc., Ardsley, NY, is designed to record continuously for 24 hours, on a single magnetic tape cartridge. High-speed playback equipment built by the same company allows the entire recorded tape to be analyzed or visually displayed in less than one-half hour. The operator can set limits on such recorded parameters as heart rate. When the playback device senses that these limits have been exceeded, it alerts the operator.

Expedition plans include transmitting the ECGs, by radio, from climbers at the summit to the medical group at the base camp. The transmitter presently available has a relatively short range, on the order of 2 to 3 miles, reports Dr. John West of the University of California Medical School, La Jolla, CA.

To increase the range, the transmitter's output stage will be modified to deliver more power, and a high-gain antenna will be added to the receiver, he says.

New process advances uniformity of thermistor

One of the problems in manufacturing thermally sensitive resistors (thermistors) is the difficulty in obtaining uniform electrical characteristics. Now, engineers at Victory Engineering Corp., Springfield, NJ report that they have developed a new thick-film process that results in chip thermistors that are not only more homogeneous but weigh less and are smaller than equivalent pressed-disc types.

The new process used to make the so-called Sensichips makes use of a slurry of metal oxides in which each grain of oxide is uniformly coated and deposited through a screen . . . as a "slab."

The green 2 by 2 in. slab is then fired, metallized (thick-film deposited) top and bottom, and fired to effect an intimate metallurgical bond. A high-speed, multiple-blade diamond saw is used to cut the slab to the required size. Conformal coatings can be applied so that the final product approaches hermeticity.

"Since the chips from any given slab or mixture are in a uniform slurry," a Victory spokesman says. "The resulting chips from any given slab or mixture are quite homogeneous in terms of electrical characteristics.

"Further, thermal response times are typically 4 seconds, as opposed to 9 seconds for competitive devices."

Sensichips are available in 0.020 in. to 0.300 in. on a side; thicknesses from 0.005 in. to 0.070 in. and resistances from 5 KΩ to 1 MΩ.

Prices of the thermistor will range between 25¢ and 50¢ in modest volume.

CIRCLE NO. 310

Biggest Wescon show since 1970 is expected

Wescon's silver anniversary, to be celebrated in the Los Angeles Convention Center from Sept. 14 to 17, will be the largest Western Electronic Show and Convention since 1970, according to Wescon officials.

Approximately 400 companies will occupy 725 exhibit units on the convention floor, to be seen by 30,000 to 35,000 visitors.

A program of 35 half-day sessions will be held—five sessions at a time, with full-manuscript preprints available for most of the papers, and audio tapes of the discussions.

The exhibits will be presented in product-interest categories: components and microelectronics; instruments and instrumentation, production and packaging equipment, and computers, peripherals and communications.

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CIRCLE NUMBER 18

Your next digital logic analyzer.

Biomation's new 851-D 8-channel, 50 MHz logic analyzer.

Digital logic analyzers are revolutionizing the solutions of design and trouble-shooting problems. Biomation, building on our early waveform recording technology, has created the tools you need for your fast new digital world. We offer the most complete line of logic analyzers anywhere. And our thousand-plus customers have helped us develop the most useful features for real-world problems of digital system design and test. Our new 851-D catches, records and displays 8 channels of high speed logic. It is the slickest handling, most cost-effective logic analyzer we've seen yet. But don't take our word for it. Check over the features for yourself.

• Ideal companion for your 2-trace portable scope • Portable and self-contained • 8 channel • 50 MHz • Digital delay for precise trigger control • Accepts synchronous clock input (0° or 180° phase) • Provides internal clocking • Catches glitches as *narrow* as 5 ns • Pre-trigger recording • 512 bit per channel memory • Captures 512 words before, after, or around the trigger • Expanded and mixed display • Constant brightness expand to X20 • Combinational "true" trigger • "Any-change" trigger • Built-in delay (4 digit) • Latch mode (catches single pulses) • Adjustable threshold levels for channels 1-4 and 5-8 • Step-and-wait cursor control • Steps through data one bit at a time • Price: $3575. • Delivery: 30 days A.R.O.

What next?

If you want to see a demo, right now, of our new 851-D or any of our digital logic analyzers (we have both less expensive and more powerful models), pick up the phone and call (408) 255-9500. Ask for Roy Tottingham at ext. 851 D. Or circle the reader service number and we'll send data. Biomation, 10411 Bubb Road, Cupertino, CA 95014.

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(851-D shown actual size.)

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TWX 910-338-0226

CIRCLE NUMBER 19

To use custom LSI or μPs? That is often the question...

Today's design engineer faces a problem: Should he design a new project in-house using a microprocessor, or should he buy a custom LSI circuit from an outside vendor?

Most of the time, the decision isn't easy. The engineer must consider both circuit-development cost and time. These must be balanced against production costs and future design changes.

Sometimes the nature of the product itself may dictate the use of either a custom LSI or a μP. The size of the final product may freeze the choice. It would be nearly impossible to make a μP-based wristwatch and still have it fit on a wrist, and the power consumption would also rule against a watch application. Similarly, most μPs are not fast enough to handle numerous I/O operations on a real-time basis, nor are they structured for a "soft-fail" application such as an automotive controller.

"Engineers are continually forcing μPs into applications where μPs are not suited—high volume applications, where system cost and the limitations of having extra flexibility show up," says John Hall of MicroPower Systems, Santa Clara, CA. "You can mechanize a clock with a μP, but it wouldn't be cost effective."

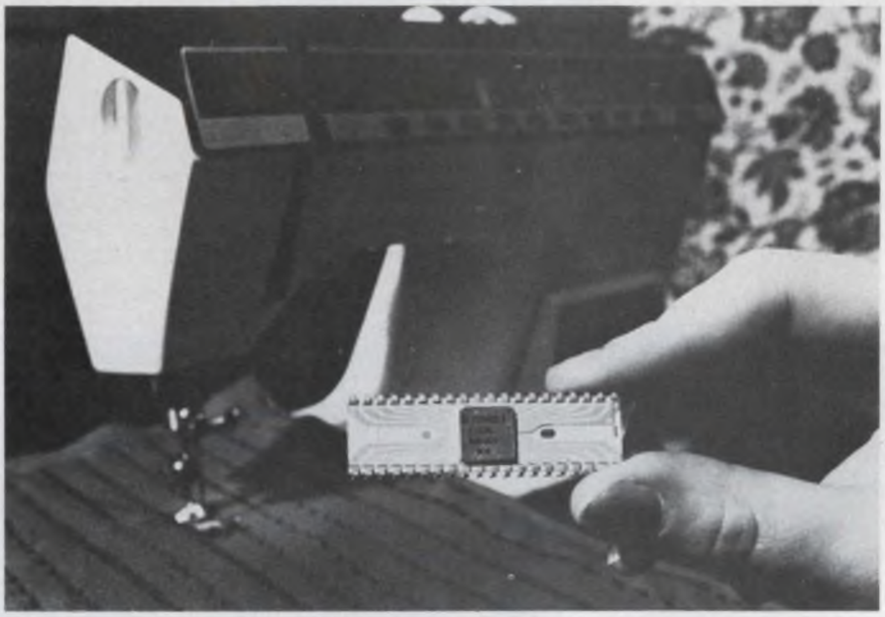
Ben Anixter of Advanced Micro Devices, Sunnyvale, CA, carries this thought one step further: "Historically, custom circuits always cost more than standard products, although in specific systems standard circuits can represent an overkill or underkill solution."

And that's really the point. How *does* the designer tell which approach is better in his particular situation?

He looks at the number of systems he must build, and he looks at the time it will take to build them . . . and at the manpower and assembly requirements.

He looks at the final product's performance and its required flexibility . . . and at the money required for start-up and at the reliability of custom parts vendors.

Finally, he looks at his crystal ball and projects the project's future. With all this in mind, he sets the project's course and proceeds to implement his decision.



Sewing machine control chip replaces 350 mechanical parts. AMI made the custom LSI circuit to Singer's specifications.

How many systems? When?

"Custom LSI can be attractive to us at the ten thousand pieces per year level," claims Bill Sanderson, custom MOS manager at National Semiconductor, Santa Clara, CA. But most other IC houses require a minimum order committment of 30,000 to 100,000 parts to do business. Generally, the larger the volume of circuits required, the more desirable the custom LSI business becomes for both vendor and customer.

This point is illustrated by the video games market. Home video games sell in large quantities for a low average selling price, and thus are a prime candidate for custom LSI (and, in fact, they are predominantly custom LSI.)

Coin operated arcade-type video games sell in smaller quantities, have more diverse functional requirements, and command a higher selling price. These are generally μP controlled.

Appliance controllers, keyboard encoders, automotive controllers, and electronic organ circuits all are being made today using custom LSI. The television industry is

---

Jim Gold
Western Editor

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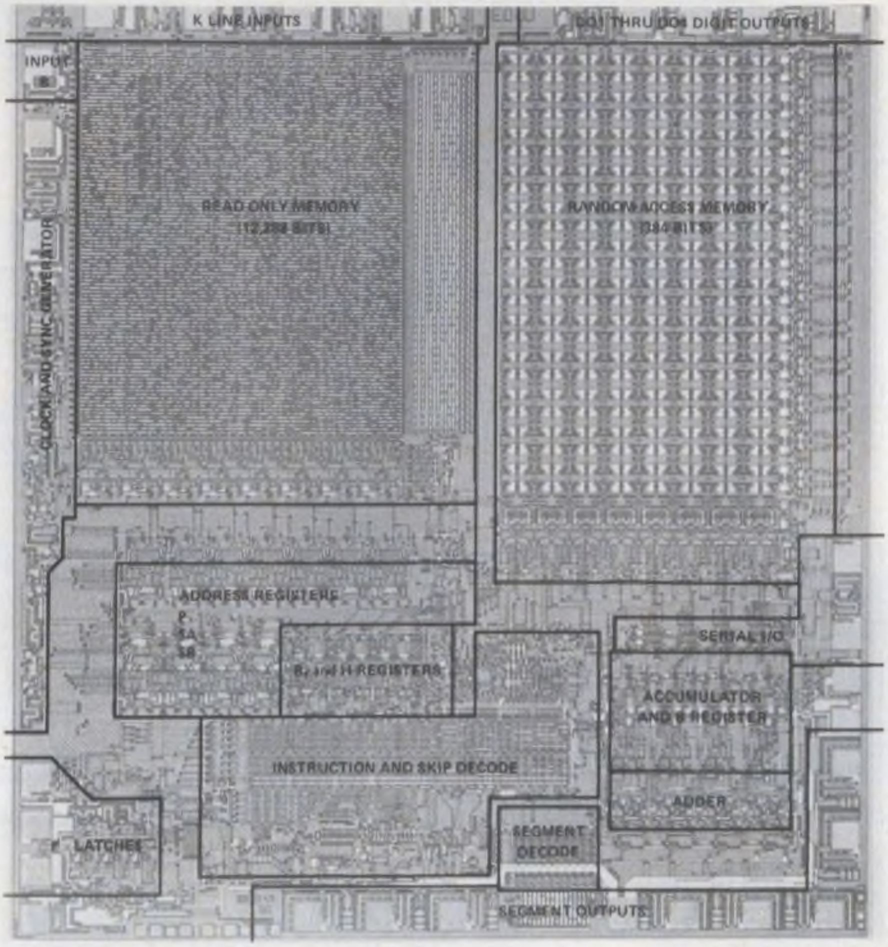

Programmable calculator chip from National Semiconductor processes 4-bit data words and 8-bit instruction words. It contains all system-timing, arithmetic and logic, RAM, and control-ROM functions.

heavily into custom LSI due to the industry's high-volume, very cost-conscious posture.

But there is a practical limit that is reached as the cost of the electronics becomes a smaller and smaller portion of the cost of the finished product, and other factors override volume considerations. Factors such as time.

The time required to produce prototype quantities of custom LSI circuits is an important issue for the designer. Generally six to nine months is a realistic figure, but various manufacturers are developing techniques for reducing it.

American Microsystems, Inc. (AMI) of Santa Clara, CA, is developing a computer-aided layout and artwork generation system, and Signetics has a standard building-block Composite Cell Logic for use on custom circuits. The Signetics approach reduces to about 20 weeks the time needed to prototype quantities at the 300 to 400-gate level of complexity.

"Custom chips in ten weeks for $10,000 are not far off," with improved design and layout aids, according to Jim Meyer of Silicon Systems in Santa Ana, CA.

Time is an important concern in using custom LSI, because in many instances there is a real risk that someone will beat you to the marketplace.

"Future shock is on us in spades," emphasized Bob Lloyd, National Semiconductor's group director for MOS/LSI systems. "The useful manufacturing life of equipment is getting shorter, and sometimes response time in getting to market is more important than manufacturing cost."

Prototype first-generation systems frequently are designed with μPs in them, so they can get into the marketplace quickly, while custom circuits are developed to replace the μPs to lower costs later. "Microprocessor-based systems get to market sooner than hard-wired systems, achieve a greater market share, exhibit longer usage lifetimes, and are more profitable," stated Bill Baker, group director for μPs at National Semiconductor.

The custom LSI vendor is quick to point out that substantial savings can be achieved using their approach in not having to hire hardware, software, and interface engineers to support a μP development project. (This engineers team must also be charged with selecting the correct μP to do the job). In addition, software documentation is not required for the custom LSI part, unless it is programmable.

It is true too, that a number of the standard μP manufacturers have spent significant amounts of money on μP-support hardware and software. Some μPs, such as PACE and SC/MP from National Semiconductor, are grouped into "families" so that understanding of one greatly facilitates learning the other.

Already some μPs are departing from the scene, and the designer who choses the wrong μP for his system may have to redesign if his chosen one is discontinued. Custom circuits, on the other hand, are contracted for on an individual basis and cannot, with impunity, be discontinued.

System assembly costs are also reduced by using custom LSI. There are fewer parts in inventory since one custom chip usually replaces a μP *plus* support chips. There are fewer leads to solder, and thus higher reliability and lower assembly costs.

Smaller, cheaper power supplies can be used with custom LSI designs generally, too.

Performance and flexibility

Microprocessors tend to have only digital inputs and outputs, but custom LSI may have any type of communication with the outside world that the user is willing to pay for. Custom ICs can be designed with specific I/O functions on-chip—for example, triac drivers, or special automotive-sensor interfaces.

Where the particular application is input/output intensive, the implementation leans toward a custom

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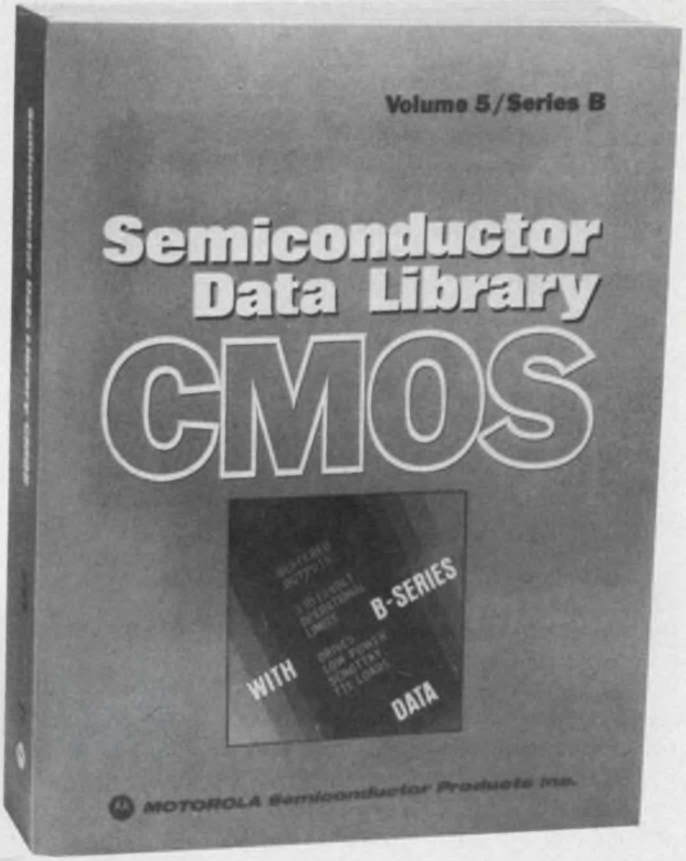

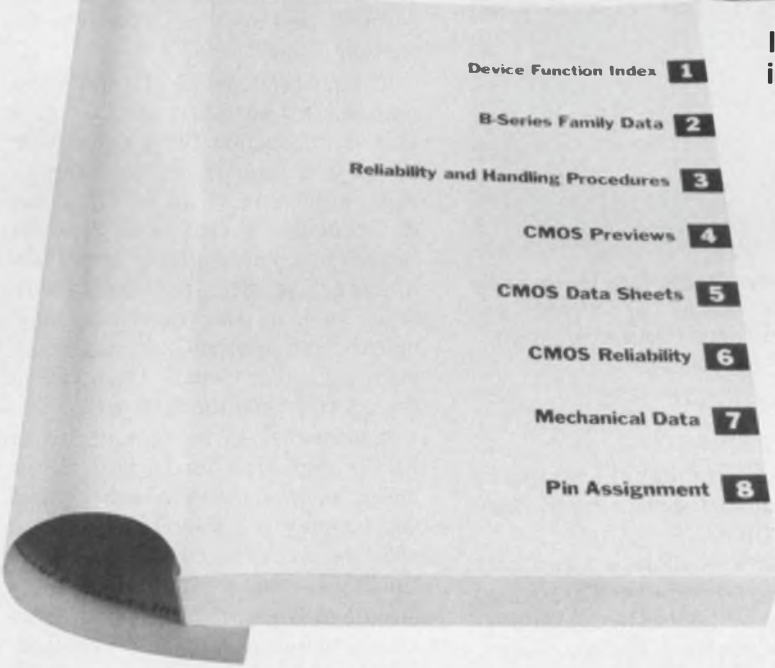

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chip. But on the other hand, where it is computation intensive, the μP would gain an edge. If the I/O intensive application could be structured into a bus-oriented design, the bus-oriented μP, of course, would be preferred.

Alternatively, applications requiring much floating-point arithmetic might demand either a sophisticated μP or even a minicomputer. The μP is a general-purpose device, and in the absence of other considerations, unless sufficient use is made of its generality, a custom circuit may be a better choice.

A μP is ideally suited for applications in self-diagnostic systems, or systems that can be field-modified to upgrade performance.

In fact, the advent of the μP allows the manufacturer of many similar products to take advantage of the benefits of mass production. He may initially make all of the products identical, and then customize them by providing individual control ROMs for the μPs. For example, one generalized traffic-light controller may be mass-produced, and customized for each street installation by ROM coding.

The μP approach allows simple modification of the circuit operation with software changes, where the custom circuit has only the flexibility it was designed with. This is significant. For example, a recent seatbelt interlock design had to go through over five iterations of functional design before it was acceptable. It used custom-LSI circuitry, for a μP-based design, on the other hand, only the ROM would have had to be changed.

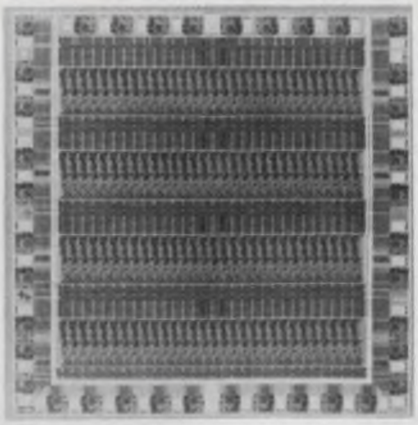
Flexibility may also be needed to respond to competitors' moves in the marketplace.

Start-up costs and risks

"The custom-LSI producer has to get his development money in advance, otherwise there's always the risk that the customer will cancel halfway through the development process," states Clement Lee, LSI product manager for Signetics.

The figures on start-up charges vary from company to company, but they generally range from $25,000 to $60,000, with $35,000 as a good average.

But the dollar-commitment includes more than the initial start-up costs. Custom LSI vendors also generally require a commitment to buy a certain minimum quantity of parts at preset prices over some period of time.



158 TTL NAND gates await connections to become a custom circuit. TRW Systems uses this approach to provide six-week turnaround to working parts.

High-density CMOS CB-frequency synthesizer made by MicroPower Systems to Fanon/Courier's design.

The larger IC houses frequently require a guarantee of $250,000 to $1-million in profitable sales revenues to institute a custom project. Smaller vendors require correspondingly fewer guaranteed sales.

And there are always some risks in buying custom LSI. One risk is the problem of second-sourcing. It does little good to be able to point to a contract in court when your custom LSI house has trouble delivering parts. Second-sources for custom parts can be as important as for standard ones.

"I don't want to do custom business with you if you don't own the mask set, according to Ron Hammer, CMOS product manager for Intersil in Cupertino, CA. "I've never worked for a semiconductor company that didn't have problems occasionally producing products. It's not fair to the customer, nor to the company to sole-source custom products."

But only just recently have custom LSI vendors started cooperating on sharing the process parameters needed to allow use of the same photomasks on two vendors' wafer-fabrication lines. Many processes are still not second-sourced, so the danger of process problems affecting deliveries still exists.

Many IC houses do not like being used merely to process wafers using customers' masks, and Advanced Micro Devices is one.

"Some customers see the vendor as a foundry, remarks Ben Anixter. "Just processing wafers to someone else's masks is not cost effective. The only time to do that is when the industry is in a slump. There just isn't sufficient value-added to make a profit. Capitalism is risk-reward, that's very foreign to the custom circuit guy."

The custom circuit offers the potential user security, in that it is almost impossible for a competitor to copy it exactly in less than a year, according to an LSI feasibility study by MicroPower Systems. Security is particuliarly important in feature-sensitive consumer industries, such as the television, automotive, and appliance arenas. However, a custom circuit often can be copied functionally by a μP.

Another risk in using custom LSI is that after an IC is designed based upon a breadboard circuit, the IC may not function the same way the breadboard did. Propagation delays on a single integrated circuit are faster than in communicating between chips. Circuit loading is different, and power dissipations change.

Some of these problems can be sidestepped if you use techniques for avoiding race conditions, and employ totally clocked systems. These risks of device nonfunction can be minimized by consultation with custom-LSI vendors.

"The high-volume user is taking us to a more custom product. As a result, we have to take the fat out

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of our processors," explains Joe Mingione, director of custom products at AMI. "Dedicated processors make a lot of sense—the automotive area comes to mind."

The markets for video games, microwave ovens, whitegoods timers, television, sewing machines, and telecommunications are also fields where custom μPs are now being used.

"If the customer needs the I/O-control-oriented functions of the F-8, there's no way that custom circuits can compete in function. And this holds for the TMS-1000 and 8048, too, claims Don Winstead of Fairchild Micro Systems, San Jose, CA. "We expect to see prices in the $3 to $5 range in 100k quantities on these."

These parts and the new PPS-4/1 introduced by Rockwell International in Anaheim, CA, are true μPs, but with customer-specified ROM and RAM on-chip. The F-8 is typical, with a $1500 charge for masking the ROM and six week delivery on custom-masked parts.

Calculator-oriented μPs

The requirement for families of hand-held calculator products with ever-increasing repertoires of instructions led to small, cheap, simple calculator-oriented processors whose initial hallmarks were keyboard entry and LED-display outputs. These have been expanded in function to BCD output as well, and are well suited to the minimum-system, dumb-controller market. Uses in parking meters and appliance timers, or as computation blocks for μP-based systems, are naturals for this kind of product.

The calculator-oriented processor also, when it does not have all of its ROM and RAM on-chip, may be structured using separate instruction and data busses to simplify programming and optimize memory requirements.

The cost of modifying a calculator-oriented processor (COP) for a custom application is in the $5000 to $10,000 range, and about three months are required, according to Bob Lloyd.

"We're seeing a trend toward general-purpose architectures, and general-purpose designs," he explained, "but not a general-purpose chip. We're seeing designs where we can change either the digit length or PLA terms, for specific applications or to make a specific product."

The easy way out

Finally, for the lucky few designers whose requirements are for small circuits, there is the do-it-yourself approach to custom LSI, in which a standard IC with many unconnected transistors, gates, and other components is produced in large quantities by an IC manufacturer. Then only a customer-specified metal interconnect is required to produce a custom circuit.

In this technique, frequently the designer himself specifies where the metal runs. The only problems are: Does the chip have enough parts, and can they be connected to do the job? But fifty parts delivered in three weeks for $1800 is an attractive incentive for exploring this route. ■■

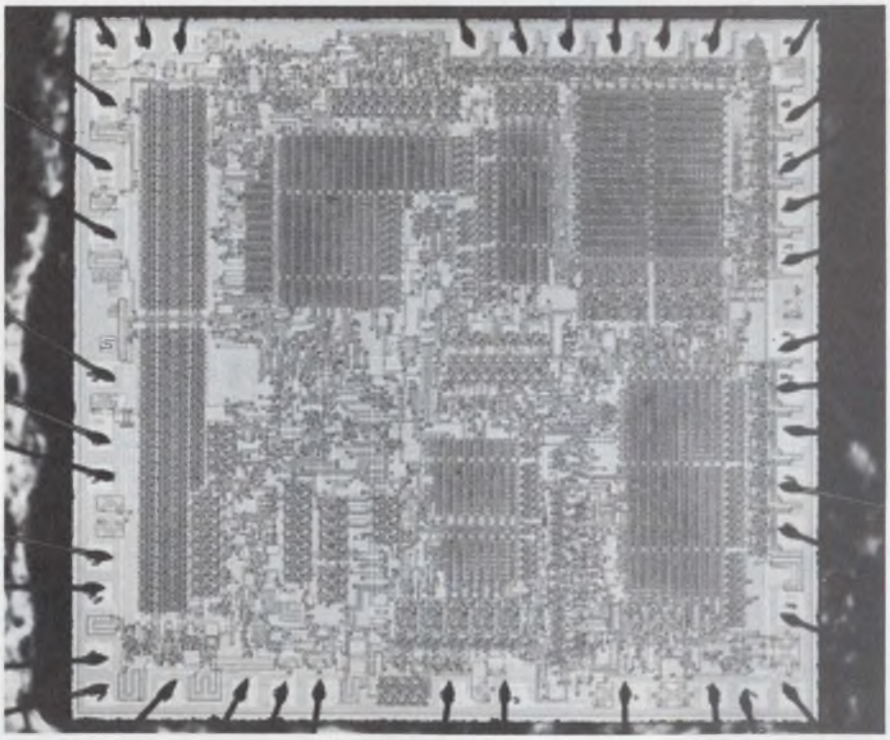
Doing it in custom LSI

The first thing the designer must do is define all of the circuit's characteristics as well as possible. That means identifying input and output functions and electrical parameters, and outlining the timing relationships between inputs and outputs. It also means specifying power-supply voltage ranges and operating temperature range.

A schematic or block diagram should be generated to accomplish the required function, and it should be analyzed for freedom from race conditions, and susceptibility to malfunctions due to illegal input state conditions. Breadboard and computer simulation may well be advised in analyzing the schematic before commiting it to silicon.

Then vendors of custom LSI should be contacted to determine the best process and company to manufacture the parts. The complexity of the circuit may play a part in determining the company chosen. While the state of the art in producing commercially feasible LSI is now in the 5000-gate complexity range, many companies are limited to the 500 to 1000-gate custom business.

Having chosen a vendor, the next steps are to negotiate a contract, pay your money, and receive your parts.



Automatic telephone dialer, a custom LSI circuit that uses μP techniques by Synertek, Santa Clara, CA.

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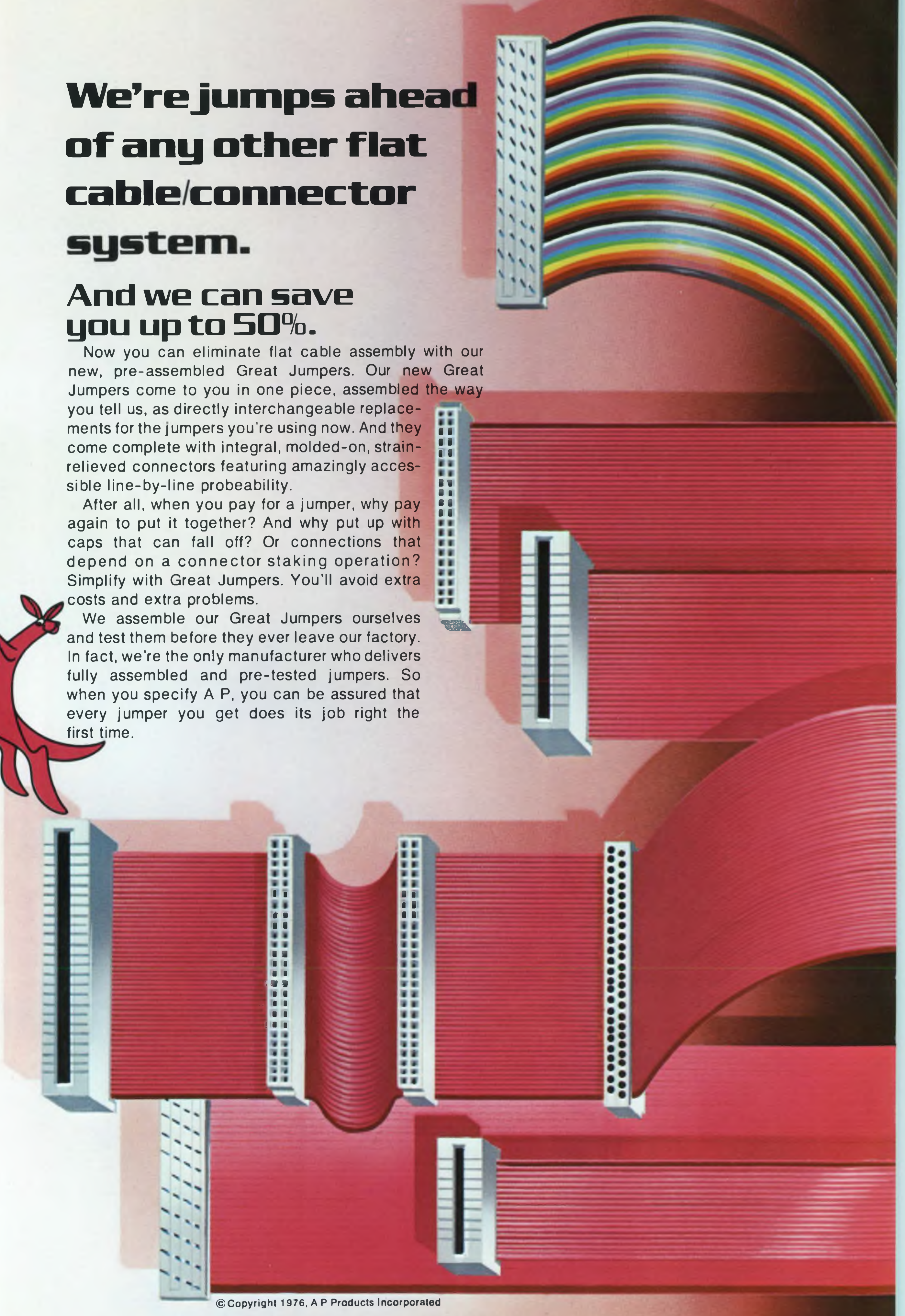

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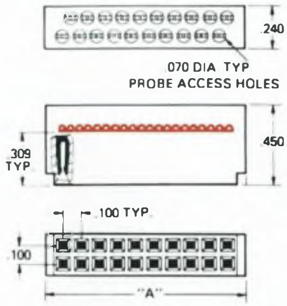
Second, choose your connectors.

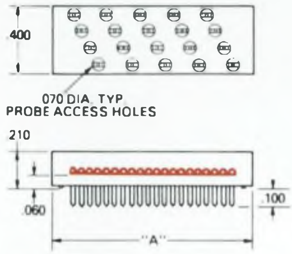
	Top View	Side View	Right Connector	Contacts Left	Contacts Right	Style Code
Left Connector (Socket) 	**Stripe Up**		None	Down	N/A	922501
			Socket	Down	Down	922521
			PCB	Down	Down	922522
			Card-Edge	Down	Down	922523
			Socket	Down	Up	922531
			PCB	Down	Up	922532
			Card-Edge	Down	Up	922533
	Stripe Down		None	Down	N/A	922511
			Socket	Down	Up	922541
			PCB	Down	Up	922542
			Card-Edge	Down	Up	922543
Left Connector (PCB) 	**Stripe Up**		None	Down	N/A	922502
			Socket	Down	Down	922526
			PCB	Down	Down	922524
			Card-Edge	Down	Down	922525
			Socket	Down	Up	922536
			PCB	Down	Up	922534
			Card-Edge	Down	Up	922535
	Stripe Down		None	Down	N/A	922512
			PCB	Down	Up	922544
			Card-Edge	Down	Up	922545
			Socket	Down	Up	922546
Left Connector (Card-Edge) 	**Stripe Up**		None	Down	N/A	922503
			Socket	Down	Down	922528
			PCB	Down	Down	922529
			Card-Edge	Down	Down	922527
			Socket	Down	Up	922538
			PCB	Down	Up	922539
			Card-Edge	Down	Up	922537
	Stripe Down		None	Down	N/A	922513
			Card-Edge	Down	Up	922547
			Socket	Down	Up	922548
			PCB	Down	Up	922549

Socket Connector



No. Contacts	Dim. "A"
20	1.160
26	1.460
34	1.860
40	2.160
50	2.660

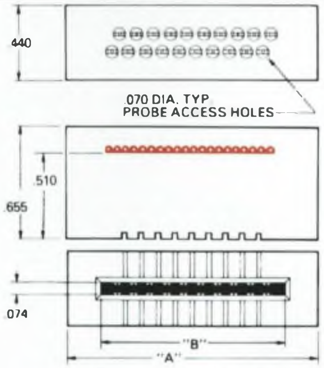
PCB Connector



No. Contacts	Dim. "A"
20	1.200
26	1.500
34	1.900
40	2.200
50	2.700

Request Bulletin 7.04 for PC board drill patterns.

Card-Edge



No. Contacts	Dim. "A"	Dim. "B"
20	1.500	1.100
26	1.800	1.400
34	2.200	1.800
40	2.500	2.100
50	2.980	2.600

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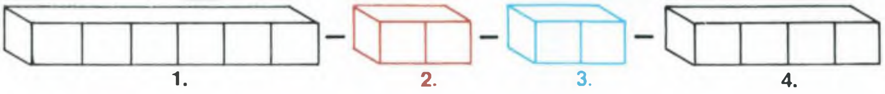

1. Enter 6-digit style code (see chart)
2. Indicate whether 20, 26, 34, 40 or 50 contacts in connector
3. Enter "01" for Electric pink solid conductor cable.
   Enter "02" for Electric pink stranded conductor cable.
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4. Enter tip to tip length in inches.
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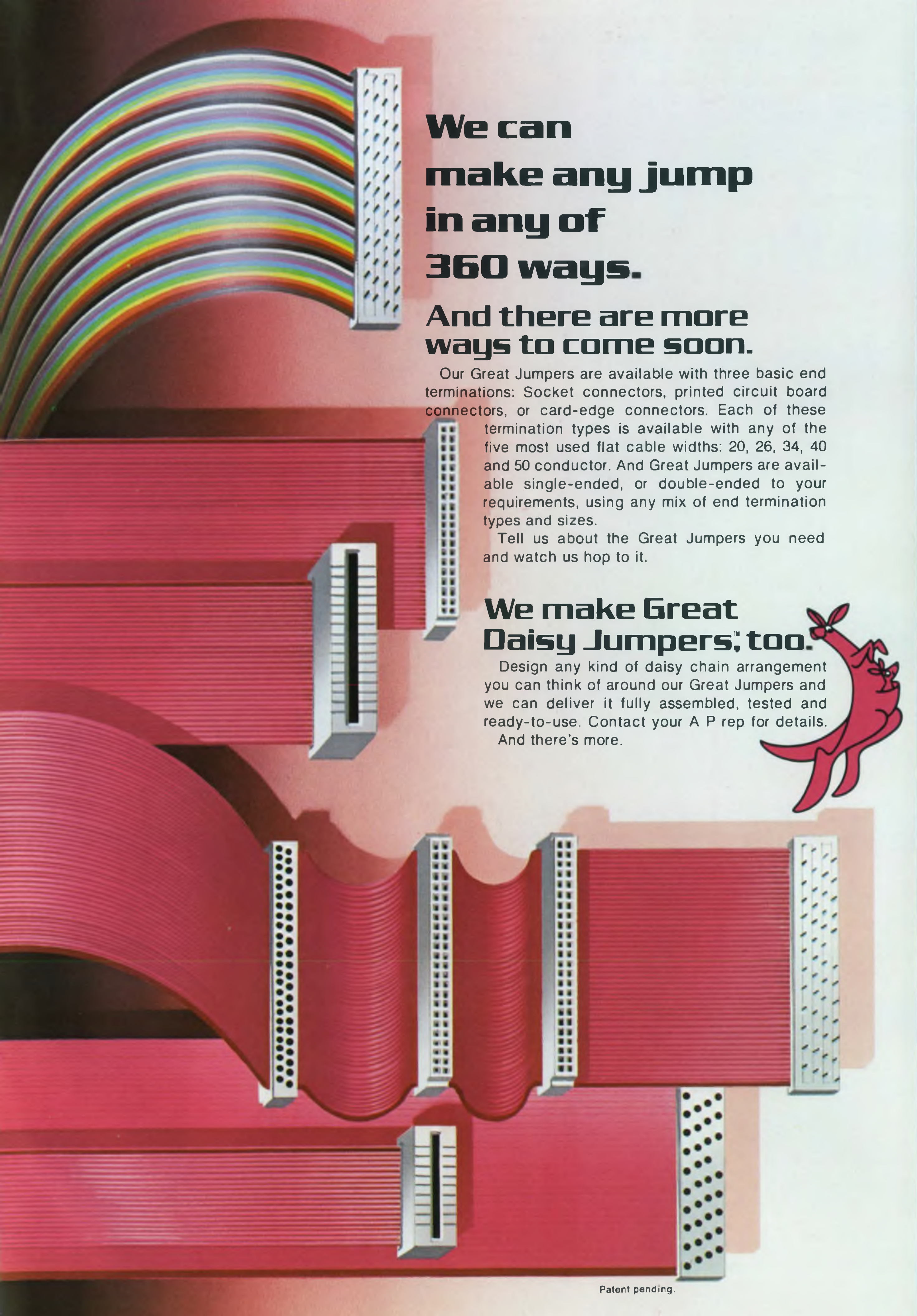

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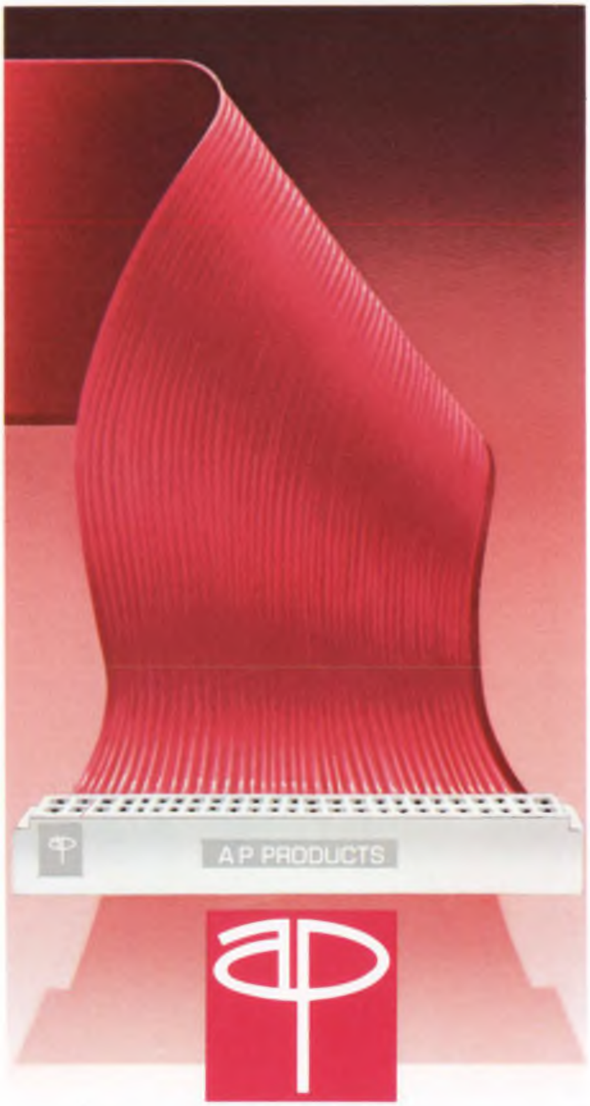

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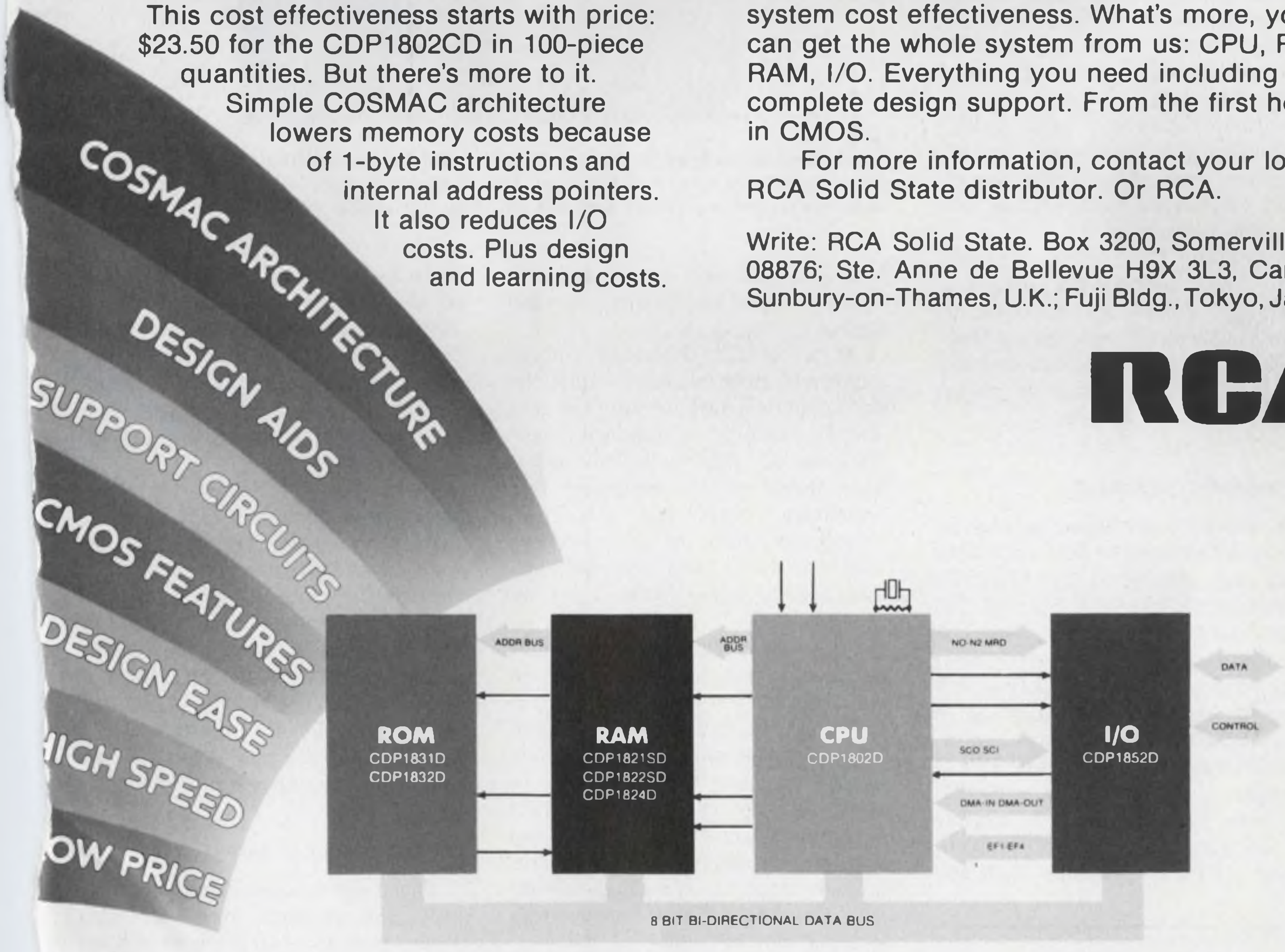

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CIRCLE NUMBER 210

Progress in gigabit logic reported for super-fast switching uses

Interest and activity in gigabit logic (10^9 b/sec) is increasing. Current work is aimed at developing discrete logic circuits, testing already-built discrete circuits, and implementing high-density integrated circuits.

For the first time, the annual IEEE MTT International Microwave Symposium (held last month in Cherry Hill, PA) devoted a full session to progress in gigabit logic, with speakers from the United States, Germany and Japan reporting progress in a variety of areas.

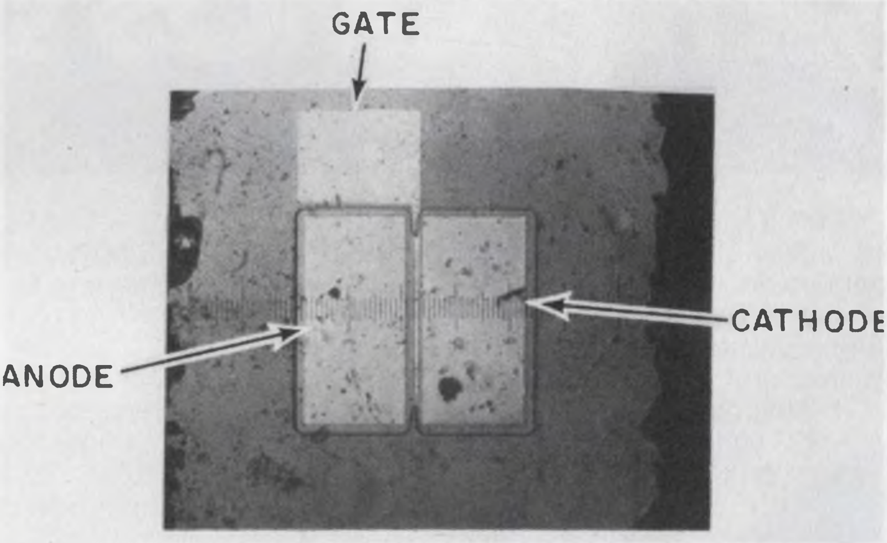
One of the many applications that await development of gigabit technology is a fast analog to digital (a/d) converter for today's sophisticated high-speed radars. Another area of potential benefit is in improving radar signal correlation techniques.

Although the words "gigabit logic" may conjure up images of ultra-fast computers gobbling up data at speeds of more than a thousand megabits per second, development of such machines is still a long way in the future.

Picosecond switching

A recently developed solid-state device of extremely fast switching time was described by Chainulu Upadhyayula of RCA Sarnoff Research Laboratories, Princeton, NJ.

Known as a Transferred Electron Logic Device (TELD), this element operates basically as a Gunn-Effect diode, but with one essential distinction. . . . the TELD contains a third element, a Schottky gate. This control gate, similar to the gate in a field-effect transistor (FET), provides isolation between input and output, and also ensures unidirectionality of the signal.



Multi-level mesa-type TELD can switch signals in picoseconds. Gate length = 2μ. Cathode to anode spacing = 12μ. Cathode-to-gate distance = 1 to 2μ. Average width of channel between cathode and anode = 150μ.

At a certain threshold voltage (approximately a few volts) the volt-ampere characteristic of the TELD exhibits a negative slope. Because of this negative resistance characteristic, extremely fast transition times are possible. Switching times of 20 to 50 ps (10^{-12} s) have been reported, and even shorter times (5 to 15 ps) are possible.

Present-day FETs are capable of extremely fast switching too, on the order of 100 ps or less. But for FETs the cutoff frequency—and hence the rise time—is determined by the geometry of the device, in particular by the source-to-drain spacing. In general, the closer the spacing, the higher the cutoff frequency. Present technology is limited however in how narrow this spacing can be made.

In the case of TELDs the switching time (actually the domain formation time) is a function of the properties of the material rather than the geometry. Thus the switching time limitation imposed by the source-to-drain spacing is eliminated. The result is a higher cutoff frequency and a faster rise time.

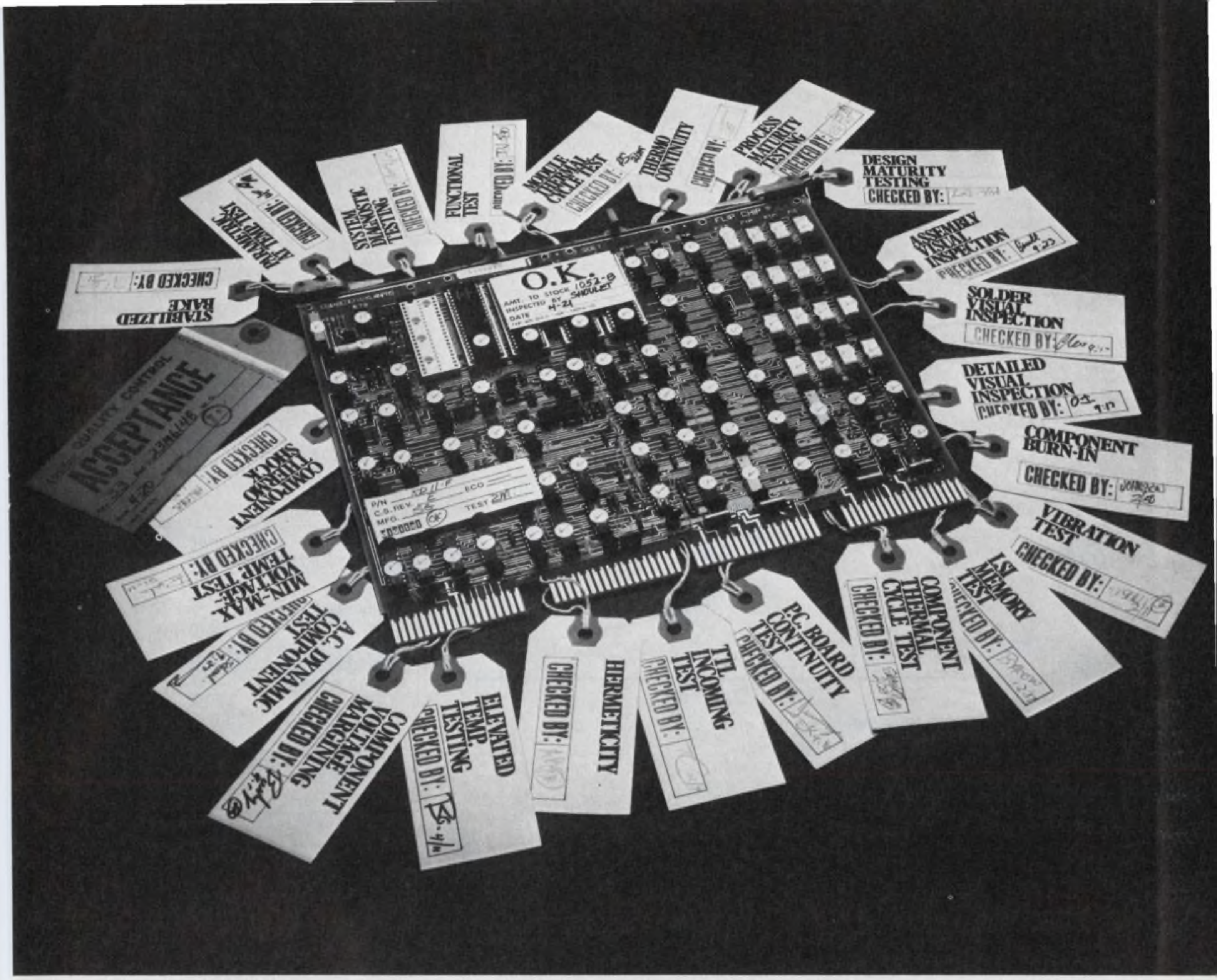
In his paper, "Transferred electron logic devices (TELDs) for gigabit-logic-rate signal processing," Upadhyayula reports that these devices are not only available, but are already being tested in specific circuits, such as (for example) threshold logic circuits and two-input AND gates.

One unit has been successfully tested at 1.25 GHz, "but that is certainly not the upper limit," he says.

On the practical side

There are a number of practical uses for gigabit logic circuits. These include: fast-Fourier transform calcualtors, a/d and d/a converters, and time of arrival sys-

Samuel Derman
Associate Editor



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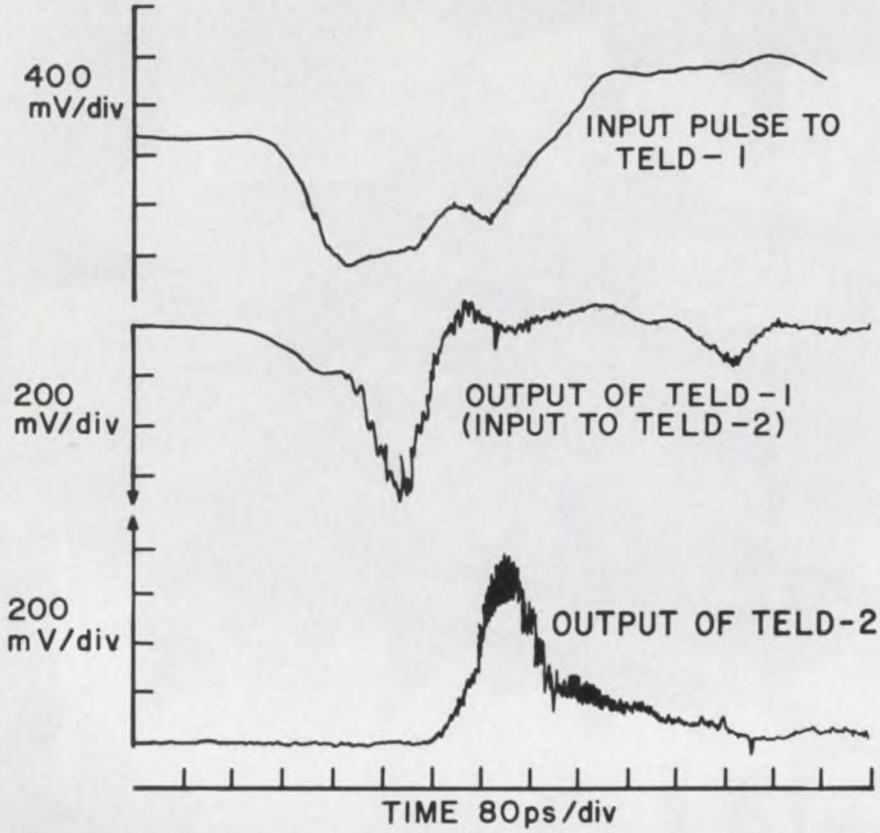

A cascade of two TELD threshold circuits delivers an output pulse of about 1 V and less than 100 ps-width at half-height.

Properties of OAT bipolar technology

OAT bipolar transistor—physical dimensions	
Emitter width (also contact width)	emitter con- 3μ or 4μ
Base contact width	4μ
Metal overlap over contact	2μ each side
Metal to metal spacing	2μ
Minimum size transistor (to isolasion centerlines)	$44\mu \times 55\mu$

OAT bipolar transistor—electrical characteristics

$f_T \geqq 3.5$ to 5 GHz
$C_{CO} \simeq 0.14$ pF at $V_{CB} = 0$ volts
$C_{EO} \simeq 0.08$ pF at $V_{EB} = 0$ volts
$C_{CS} \simeq 0.16$ pF at $V_{CS} = -3$ volts
$I_C \simeq 2$ mA
$r_e \simeq 60$ ohms

Costas demodulator multiplier measured performance	
Operating frequency	dc to > 2 GHz
Input level	$\simeq$ 40 mvpp
Differential mode gain	24.6 db
Common-mode gain	−32 db
Dynamic range	41 db
Power supply rejection	85 db
DC power	±9 volts @ 7.3 ma

tems. The last is used for distinguishing two events very closely spaced in time.

The lack of speed of currently available a/d converters is one of the limitations of present day high speed radars, declares Max Yoder of the Office of Naval Research, Washington, DC, and chairman of the gigabit-logic session. "The next major thrust in radar-system design will probably come about when a/d converters of much higher speed are developed" he says.

In pointing out comparisons between TELD devices and more conventional high-speed circuit elements, Upadhyayula notes that TELDs consume about twice as much power as emitter-coupled logic (ECL) devices. But the speed of processing is ten times faster than for the fastest ECL.

"Applications exist for transfer-electron logic devices where processing time is very important and where only a handful of these devices is needed," Upadhyayula says.

"Applications for high-speed computers however, are many years away because computers generally need thousands of similar devices, all of proven reliability. Present Technology in TELDs is not yet at that stage," he points out.

Other materials, such as Indium gallium antimonide, consume only one-fourth the power of present gallium arsenide devices. Therefore, they may be more suitable for gigabit integrated circuits, he adds. But these newer, exotic materials are not yet easily available, although they are already being produced in Japan.

Very fast bipolar ICs

In the field of analog signal processing, development of a very fast silicon bipolar integrated-circuit technology is reported by Dave Breuer, manager of the high-speed bipolar department at TRW Systers, Redondo Beach, CA. This technology achieves operating speeds in the 1 to 2 GHz range, and has the capability of being fabricated into as many as 5000 devices per die.

Such high-speed, high-density circuits are possible through a new technology called OAT (Oxide Aligned Transistor) technology, described in a paper entitled, "A silicon monolithic technology for 1 to 2-GHz analog signal processing," by TRW's Breuer, Dale Claxton, and Albert Cosand.

Advantages of the OAT technology are the following:

- Smaller device dimensions and lower junction capacitance. Thick-field oxide provides low parasitic capacitance.
- Smaller device dimensions for a given mask and alignment capability. One mask pre-aligns a number of subsequent diffusions. This offers the promise of high-complexity, large-scale integration.
- Improved resistance to radiation due to the reduced PN junction area.

Development of OAT technology results in integrated circuit (IC) transistors with high frequency cutoff (f_t) values in the 3.5 to 5-GHz range. Typical dimensions and electrical characteristics of such transistors are shown in the table.

The TRW process also enables fabrication of IC resistors that match to better than 1%, and that have parasitic capacitances to the substrate as low as 0.02 pf per

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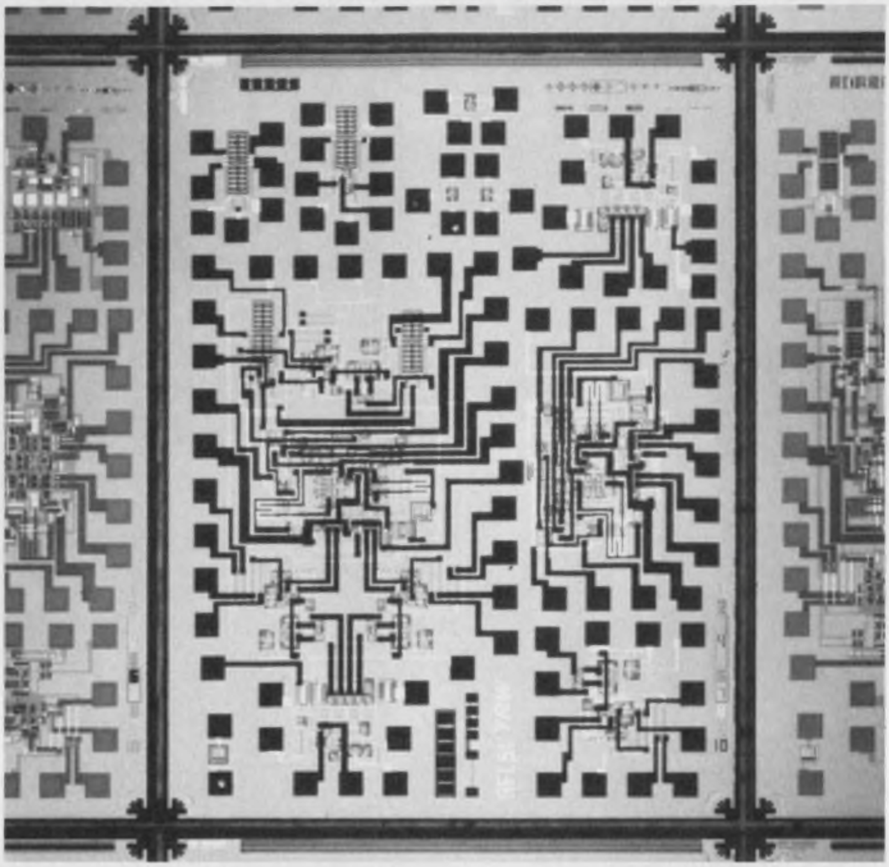

TRW's OAT technology offers promise of high-speed, high-density integrated circuits for analog signal processing.

mil². Such low stray capacitance permits, for example, the fabrication of a 200-Ω resistor with a substrate capacity of only 0.01 pf. This is in contrast to the figure of 0.05 pf for conventional diffused resistors of this type.

The first experimental application of the OAT process in a high-frequency analog circuit is as a multiplier for a Costas demodulator, a two-phase demodulator used for receivers.

Although the demodulator was designed to operate at 500 MHz, the phase detector was reported to give the correct transfer characteristics up to frequencies as high as 4 GHz.

The table lists the measured performance characteristics of the multiplier.

In still another paper, experiments with gallium-arsenide (GaAs) MESFETS for regeneration and amplification of very fast pulses were described by a team of West German scientists from the Technical University of Aachen. Pulses with speeds up to 5 Gbits/s, they reported, could be used for pulse-code modulation (PCM) of a laser in an optical communication system.

Pulse-sharpening factors of approximately three, could be achieved, they found. The sharpening factor is defined as the ratio of input-to-output pulse rise-time. A voltage amplification of 2, at 50 ohms, for output pulses of 100 ma, is attainable with pulse rise times as short as 53 ps at the output, the authors say.

Further work in high-speed regeneration of high bit rate PCM signals was described by B. Bosch, U. Barabas, U. Wellens, and U. Langmann of Ruhr University, Federal Republic of Germany. Two experimental hybrid integrated circuits using step-recovery diodes were tested at 300 Mbits/s and 1 Gbit/s, they report.

Progress in multiplexing and demultiplexing techniques in the Gbit range—with an experimentally measured bit rate of 1.8 Gbits/s —was reported by Klaus Mause of the German Post Office Research Institute.

From Japan, a group of scientists at Tokyo University described the successful modulation of a semiconductor laser at 500 M bits/s using TELDs. They also report using TELDs in high-speed logic systems. ■■

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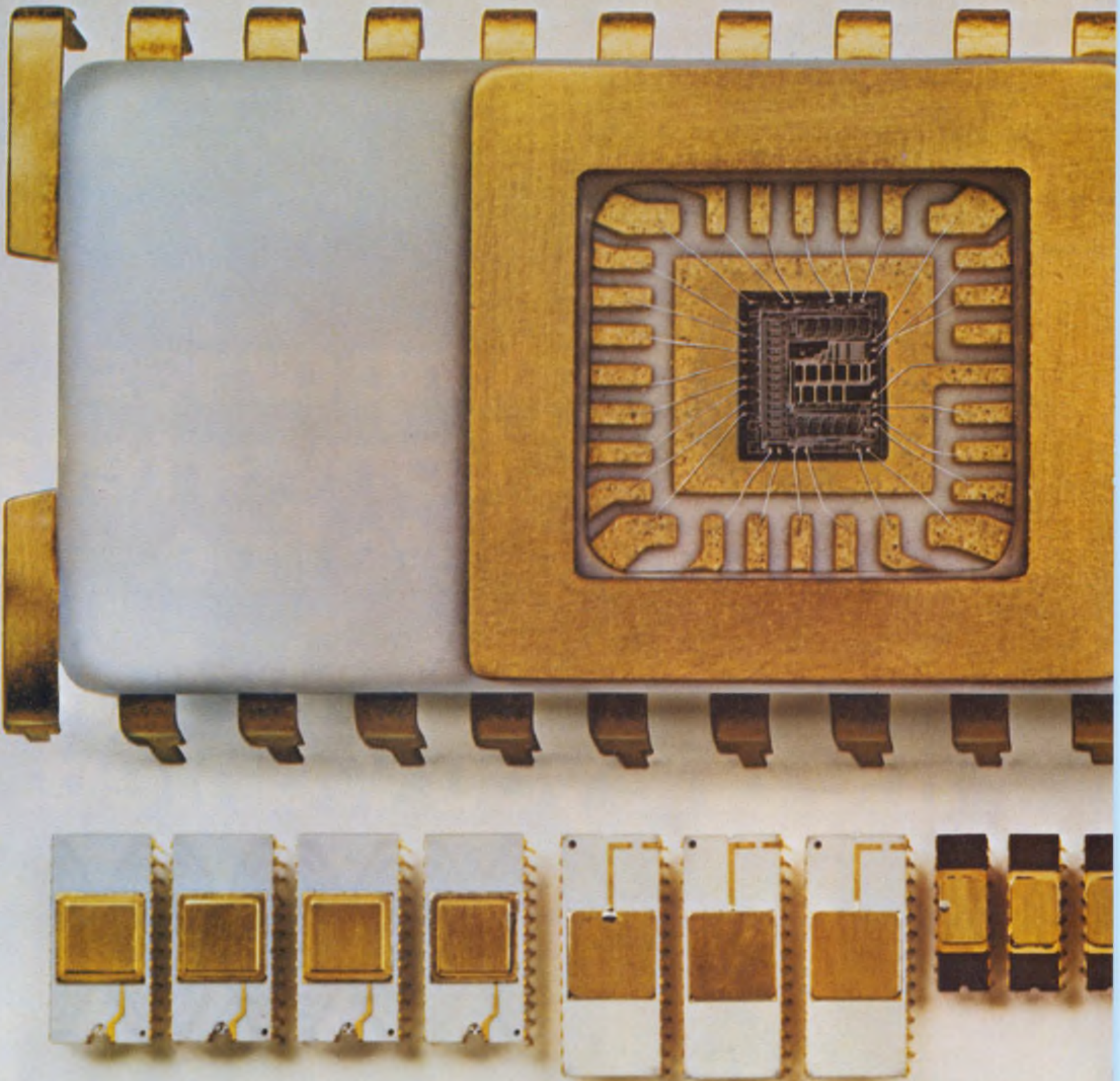

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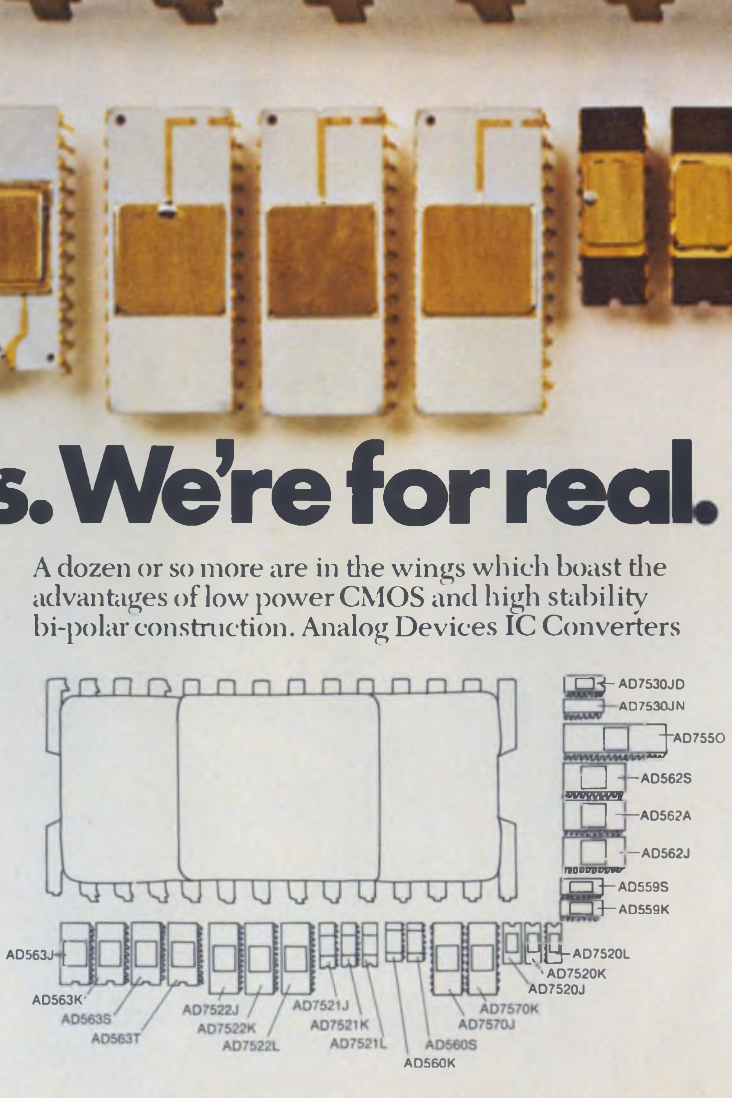

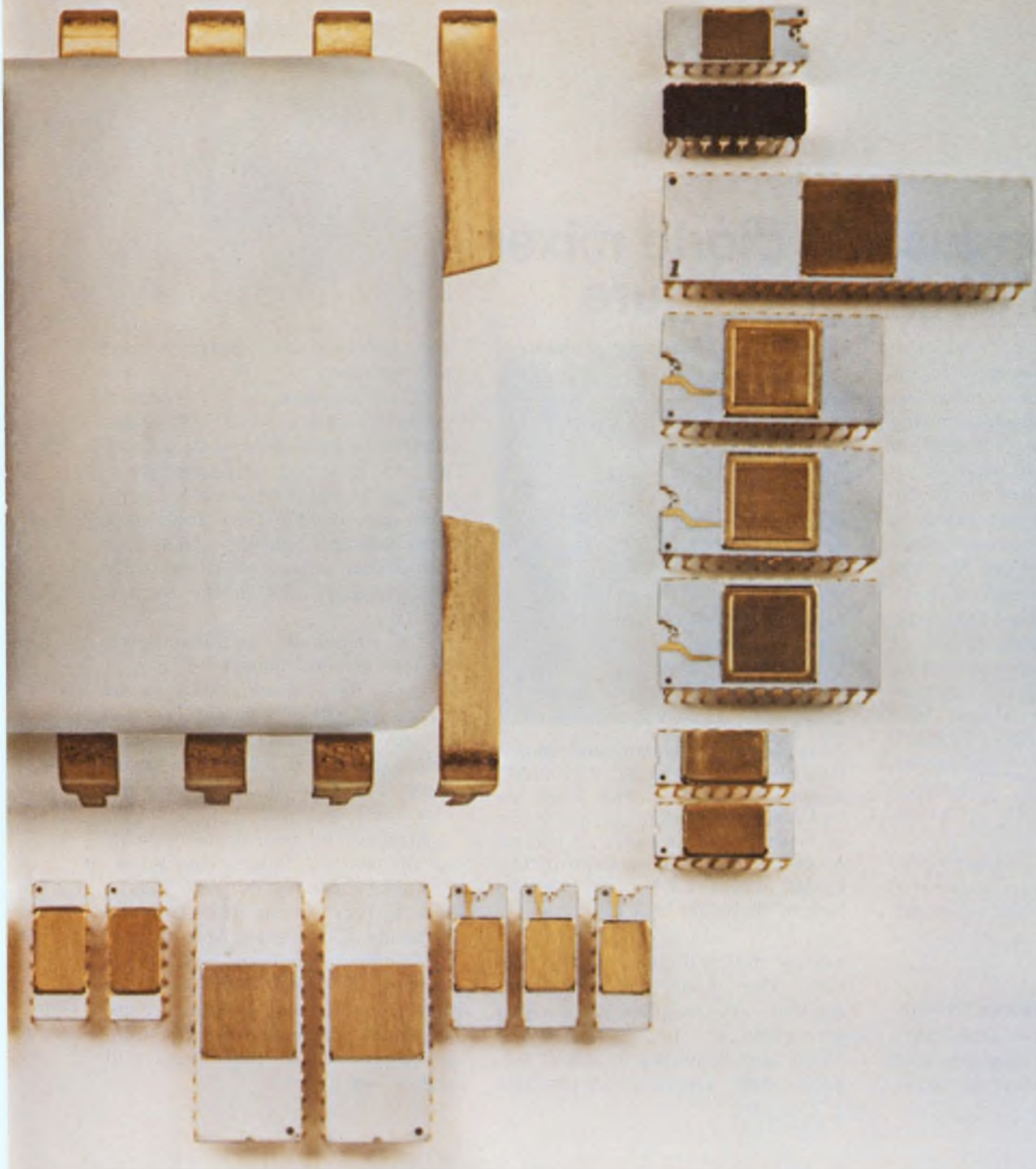

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CIRCLE NUMBER 27

Superconducting diode mixer gives paramp noise figure

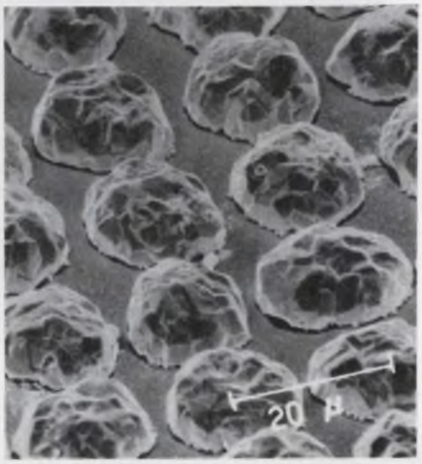
Noise temperatures previously possible only with parametric amplifiers or masers have now been achieved with a resistive mixer. The best results ever achieved by that device have been reported by Dr. Arnold Silver, director of the Electronics Research Laboratory at Aerospace Corp., El Segundo, CA.

At X-band, the mixer has 7.5-dB conversion loss and a 1.1-K diode noise temperature which results in a noise temperature of only 6.2 K. The superconducting Schottky diodes used have gallium arsenide structures and lead metalization. (See "Superconducting Diode Promises Tenfold Decrease in Mixer Noise," ELECTRONIC DESIGN No. 10, May 10, 1974, p. 30.)

The diodes will superconduct when the temperature is lowered below 7.23 K. The best performance reported so far is for a diode cooled to 1.1 K.

Diode in ridge-waveguide mount

The mixer mount consists of a 90-Ω X-band ridge-waveguide with an adjustable back short for minimizing the coefficient of rf reflection. The diode and contacting whisker are mounted across the waveguide in the center of the ridge, and connected to a 50-Ω terminal. This arrangement provides the intermediate-frequency port and dc bias.



This scanning-electron-microscope view of several super-Schottky diodes shows the lead plating over the GaAs diode. Electrical contact to one or more dots is made with a contact whisker. These superconducting diodes have a 1.1-K noise temperature when cooled to 1.1 K.

The microwave input is connected through a broadband step transformer to a 30-dB directional coupler for local oscillator insertion.

Measurements of noise temperature are made with a local-oscillator power level of −46.4 dBm and a bias voltage of 0.6 mV. The rf frequency used in the tests is 10 GHz.

The same diode has a remarkable noise-equivalent power of 5.4 × 10^{-16} W/Hz$^{1/2}$, when used as a detector instead of a mixer. That is measured at a bias level of 1 mV, and is orders of magnitude better than any other diode detector yet reported.

Although all measurements made so far are at X-band, the super-Schottky diode should work just as well up into the mm-wave frequency bands, Silver says. Aerospace is investigating indium antimonide instead of gallium arsenide for millimeter-wave super-Schottky applications, although some researchers there believe that GaAs will suffice. ■■

RPVs get millimeter-wave radar

The Army's remotely-piloted vehicles (RPVs) will carry millimeter-wave radars for their battlefield surveillance work because of the high resolution the extremely high-frequency equipment provides in proportion to its small antenna size.

To get the same resolution at lower frequencies, a much larger antenna would be needed.

The disadvantage of millimeter waves—that they are attenuated by fog and rain—is not an obstacle because the RPV will be flying close enough to its target to "brute force" through any precipitation.

RPVs, the small, unmanned aircraft being developed for missions where aircraft are highly vulnerable, will be launched and recovered by ground units near a battlefield. They will send their radar data back by telemetry.

The radar is being built for the Army by the Norden Div. of United Technologies, Norwalk, CT.

"We feel that millimeter-wave technology is ready to move out of the laboratory and into flight vehicles," says Norden's president Peter L. Scott.

The initial experimental flight model will be flown and evaluated by the Army in an Army aircraft. ■■

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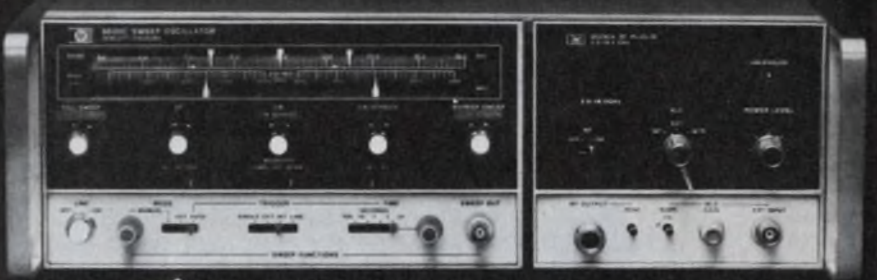

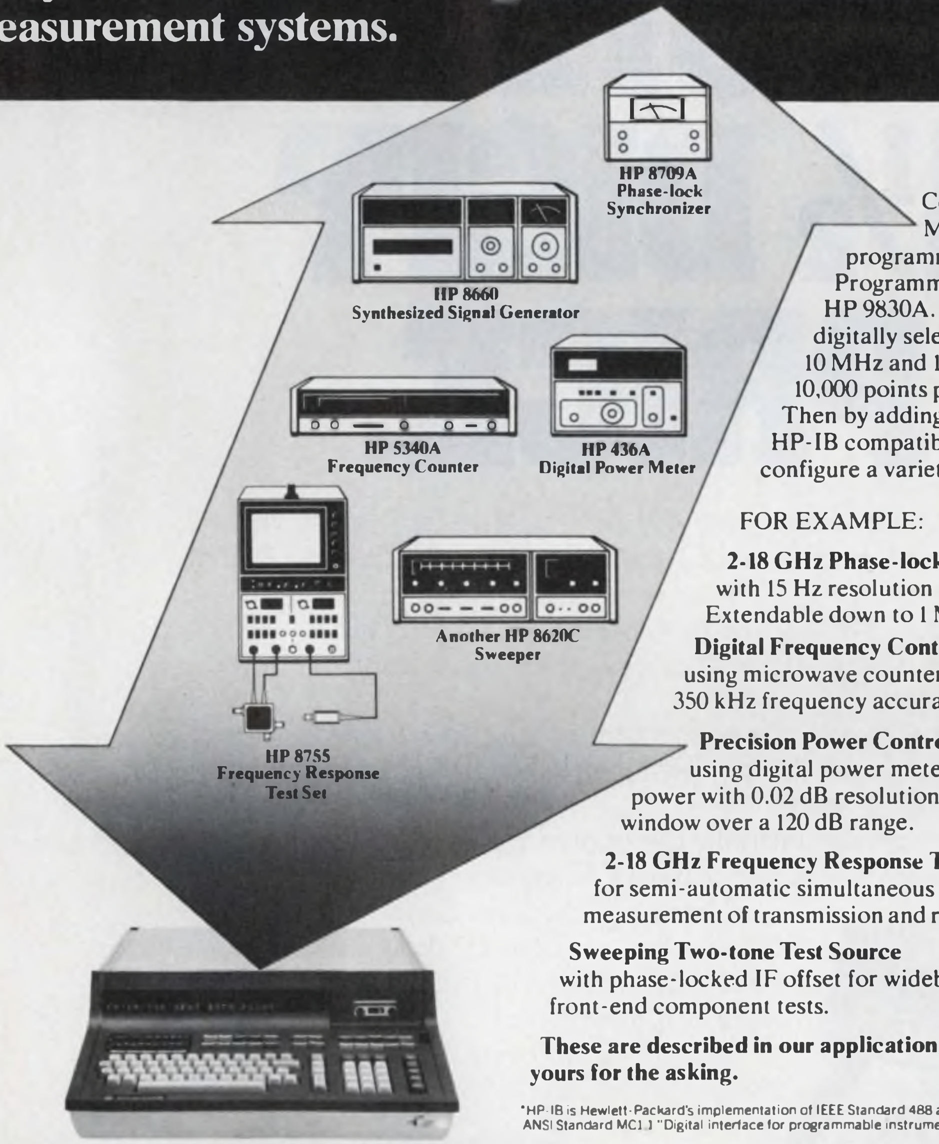

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80dB normal mode noise rejection produces a 10,000:1 reduction of excess noise. A full decade better than the 1,000:1 reduction of comparable instruments.

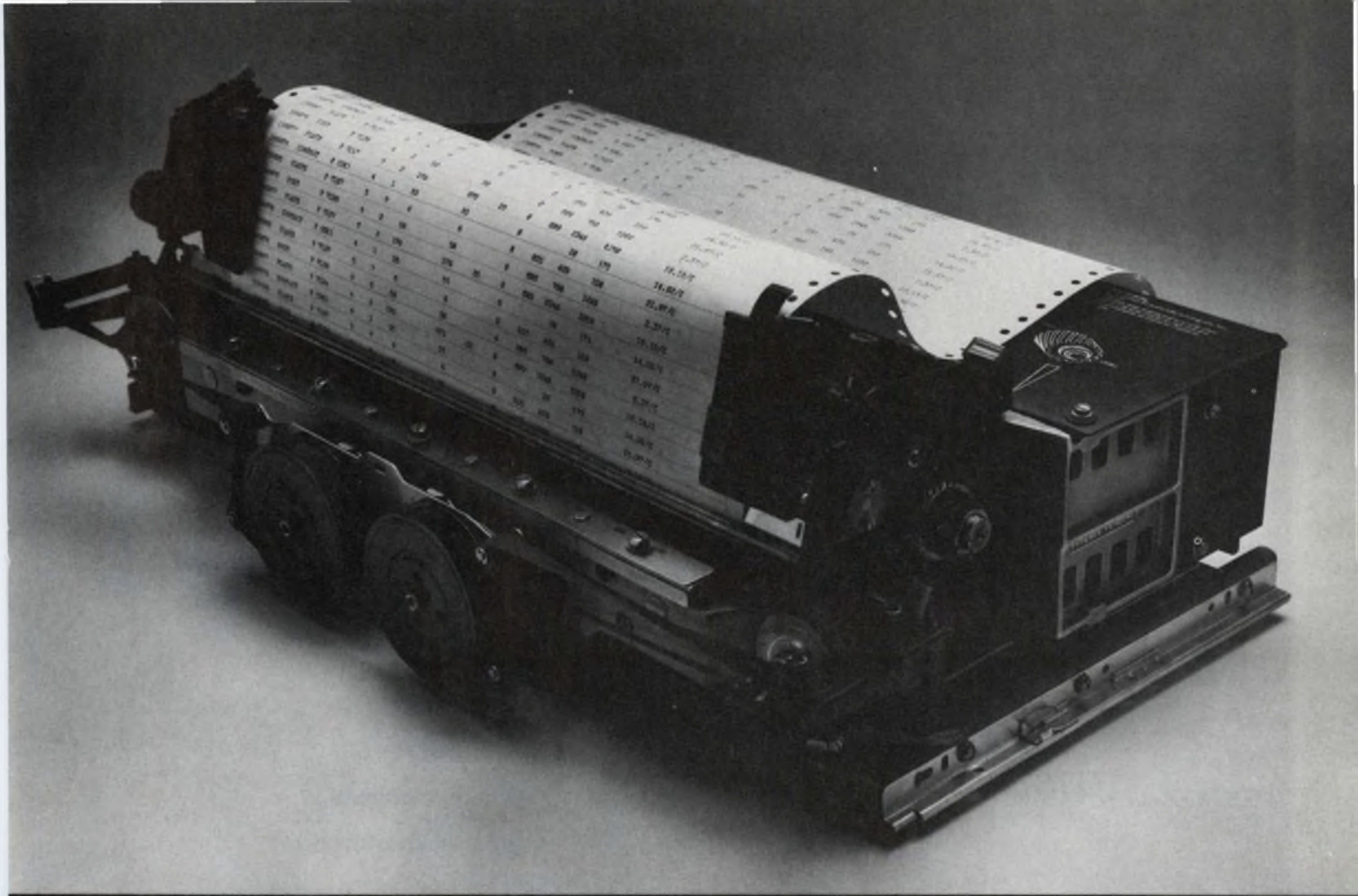
Loading errors are virtually eliminated by the 4600's 10,000MΩ input impedance on the two lowest DC voltage ranges.

There's a lot more. Send for a free catalog on our new 4½ digit 4600 multimeter. And find out how to get 5½ digit accuracy without paying for it.

Dana Laboratories, Inc., 2401 Campus Dr.,
Irvine, CA 92715. 714/833-1234.

DANA®
Others measure by us.

FOR PRODUCT DEMONSTRATION CIRCLE 168 **FOR LITERATURE ONLY CIRCLE 169**



132 columns. Over 300 lines per minute. Under $2000.*

In printers, it's not just a question of how much they cost, but one of how much you get for your money. And on a price/performance basis, nothing even comes close to the Teletype® model 40 OEM printer.

Besides getting a 132-column, heavy-duty impact printer that delivers over 300 lpm for less than $2000, you also get a printer with outstanding flexibility and reliability.

The big reason behind the model 40's price/performance advantage over the competition is our unique design. Even though it operates at speeds over 300 lpm, wear and tear is less than you'd find in a conventional printer operating at a much slower speed. Fewer moving parts and solid-state components add up to increased reliability and reduced maintenance.

We'd be ahead if we just stopped there, but the model 40 also offers you a number of other features. Like a choice of character sets, operator-adjustable form width and form length, parity error indication, and a built-in self-test feature, just to name a few.

For complete information, please contact our Sales Headquarters at:
5555 Touhy Ave., Skokie, Ill. 60076. Or call Terminal Central at: (312) 982-2000.

TELETYPE ®

The Teletype model 40 OEM printer. Nothing even comes close.

Teletype is a trademark and service mark registered in the United States Patent and Trademark Office.
*80-column-version available for under $1400.

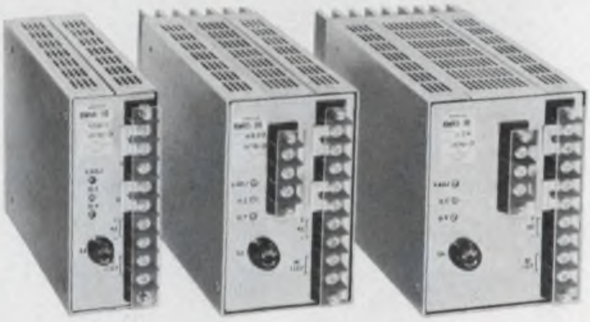
CIRCLE NUMBER 30

an announcement of importance
from **KEPCO** and **TDK**

switching power supplies

3-groups of modular style voltage stabilizers: 50 watts, 100 watts and 150 watts; 5V models to 24V models.

These stabilizers are produced by TDK Electronics Co. Ltd., of Japan, an acknowledged leader in ferrite manufacturing technology, and are sold and serviced in the U.S.A. by Kepco Inc., a 30-year veteran of the power supply industry.



the new RMK power modules feature

- Small size
- High efficiency
- No derating to +50° C
- Overvoltage protection
- Logic level on/off control
- Soft start
- High frequency switching

50 WATT MODELS:

MODEL	d-c OUTPUT RANGE VOLTS	AMPS	PRICE
RMK 05–10	4.5–5.5	0–10	$210.00
RMK 09–06	8.0–10.0	0–6	210.00
RMK 12–05	10.0–13.5	0–5	210.00
RMK 15–04	13.5–16.5	0–4	210.00
RMK 24–02	21.5–26.5	0–2	210.00

100 WATT MODELS:

RMK 05–20	4.5–5.5	0–20	299.00
RMK 09–10	8.0–10.0	0–10	299.00
RMK 12–08	10.0–13.5	0–8	299.00
RMK 15–07	13.5–16.5	0–7	299.00
RMK 24–04	21.5–26.5	0–4	299.00

150 WATT MODELS:

RMK 05–30	4.5–5.5	0–30	399.00
RMK 09–16	8.0–10.0	0–16	399.00
RMK 12–12	10.0–13.5	0–12	399.00
RMK 15–10	13.5–16.5	0–10	399.00
RMK 24–06	21.5–26.5	0–6	399.00

50 W size: ≈2 ⅛″ H x 5 ⅛″W x 7½″D
100 W size: ≈3¼″ H x 5 ⅛″W x 8¾″D
150 W size: ≈4 1⁄16″ H x 5 ⅛″W x 8¾″D

all KEPCO products are backed by a firm 5-Year Warranty

For complete specifications, write Dept. FL–05

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CIRCLE NUMBER 31

Technology export policies contested

The Pentagon is resisting efforts by high-technology industries—particularly electronics—to liberalize policies governing export of U.S. technology.

The issue is currently before the House International Relations Committee, where Peter F. McCloskey, president of the Computer and Business Equipment Manufacturers Assn., testified that the Secretary of Defense should be able to deny an export license only if he could prove the technology would aid the recipient country's military capability. Under the current Export Administration Act, which expires Sept. 30, the Defense Secretary has broad powers to withhold technology if it "possibly" enhances such a capability. McCloskey spoke for a group that also includes the Electronic Industries Assn., WEMA and the Aerospace Industries Assn.

Dr. George H. Heilmeier, director of the Defense Advanced Research Projects Agency, responded later in a speech before a labor group that the U.S. should be cautious about what it sells overseas and should be sure to get a fair price. He noted that in the past U.S. companies were content to sell technology cheaply because they had already recovered their basic costs, including market development, in the domestic market. "The days of such generosity are over," Heilmeier said. "The time for hard-nosed dealings, even with our allies, is upon us."

Also urging caution in technology exchange was Dr. Fred C. Ikle, director of the Arms Control & Disarmament Agency, which is an independent government agency. Ikle warned that it is hard to determine end use of the technology. "The equipment for producing circuits used in pocket calculators may also be used for guidance computers of missiles," he said.

Foreign military sales bill goes to conference

House and Senate conferees will try to reconcile differences in the arms-control bills passed by their respective chambers following Senate passage of a more liberal measure than the one that cleared the House.

The Senate voted to give Congress a veto power over any weapons sale of $25 million or more regardless of whether it was handled by the U.S. government or an individual company, but rejected the House-passed ceiling of $9 billion in arms sales per year. Both bills would require the Defense Dept. to notify Congress of a proposed sale, and Congress would have 20 calendar days to overrule it.

In the midst of the debate the General Accounting Office released a study showing that foreign military sales handled by the U.S. government had risen from less than $1 billion in 1970 to $10.8 billion in 1974, but have since dropped to $9.5 billion in 1975 and are expected to drop further to $8.2 billion this year. Unfilled orders have risen dramatically, however, from about $5 billion in 1971 to $24 billion last year.

Navy seeking family of CCDs

The Naval Electronic Systems Command, which has sponsored exploratory development of charge-coupled devices (CCDs) since 1972, is planning a new program to create an entire family of CCD sensors for advanced camera systems.

The objective is to have a set of modules that could be configured to meet future Navy electro-optical requirements. Under Navy finding (mostly with Fairchild Camera & Instrument Corp.) the CCD program has already yielded linear image-sensors (1 × 500 and 1 × 1000) and two low-light-level area image-sensors (244 × 190 and 488 × 380) plus a 1 × 1728 linear imaging-chip and a 128 × 128 time-delay and integration-imaging chip in development.

NASA seeks to put industrial facilities in space

Two firms will receive study contracts this fall from the National Aeronautices and Space Administration to investigate possibilities for "space industrialization"—the use of space stations for industrial purposes. The awards are part of NASA's on-going search for new missions for the Space Shuttle.

Internal studies by NASA have already identified electrical power generation as one promising application. And because of the weightless conditions that prevail in space, semiconductor materials might be profitably manufactured as well as certain medicines.

The new studies will last 16 months and concentrate on determining how space facilities could be used in the 1980-2010 period. First operational mission of the Space Shuttle is scheduled for 1980, but that vehicle is limited to 30-day orbital missions.

Earlier, NASA awarded parallel contracts of about $700,000 each to Grumman Aerospace and McDonnell Douglas Aeronautics to define space stations that could be orbited after 1985.

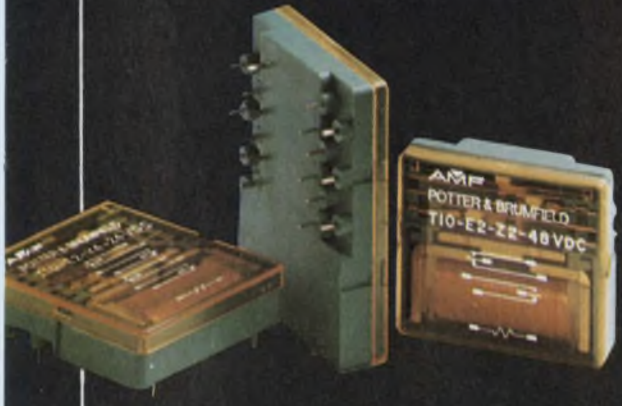
Capital Capsules:

The Navy, this month, will begin using the UHF channels for ship communications on the Marisat satellite launched by Comsat General Corp. June 9 from Cape Canaveral. The satellite will provide another 550 kHz of bandwidth over the Pacific in addition to the identical Marisat launched over the Atlantic Feb. 19. A third Marisat will give the same coverage over the Indian Ocean before the Navy launches its own communications satellite late next year. . . . **The Electronic Industries Assn. is claiming a victory in the recent International Electro-technical Commission Council decision to establish an international voluntary certification system for electronic components.** Each participating country will establish a national supervising inspectorate to examine companies' production, organization and quality-control procedures. EIA expects the system to be operational on an international basis within 12 to 18 months.

CIRCLE NUMBER 32 ▶

SQUEEZE PLAY.

T10 relays by P&B let you mount your pc boards on 0.5″ centers. They work in tight spots like a pro.



T10s are only 0.375″ high. The lowest profile 3 amp relay in the Potter & Brumfield line.

They provide 0.1 to 3 amp switching @ 28V DC in 2, 4, and 6 pole models. Coil ratings are 6, 12, 24, and 48V DC. Permissive make, gold-flashed silver contacts are noted for low contact bounce, long operating life. Bifurcated contacts for low level switching are also available.

These relays are compatible with TTL and CMOS peripheral driver ICs, and TTL and CMOS buffers wired for current sharing. Ideal for telecommunications, copy and reproduction machines as well as computers and peripheral equipment.

Put a squeeze play on costs. Prices are as compact as the relays themselves.

For full information on the T10 series and all P&B relays, see your Potter & Brumfield sales representative or P&B Pro Shop distributor. Or, contact Potter & Brumfield Division AMF Incorporated, Princeton, Indiana 47671. Telephone: 812/385-5251.

European address: Electrical Products Group, AMF International Limited, AMF House, Whitby Road, Bristol B54 4AZ, England. Telephone: (0272) 778383, Telex: 449481, AMMAFOCO, BRSTL.

Go with the Pros and you can't go wrong.

AMF
Potter & Brumfield

MICROMINIATURES FLEXIBLE INTERCONNECTIONS SYSTEMS CAPABILITY

We put it all together for you! Your single source for complete systems capability in flexible interconnections and microminiature connectors is Cannon. We offer you a complete system, 100% electrically and mechanically checked out, ready to plug into your assembly.

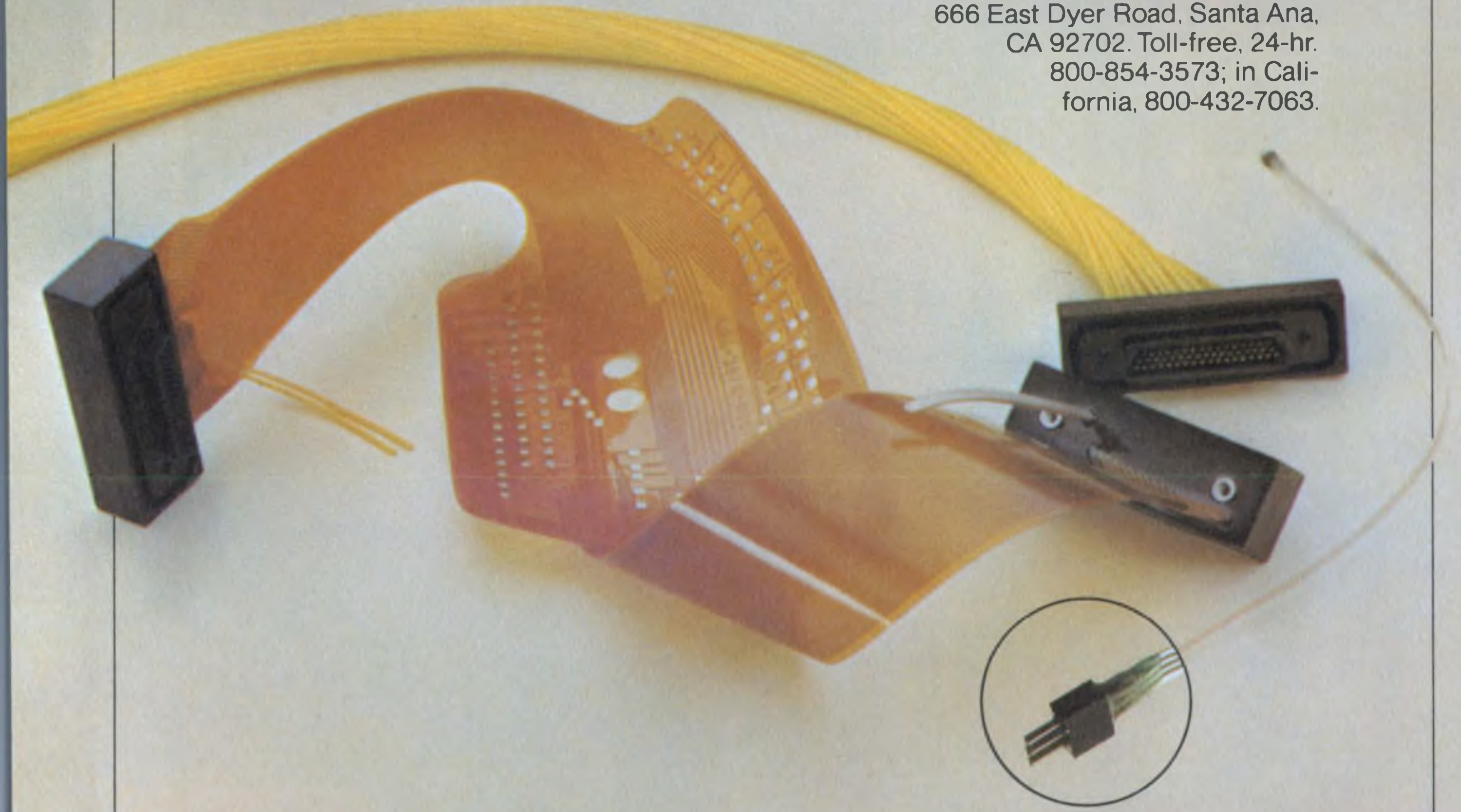
The best feature of this total capability? **It lowers your total installed cost.** And that's your real cost!

We can custom manufacture your flexible circuitry and assemble your complete interconnection system. Shielded wire, coaxial cable can be assembled with the most reliable microminiature connectors available.

Other pluses to think about: You can cut system costs as much as 50%, reduce weight and space up to 80% and eliminate point-to-point wiring, bundling and lacing. Solve those difficult density problems.

Cannon microminiature custom cable terminations can help you trim the costs inherent in your in-house hard wiring or harnessing—expensive engineering time, assembler training, quality assurance setup, inventorying, materials scrap and wastage.

There's much, much more you should know about Cannon's interconnection innovations and how they can lower your installed costs. Send for our "Cannon Cost Cutters" brochure. ITT Cannon Electric, 666 East Dyer Road, Santa Ana, CA 92702. Toll-free, 24-hr. 800-854-3573; in California, 800-432-7063.



Six decades on the leading edge of interconnect technology.

CANNON ITT

CIRCLE NUMBER 29

If practically anyone can build a programmer for these proms who needs Data I/O?

Practically anyone who understands semiconductor memory can make a box to program a PROM, or maybe two different PROMs. That may be fine today, but the way things are, you could be programming ten or twenty different PROMs tomorrow.

Only a Data I/O PROM Programmer will program them all—165 at last count.

Our Programmer V lets you enter data in a variety of input modes (keyboard, master ROM, paper tape, computer, etc.), review the data, and then select from a variety of output modes.

Our MOS Memory Module Programmer can program eight MOS PROMs simultaneously, with eight different programs, in less than 30 seconds!

We also make a portable programmer, FPLA programmer and the Romulator.™ The Romulator allows you to emulate/simulate PROM operation—in your circuit—without PROMs. PROM data is easily altered and updated on the Romulator keyboard, all prior to PROM programming.

Data I/O programmer calibration standards let you calibrate to each PROM manufacturer's specs before you program, insuring maximum yields and reliability.

Data I/O total three point service.

1. Every Data I/O customer receives a quarterly update on currently available PROMs.
2. Through our direct (computerized) mailing program, Data I/O customers are kept constantly up-to-date on PROM specification changes and technological innovations.
3. Nine field offices in the U.S.A. and 22 distributors worldwide provide our customers with direct sales support, installation, operator training and service.

Get the facts

If you would like to know more about our products, or want copies of our quarterly PROM Comparison Chart and PROMBiTS (our periodic technical bulletin on PROM applications and innovations), mail this coupon or call one of our offices. Data I/O Corporation, P.O. Box 308, Issaquah, Washington 98027.

Name____________________

Title____________________

Company____________________

Address________________ M/S________

City/State/Zip____________________

Data I/O

CIRCLE NUMBER 34

Data I/O offices: New York area—201/832-1487; Washington D.C. area—301/652-7240; Chicago area—312/884-1335; Dayton area—513/435-4440; Dallas area—214/349-0877; Tulsa area—918/865-4111; Los Angeles area—714/998-9151; San Jose area—408/732-8246; Boston area—603/888-3850; Seattle area—206/455-3990; Europe: Amsterdam—020/186855, TELEX—16616.

Opening new frontiers with electro optics

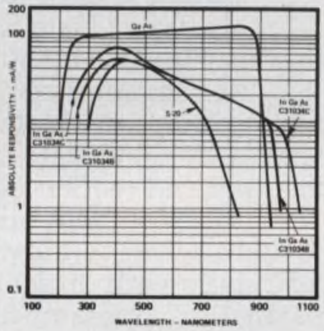
High resolution CRTs: 1 to 2 mil line widths. Fine choices for photorecording.

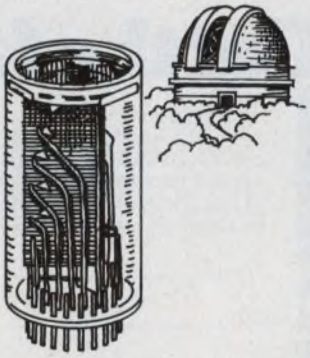
Get the most from your COM, photocomposition or medical imaging system with RCA CRTs. Clear, sharp photographic records result from our special combination of electron gun design, phosphor material synthesis and fine-grain phosphor deposition. And you can count on us to meet your volume needs. The 5" dia. 4869 or 4870, with 1-2 mil line widths, have optically flat faceplates, magnetic deflection and electrostatic or magnetic focusing. Special needs? See us — we have others to suggest.

Circle 291

See more with the most sensitive RCA photomultiplier tube.

Astronomers and spectroscopists, RCA has 2" dia., 11-stage PMTs with the characteristics you need. For critical photon counting applications, the GaAs C31034A has the highest known photocathode responsivity over its entire 200-930 nm spectral range, plus dark noise of only 100 cps max. at −20°C. You can also get lower dark count rates, to 12 cps max. With InGaAs types you get extended spectral ranges, to 1030 nm. These are just a few of RCA's wide line of PMTs for all types of low-light-level detection systems.





Circle 292

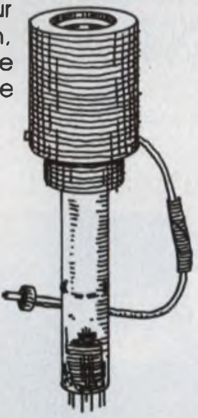
Projection kinescopes for clear, bright large-screen TV.

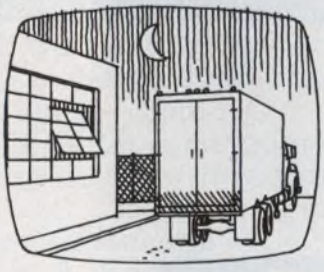
From our 3-in. dia. tubes for small meeting rooms to the big 7-in. dia. size for theaters and other larger viewing areas: RCA gives you one of the broadest lines to choose from. We offer electrostatic and magnetic focus types for Schmidt and dioptric systems, for color and monochrome. All with the power needed for bright, clear images. If you have unusual system requirements, we can help.

Circle 293

How to make your CCTV camera so sensitive it can see by starlight.

Apollo astronauts used cameras with RCA Silicon Intensifier Tubes to take TV pictures even within the moon's dark shadows. These tubes may be ideal for your new CCTV camera, too...whether it's for surveillance, astronomy or other uses where scene light levels can range down to 1x10 $^{-4}$ fc. Our line, the industry's broadest, includes 16, 25 and 40 mm types. 16 mm tubes are available with a new target that minimizes blooming effects. In fact, no matter how unusual your application, chances are we have the camera tube for it.





Circle 294

If electro optics can solve your problem, remember: EO and RCA are practically synonymous. No one offers a broader product spectrum. Or more success in meeting special needs. Call on us for design help or product information. RCA Electro Optics, Lancaster, PA 17604. Phone 717-397-7661.

RCA

How about CMOS microprocessors for temperature and noise immunity?

CMOS μPs, while far less popular than those made of NMOS, have a number of advantages. Alex Young, manager of Microprocessor Engineering at RCA, speaks on the use of the CMOS technology for manufacturing microprocessors.

CMOS microprocessors are more rugged and more easy to use than μPs made by other technologies because the process is inherently more resistant to variations in temperature, power-supply voltage and noise interference.

First, all of our devices are designed to operate over a temperature range of −55 to 125 C. Dynamic NMOS microprocessors, in contrast, use circuit techniques that make it difficult to extend operation past the 70 or 80-C area.

In dynamic NMOS devices, operation of logic elements depends upon stored charge held by the internal capacitive nodes. As temperature rises, there is an increase in leakage from these nodes, which imposes a severe limitation on dynamic operation at high temperatures. In addition, static NMOS logic uses a passive pullup transistor as the load for the switching transistor. The operating characteristics of both transistors degrade with high temperature

(continued on page 54)

Evaluation board helps users assess 6800 components

The latest microcomputer on a board—the M6800B Evaluation Module II from Motorola (P.O. Box 20294, Phoenix, AZ 85036. 602-244-3465)—offers a quick and easy way to assess the capabilities of the 6800 family.

Measuring only 9.75 × 5.75 × 0.062 in., the module includes the following components: 8-bit μP, 128 × 8-bit RAM, 1024 × 8-bit ROM, PIA (peripheral-interface adapter), ACIA (asynchronous communications-interface adapter), clock oscillator and bit-rate generator.

The mask-programmed ROM contains a diagnostic/debug program known as Minibug II. Two of the RAMs provide 256 bytes for user programs; the remaining RAM is used as a scratch pad by Minibug II. The PIA provides two 8-bit bidirectional I/O ports, and the ACIAs serve as serial I/O interfaces. The module will operate with either a TTY terminal at a baud rate of 110 or an RS232C-type terminal at 300 baud.

Available sockets on the module accommodate 512 × 8 or 1024 × 8-bit PROMs containing user-generated programs. Also resident editor and assembler programs, which require 8-k bytes of memory can be used. Module II requires supplies of 5, 12 and −12 V.

The new board costs $795. Delivery is from stock.

CIRCLE NO. 501

(continued from page 53)

so the logic levels also vary radically.

Temperature affects static CMOS microprocessors less severely, however. Operation is static, and so is not determined by capacitive charge holding. Instead, data are stored in flip-flops. Further, HIGH and LOW states are determined by two active transistors connected in series. For each logic state, one transistor is switched off and the other is switched on. As temperature varies, the changes in characteristics of one transistor are largely cancelled out by those of the other.

Generally, the operating power dissipation of CMOS μPs is an order of magnitude less than for other microprocessors. CMOS μPs typically dissipate 10 mW with a supply voltage of 5 V and with a 3.2-MHz clock. (NMOS units typically dissipate 350 to 1000 mW under similar conditions.) Peripheral-buffer, interface, and memory circuitry can also be CMOS, so an entire system can be run on low power. Quiescent power dissipation is three orders of magnitude less than for NMOS microprocessors.

CMOS microprocessors also have non critical power-supply requirements. Our CDP-1802, for example, is specified to operate over a range of 3 to 12 V with a maximum voltage of 15 V. Most other μPs require several positive and negative power supplies, or one supply regulated within 10 %.

When external digital signals drive CMOS, greater voltage noise on the line may be tolerated than when bipolar or NMOS devices are being driven. CMOS inputs have a 30%-of-supply-voltage noise immunity by design, and they are tested to that spec. Most other types have much less immunity.

Microprogrammable processor boosts Nova mini's performance

You can turn a Nova minicomputer into a parallel, multiprocessing system by plugging in some Micro-N microprogrammable processors. The Micro-N, developed by Educational Data Systems (17981 Sky Park Circle, Irvine, CA 92707. 714-556-4242), enhances the computing power of any Nova minicomputer by implementing user-defined, procedure-oriented macro-instructions.

Microprograms of the Micro-N can run in parallel with normal processing of the Nova CPU and at much higher speeds. Applications include floating point arithmetic, either binary or decimal, character string processing, graphics control, matrix operations, sorting, and control of special devices.

The Micro-N occupies a board slot in the computer chassis and includes a high-speed microprograms from either the Nova's memory or from its own PROM.

The Micro-N occupies a board slot in the computer chassis and includes a high-speed processor with four accumulators, up to 4 kilowords of PROM to hold microprograms, and up to 64 words of RAM for temporary scratch-pad storage. The processor is driven by a 20-MHz clock, and most operations take only 100 ns, including instruction-fetch and execution.

A floating-point decimal arithmetic version of the Micro-N (Model 400-Pl-R) is also available. The microprogrammable Micro-N Model 400 with 64 words of RAM costs $1850 in single quantity. The floating-point decimal arithmetic version, 400-Pl-R, with 64 words of RAM, costs $2250.

CIRCLE NO. 502

Low cost printer connects to a 6800 μP system

A 40 column printer complete with drive electronics, 6800 microprocessor interface, power supply and hardwood and plastic cabinet sells for $450.000 (single qty). It can print at a 100 char/s rate, in either direction. Delivery is from stock.

Electronic Products Associates, Inc., 1157 Vega St., San Diego, CA 92110, (714) 276-8911.

CIRCLE NO. 503

Timing and state displays in one logic analyzer from Tektronix

FORMATTABLE MEMORY. 16 channels x 256 bits at 20 MHz
8 channels x 512 bits at 50 MHz
4 channels x 1024 bits at 100 MHz asynchronously; 50 MHz synchronous sampling.

DIGITAL DELAY. Use the 7D10 to delay by 99,999 events or words to access virtually any location in a data stream.

CURSOR. For easy visual interpretation and timing comparisons. Converts selected word from timing to binary format.

PRE-TRIGGER. For viewing faults before the trigger. Also offers center-trigger and post-trigger modes.

16-CHANNEL WORD RECOGNITION. Two additional qualifiers provide 18-bit parallel pattern recognition.

The 7D01 gives you both logic timing and state information in the same display. And many other features you'll probably need in a logic analyzer. The display is large and easy to read, as you can see from the photograph. It's easy to interpret, too: the trigger marker identifies the pre, center, or post-trigger point; the cursor you position yourself for binary readout of a particular word. You also get some other important logic analysis capabilities. Formattable 16-channel data acquisition plus a formattable 4k memory: acquire 4, 8, or 16 channels and store 1024, 512, or 256 bits at a time. Asynchronous timing resolution to 15 ns, synchronous operation with external clock rates to 50 MHz. Built-in word or pattern recognition. Active 1 MΩ/5 pF probes that won't load down the circuit under test.

One possible logic analysis system, the 7D01, the 7603 mainframe, and the 7D10 delay-by-events units, allows you to delay by up to 99,999 events (or words) and lets you access virtually any point in a data stream.

The 7D01 operates in any 7000-Series mainframe. If you already own a 7000-Series lab oscilloscope, you're that much closer to moving into high-performance logic analysis. For example, in a 4 compartment mainframe you can have a logic analyzer and a real-time oscilloscope in the same instrument mainframe. Either way, you benefit from the ongoing expansion of the 7000-Series line, both in the analog world and the digital domain.

Buy the 7D01 Logic Analyzer for $3,195 and the 7603 Oscilloscope mainframe for $1,850. Add digital delay with the 7D10 for $925.

Send for the technical details in our brochure, "Tektronix Logic Analyzers." Call or write Tektronix, Inc., P.O. Box 500, Beaverton, OR 97077.

U.S. sales prices F.O.B. Beaverton, OR. The 7D01 Logic Analyzer is currently available only in the U.S.A.

The 7000 Series
more than an oscilloscope

TEKTRONIX®
committed to technical excellence

FOR TECHNICAL DATA CIRCLE #273
FOR DEMONSTRATION CIRCLE #274

Prototype system for 12-bit micros uses PDP-8 software

Take the problems out of prototyping 12-bit microprocessor systems by using Intercept—a benchtop development tool. Developed by Intersil (10900 N. Tantau Ave., Cupertino, CA 95014. 408-996-5000), it duplicates all functions and timing of the IM6100 μP and related devices.

Intercept provides access for I/O devices through a built-in typewriter interface, and has a built-in control panel, and space for additional memory. The system can also operate with many PDP-8/E paper-tape programs from Digital Equipment Corp.

The machine can be split into three parts: the 6902, CPU and TTY interface; the 6901-M4KX12, 4 k × 12 static RAM; and the 6900-CONTRL control panel. Intercept costs $2850; delivery time is four weeks.

CIRCLE NO. 504

Floating-point firmware available for Intel MSC-80

Floating-point numbers can be manipulated on the Intel MCS-80, 8080 development system using the program in PROMS. The programs are being sold by Recognition Systems, who had previously written programs for 8008-based systems. The floating-point numbers have a 16-bit mantissa and 7-bit characteristic, both in two's complement form.

The programs are accessed as subroutines in the user's main program. The subroutines include multiply, divide, add, subtract, square root and conversion to fixed-point numbers. Execution times run to 7.5 ms for the first four subroutines mentioned above, to 30 ms for square root, and up to 1.5 ms for conversions.

Recognition Systems, Inc., 15531 Cabrito Rd., Van Nuys, CA 91406. Price: $495, stock.

CIRCLE NO. 506

Basic language compiling package designed for 8080 system

You can now write an applications program for the 8080 μP in Basic, then compile and debug your program on an Intel MDS prototyping system containing 32-k bytes of memory. The Micro Basic I, a Basic language compiling system, consists of text editor, compiler, debugger and object-code support subsystems. Other available high level languages have several drawbacks. They are generally adaptations of IBM's PL/M —Intel's PL/1, for example—and can run only on a large computer where there may be continual charges for use.

The compiling system was developed by the Ryan-McFarland Corp. and is available from Hamilton/Avnet Electronics. It costs $325 delivered on fanfold paper tape with all applications literature. The literature is available separately for $10.

The text editor, compiler and debug subsystems in Micro Basic I are used for applications-program development. When all parts of the program have been corrected and compiled into object code, only the object's code-support subsystem needs to be included in your product.

That subsystem comes in two versions. The simpler one includes only the routines necessary to execute the compiled applications program—arithmetic, string-handling, I/O and control routines. The more complex version includes all of that, plus a loader that links together and relocates one or more compiled programs. Either subsystem is available in PROMs for installation in your product.

Ryan McFarland Corp. 608 Silver Spur Rd., Rolling Hills Estates, CA 92274. (213) 377-2353.

CIRCLE NO. 507

The portable logic analyzer

16-CHANNEL WORD RECOGNITION. *Event digital delay to 99,999; delay by words or clock pulses.*

FORMATTABLE MEMORY. *16 channels x 256 bits at 20 MHz*

8 channels x 512 bits at 50 MHz

4 channels x 1024 bits at 100 MHz asynchronously; 50 MHz synchronous sampling.

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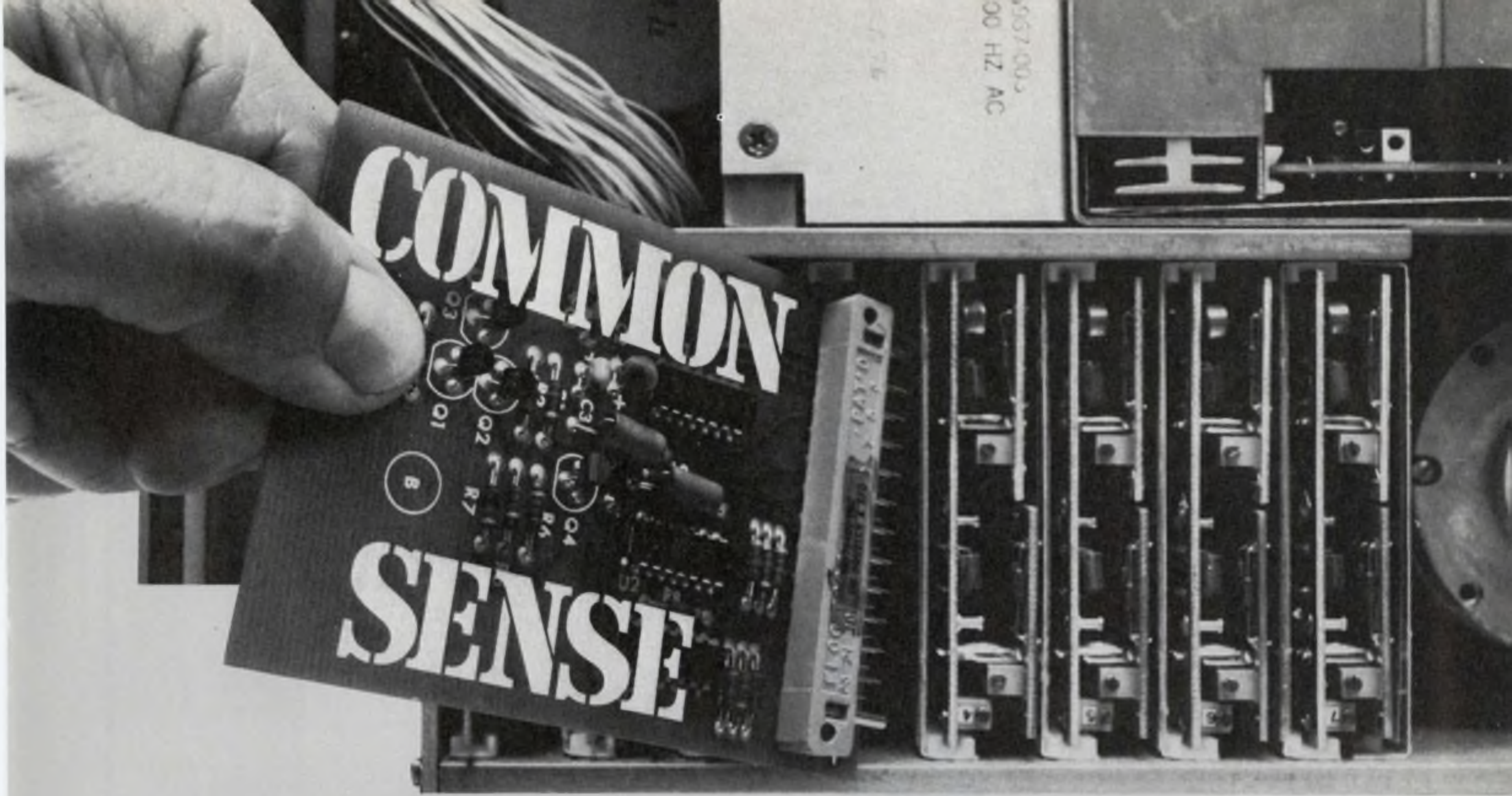

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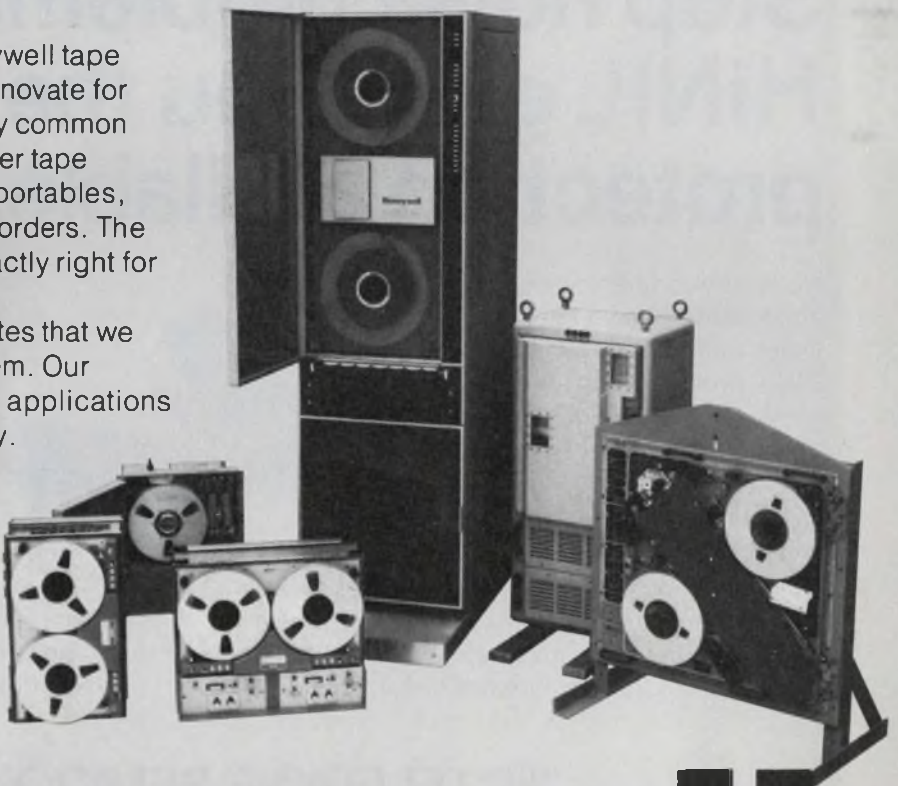

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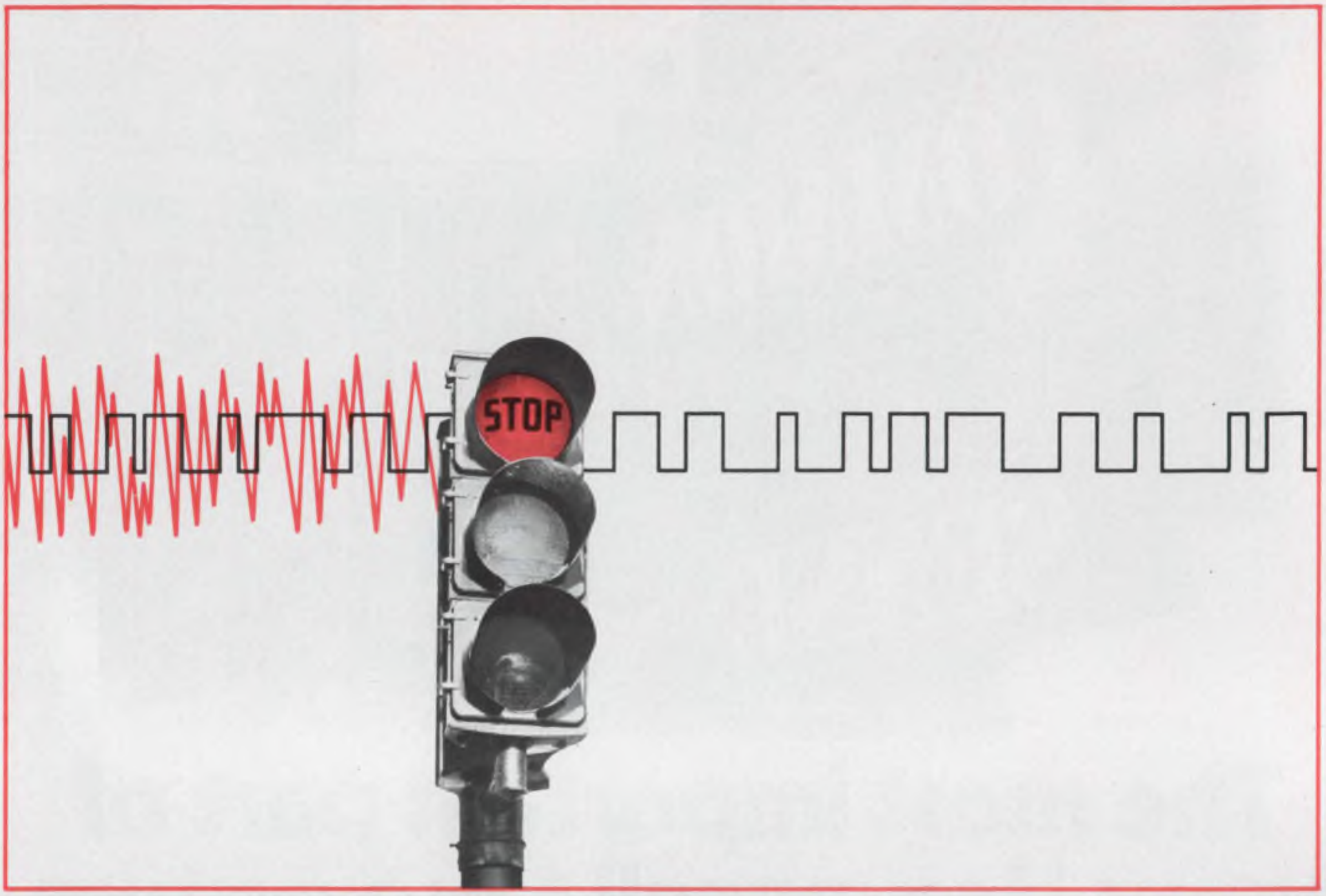

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CIRCLE NUMBER 38

Editorial

Plan ahead

Charlie and Joe run small instrument companies that they started at about the same time. But Charlie's company isn't quite so small anymore, and it's still growing fast.

That's strange because Joe's the guy who knows management techniques and, above all, he knows about planning. He keeps his senior people busy writing detailed plans and reports, so they know exactly what products they'll make five years from now. Charlie doesn't operate that way. He keeps his people busy developing products rather than plans. He doesn't give them much time to write plans and reports.

Charlie and Joe are ardent competitors. If you could listen to them, you'd know that Joe was the better manager. He's the one with the five-year plan. He's the one with reams of reports, most of which, unfortunately, he hasn't had time to read. He knows the products his company will be developing five years from now. Charlie, on the other hand, feels he's not smart enough to worry about 1981. In fact, he says, it's tough to figure what to do tomorrow—a problem Joe solved back in 1971.

It's not surprising that Joe feels contemptuous of Charlie since, in his ignorance, Charlie sees little use for paper. He sees it merely as a necessary evil. He concedes the need for some reports and plans but insists that his people condense them to a page or two. Joe, on the other hand, feels that the world is built on paper. His executives are doing a terrific job, he feels, when they deliver a 76-page report, complete with charts and other illustrations.

Unfortunately, the customers aren't buying paper. They're buying Charlie's instruments, which were designed a few months ago. They aren't buying Joe's instruments, whose design began five years ago.

If only they could read the books that Joe has read and attend the management conferences that prove you can't succeed without lots of plans. And paper.

George Rostky

George Rostky
Editor-in-Chief

1776-1976

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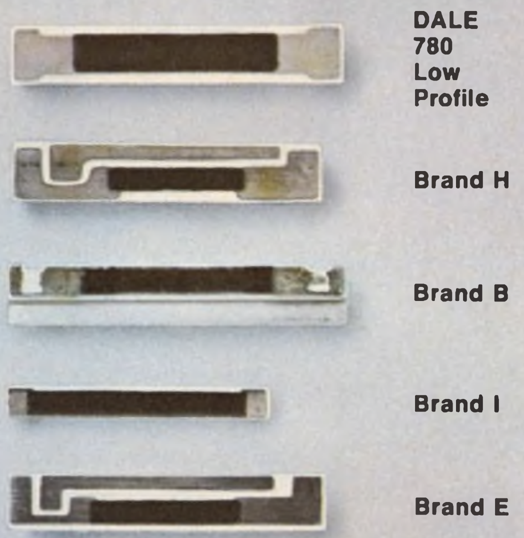

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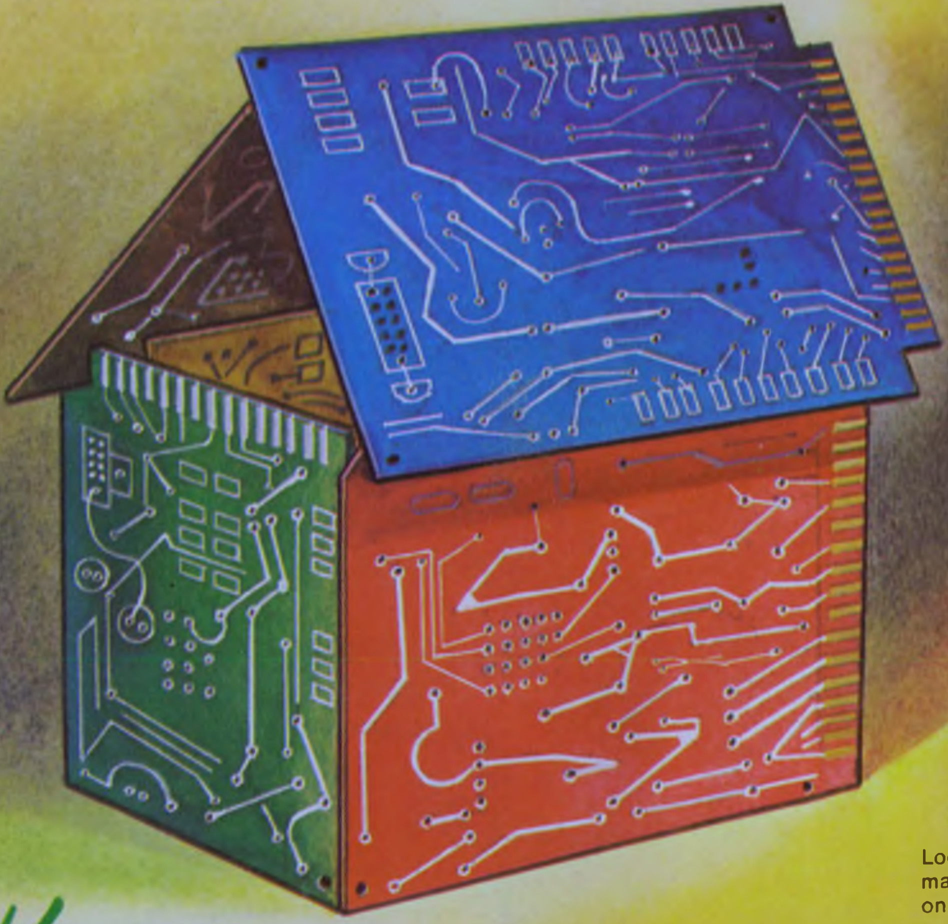

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When the single-chip MC6800 microprocessor was introduced in 1974 by Motorola, it offered designers three advantages over competing 8-bit units. It offered a dual bus structure for data and address lines and software-controllable interface elements. Further, it could operate from a single, 5-V supply. Several other companies have since introduced μPs with similar features, but so far few have equalled the flexibility of the interface circuits and the wide range of circuits available.

The software-programmable input/output elements—the peripheral interface adapter (PIA), the asynchronous-communications interface adapter (ACIA) and the synchronous serial data adapter (SSDA)—provide standard hardware interfaces, but can be switched under software control to act as either an input or output port. The single-supply operation of the μP, its associated I/O circuits and its memory circuits, permit full compatibility with TTL-level signals and power supplies.

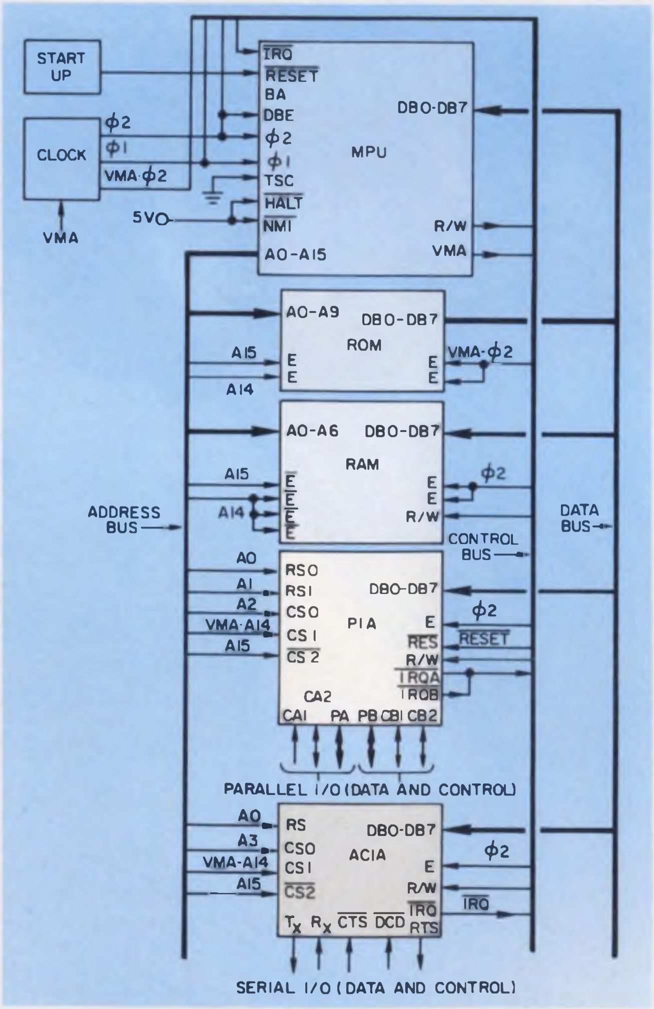
Systems go together simply

Only five circuits are needed to form a minimum microcomputer system: an MC6800 μP, an MC6820 PIA or 6850 ACIA, a RAM or ROM for program storage, an MC6870 system clock, and, of course, a power supply (Fig. 1). The components are linked together by an 8-bit data bus and a 16-bit address bus.

The current family of M6800 circuits is listed in Table 1. The newest device in the family is the XC6852—a synchronous serial-data adapter (SSDA). This circuit is used to synchronously transfer blocks of data to and from the system data bus. The 6800 can address up to 65,535 memory bytes. Since each I/O device is treated as a location in memory, the system can theoretically handle as many I/O ports as there are memory locations.

All the timing functions are controlled by the two-phase system clock, which can be set for any frequency from 100 kHz to 1 MHz. The clock modules are thick-film hybrid circuits that contain a crystal oscillator and waveshapers, as well as TTL and NMOS level drivers.

The other support circuits listed in Table 1 are NMOS, except for the bus transceiver, extender and buffers, and clock buffer, which are bipolar. And all circuits operate from a 5-V source—with the exception of the MCM6832, 68708, 6604 and 6605 memories. The four excep-



1. **The simplest microprocessor-based computer** can be built with only three or four chips, a clock and a power supply. All communication takes place over an 8-bit data bus and a 16-bit address bus.

Tom Mazur, Supervisor, Technical Communications, Motorola Semiconductor Products Inc., Phoenix, AZ 85008.

tions require additional +12 and −5 V sources. On the 6800, address and data-bus lines are buffered by three-state drivers for added interfacing ease.

The PIA permits a data interface to instruments and other sources of parallel digital data (Fig. 2a). It has two 8-bit bidirectional busses and four interrupt/control lines. One of the output busses is CMOS compatible and the other is TTL-compatible.

For serial-data interfaces, the ACIA can provide serial-to-parallel data conversion (Fig. 2b). It can simplify the interface requirements between the μP and such serial devices as modems, typewriter terminals and printers. The SSDA performs a similar function as the ACIA, but for synchronous serial data (Fig. 2c). This unit is useful for transferring large blocks of data, as found in disc or tape memory systems.

Also available is a low-speed modem that can serially transmit data at rates of up to 600 bits/s over voice-grade telephone lines (Fig. 2d). It translates TTL-level data to and from FSK (frequency-shift keyed) signals. Available memory circuits are in industry-standard pinouts to simplify interconnections and component selection.

Using the MC6800

To control the 6800 μP, there are only six registers within the IC that have to be accessed (Fig. 3). With these six registers you can control the external memory and peripheral devices. Memory can be added in any sized block, up to 64-k. All peripheral circuits connect to the data and address busses, and to the μP's control lines.

The assembly listing of a program that adds four numbers is shown in Fig. 4. Addition is set to take place in accumulator A, although accumulator B could have been selected just as easily. The assembler recognizes some special symbols in the operand field to indicate mathematical notation: a # means that the immediate address mode is to be used; a $ indicates that a hexadecimal value will follow; a % indicates that a binary number will follow; and no symbol indicates that the number is in decimal notation.

An assembler directive, ORG (origin) assigns an initial address to the program counter (PC). The RMB (reserve memory bytes) directive reserves a temporary location in memory for the results of the addition. A randomly selected label, TEMP, represents the address chosen for the temporary storage location. The mnemonic operators LDA (load accumulator) and ADD (add) represent two-byte, two-cycle instructions that will be executed in the immediate address mode. The operator STA (store accumulator) is a 2-byte, 4-cycle instruction that will be executed in the direct address mode if the address of the operand is within the lowest 256 bytes of memory space. Finally, the directive MON (return to console) indicates that the end of the source file has been reached.

Let's step through this program to see how the μP actually carries out the commands. Lines 00100 and 00110 just identify the program and tell the μP to set the PC to 000A. The next line sets up a temporary storage location called TEMP. When phase 1 of the clock goes low the PC is incremented to 000B. The next time phase 1 goes high, 000B is gated onto the address bus, and when phase 1 goes low again the PC increments to 000C.

When phase 2 goes high the contents of location 000B are put onto the data bus and when the phase 2 clock goes low the data on the data bus are gated into the instruction register where the internal ROM can decode the instruction. The contents of 000B are 86 (hex)—the op code for an LDA A (load accumulator A in the immediate mode) instruction.

Phase 1 again goes high and the contents of the PC are gated onto the address bus. When phase 1 goes low, the PC increases to 000D. When phase 2 goes high the contents of 000C, which are 19 (hex), are put on the data bus and after phase 2 goes low, the contents of location 000C

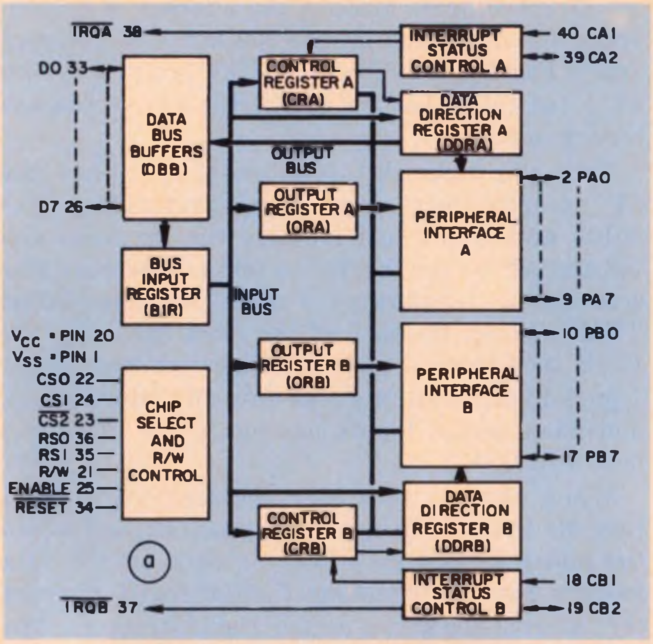
Table 1. 6800 System components

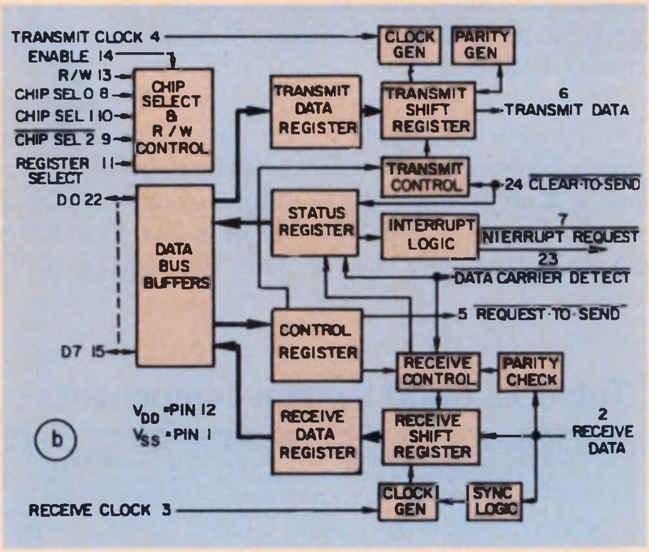
Model	Description	Price
MC6800	Microprocessing Unit (MPU)	$29.95 (50-99)
MC6820	Peripheral Interface Adapter (PIA)	$12.00 (100-999)
MC6850	Asynchronous Communications Interface Adapter (ACIA)	$12.00 (100-999)
XC6852	Synchronous Serial Data Adapter (SSDA)	$15.00 (100-999)
MC6860	0-600 bps Digital Modem	$14.00 (100-999)
MC6862	2400 bps Modulator	$21.00 (100-999)
MC6870A MC6871A MC6871B	Two-Phase Microprocessor Clocks	$18.40 $20.00 $20.00 (50-99)
MC6880/ MC8T26L	Quad Three-State Bus Transceiver	$ 3.95 (100-999)
XC6881/ MC3449P	Bi-Directional Bus Extender/Switch	$ 3.50 (100-999)
XC6885-88/P XC8T95-98P	Hex Three-State Buffers/Inverters	$ 1.65 (100-999)
MCM6810L	128 × 8-Bit Static RAM	$ 7.00 (100-999)
MCM6830L	1024×8-Bit Read-Only Memory	$13.80 (100-999)
MCM6832L	2048×8-Bit Read-Only Memory	$18.40 (100-999)
MCM68308 MCM68317 MCM68708	1024×8-Bit Read-Only Memory 2048×8-Bit Read-Only Memory 1024×8 Bit Alterable ROM	Consult Factory
MCM6604L	4096-Bit Dynamic RAM	$13.95 (100-999)
MCM6605L	4096-Bit Dynamic RAM	$20.50 (100-999)
MPQ6842	MPU Clock Buffer	$ 2.75 (100-999)

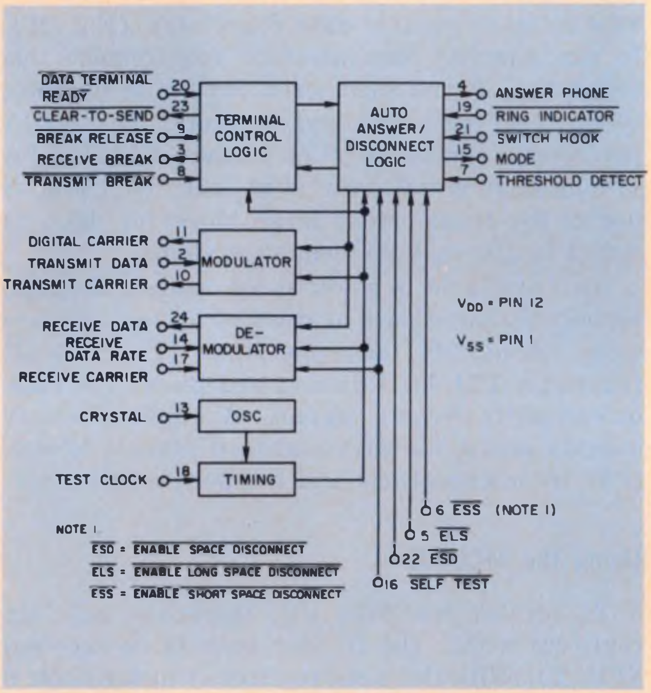
are loaded into accumulator A. At this point the decimal number 25 is in the accumulator.

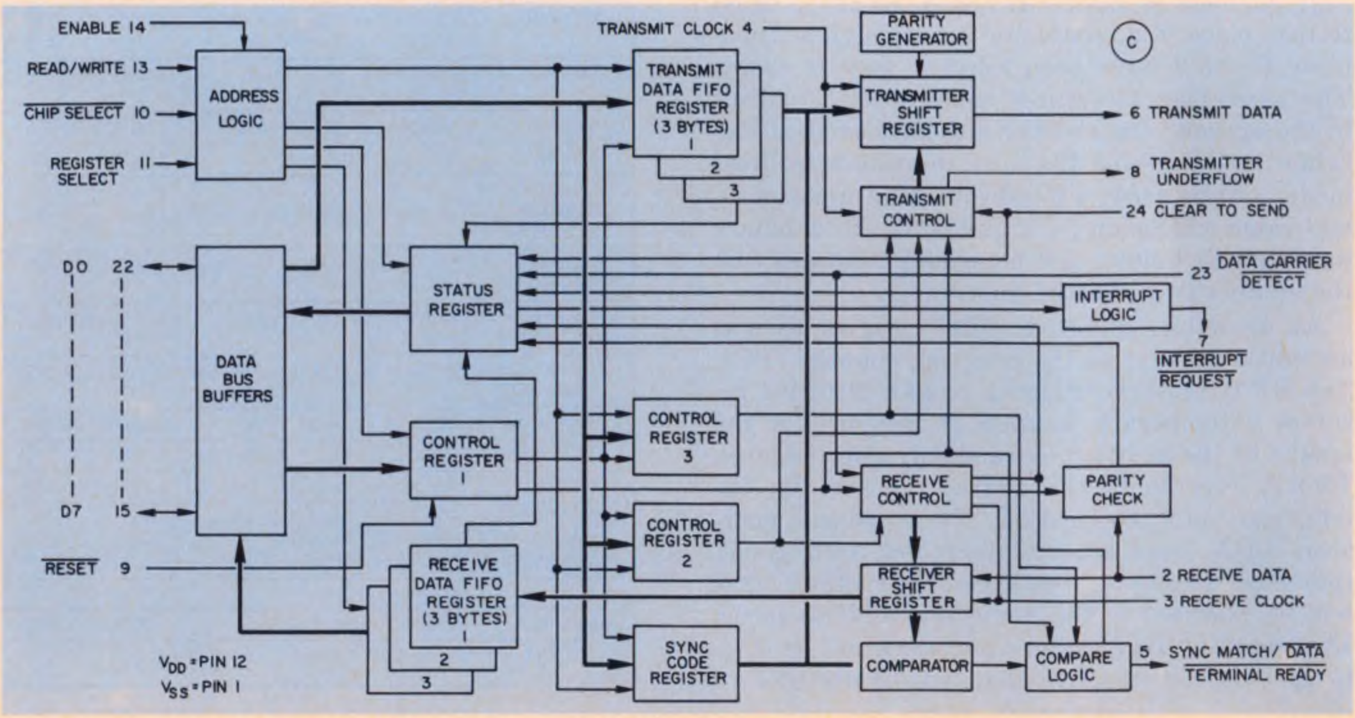
The next three instructions follow the same routine, adding the numbers 35 (decimal), 32 (hexadecimal) and 10001 (binary) to the accumulator. The PC has now been increased to 0013, and that value appears on the address bus.

The byte from location 0013 is fetched and interpreted to be an STA A, direct instruction.

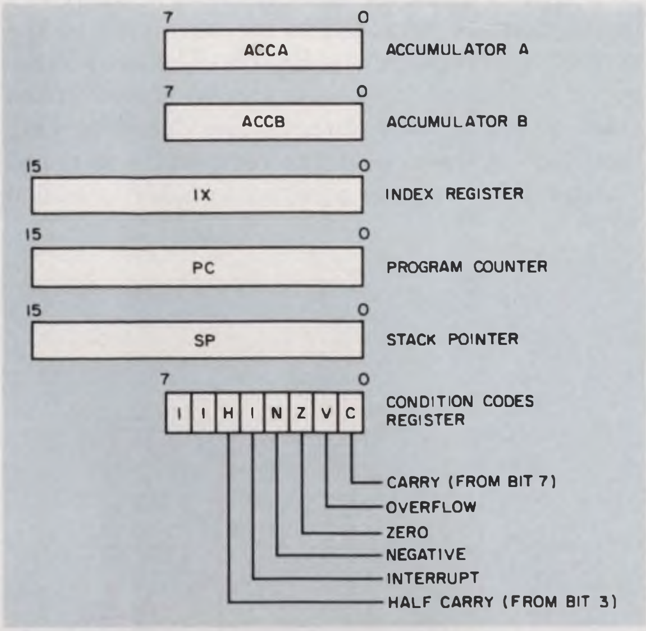




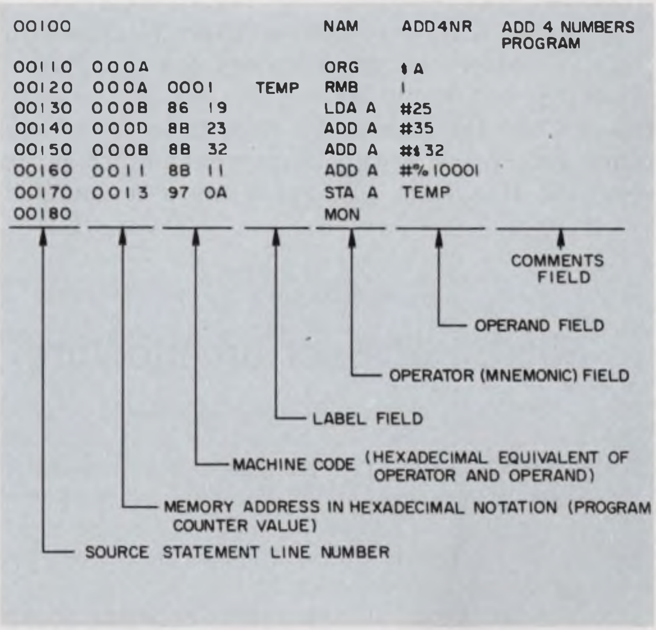




2. **The four most often used peripheral devices,** the peripheral interface adapter (a), the asynchronous communications interface adapter (b), the synchronous serial interface adapter (c) and the modem (d), help the 6800 communicate with the outside world. All units operate from a single supply and are TTL compatible.



3. **When you program the 6800,** you will find there are only six user-accessible registers that must be controlled to get the microprocessor to function.



```
00100                          NAM    ADD4NR    ADD 4 NUMBERS
                                                PROGRAM
00110  000A                    ORG    $A
00120  000A  0001       TEMP   RMB    1
00130  000B  86 19             LDA A  #25
00140  000D  8B 23             ADD A  #35
00150  000B  8B 32             ADD A  #$32
00160  0011  8B 11             ADD A  #%10001
00170  0013  97 0A             STA A  TEMP
00180                          MON
```

4. **You can break apart the assembly listing** of any program into its different fields for easy deciphering and debugging.

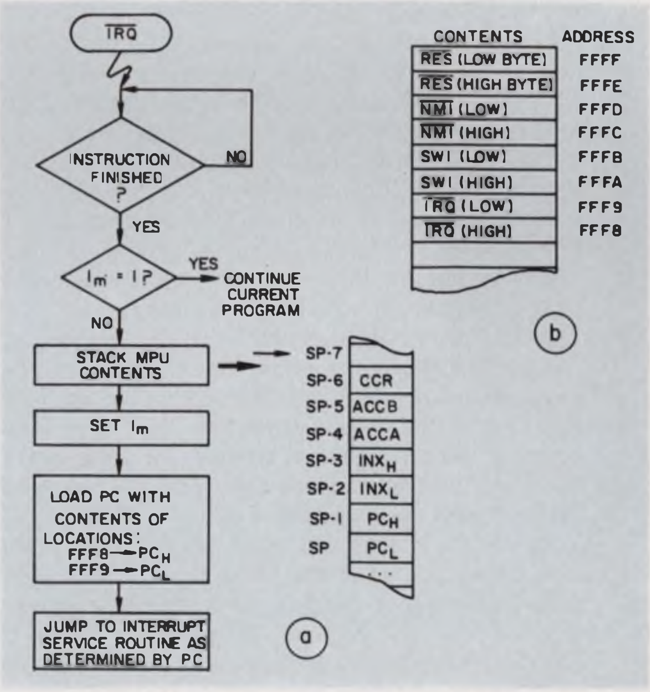
When phase 1 goes low the PC is incremented to 0014 and then when phase 2 goes high 0014 is loaded onto the address bus. After phase 2 goes low, the contents of location 0014 are transferred to the address bus. The next clock cycle gates the contents of the accumulator into the location specified by the address bus.

Many of the instructions, such as the ones used in this example, affect the status of the Condition-Code-Register (CCR) bits. Each bit may be set or cleared as a result of an instruction. For diagnostic purposes, the status of the six active bits of the CCR may be displayed after each instruction execution.

Internally, the 6800 operates in a synchronous mode, processing data-bus information at a rate determined by the clock. There are, though, many applications that require asynchronous data-handling capabilities. The M6800 system can handle these applications by delegating many of the routine peripheral-control tasks to the I/O interface devices. Each peripheral can be treated as a memory location and then addressed only when it requests an interrupt.

Interrupts divert the processor

The 6800 has three hardware interrupts—the Reset ($\overline{\text{RES}}$), Non-Maskable Interrupt ($\overline{\text{NMI}}$) and Interrupt Request ($\overline{\text{IRQ}}$). Software-based interrupts such as the SWI (software interrupt—initiates action) and the WAI (wait for interrupt) can be incorporated into a program. Except for the $\overline{\text{RES}}$ input, all interrupts cause the 6800 to store the current contents of the user-accessible registers (accumulators A and B, index register, program counter, and condition-code register) in read/write memory locations known as the stack—a last-in first-out memory space. A stack-pointer register assigns the contents of the stack to seven sequential locations and is used to retrieve the contents of the registers after the



CONTENTS	ADDRESS
$\overline{\text{RES}}$ (LOW BYTE)	FFFF
$\overline{\text{RES}}$ (HIGH BYTE)	FFFE
$\overline{\text{NMI}}$ (LOW)	FFFD
$\overline{\text{NMI}}$ (HIGH)	FFFC
SWI (LOW)	FFFB
SWI (HIGH)	FFFA
$\overline{\text{IRQ}}$ (LOW)	FFF9
$\overline{\text{IRQ}}$ (HIGH)	FFF8

5. **After an $\overline{\text{IRQ}}$ interrupt request is given,** the μP finishes its current instruction, dumps the contents of its user-accessible registers into the stack and services the interrupt (a). Permanent memory assignments for the interrupt service requests are placed in the last few memory addresses (b).

interrupt is serviced.

A typical $\overline{IRQ}$ service-flow chart is shown in Fig. 5a. After the μP registers are put into a stack, the Interrupt Mask (IM) bit of the Condition Code Register is set high to lock out any other interrupts until the current interrupt is serviced. If system interrupts must be handled on a priority basis, a Clear Interrupt Mask (CLI) instruction can be added to the beginning of the current interrupt-service routine. Then any number of additional interrupts can be nested in the stack awaiting their turn for service. The only limitation is the size of the read/write memory.

After IM is set, the program counter is loaded

Microprocessor architecture

The MC6800 microprocessor is a single-chip, 8-bit parallel processor housed in a 40-pin dual in-line package. The μP has a variable-length stack, maskable interrupt vectoring, direct memory addressing capability and six internal registers, as well as 72 variable-length instructions and seven addressing modes.

Inside the μP are three 16-bit registers, which form the Stack Pointer, Program Counter and Index Register. There are also three 8-bit registers that are known as the condition-code register and accumulators A and B. Since the address register is 16 bits wide, up to 64-k words can be directly addressed.

The stack pointer contains a 2-byte register that holds the address of the next available location in an external push-down/pop-up stack (usually part of the external RAM). The stack is usually used to store the contents of the program counter, accumulators, index register, and other information necessary for the μP to resume operation after an interrupt is serviced.

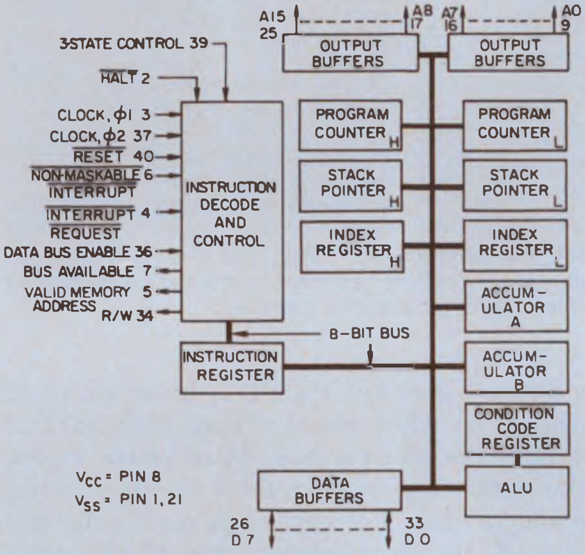
The arithmetic and logic section of the μP (the ALU) does all the bit manipulation under instruction-set control. In conjunction with the ALU, the two accumulators hold the data that go into and come out of the logic array.

The instruction register, along with the on-chip decoder and control-logic array, manage the internal operations of the μP. Combinations of commands and addressing modes produce a total of 197 executable instructions that are assembled in one, two or three bytes of machine code.

A two-phase clock controls all the timing of the μP. On the first phase the contents of the program counter are transferred to the address bus. The Valid-Memory-Address line then goes high to indicate a valid address is on the bus. On the negative transition of the clock, the program counter gets incremented.

When phase 2 of the clock goes HIGH, data are put on the data bus. (The direction of data flow—to or from the μP—is determined by the Read/Write control line.) Then, when phase 2 goes LOW, data are latched into either the μP or the memory. This sequence occurs every time the μP addresses a location and transfers a data word.

Incoming commands go into the instruction register and are then decoded by the Instruction Decode and Control array, which in turn controls the ALU. All the registers and input and output buffers are interconnected on an 8-bit-wide data bus.



The nine control lines available on the MC-6800 package permit various machine operations or provide special control functions. The Go/Halt line permits you to stop all μP operation when put into the Halt position (LOW). The Three-State Control line permits you to cause the Read/Write line and all the address lines to go into the OFF (high impedance) state. You can then use the address bus for DMA applications.

The Read/Write line tells the peripheral devices whether the μP is in the read (HIGH) or write (LOW) state. When the Three-State Control line goes HIGH, it forces the R/W line OFF (high impedance). A Valid Memory Address line tells the memory and peripheral devices that the information on the address bus is a valid address.

For control of the data bus, two lines are available—the Data Bus Enable, which enables the bus drivers when it is placed in the HIGH state, and the Bus Available which, when brought HIGH, indicates that the μP has stopped and that the address bus is available.

with the contents of two memory locations that are permanently assigned to the $\overline{\text{IRQ}}$ interrupt (Fig. 5b). The addresses, listed in hexadecimal, are the uppermost locations of the available address space. These locations should contain the addresses of the first instruction of each interrupt routine. Once the interrupt is serviced, a Return from Interrupt instruction (RTI), placed at the end of the routine restores IM and the μP returns to whatever it was doing prior to the interrupt.

The $\overline{\text{NMI}}$ interrupt is similar, except that it only waits until the current instruction is finished before storing the registers in the stack, instead of waiting until the $\overline{\text{IRQ}}$ line is reset by the current program. In effect, the $\overline{\text{NMI}}$ request has a higher priority than $\overline{\text{IRQ}}$, and is often used with a power-failure sensing circuit or with a peripheral unit that must be immediately serviced.

The $\overline{\text{RES}}$ interrupt differs from the other two in that it immediately sets IM, loads the program counter with the contents of the location assigned to $\overline{\text{RES}}$ and jumps to a service routine. This interrupt is normally used following power-on to begin a program that sets the initial conditions of the μP and the bus.

Hardware interrupts usually occur at random intervals, but software interrupts are usually planned and occur at predetermined points on a program to aid in debugging.

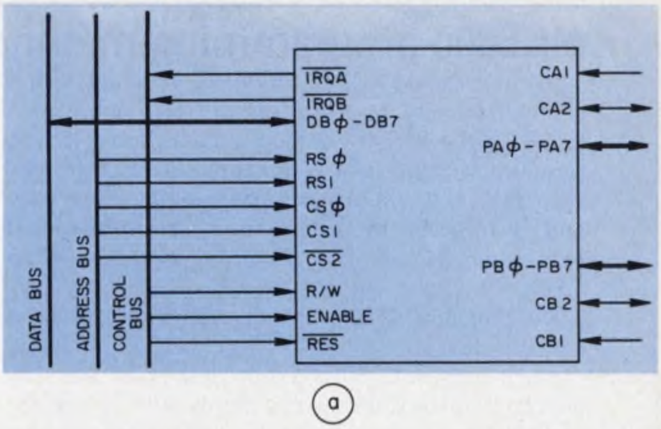
Interfacing to the system bus

Various peripheral circuits used to interface to the outside world can be controlled by software. Each of the units must be connected to both the data, address and control busses.

The PIA provides two 8-bit bidirectional data busses through pins PA0 to PA7 and PB0 to PB7 and four interrupt/control lines—CA1, CA2, CB1 and CB2 (Fig. 6a). The peripherals on side A are 5 V, CMOS compatible. The ones on side B are TTL compatible. The data flow occurs between the PIA and μP over eight bidirectional lines, DB0 to DB7. Five additional lines connect to the system's address bus.

A peripheral can signal the μP for service via the $\overline{\text{IRQA}}$ and/or $\overline{\text{IRQB}}$ lines. If necessary, the μP can acknowledge the request via the CA2 and CB2 lines. Since data transfers on the 6800 data bus usually take place on the phase-2 portion of the clock cycle, the phase-2 signal is used by the PIA as a timing reference. It is connected to the enable pulse input of the PIA. Direction of data flow is controlled by the μP R/W line, which is connected to the matching line on the PIA.

The ACIA serial-to-parallel interface circuit can be configured under software control to handle any of eight preset serial codes (Fig. 7a).



RS1	RS0	Control register bit		Location selected
		CRA-2	CRB-2	
0	0	1	×	Peripheral register A
0	0	0	×	Data direction register A
0	1	×	×	Control register A
1	0	×	1	Peripheral register B
1	0	×	0	Data direction register B
1	1	×	×	Control register B

× = Don't care

ⓑ

	7	6	5 4 3	2	1	0
CRA	IRQA1	IRQA2	CA2 control	DDRA access	CA1	control
	7	6	5 4 3	2	1	0
CRB	IRQB1	IRQB2	CB2 control	DDRB access	CB1	control

ⓒ

6. **The PIA connects into the 6800 system** with eight bidirectional data lines, five address lines and another five control lines (a). Register selection for the output port and for the flow direction can easily be done under software control (b and c).

It connects to the data, control and address busses in the same way the PIA does (Fig. 7b).

Separate inputs are available on the ACIA to permit clocking of transmitted or received data, at frequencies of 1, 16 or 64 times the data rates. Counters in the ACIA can be programmed by the μP to divide external clock signals by 1, 16 or 64. Received-data synchronization is accomplished internally in the ÷16 and 64 modes. There are also three control lines that permit limited control of a peripheral such as a modem.

There is also an extra safety feature on the ACIA. As power is applied to the adapter, an internal circuit detects the power-line transition and holds the registers in a reset condition to prevent spurious outputs from affecting a peripheral that might already be operating.

The SSDA interface circuit appears as two

MC6800 programming methods and mnemonic definitions

To get a good look at the basic instruction set of the MC6800, you can divide it into accumulator and memory, index register and stack, jump-and-branch and condition-code instructions (see table). Each instruction requires one byte and is followed by either one or two additional bytes—of an address location, data or even another instruction.

The MC6800 offers seven different ways to address data:

(1.) Inherent. This mode lets you use the operand as the address for the data to be manipulated. The operand may be either one or two bytes long.

(2.) Accumulator. Although similar to inherent addressing, in this mode the operator defines the location being addressed.

(3.) Immediate. In this mode, the byte following the instruction is used as the operand of the instruction. No reference to the memory need be made.

(4.) Direct. For direct addressing, the μP can only reach locations 0 to 255 because only a single-byte operand is used. After an instruction is encountered in this mode, the μP looks at the program counter's contents, adds one and uses that number as the location of the data word.

(5.) Extended. This mode is similar to the Direct mode except that a 2-byte operand is used, thus permitting the μP to reach the remaining memory locations, 256 to 65,535. After an instruction is encountered, the μP looks at the contents of the program counter, adds one and uses that number as the first half of the memory address. This repeats and the original value of the program counter plus two becomes the second half of the memory address.

(6.) Relative. You can specify a memory location whose address, relative to the value in the program counter, can be up to 125 locations below that value or up to 129 locations above the value. To go further than the 129 locations requires an unconditional jump, jump to subroutine or return from subroutine.

(7.) Indexed. The numerical address is not fixed, but depends on the contents of the index register.

Addressing-mode selection is made when the

Nomenclature

ACCA	Accumulator A	IXL	IX, lower order 8 bits
ACCB	Accumulator B	PC	Program counter, 16 bits
ACCX	Accumulator ACCA or ACCB	PCH	PC, higher order 8 bits
CC	Condition code register	PCL	PC, lower order 8 bits
C	Carry bit of CC	SP	Stack pointer, 16 bits
V	Two's complement overflow indicator bit of CC	SPH	SP, higher order 8 bits
Z	Zero indicator bit of CC	SPL	SP, lower order, 8 bits
N	Negative indicator bit of CC	M	A memory location (one byte)
I	Interrupt mask bit of CC	M + 1	The byte of memory at location 0001 plus the address of the location indicated by M
H	Half carry bit of CC		
IX	Index register, 16 bits	REL	Relative address
IXH	IX, higher order 8 bits		

Accumulator and memory instructions

Operation	Mnemonic	Description
Add	ADDA ADDB	Adds contents of ACCX and contents of M; places results in ACCX.
Add accumulators	ABA	Adds contents of ACCB to contents of ACCA; places results in ACCA.
Add with carry	ADCA ADCB	Adds contents of C bit to the sum of the contents of ACCX and M; places results in ACCX.
Logical AND	ANDA ANDB	Performs logical AND between the contents of ACCX and contents of M; places results in ACCX.
Bit test	BITA BITB	Performs logical AND comparison of contents of ACCX and M and modifies N, Z and V bits of CC. Contents of ACCX and M are not changed.
Clear	CLR CLRA CLRB	The contents of M or the contents of ACCX are replaced with zeros.
Compare	CMPA CMPB	Compares the contents of ACCX and M and modifies the N, Z, V and C bits of CC. Contents of ACCX and M are not changed.
Complement, 1s	COM COMA COMB	Replaces each bit of the contents of ACCX or M with its one's complement.

programs are written. If you manually translate the program into machine code, the addressing mode is inherent in the operation code.

Several different methods of generating the machine-level codes are available to the programmer. For in-house development you can use an assembly program available either from time-sharing services or from the EXORciser development system. Time-sharing services also offer a high-level language called MPL (a subset of PL/1) that is especially handy for applications that involve mathematical computations of data.

The compiler program of MPL translates source statements into M6800 assembly-level programs. Already written assembly-level instructions can be embedded in the compiled program to permit optimization when programs are already available. An assembler program then takes the assembly-level program and makes two passes in the first, it assigns numerical values to source-statement labels, then checks syntax and lists errors. On the second pass, undefined symbols from pass one are defined and an assembled listing is provided. The assembler has 12 directives, which can be used to assign data values, allocate memory and control the sequencing and formatting of programs.

Also available are an interactive simulator program that duplicates, on a host computer, the exact execution of the assembled machine-language program. Another useful program is the Build Virtual Machine, which permits you to reorganize the software you have under development. This program helps to determine and minimize memory requirements.

For development systems such as the EXORciser, a macroassembler is available. Macroinstructions represent a sequence of assembly-level instructions. The macros simplify program development, when instruction sequences must be repeated, by providing the programmer with a shorthand notation of the sequences.

In the EXORciser, the Evaluation Module II and in the Design Evaluation Kit, available firmware includes EXbug, MINIbug and MIKbug, respectively. These programs contain routines for loading user programs, for debugging them and for providing interactive control of the prototype system.

Complement, 2s (negate)	NEG NEGA NEGB	Replaces each bit of the contents of ACCX or M with its two's complement.
Decimal adjust, A	DAA	Adjusts contents of ACCA and C bit to represent correct BCD sum and carry after an ABA, ADD or ADC operation on a BCD operand.
Decrement	DEC DECA DECB	Subtracts one from the contents of M or ACCX.
Exclusive OR	EORA EORB	Performs logical Exclusive OR between contents of ACCX and M; places results in ACCX.
Increment	INC INCA INCB	Adds one to the contents of M or ACCX.
Load Accumulator	LDAA LDAB	Loads contents of M into ACCX.
OR, Inclusive	ORAA ORAB	Performs logical OR between contents of ACCX and M; places results in ACCX.
Push data	PSHA PSHB	Contents of ACCX stored on stack at the address contained in SP; SP then decremented by one.
Pull data	PULA PULB	SP incremented by one; ACCX loaded from stack, from the address contained in SP.
Rotate left	ROL ROLA ROLB	All bits of ACCX or M shifted left by one bit. Bit 0 of the byte loaded with the initial C bit. C bit loaded with the initial MSB of ACCX or M.
Rotate right	ROR RORA RORB	All bits of ACCX or M shifted right by one bit. Bit 7 of the byte loaded with the initial C bit. C bit loaded with the initial LSB of ACCX or M.
Shift left, arithmetic	ASL ASLA ASLB	All bits of ACCX or M shifted left by one bit. Bit 0 of the byte loaded with zero. C bit loaded with the initial MSB of ACCX or M.
Shift right, arithmetic	ASR ASRA ASRB	All bits of ACCX or M shifted right by one bit. Bit 7 of the byte loaded with a zero. C bit loaded with the initial LSB of ACCX or M.

Operation	Mnemonic	Description
Shift right, logic	LSR LSRA LSRB	All bits of ACCX or M shifted right by one bit. Bit 7 of the byte held constant. C bit loaded with the initial LSB or ACCX or M.
Store accumulator	STAA STAB	Store the contents of ACCX at M; the contents of ACCX remains unchanged.
Subtract	SUBA SUBB	Subtract the contents of M from ACCX; place the results in ACCX.
Subtract accumulators	SBA	Subtracts the contents of ACCB from ACCA; places results in ACCA. Contents of ACCB not affected.
Subtract with carry	SBCA SBCB	Subtracts the contents of M and C from ACCX; places results in ACCX.
Transfer accumulators	TAB TBA	Moves contents of ACCA to ACCB (TAB) or vice versa (TBA). The contents of the transferred accumulator are not changed; the contents of the receiving accumulator are changed.
Test, zero or minus	TST TSTA TSTB	If MSB of ACCX or M is one, then the N bit of CC is set to one. If the contents of ACCX or M are all zeroes, then the Z bit is set to one.
Index register and stack manipulation instructions		
Compare index register	CPX	The contents of IXH and IXL are compared to M and M+1, respectively. The N,Z and V bits of CC are affected.
Decrement index register	DEX	Subtracts one from the index register. Z bit of CC is affected.
Decrement stack pointer	DES	Subtracts one from the stack pointer. CC not affected.
Increment index register	INX	Adds one to the index register. Z bit of CC is affected.
Increment stack pointer	INS	Adds one to the stack pointer. CC not affected.
Load index register	LDX	Loads IXH and IXL with contents of M and M+1, respectively. The N,Z and V bits of CC are affected.
Load stack pointer	LDS	Loads SPH and SPL with the contents of M and M+1, respectively. The N,Z and V bits of CC are affected.
Store index register	STX	Stores IXH and IXL at locations M and M+1, respectively. The N,Z and V bits of CC are affected.
Store stack pointer	STS	Stores SPH and SPL at locations M and M+1, respectively. The N,Z and V bits of CC are affected.
Transfer from IX to SP	TXS	Loads SP with contents of IX minus one. Contents of IX unchanged.
Transfer from SP to IX	TSX	Loads IX with contents of SP, plus one. Contents of SP unchanged.
Jump and brand instructions		
Branch always	BRA	Branch to the address equal to PC+0002+REL.
Branch if carry clear	BCC	Branch to the address equal to PC+0002+REL, if the C bit = 0.
Branch if carry set	BCS	Branch to the address equal to PC+0002+REL, if the C bit = 1.
Branch if equal to zero	BEQ	Branch to the address equal to PC+0002+REL, if the Z bit = 1.
Branch if ≥ zero	BGE	Branch to the address equal to PC+0002+REL, if the logical Exclusive OR of N and V bits = 0.
Branch if > zero	BGT	Branch to the address equal to PC+0002+REL, if the contents of Z+ [N + V] = 0.
Branch if higher	BHI	Branch to the address equal to PC+0002+REL, if the logical AND of C and Z bits = 0.
Branch if ≤ zero	BLE	Branch to the address equal to PC+0002+REL, if the contents of Z+ N + V = 1.
Branch if lower or same	BLS	Branch to the address equal to PC+0002+REL, if the contents of C+Z = 1.

Branch if < zero	BLT	Branch to the address equal to PC+0002+REL, if the contents of N + V = 1.
Branch if minus	BMI	Branch to the address equal to PC+0002+REL, if the contents of N = 1.
Branch if ≠ zero	BNE	Branch to the address equal to PC+0002+REL, if the contents of Z = 0.
Branch if overflow clear	BVC	Branch to the address equal to PC+0002+REL, if the contents of V = 0.
Branch if overflow set	BVS	Branch to the address equal to PC+0002+REL, if the contents of V = 1.
Branch if plus	BPL	Branch to the address equal to PC+0002+REL, if the contents of N = 0.
Branch to subroutine	BSR	Branch to the address equal to PC+0002+REL. PC+0002 stored in the stack.
Jump	JMP	PC loaded with a numerical address; a jump to that location occurs.
Jump to subroutine	JSR	PC incremented by 0002 (indexed address mode) or 0003 (extended address mode), then stored in the stack. PC loaded with a numerical address; a jump to that location then occurs.
No operation	NOP	Advances PC; no other registers affected.
Return from interrupt	RTI	CC, ACCX, IX and PC restored in the states that were saved in the stack.
Return from subroutine	RTS	SP incremented by one; PCH loaded with the contents of the location specified by SP. Again, SP is incremented by one; PCL loaded with the contents of the location specified by SP.
Software interrupt	SWI	PC incremented by one; then PC, IX, ACCX and CC stored in the stack. SP decremented by one after each byte is stored. I bit then set and PC then loaded with the address specified by the software.
Wait for interrupt	WAI	Registers operated on and saved as in SWI instruction, except I bit is not set. Program execution suspended until interrupt occurs on IRQ line. When IRQ goes low, and provided that the I bit is clear, program execution proceeds as in SWI.
Condition code register manipulation instructions		
Clear carry	CLC	Carry bit reset to zero.
Clear interrupt mask	CLI	Interrupt bit reset to zero.
Clear overflow	CLV	Overflow bit reset to zero
Set carry	SEC	Carry bit set to one.
Set interrupt mask	SEI	Interrupt bit set to one.
Set overflow	SEV	Overflow bit set to one.
Transfer from ACCA to CC	TAP	Transfers the contents of bit 0 through 5 of ACCA to the corresponding bit positions of CC. Contents of ACCA not changed.
Transfer from CC to ACCA	TPA	Transfers the contents of bit 0 through 5 of CC to the corresponding bit positions of ACCA. Bits 6 and 7 of ACCA are set to one. Contents of CC not changed.

memory locations to the μP. Internally there are actually seven registers. Data transferred to and from a peripheral must be accompanied by clock signals that are synchronized to the data. Transfer rates of up to 600 kilobits/second are possible. A power-on protect feature, similar to one in the ACIA, is also included.

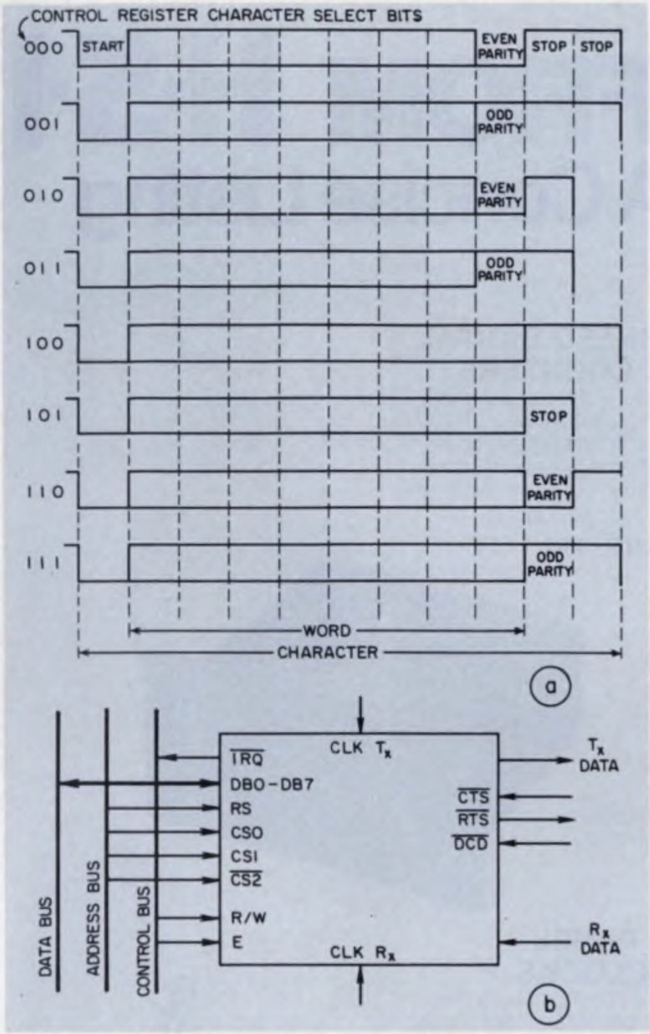
To speed data flow over a telephone line, the low-speed modem circuit can operate in full-duplex, half-duplex or simplex modes. It can also be used in the answer or originate mode and can respond to a hang-up request. When the circuit is used to originate a call, the output will be a 1070-Hz signal for a space (ZERO) and a 1270-Hz signal for a mark (ONE). When the modem answers a call its modulator output will be 2025 Hz for a space and 2225 Hz for a mark.

A wide range of memory types and sizes is

Table 2. Support software and hardware

Support software	Available versions for:		
	Time-sharing systems	In-house computer systems	Design instrumentation
MPL compiler	GE International System; UCS	Sigma 9, Honeywell 6000, IBM 360/370 CDC6000	
Assembler	GE; UCS: Dentsu; Honeywell-Bull	Sigma 9, HP2100 IBM 360/370, NOVA, Honeywell 6000, CDC6000, PDP11	Resident editor/assembler versions for EXORciser and evaluation modules
Simulator	Same as assembler	Same as assembler	
Build virtual machine	Same as assembler		
HELP	Same as assembler		
Macro assembler			Resident version
EXBUG			EXORciser firmware
MINIBUG II			Evaluation Module II firmware
MIKBUG			Design evaluation kit firmware

Support hardware	Description
EXORciser	Basic EXORciser consists of an MPU module, debug module, baud rate module, power supply and chassis.
EXORciser optional modules	input/output, ACIA, PROM programmer, wrapped wire and extender modules. 2k × 8 static RAM, 8k × 8 dynamic RAM, 16k × 8 dynamic RAM, EROM/RAM,
System analyzer	Used to monitor and modify programs; contains 4k-bytes of RAM plus hex display and I/O control logic. The SA can be installed in the EXORciser or used as an independent, portable test instrument.
User system evaluator	For prototypes developed or transferred outside of the EXORciser chassis, and for production level testing, USE can be employed for test and debugging purposes. Operating with a single, shared-processor, the USE/prototype interface can be changed at will, allowing elements of the prototype to be tested and debugged in real time.
Component tester	Functionally tests the M6800 MPU, PIA, ACIA, ROM and RAM. Up to eight test heads can be connected to a single EXORciser for volume testing.
EXORdisk	A twin-drive floppy disk peripheral for the EXORciser that provides a low-cost-per-bit storage medium. Included with the EXORdisk is a disk operating system called EDOS.
EXORtape	A high speed papertape reader for the EXORciser. Data can be loaded at rates of up to 250 characters per second.
Evaluation Module II	A microcomputer on a single board; contains an MPU, 3 RAMs, 2 ACIAs, a PIA, an MC6871A clock oscillator, an MC14411 bit rate gen., data, address and control bus and peripheral interface buffers. A ROM contains the MINIBUG II loader/diagnostic program. Two of the RAMs provide 256 bytes of storage for users' programs. A 24-pin socket on the board will accommodate 2704 or 2708 type PROMs that contain user-generated firmware. The module interfaces with a TTY or RS232C data terminal.
Design evaluation kit	A low-cost microcomputer kit; contains an MPU, 2 PIAs, an ACIA, 2 RAMs, and a ROM that holds the MIKBUG loader/diagnostic program. One of the RAMs provides 128 bytes of storage for users' programs. The kit interfaces with a TTY or RC232C data terminal.



7. **A three-bit input to the control register** of the ACIA can set any of eight serial word formats (a). The ACIA connects easily to the general system bus (b). The eight bidirectional data lines are still needed. Only four address lines and three control lines are necessary.

available for use with the 6800 μP. Some typical sizes include the 128 × 8, byte-oriented RAM and the 1024 × 8, byte-oriented ROM. The RAM is a static unit and requires no refresh. It has TTL-compatible inputs, a bidirectional, three-state I/O bus and four negative and two positive chip-enable lines.

The 8-k ROM is mask programmable and has four enable lines. The enable lines are defined by the customer, when the mask is designed, to be either positive or negative. Input lines are TTL-compatible and there are three-state outputs.

Access time of the RAM can be as short as 350 ns to as long as 1 μs for the read function, depending upon the model selected. The ROM has an access time of 500 ns.

Other sizes of RAMs and ROMs are also available, along with clock buffers, alterable ROMs, dynamic RAMs, bus extenders and three-state buffers.

When the M6800 system runs at full speed (that is, at a clock rate of 1 MHz) memory components must have access times of 575 ns or less. Of course for cost tradeoffs slower memories can be used if the clock rate is decreased, or if you switch to dynamic memories that can be accessed faster but which require extra refresh circuitry.

The MC6800 uses two nonoverlapping clocks that time the execution of a program. Dynamic RAMs place an additional constraint on the clock: the output phases can be held in one state no longer than 5 μs without affecting the contents of the dynamic RAM.

Development aids fill most needs

A comprehensive array of support software and system-development tools is available from Motorola and other companies. The most powerful of these tools is the EXORciser. It contains a complete M6800 operating system, and built-in firmware to help design and debug prototype systems. The basic EXORciser consists of three plug-in boards, a power supply and a chassis. The three modules are the μP card, the debug card and a baud-rate module. The μP and debug cards each require one of the 14 card slots in the EXORciser chassis. The other 12 slots are available for custom-designed interfaces and circuits.

On the μP card is the μP, a clock, bus control logic, and clock-control circuit and three-state buffers.

The debug module contains ROMs, RAMs, a PIA, an ACIA, a PROM and an assortment of logic, buffers and opto-isolators for bus control and for data-terminal interfaces. Firmware on the board consists of the EXbug loader/diagnostic program.

On the baud-rate module is a crystal-controlled bit-rate generator that permits data rates of 110 to 9600 baud. The chassis power supply provides 5 V at 15 A, 12 V at 2.5 A and -12 V at 1.5 A to handle almost any circuit requirements.

For smaller design applications, the MEK-6800D1 Design Evaluation Kit or the M6800B Evaluation Module II are available. The MEK kit consists of a printed-circuit board and M6800 family ICs. Also included is a ROM that contains MIKbug, a debugging routine.

The Evaluation Module II is a self-contained microcomputer on a single board, similar to the Design Evaluation Kit, except that it comes completely assembled. It contains a μP, three RAMs, two ACIAs, a PIA, a ROM, a clock oscillator and a bit-rate generator. Also included are the data, address and control-bus buffers. ■■

The first article in this series appeared in the April 26 issue. Part 2 covered the 8080 and appeared in the May 10 issue. Part 3 discussed the F8 and appeared in the June 7 issue. The next article in this series will appear in the August 2 issue.

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CIRCLE NUMBER 46

Bring up your μP "bit-by-bit."

With a systematic, section-by-section approach you can test both hardware and software in less time.

Unless you enjoy spending weeks or months in unraveling complex puzzles, take a systematic approach when you develop μP-based systems.

Two basic procedures underpin the approach: turn the system on one piece at a time, and debug software and hardware together. The tool that allows all this is the logic-state analyzer.

With the analyzer, you can develop a μP system with the same technique you usually use to develop a cascaded amplifier. That is, you usually turn on and check out the amplifier one section at a time by injecting a signal into the input and measuring the output of each section with a voltmeter, spectrum analyzer or oscilloscope. In turning on μP systems, analyzers offer a similar approach, and so ease the development process.

In operation, analyzers measure information transfer—program addresses, program instructions or any data that appear on any of the busses or ports within the μP system.

One analyzer can display sixteen 16-bit data words at one time, or sixteen 32-bit words with a companion analyzer. These words are displayed as ONEs and ZEROs and are selected with a pattern trigger and digital delay (Fig. 1).

The pattern, or data word, is selected by setting the 32 pattern-trigger switches to high, low, or off. The delay can be such that the display starts anywhere from 15 words before the pattern trigger, to 99,999 words after the trigger. Since the analyzer has a digital memory, data can be captured single-shot and displayed indefinitely.

Another useful analyzer feature is an output that can trigger a scope at any byte in a digital process. With the trigger, you can examine waveforms in detail.

1. **A functional display of ONEs and ZEROs** gives designers an overview of the operation of a digital system. Words are captured in the analyzer's memory.

Sequential operations cause problems

In developing a systematic process for turning on a μP system, remember that it's the data transactions on the various busses that determine a system's function. Consider the μP system of Fig. 2. If all of the elements in this system are wired up, plugged in and turned on, chaos will almost surely result. Any small wiring mistake or logic error can cause the system to run amok.

Such alarming behavior results because the entire system is one giant digital-feedback loop. The next value of the program counter depends on the current instruction, but the latter depends on the current value of the program counter.

Interchanging two address lines causes the instructions to be executed in an entirely random sequence. A small logic error, which allows two ROMs to respond simultaneously to an address, will cause the outputs of the ROMs to be wire-ANDed, again putting entirely random instructions on the data bus.

Similarly, data stored in memory—to be read back later for conditional branches—are determined by instructions executed long ago, and the instructions to be executed in the future depend upon those stored values. Current or post values of the I/O ports also participate in decisions that affect future operation.

The only reasonable approach to turning on such a system is to break the feedback network

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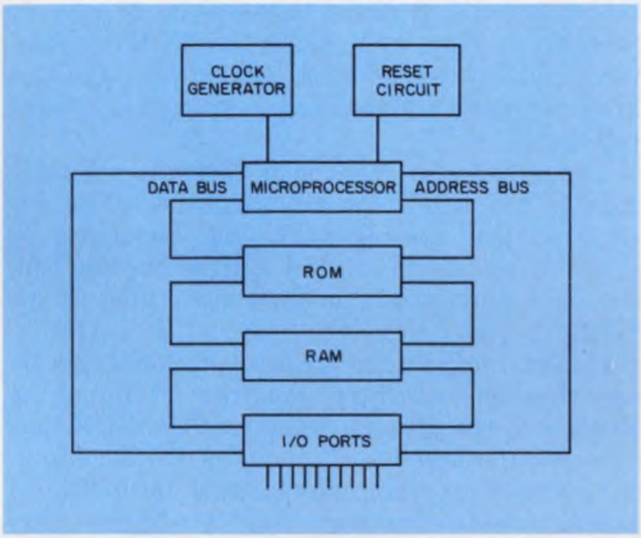


2. **Generalized microprocessor system** contains fixed programs in ROMs and data in RAMs. Interaction between the memory and μP appears like a feedback loop.

into pieces, so that each piece can be turned on independently.

The first candidates for turn on are the clock generator and reset circuits. These relatively simple timing circuits are best tested with a scope for proper timing and waveshape. Once these circuits are within specs, the next step is to check the interaction between the μP and the ROM.

A crucial path: μP to ROM

The linkage between the ROM (or RAM) and the μP is the first to be established because with this link, the processor can be programmed to serve as a signal generator for testing the remaining blocks. The linkage is tested in three steps:

First, you must establish that the NOP (no operation) instruction is being transmitted correctly to the processor. Second, establish that the program addresses are transmitted correctly to the ROM. Finally, determine that the ROM interprets the program addresses correctly.

To perform the first step, plug in only the μP and put the NOP code on the data bus (Fig. 3a). In forcing the data bus to NOP, realize that many μPs will try to put data onto the bus during an operating cycle. If the data bus is simply wired to the NOP state, then the data-output buffers in the μP can be destroyed. You can avoid this problem in two ways.

Since the μP data inputs are usually high impedance, the data bus can be forced safely to NOP with large resistors. Or, it can be forced to NOP through a set of three-state gates. Connect the three-state control to the processor read/write line so that the gates are active only when the processor reads data.

This set-up will cause the program counter in the processor to increment. That is, the processor will execute a NOP, increment the program counter, execute the next NOP, and so on. You can easily measure the counting sequence on the address bus with the analyzer. Simply connect the 16 data inputs to the address bus at the ROM socket, and connect the clock input to the data-transfer processor clock.

The count sequence also can be easily verified. Just trigger the analyzer on 0000_{16}, increment the delay generator through several values, and compare the count displayed on the state analyzer with the delay setting. Obviously, the count (in decimal) and the delay value will be equal if the ROM receives correct addresses.

In this way, you verify that the processor is executing NOPs and that the addresses are correctly transmitted to the ROM. If the addresses do not form a counting sequence, then an examination of the address pattern should quickly reveal if address lines are interchanged or are inactive, or the processor is executing an unexpected branch instruction.

If you suspect that the processor is not executing NOPs during the instruction read phase, then connect the state analyzer to the data bus directly at the processor.

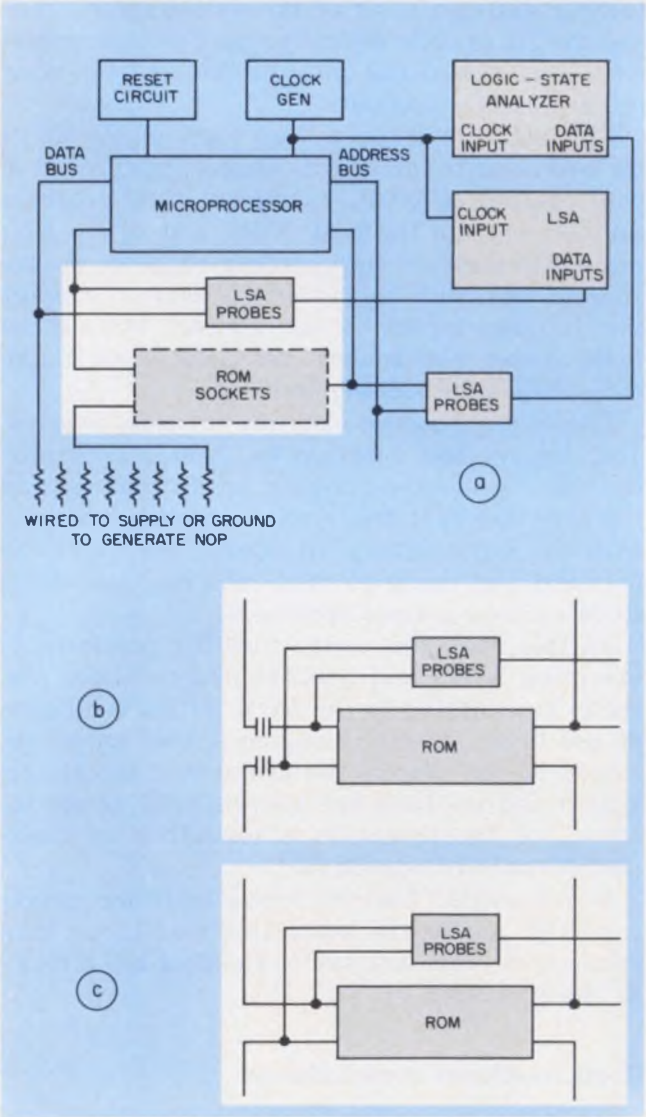
Check waveforms at each change

At this point, it is also important to examine the waveforms on the busses and the control lines. Any incorrect timing, marginal voltage levels, noise or crosstalk should be eliminated before proceeding. In fact, you must do this every time you add a new block to the system. Any input or output hung onto a common line can cause a problem.

The analyzer's scope-trigger output is very useful, especially as more blocks are added. For example, to examine the waveforms on the data bus when the bus is driven by the RAM outputs, you need only trigger the analyzer on the RAM read address or on the address of the RAM read instruction, then trigger the scope with the analyzer's pattern-trigger output.

Although such testing may seem needlessly repetitive, it takes very little time if there is no problem, and saves a great deal of time, if there is one by pinpointing the troublesome block.

Next, plug in some ROMs with known stored information and connect only the address lines and chip-select logic (Fig. 3b). Since the instructions returning to the processor are still NOPs, the program counter will continue a simple count. This time, however, the ROMs will cycle through all possible addresses so that you can measure the ROM outputs with eight data inputs to the analyzer.



3. **To check transactions between** the μP and ROM requires three steps. The first step verifies NOP transmission (a), the second checks ROM addressing (b) and the last step tests the completed link (c).

Keep 16 data inputs connected to the address bus, if possible. It isn't necessary to measure all possible values of ROM output, but you should check sufficiently to verify that the correct ROM is selected and that every ROM is addressed correctly.

Since not all 65-k addresses are ordinarily allocated to ROM, it might be necessary to connect temporarily some pull-ups to the ROM outputs. With pull-ups, an address outside the allocated ROM addresses will generate a known data word (all highs).

You should also check some addresses outside those of the ROM to verify that the ROMs are off when they are not addressed. Remember to check the waveforms on the address bus and central lines, particularly on the control lines of the ROMs.

Finally, complete the processor-to-ROM link by removing any circuitry required to force the NOPs onto the μP and connecting the ROM outputs onto the data bus (Fig. 3c). A ROM containing a simple program, with several unconditional jumps, should be installed (Fig. 4). Verify operation of this program by monitoring the address bus with the analyzer.

The program includes RAM access and I/O instructions so that the RAM and I/O control cycles can be checked before the RAM and I/O devices are installed. The timing of these cycles is easily checked. Just use the analyzer to trigger a scope at the beginning of each RAM or I/O instruction.

It isn't necessary to monitor the data bus—unless there is a problem—because the sequence of program addresses is ample to verify proper execution of the program. Although only a very simple program is required to test the μP-to-ROM data link and the RAM and I/O control cycles, a more elaborate program can be used if desired.

Debugging RAM and I/O

In no case, however, should any branches on RAM or I/O instructions be used at this point, as the RAM and I/O blocks have not yet been turned on and debugged. If enough ROMs are available, the test ROM, and any others used in the turn-on procedure, should be saved for future units.

The checkout of the μP-to-ROM data link is by far the most tedious. The reason is that this link must always be a feedback process. That is, each instruction depends on the address, and each address depends on the previous instruction.

The RAM and I/O blocks can be turned on much more directly, and in any order. If you choose the RAM first, you can connect it to the system in one operation.

With the RAM connected, run the ROM test program briefly to verify operation. Pay particular attention to the timing of the RAM control signals during the RAM read and write instructions. The usual cause of failure at this point is a shorted address or data line, two lines shorted together, or an unwanted RAM response.

Again, the analyzer will reveal quickly the location of the problem, and a scope triggered from the analyzer will show the nature of the problem. With the ROM program verified, now run a RAM test.

A RAM test program should write to every location in memory, then read each location back and verify the data. With an eight-bit-wide memory, watch out for a pitfall:

The eight bits of memory represent only 256 states. Conventional memories are usually much longer. This means that each possible data pattern must be written several times to fill the memory. If the same data are written into each block of 256 words, an error in any of the higher order addresses can be masked.

An extreme example of such masking is the case where all address lines (A8 to A15) are disconnected. Any simple perturbation of the 256-word pattern—such as shifting the pattern one word location in each block—will reveal the problem (Fig. 5).

For example, if you count from 0 to 255 in the first block, you should count from 1 to 255, then go back to ZERO in the next block; next, count 2 to 255, and go back to ZERO and ONE in the next block, and so on. The flowchart of an effective RAM-module test program is shown in Fig. 6. Remember, this test verifies that the memory system is working correctly—it does not check each cell of each memory location.

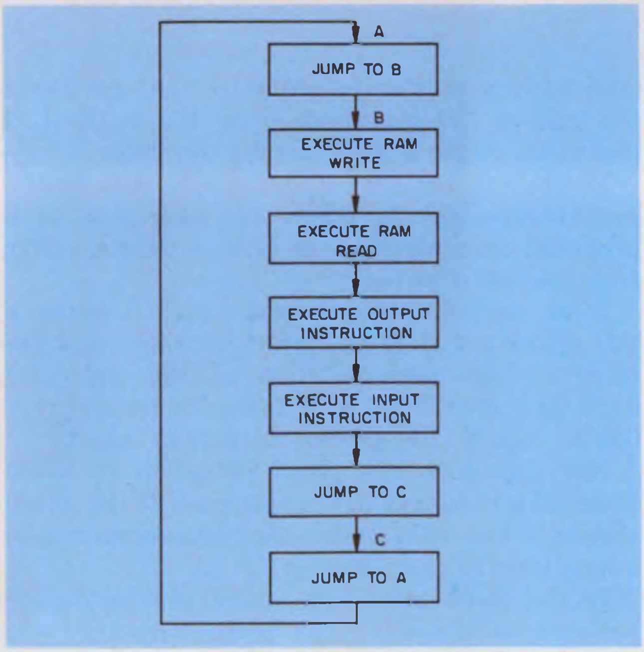
Again, if you design the program so that all locations are written and then read back, the analyzer quickly shows whether the data are correct. An oscilloscope triggered by an analyzer shows whether the waveforms are correct.

Although the I/O block is relatively easy to turn on, the discussion here is somewhat general since I/O structures vary more than other blocks from one μP system to another. The main point is to test the I/O ports before connection to peripheral devices, such as keyboards, displays, or circuits to be controlled. The first step is to put the ROM test program back in, and verify that the control timing is correct with the ports connected during the I/O instructions.

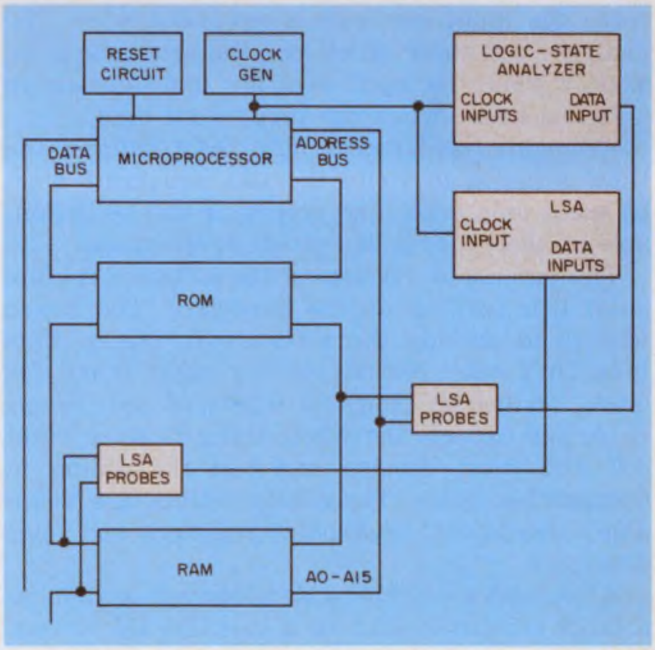
You can check the output ports easily with a simple program that first sets all the ports to ZERO, then sets each port in turn to ONE, and finally sets each port back to ZERO one at a time. When testing the output ports, connect the analyzer to one block at a time.

If sufficient data channels are available on the analyzer, connect these to the address bus as well (Fig. 7). The object of this exercise is to see if the output ports are connected in the proper order and can be set both high and low.

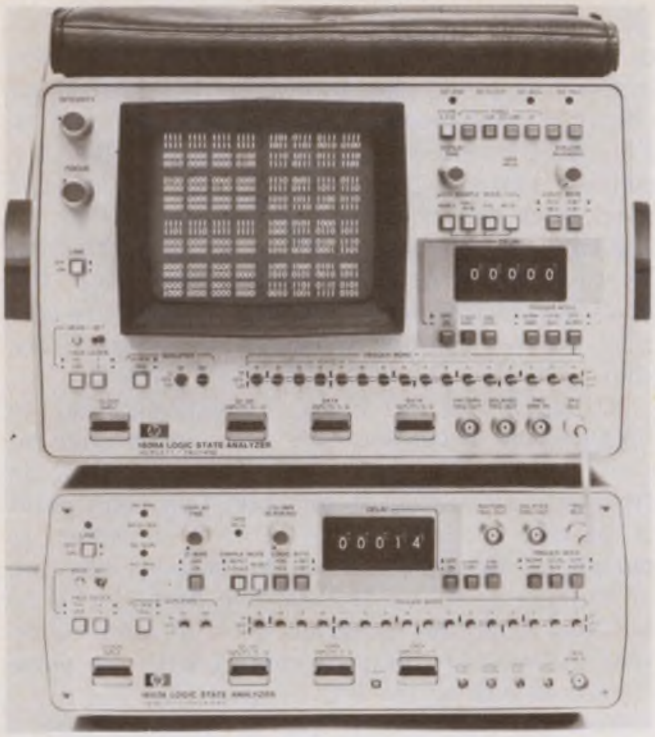
The input ports are similarly tested. The program should check for each input high, then for each input low.



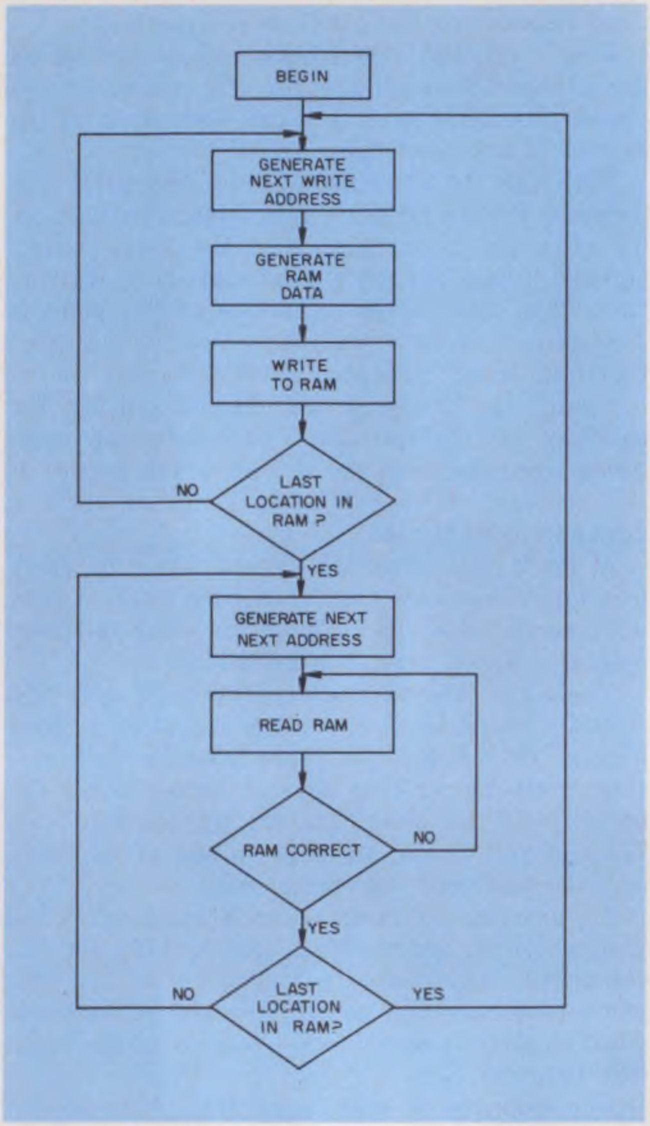
4. **Verification program** checks out the ROM-to-processor data link. Also checked are I/O control cycles.



5. **Test set-up to turn on the system RAM** verifies the writing and reading of each location in memory.



Logic state analyzer shows up to sixteen 32-bit words at a time. Data are put into memory when the instrument recognizes a selected word or are captured after a set delay.



6. **RAM-module test program** wrings out memory system operation, as monitored by the logic analyzer.

The test, of course, is performed by a program that loops until the input under test is forced to the desired state, then jumps to another loop (Fig. 8). A simple approach is to pull all of the inputs either high or low, whichever is easier, through a resistor.

Assuming you selected the "high" approach, write a program that has two loops: the first to test for a specific input low and the second for that input high. While the analyzer monitors the address bus and at least the one input under test, force the input low with a grounded wire. The analyzer will show which loop the processor is in, exactly when the input went low and—usually in a second pass—when the input went high.

Although this process may seem tedious, the time required to write the test programs must be spent only once. The programs will be invaluable at every phase of system development.

The process of developing the software is quite a bit like turning on the hardware. The major idea is to develop the software in pieces. This idea isn't new. Nobody in his right mind sits down, writes six-thousand words of code, plugs it in, and expects the whole thing to work right off. You must develop and test the coding in manageable bytes. Three alternatives are available: simulators, breakpoint registers and logic analyzers.

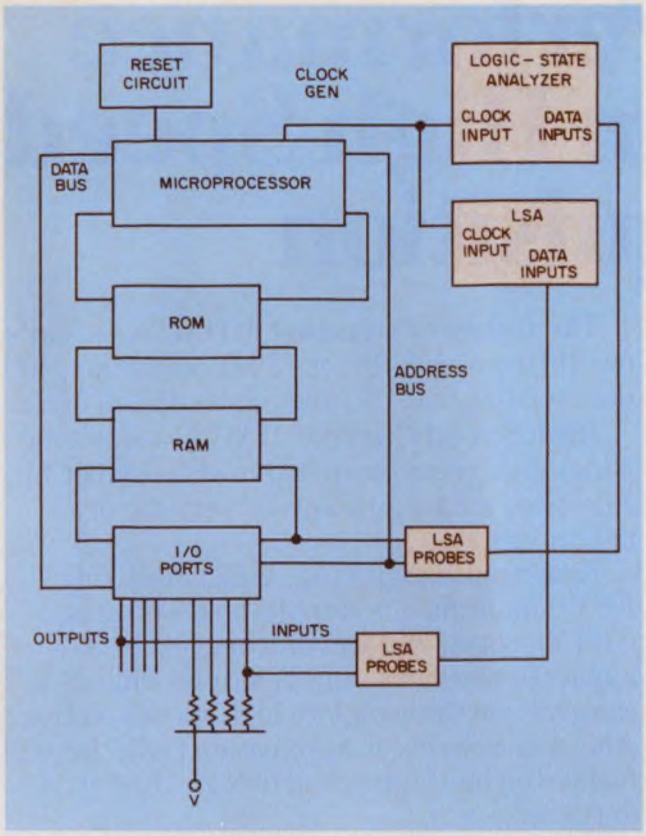
A simulator—either a development system or a large computer—can be a valuable aid in testing such complex algorithms as sorting routines or mathematical functions. But it is difficult to adequately simulate the software that performs the bulk of I/O operations—and it's at the I/O ports that major trouble usually develops.

Breakpoint registers and a single-step button are another way to follow the operation of a program. Such registers, or control panels, suffer from several drawbacks:

First, to build the control panel requires a fair amount of time and effort. Second—and far more serious—the operation of the processor must be slowed down by a factor of several million to observe the process at human speeds.

Not only does this great reduction in speed cause major changes in the operation of the whole system, it can make even a simple algorithm take a long time to complete.

In the third technique, using the logic-state analyzer, it doesn't really matter whether the software has been simulated beforehand or not. (Although, as mentioned before, if a simulator



7. **Test the I/O ports** before you connect the system's peripherals. First, verify control timing.

is available, it can be a help in developing some parts of the software.) One clear advantage of the analyzer approach is that the hardware and the software are debugged in parallel instead of in series. Another is that the analyzer can monitor the program flow in real time.

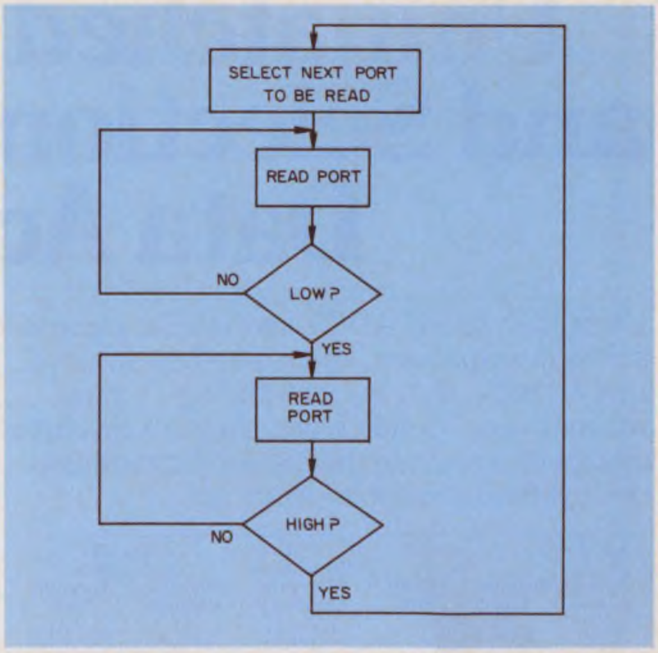
In debugging software, you use the analyzer in the same way as when debugging hardware. In fact, most of the hardware debugging techniques are simply a matter of monitoring the flow of a simple program, then fixing the hardware when the program does not work.

The process of debugging software, as it usually arises, is really more a problem of identifying a problem, deciding how the software and hardware contribute to the problem, then doing the fix.

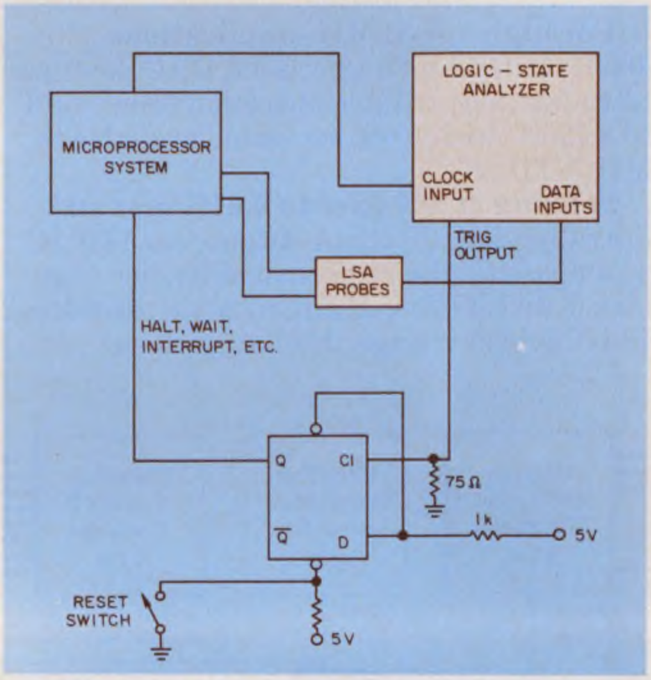
In pinpointing whether software or hardware is the culprit, the logic analyzer excels. Once the hardware is checked out—from the lock and reset generators, to the I/O ports—the software can be loaded in small blocks and tried out.

Although you can debug the software in any order, several rules may be helpful. It is usually best to turn on the keyboard or other entry device first, then any display or output device. Next, turn on the hardware and software together.

Note that the logic-state analyzer can serve as a breakpoint register. Connect its trigger output to a flip-flop and use the flip-flop output as the break signal (Fig. 9). ■■



8. **Input-port test program** loops around to force the desired state, then jumps to another loop.



9. **Connect the analyzer's trigger output** to a flip-flop, and the instrument can halt or interrupt μP action.

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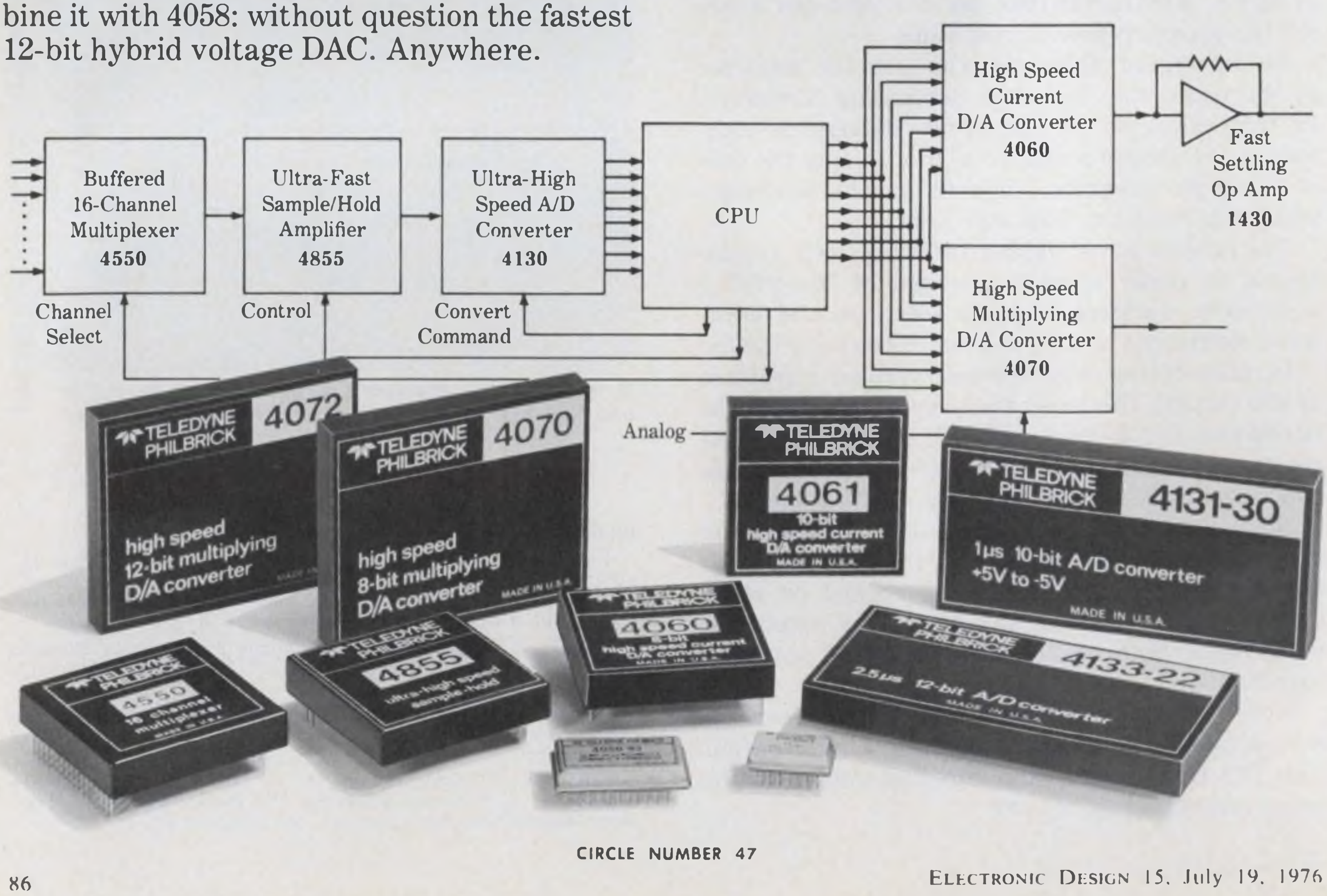

CIRCLE NUMBER 47

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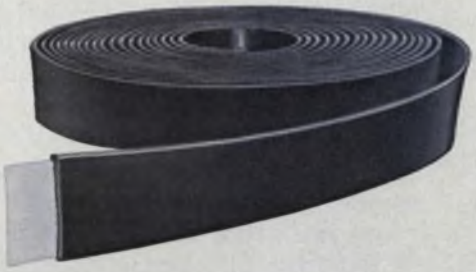

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CIRCLE NUMBER 48

Get simultaneous analog outputs from your microprocessor-based system. Sequential addressing delays can be eliminated if you add extra data latches.

Interfacing digital-to-analog converters to a microprocessor is a straightforward job. Just connect them to the output bus and assign them channel numbers. Each converter will then deliver its analog output when addressed. But this isn't sufficient if you need several simultaneous output changes because individual addressing creates time delays between adjacent channel outputs.

You can avoid the time delays by first having the data for all channels stored in an array of buffer latches and then, after all channels are loaded, strobing the d/a converters so they all get the data at the same time.

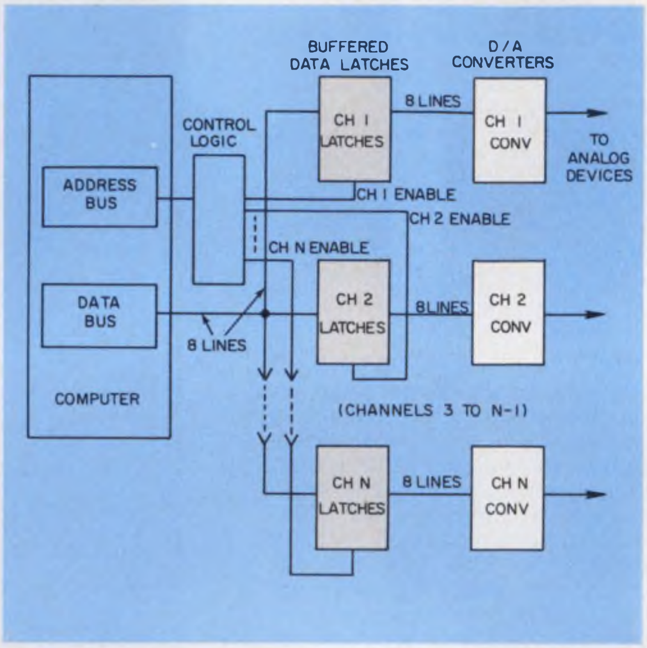
A typical sequential system for multiple analog outputs has data transferred from the processor to the Channel-1 data latches using software commands and external control logic (Fig. 1). As soon as the data are latched, d/a conversion for Channel 1 begins.

The computer then generates a second set of software instructions that transfer data to Channel 2's data latches. When the new data are latched, conversion on Channel 2 begins. This process repeats until all data-output channels are accounted for.

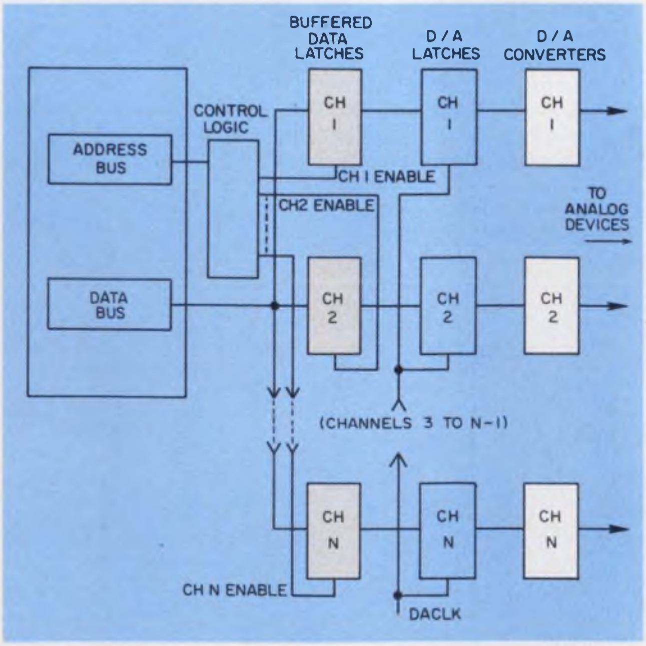
For a given computer or microprocessor, the time interval between the beginning of the d/a conversion on one channel and that of the next channel can be calculated. All you need to assume is that all output data are already stored in the computer memory so that all transfer times are the same.

Let's use the National Semiconductor (Santa Clara, CA) IMP-16 microprocessor as a specific example of how the two data-output methods compare.

With conventional sequential addressing, to send data to an output channel requires three instructions for the first channel and two instructions for each additional channel. The first channel needs an instruction that identifies that



1. **A sequential-output d/a-converter interface** can delay the signals by approximately 20 μs for each channel fed by the computer.



2. **To obtain simultaneous analog outputs** from a multichannel d/a converter system, use an extra set of latches to hold the digital words.

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channel's address. For all subsequent channels, the new address can be entered as part of the output instruction.

The two main instructions required include the LD command, which takes the stored data and sends them to a location from which they can be transferred to the output channel selected. The other command, ROUT, transfers the data from the computer to the output channel. A simple output program for this sequence is shown in Table 1.

Execution time of the two instructions on the IMP-16 requires a little less than 20 μs. Therefore the time interval between the beginning of d/a conversion on one channel and on the next is 20 μs. Also, if there are N channels, the d/a conversion on the Nth channel would begin (N-1) × 20 μs after the first channel—a considerable delay if you need simultaneous changes.

Extra latches eliminate the delay

There is an alternative (Fig. 2) for applications where time delays like the one just described are intolerable. An additional set of data latches for each channel can be added to hold data before strobing the d/a converters. Data are transferred from the computer to the extra latches in the same way they were transferred to the converters, as explained earlier. However, the d/a converter latches are disabled. After data have been transferred to all N channels, a pulse from the computer or generated externally enables the d/a converter latches and transfers data to all converters simultaneously so that all converter outputs will change at the same time.

Let's see how this simultaneous interface circuit goes together for a dual-output system. Data transfer from the computer is accomplished by use of software instructions, a decoding circuit and the d/a converter interface. The software routine needed is shown in Table 2 and the decoding circuit and d/a interface are shown in Figs. 3 and 4, respectively.

The software places data on the computer's buffered 16-bit data-out bus (BDO), loads the correct address on the 16-bit address bus (ADX) and supplies the decoder and interface circuits with pulses to control the latches. Data that go to the BDO bus must originate in the IMP's accumulator 0 (AC0).

The first instruction shown in Table 2 (line 100 loads data into AC0 from wherever they are currently being stored. The address sent to the ADX bus is the sum of the contents of accumulator 3 (AC3) and the seven-bit channel address specified in the output instruction, ROUT N.

Table 1. Sequential output program

Program address	Label	Command	Comments
50	DATA1:	.WORD 75A6	
51	DATA2:	.WORD 6847	
52	DATA3:	.WORD FF83	
53	DATA4:	.WORD 8000	
100	WAIT:	BOC 0D, WAIT	; Program is halted ; at line 100 until signal ; is received on condition ; bit "0D" indicating it ; is time for computer ; to output data.
101		LI 3, 18	; Places device address 3 ; + channel address 0 in ; accumulator 3.
102		LD 0, DATA1	; Place contents of DATA1 in AC0
103		ROUT 0	; Data are output to ; channel 0 of device 3
104		LD 0, DATA2	; Contents of DATA2 ; are placed in AC0
105		ROUT 1	; Data are output to ; CM1 approx. 20 μs ; after data were output ; to CM0
106		LD 0, DATA3	
107		ROUT 2	; Data are output to ; CH2 approx. 40 μs ; after data were output ; to CH0
108		LD 0, DATA4	
109		ROUT 3	; Data are output to ; CH2 approx. 60 μs ; after data were ; output to CH0

Table 2. Simultaneous output program

Program address	Label	Command	Comments
50	DATA1:	.WORD 0125	; DATA1 & DATA2 are memory
51	DATA2:	.WORD 0672	; locations containing stored ; data
100		LD 0, DATA1	; Load AC0 with contents of DATA1
101		LI 3, 18	; Load AC3 with 18 hexadecimal
102		ROUT 0	; Add 0 to AC3 and send the ; sum to ADX BUS, send con- ; tents of AC0 to BDO BUS, ; pulse WRP and WRPA lines.
103		LD 0, DATA2	; Load AC0 with contents of DATA2
104		ROUT 1	; Add 1 to AC3 and send sum ; to ADX BUS, send contents ; of AC0 to BDO BUS, pulse ; WRP and WRPA lines.

You have the option of how to allocate the word for the address bus. In the system shown, bits 3 to 6 identify an interface device and permit up to 16 peripheral units. The three remaining bits, 0 through 2, correspond to the channel code for a particular device. This lets each device handle up to eight channels. The nine bits remaining can be used for further system expansion should the need arise.

The address for the first channel is given on lines 101 and 102 of Table 2. The sum specifies channel 0 of device 3 (the d/a interface). Execution of line 102 transfers this address to the

ADX bus, sends the contents of AC0 to the BDO bus and provides two latching pulses, WRP and WRPA.

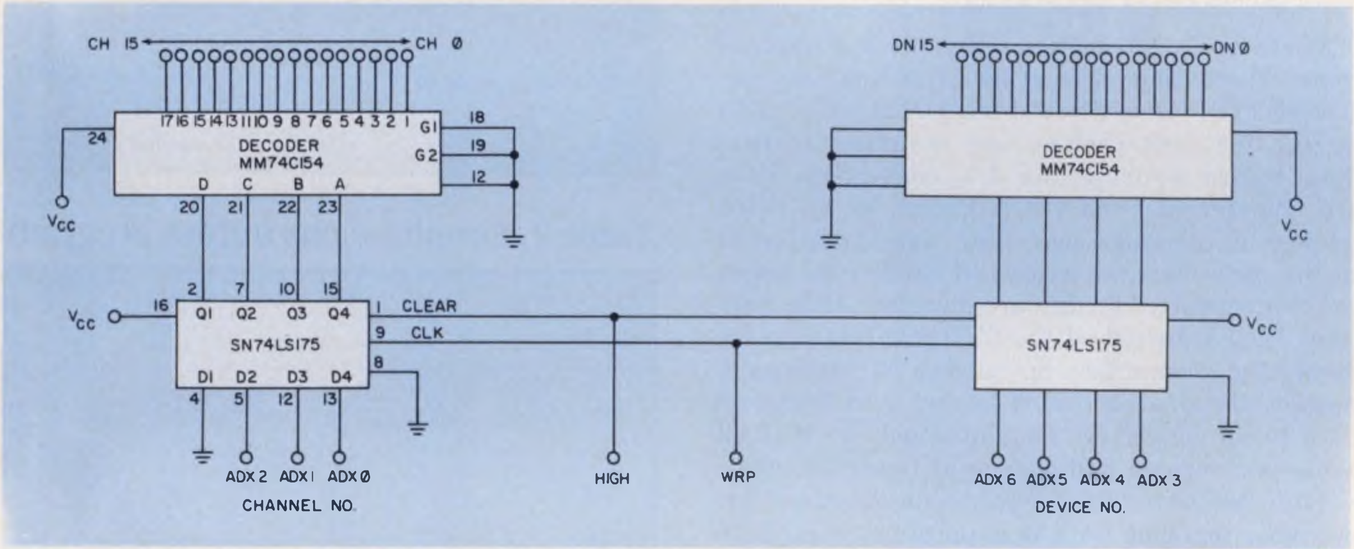
Program lines 103 and 104 repeat the process for Channel 1. Line 103 loads the new data into AC0 and line 104 updates the address, sends the address and data to their respective busses and supplies the two latching pulses.

When the device and channel numbers are transferred to the ADX bus, they also appear on the input lines of the 74175 latches in the decoder circuit of Fig. 3. The WRP pulse latches the address, then the two 74154 decoders can enable the proper device-number and channel-number lines. A selected decoder line is LOW, while all unselected lines are HIGH. Decoder timing relationships are shown in Fig. 5a.

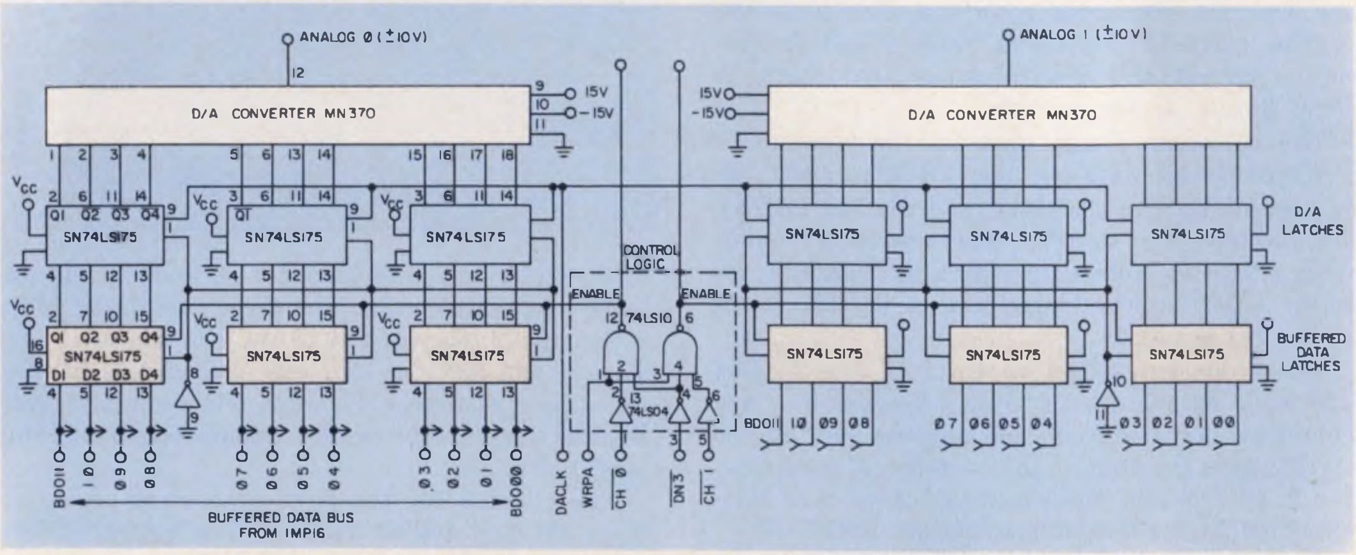
When data are transferred to the BDO bus they also appear at the input lines to the buffered data latches of each channel. Latching the data to the proper channel's latches is the job of the control logic circuit of Fig. 4. This circuit prevents Channel 1 from receiving Channel 0 data, and vice-versa.

Inputs to the control-logic circuit include the device-3 decoder line, Channel-0 and Channel-1 decoder lines and the WRPA line. All the decoder lines are inverted and then the inverted lines for device 3 and Channel 0 are NANDed with WRPA to provide an enabling pulse to lock Channel-0 data into the latches. Similarly, the inverted Channel-3 line and the Channel-1 line are NANDed to enable the Channel-1 latches.

The timing sequence for latching in the data is shown in Fig. 5. When the inverted device and channel numbers and WRPA are all HIGH (starting at t_1), the NAND output goes LOW. About 100 ns later, at t_2, the WRPA line goes



3. **The channel and device number** can be decoded by using a latch and a one-of-16 decoder. This system can be expanded for as many channels as you need, just by adding extra latches and decoders.



4. **The d/a-converter interface circuit** uses an extra set of data latches to buffer the computer data and store the data until all channels are loaded. A common strobe signal starts all the converters.

LOW and returns the NAND gate to a HIGH output. At the same time data on the BDO bus are latched into the data buffers.

Once all the data latches are loaded, the data can be transferred to the d/a converters by a pulse on the data clock line (DACLK). Since the data appear simultaneously (barring propagation delays) on all the converter inputs, all outputs will change simultaneously. All the d/a converter-latch outputs are inverted except for the most significant bit. This was done to convert the two's-complement format used in the IMP to the type of binary code required by the d/a converter selected, in this case a Micro Networks (Worcester, MA) MN370.

Since the circuit uses low-power, Schottky TTL, bypass capacitors should be included to eliminate any chance of faulty operation due to current spikes at the clock frequency. A 0.01-μF capacitor should be used across each package's supply leads and a 10-μF capacitor should be connected across the supply leads where they enter the circuit board.

The two-channel interface can easily be expanded to handle more channels. For instance, if eight channels are needed the following modifications must be made: For each new channel, connect up additional latches and d/a converters as shown for the two channels (in Fig. 4). Then, connect the NAND-gate inputs to the inverted decoder output of device 3, to WRPA and to a previously unused channel-decoder output, between 2 and 7.

There is an alternative to the additional data latches used for each converter (Fig. 6). Try using multiple sample-and-hold amplifiers to hold the analog signals. Since there are no latches, the d/a conversions all take place at different times. When the DACLK line is pulsed, data from d/a converters get locked into the amplifiers.

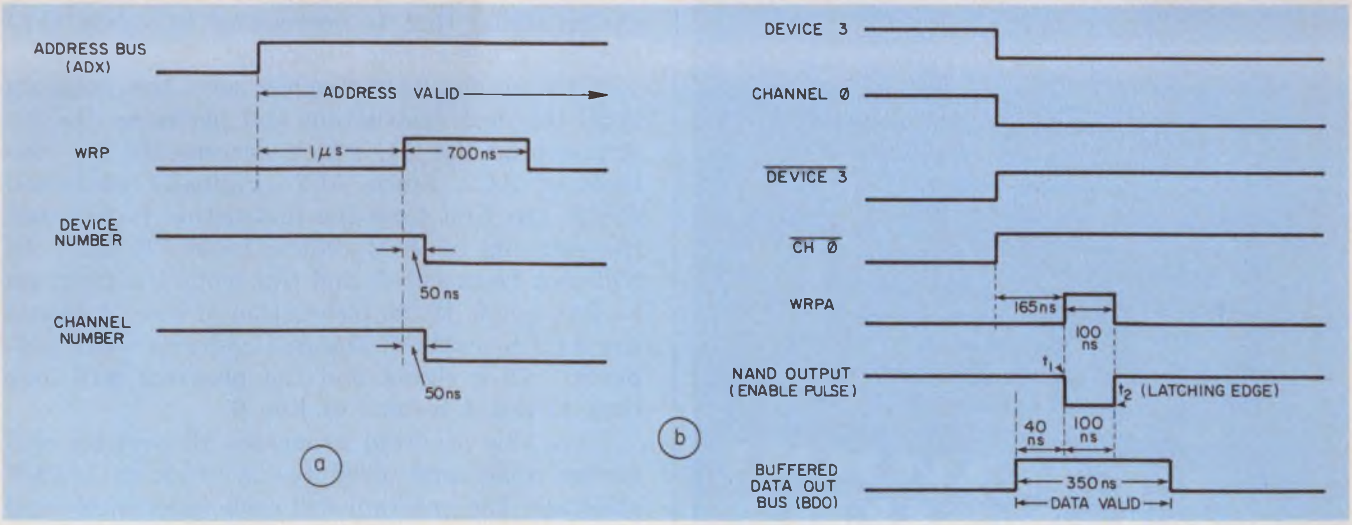
The costs of the s/h circuits are still higher than that of the extra latches, so this method really isn't economically feasible. Also, voltage offsets, drifts and decay are error sources for the s/h circuits.

Table 3. System self-test program

Program address	Label	Command	Comments
1	LOOP:	.WORD 0FFF	;12 bit counter to cycle ; through all possible codes.
2	START:	.WORD 07FF	; Represents positive full ; scale
3		LI 3, 018	; Select Device 3, CH 0.
4	LP1:	LD 2, LOOP	
5		LD 0, START	
6	LP2:	ROUT 0	; Dev. 3, CH 0.
7		ROUT 1	; Dev 3, CH 1.
8		PFLG 0	; Gate data into d/a.
9		AISZ 0, −1	; Decr d/a code.
10		RCPY 1, 1	
11		AISZ 2, −1	; Decr loop counter.
12		JMP LP2	
13		JMP LP1	
	.END		

Let the system check itself

Once you have the system up and running, every so often you can run a self-check to make sure the system is still operating properly. Table 3 lists a program that will test the operation of the d/a-converter interface. Each complete loop through the program provides a staircase output from each d/a converter. The range of each unit will vary from +10 to −10 V and if you continuously loop through the program you can see the converter outputs on an oscilloscope.



5. **Timing relationships** for the decoder circuit (a), and the d/a interface circuit (b), have no critical conditions. After the device is selected, the enable pulse transfers data from the buffers to the converters.

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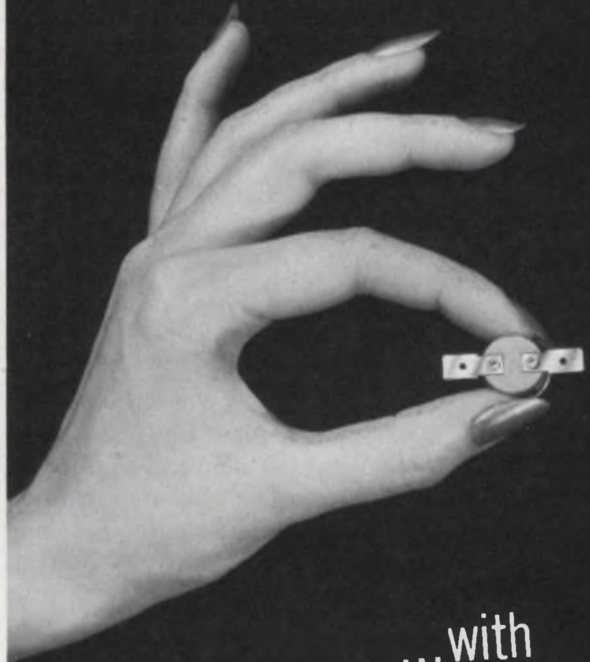

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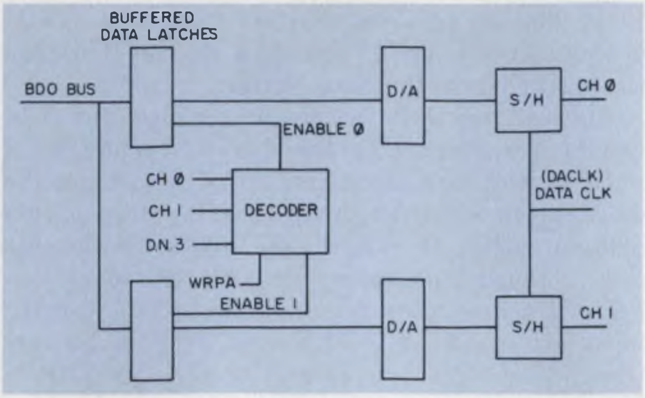


6. **An alternative to the extra data latches** uses multiple sample-and-hold amplifiers to store the analog outputs of the d/a converters.

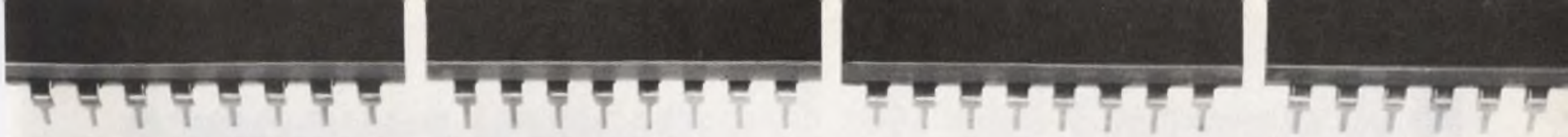
Line 1 of the program is a memory location that contains the data word 0FFF which will be used to count the number of program cycles. (All numerical values in Table 3 are in hexadecimal notation.) Line 2 defines another location that contains the data word 07FF, which corresponds to the positive full-scale value of the d/a converter. The next program line (line 3) loads the code for device 3 and Channel 0 into AC3. Hex value 18 corresponds to device 3, Channel 0. Line 4 loads the contents of LOOP (data word 0FFF) into accumulator 2 while the next line loads the contents of START (07FF) into AC0.

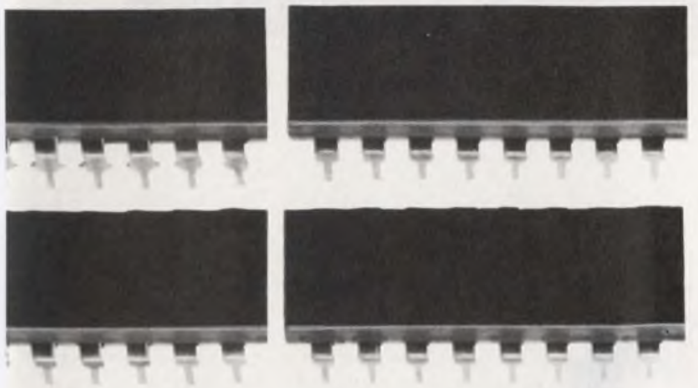
Lines 6 and 7 output the contents of AC0 into Channels 0 and 1, respectively. After these two instructions each channel's buffered latches contain the binary equivalent to 7FF. Line 8 pulses a computer flag that is connected to the DACLK line for test purposes. When the flag is pulsed, the 7FF data are transferred to the d/a converters and conversion begins.

The instruction given on line 9—add immediate, skip if zero (AISZ)—adds −1 to the contents of AC0 thus decrementing it by 1. In this way each cycle of the program will generate an analog signal that is decreasing in value, thus forming a descending staircase.

If the accumulator reaches zero, the program skips the next instruction and performs the instruction on line 11, which decrements the contents of AC2. Since AC2 originally contained 0FFF, the first time the instruction is followed the contents of AC2 reduce to 0FFE. Line 12 will then be executed, and this loops the program back to line 6. If the instruction of line 11 causes the AC2 to reach 0, the d/a converter will output a −10-V signal and the program will loop back to line 4 instead of line 6.

Thus, this program generates all possible converter codes and produces a +10 to −10-V staircase. The program will cycle indefinitely and can only be stopped by pressing the Halt or Initialize switch on the computer front panel. ■■





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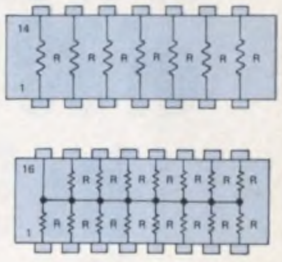

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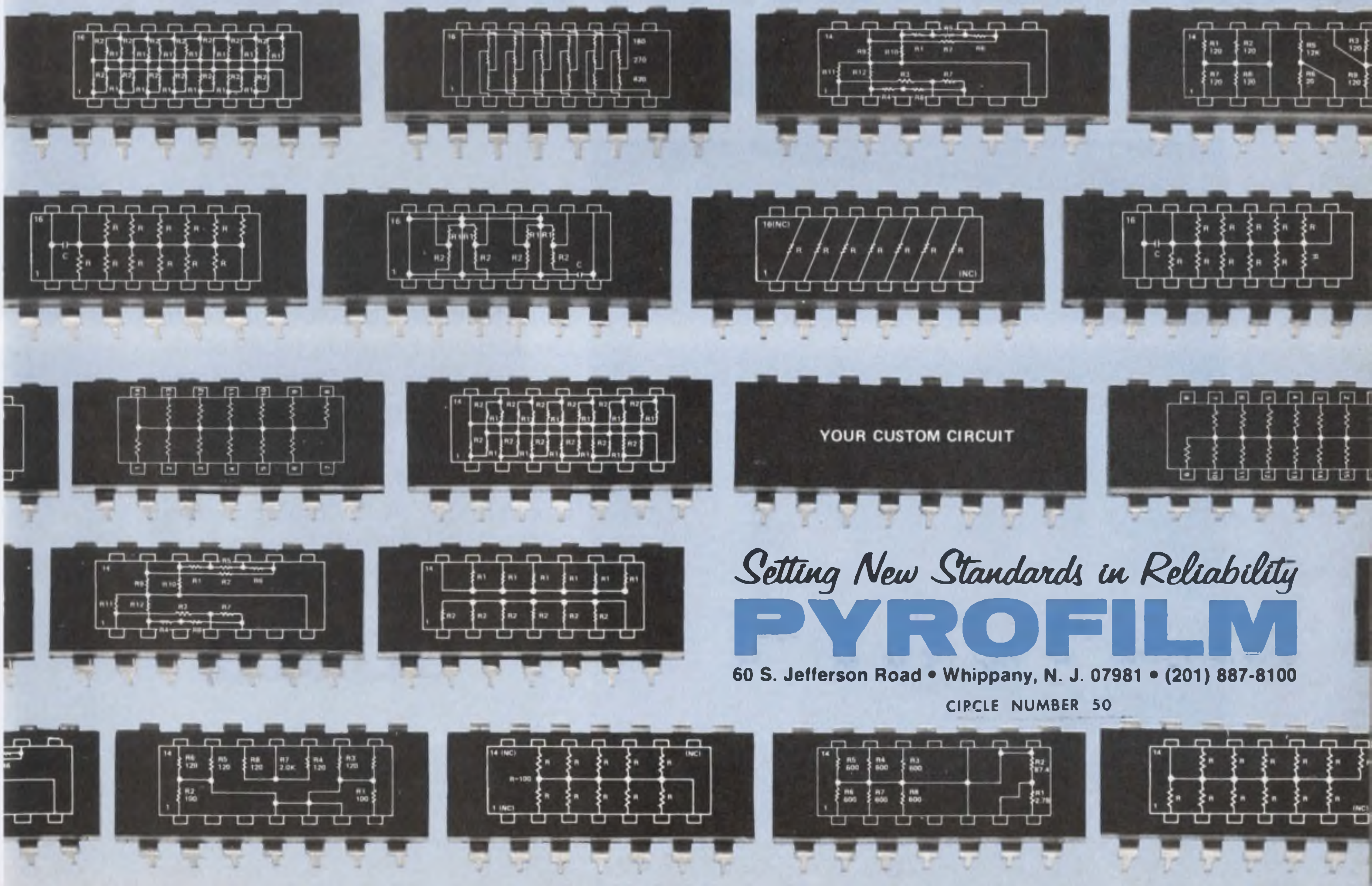

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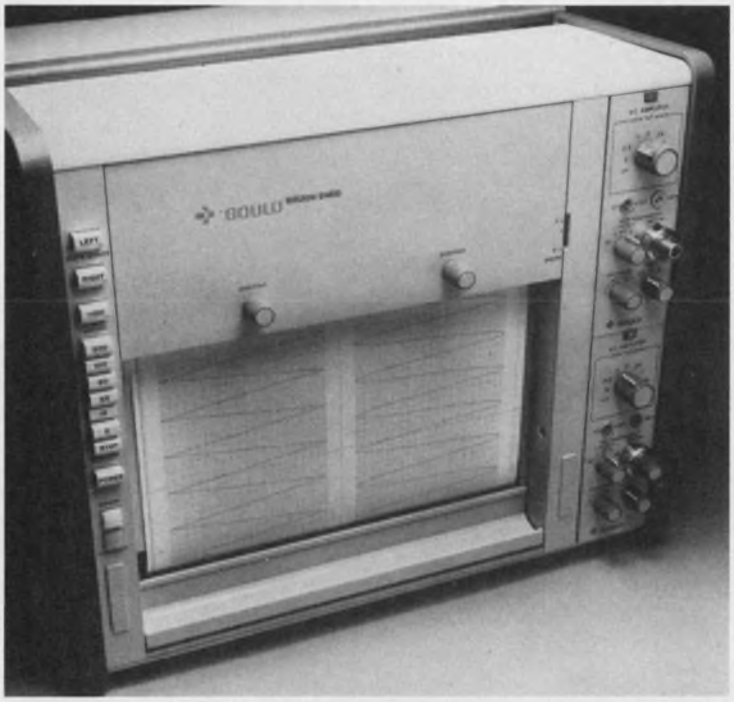

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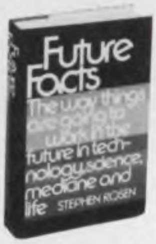

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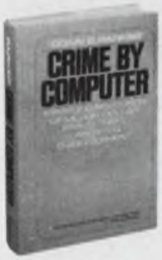

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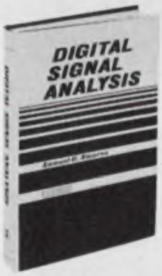

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PLAs are most useful where speed requirements are not stringent but power consumption and space are important. PLAs increase reliability many times over that of conventional logic while reducing costs by a third.

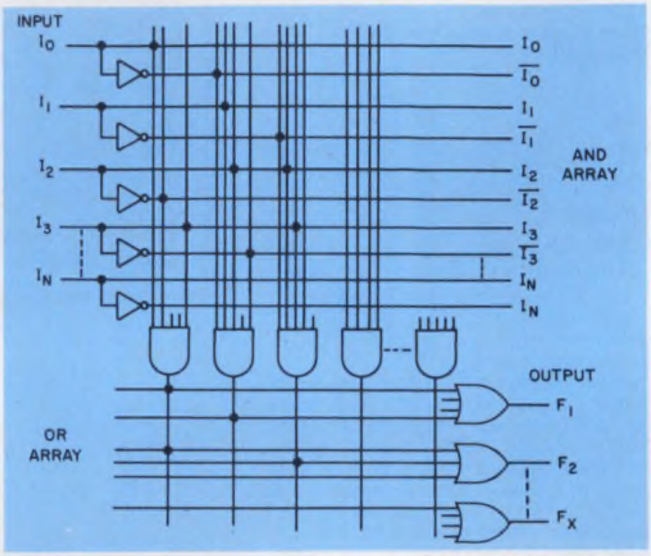
The sequential PLA, a new type of PLA which incorporates internal flip flops, is now being considered by manufacturers. This type has the advantage that it can be used in clocked systems to generate sequence-dependent outputs.

PLA performance is getting better

In the past, slow speed and high cost have kept PLAs from widespread use. Recent advances in technology, however, have produced units with propagation times of 65 ns[1], for $25 in quantities of 100 and up.

Field-programmable logic arrays (FPLAs) have also been developed, further easing program development. The FPLA's ability to set desired information in the chip after the chip has been manufactured and put in a package distinguishes it from the conventional PLA. Now that it is no longer necessary to commit large sums of money for mask charges on units that may be logically incorrect, PLA use should increase. The added interest is similar to the popularity boost experienced for ROMs when programmable ROMs (PROMs) were introduced.

In most applications, PLAs and FPLAs are interchangeable in the same manner as ROMs and PROMs. Once the final pattern has been determined by successive programming of FPLAs (or PROMs), a dedicated PLA (or ROM) is used in production.[2]



1. **The PLA is internally structured** as a set of inverters, an AND array plus an OR array with many separately programmable nodes.

PLAs are best suited for designs that use only a small subset of the total number of possible logic states. In general, PLAs have more input lines available than do ROMs. There are 14 inputs on the typical PLA, compared to ten inputs on a 1024-bit ROM.

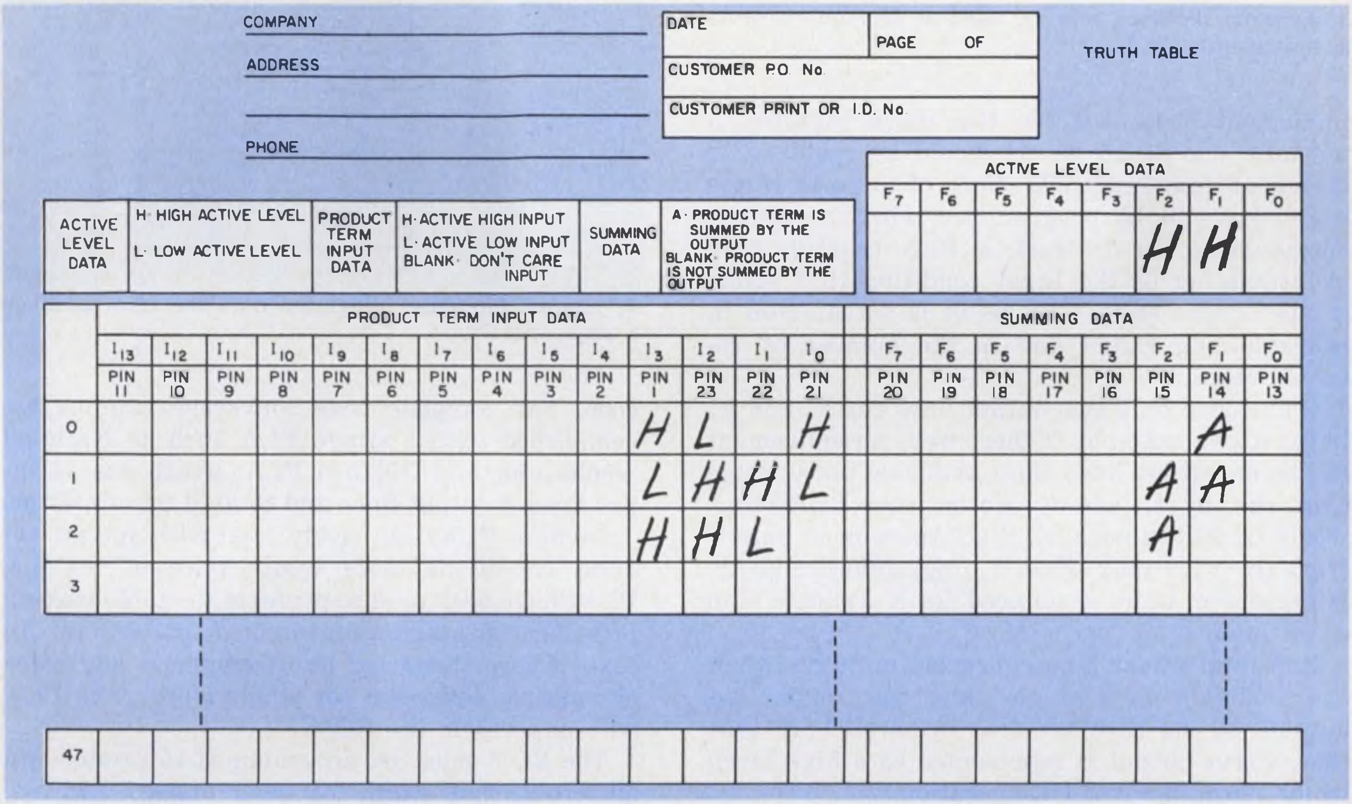
To increase the PLA's size, it is not necessary to double the array size, the way you do for a ROM, every time an input bit is added.

On the other hand, a ROM with 14 input lines has the capability of recognizing 16,384 combinations of inputs; a PLA with the same number of input lines can recognize—generate a unique output for—only a small subset of the 16,384 possible input combinations. A PLA can be used instead of a ROM when there are a large number of inputs and when only a small number of the combinations are required.

Specifying the truth table

To specify the bit pattern desired for a PLA, you must understand its internal structure (Fig. 1). Each AND gate and input buffer/inverter of the PLA generates a signal called a minterm. A minterm is the logical product of any number of

Thomas W. Mitchell, Electrical Engineer, Northern Communications Area/EPEXR, Griffiss AFB, NY 13441.



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TRUTH TABLE

ACTIVE LEVEL DATA	H- HIGH ACTIVE LEVEL L- LOW ACTIVE LEVEL	PRODUCT TERM INPUT DATA	H- ACTIVE HIGH INPUT L- ACTIVE LOW INPUT BLANK- DON'T CARE INPUT	SUMMING DATA	A- PRODUCT TERM IS SUMMED BY THE OUTPUT BLANK- PRODUCT TERM IS NOT SUMMED BY THE OUTPUT

ACTIVE LEVEL DATA							
F_7	F_6	F_5	F_4	F_3	F_2	F_1	F_0
					H	H	

	PRODUCT TERM INPUT DATA														SUMMING DATA							
	I_{13}	I_{12}	I_{11}	I_{10}	I_9	I_8	I_7	I_6	I_5	I_4	I_3	I_2	I_1	I_0	F_7	F_6	F_5	F_4	F_3	F_2	F_1	F_0
	PIN 11	PIN 10	PIN 9	PIN 8	PIN 7	PIN 6	PIN 5	PIN 4	PIN 3	PIN 2	PIN 1	PIN 23	PIN 22	PIN 21	PIN 20	PIN 19	PIN 18	PIN 17	PIN 16	PIN 15	PIN 14	PIN 13
0											H	L		H							A	
1											L	H	H	L						A	A	
2											H	H	L							A		
3																						
47																						

2. **A programming form defines** the internal connections of a PLA. This one is for the IM5200 from Intersil.

inputs, either true or inverted. (The logical expression A·B·C is an example of a minterm.) The maximum number of minterms varies from chip to chip, with 48 to 96 being common. Inputs to the AND gates are specified by the connections in the AND matrix.

The AND gate output is fed to OR gates. Connections to the OR gates are specified in the OR Matrix. In addition, some manufacturers allow programming of an inverted output.

To further understand the translation of logic into PLA hardware, refer to the coding form in Fig. 2. Each horizontal line represents one of the available gates in the AND matrix. The information entered in the product term's input-data column identifies the inputs to be connected to each AND gate as specified by an H (active high input), an L (active low input) or an X (don't care input). The summing-data section of the programming form specifies minterm connections to the OR gate inputs.

A typical truth table with given inputs and outputs might look like this:

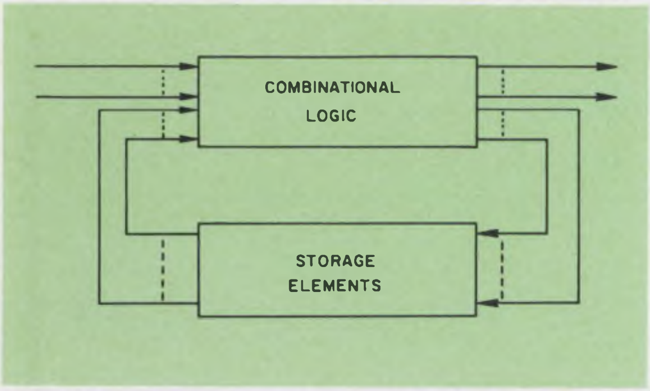
INPUTS				OUTPUTS	
A	B	C	D	F_1	F_2
H	X	L	H	H	L
L	H	H	L	H	H
X	L	H	H	L	H

The Boolean expressions for F_1 and F_2 are as follows:

$$F_1 = A\overline{C}D + \overline{A}BC\overline{D}$$
$$F_2 = \overline{A}BC\overline{D} + \overline{B}CD$$

The expressions for F_1 and F_2 are implemented in a PLA as shown in Fig. 2. (A, B, C and D are I_0, I_1, I_2 and I_3 respectively. An X in the truth table is represented by a blank in the coding form).

If a ROM were used as the decoding circuit to



3. **External flip-flops may be used** as storage elements in a sequential PLA.

implement F_1 and F_2 in the above example, a memory size of 16 words would be required to decode all four input bits. Each of these 16 words would have to be programmed with the proper output state. In contrast, a PLA requires only programming of the input condition that yields a true output state. The result is a reduction in programming effort and in the number of required chips.

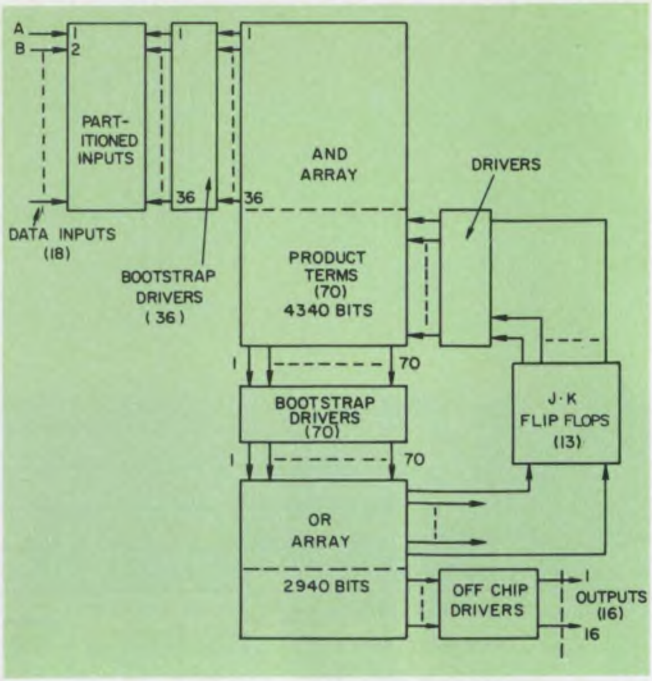
We needed only two output lines for F_1 and F_2 in the above example. If there were a requirement for more output lines than available on a single chip, the input lines of two or more PLA chips would be tied in parallel. Since there is an output from the PLA only when a programmed address is presented, there is no need for a separate chip select input.

For applications requiring more minterms than are available on a single chip, the inputs and outputs of the PLA are tied in parallel. In that case, a true output is represented by a high level, which permits wired-OR operation.[1,4]

PLAs have many applications

The PLA can also serve as an alternative to a ROM in a truth table—for code conversion from Hollerith code to ASCII code, for example. ROMs are generally used instead of random logic for such code conversion because a logical correspondence between input and output codes may not exist.

The Hollerith code is a 12-bit code. Of the possible 4096 combinations, only 96 are used for graphic characters. If a ROM is used for the code conversion, 4096 words are necessary even though only 96 of the words would contain useful information. It's clear that a PLA could perform that code conversion easily and efficiently. Each AND gate would decode the input lines to produce an output for each of the 96 possible input states. Therefore, there would be 96 minterms in the PLA solution. Each minterm would excite the proper output lines to provide the output code. The complete code conversion can be accomplished with a single PLA such as National Semiconductor's DM7575 PLA, which has 14 input lines, 8 output lines and total of 96 minterms.



4. **Internal flip-flops,** integrated onto the chip, produce a sequential PLA.

Because PLAs can easily cope with special address conditions more easily than do ROM's, PLAs have been used to perform the table look-up procedure in microprogrammed processors. In cases where there are unprogrammed addresses or multiple addresses for single words, the PLA will outperform the ROM.

The ROM must be programmed to produce an all-zero output word for each unused address. A PLA output automatically stays at an unexcited level for unprogrammed addresses.

Multiple addresses for single words in a ROM require that each individual location be programmed with the desired output word. Such extra programming work is not necessary when a PLA is used. The "don't care" input condition can be specified, thereby eliminating that term from the address.

With the addition of storage elements in a feedback path a standard sequential-logic circuit can be realized (Fig. 3).

PLAs with internal flip-flops

If 13 JK flip-flops were used as storage elements in the feedback path of a PLA, and these flip-flops were included on the same chip as the PLA, then the usefulness of the device would be greatly magnified. In such an arrangement, device inputs would not only affect the output but also the next state.

A functional block diagram of the proposed device is shown in Fig. 4.[6] To avoid race conditions from the feedback loop, a four-phase clock is used to cycle the data through the PLA. With this architecture, the PLA can be used to replace microprocessor-based logic and other types of sequential or control logic.

The PLA can be used as a sequential machine. For example, when an input of "01" is applied to the PLA, it will output BCD number 215 in sequence on the three output lines available.

An extension of the truth table presented earlier, can be used to program a PLA to solve the above problem. Identify inputs to the feedback flip-flops in the same manner that output connections were identified. Treat outputs of the flip-flops as inputs into the AND array.

To define which connections are made to the input of the flip-flops, you have several options. You can specify an S that will cause the flip-flops to be set, an R that will cause a reset of the flip-flop, or a T that will toggle the flip-flop if the line is activated. As with the normal output lines, a blank represents no connection. The flip-flop output connections to the AND array are specified in the same way as the other input lines.

An example of sequential operation appears in Fig. 5. Notice that the PLA will be in a waiting mode until an input condition of 01 appears on the input lines I_1 and I_2. Flip-flops FF_2 and FF_3 are used as a program counter, and controlled by lines 2, 3 and 4. While FF_1 is set, the counter cycles from 00 to 11 and then resets FF_1, thereby producing four time frames that can be used by the rest of the PLA.

When the PLA receives the input 01, FF_1 is set. All flip-flops must be low to prevent the PLA from receiving a second 01 code and trying to perform the instruction again before it has finished doing so the first time.

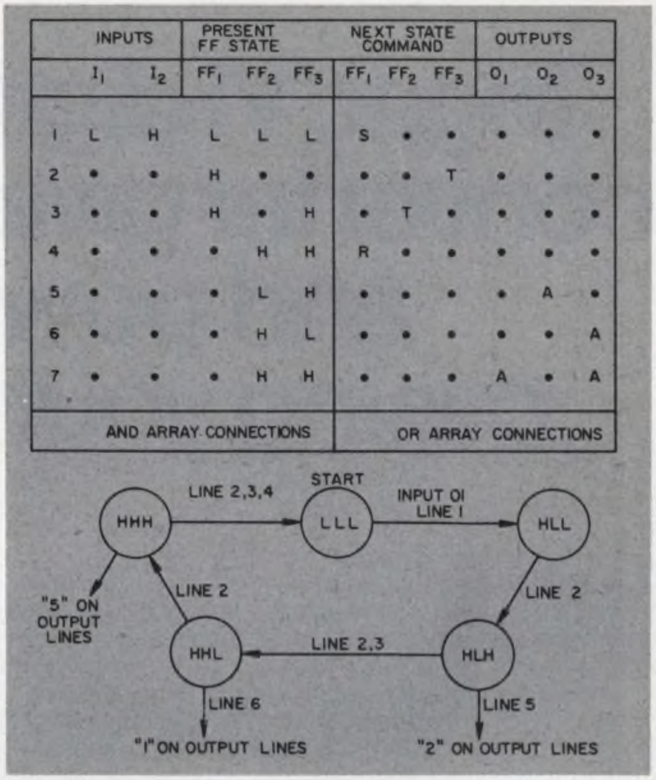
When FF_1 is set, the program counter is activated. As the program counter passes through each of its states, they are decoded by lines 5 through 7 and BCD number 215 is presented on the output lines.

Because not all of the available inputs and outputs are being used, it is possible for the PLA to operate in a parallel mode, that is, to perform two distinct functions at the same time.

Sequential logic PLAs have advantages

IBM has investigated using a PLA with a feedback feature to replace TTL logic in computer-terminal control units. A comparison between the dual-in-line-package TTL logic (DIP-TTL) and the PLA reveals the following:[7]

(1.) DIP-TTL versions require 6 1/2 (3 in. × 4 in.) printed circuit boards. The PLA version requires only 3-1/2 circuit boards.



	INPUTS		PRESENT FF STATE			NEXT STATE COMMAND			OUTPUTS		
	I_1	I_2	FF_1	FF_2	FF_3	FF_1	FF_2	FF_3	O_1	O_2	O_3
1	L	H	L	L	L	S	•	•	•	•	•
2	•	•	H	•	•	•	•	T	•	•	•
3	•	•	H	•	H	•	T	•	•	•	•
4	•	•	•	H	H	R	•	•	•	•	•
5	•	•	•	L	H	•	•	•	•	A	•
6	•	•	•	H	L	•	•	•	•	•	A
7	•	•	•	H	H	•	•	•	A	•	A
AND ARRAY CONNECTIONS						OR ARRAY CONNECTIONS					

5. **In this example of sequential operations,** the numbers "two," then "one" then "five" appear on output lines O_1, O_2 and O_3.

(2.) Seven PLAs replaced 1,731 logic circuits, approximately 250 logic circuits per PLA.

Despite this very convincing comparison, several disadvantages are present with the device. The IBM PLA has serious speed limitations. The minimum cycle time for the PLA is 500 ns. In the test circuit speed is not a limiting factor because the unit operates at 135 bits per section. At higher speeds, however, the PLA may not be able to do the job.

References

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2. Cavlan, N. and Cline, R, "Field-PLAs Simplify Logic Design," *Electronic Design*, Vol. 23, No. 18, Sept. 1, 1975.

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5. Reyling, G., "PLAs Enhance Digital Processor Speed and Cut Component Count," *Electronics*, Vol. 47, No. 16, Aug. 8, 1974.

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8. Fleisher, H., Maissel, L. I., "An Introduction to Array Logic," *IBM Journal of Research and Development*, Vol. 19, No. 2, March, 1975.

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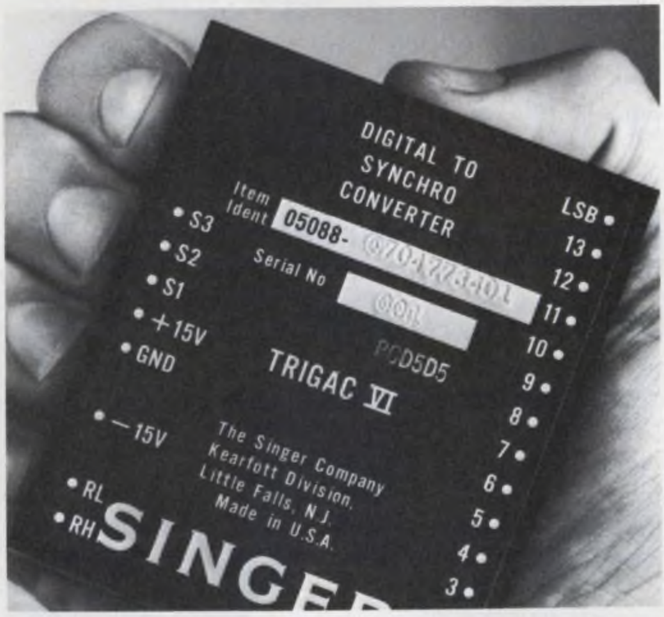

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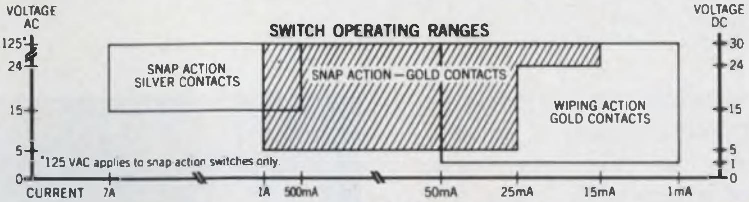
AEROSPACE & MARINE SYSTEMS

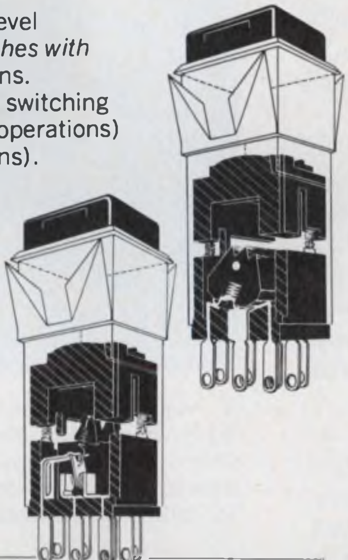
CIRCLE NUMBER 54

Dialight sees a need:

(**Need:** A switch for all reasons.)



Reason 1: Dialight offers three switch configurations to meet all your needs—*snap-action switches with silver contacts* for moderate-level applications, *snap-action switches with gold contacts* for intermediate-level applications, and *wiping-action switches with gold contacts* for low-level applications. Each of these ranges is served by two switching actions—momentary (life: 600,000 operations) and alternate (life: 250,000 operations).



Reason 2: Dialight's snap-action and wiping-action switches come in a new modular design concept . . . a common switch body for either high or low current operation. All 554 series switches and matching indicators have the same rear-panel projection dimensions.

The snap-action switching mechanism guarantees a fast closing and opening rate. This insures that contact force and contact resistance are independent of the switch's actuation speed.

In the wiping-action switch, the contacts are under constant pressure (A unique Dialight design). This insures long life with a minimum build-up of contact resistance.

Both switch types are tease-proof.

PRODUCT SELECTOR GUIDE

SWITCHING ACTIONS	Snap-Silver contacts		Snap-Gold contacts		Wiping-Gold contacts	
	SPDT	DPDT	SPDT	DPDT	SPDT	DPDT
MOMENTARY	○	○	○	○	○	○
ALTERNATE	○	○	○	○	○	○

OPTIONS

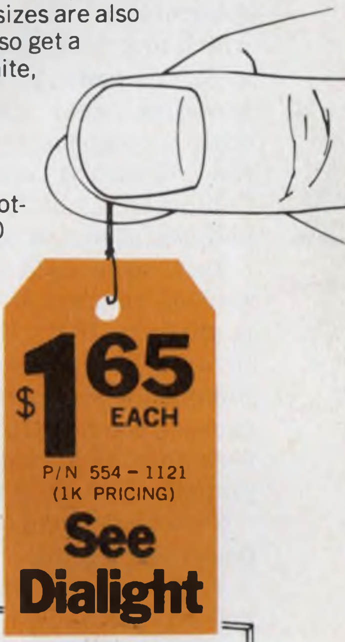
	PUSH BUTTON CAP SIZES				
	½" Sq.	⅝" Sq.	⅝" x ¾"	¾" Sq.	¾" x 1"
BEZEL MOUNTING TO ACCOMMODATE	○	○	○	○	○
BEZEL MOUNTING WITH BARRIERS TO ACCOMMODATE		○	○	○	○
PANEL MOUNTING TO ACCOMMODATE	○	○	○	○	○
MATCHING INDICATORS	○	○	○	○	○

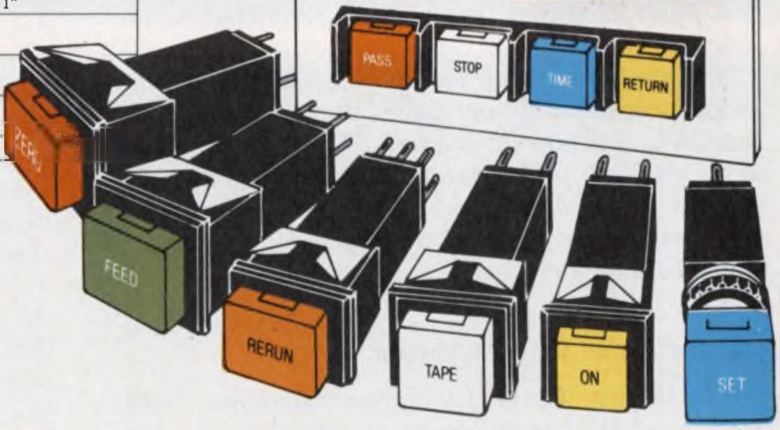
Reason 3: Dialight offers a wide variety of panel and snap-in bezel mounting switches with momentary and alternate action configurations in SPDT and DPDT types. There are over 240 switch variations to choose from.

The 554 illuminated switch, designed for front of panel lamp replacement, gives you a choice of five different bezel sizes . . . ¾" x 1", ⅝" x ¾", ¾" square, ⅝" square, and ½" square. The first four sizes are also available with barriers. You also get a choice of six cap colors . . . white, blue, amber, red, green, and light yellow . . . four different underlying filter colors . . . red, green, amber, and blue and a variety of engraved or hot-stamped legends . . . over 300 cap styles . . . over 100,000 combinations.

There is also a variety of terminal connections . . . solder blade, quick connect, and for PC board insertions.

Reason 4: Dialight's 554 series is designed as a *low cost switch with computer-grade quality.*





DIALIGHT
A North American Philips Company
203 Harrison Place, Brooklyn, N.Y. 11237
(212) 497-7600

CIRCLE NUMBER 55

Reduce circuit manufacturing costs:

Monte Carlo computer simulation finds a cost-effective mix of tight component tolerances vs individual calibration.

Computer simulation provides an inexpensive way of solving the traditional problem of achieving specified performance at minimum cost. Obviously, component cost drops with looser tolerance. Unfortunately, using inexpensive components often results in excessive labor costs to calibrate during the manufacturing process and perhaps even later on in the field.

But there is a reliable way of inexpensively determining the "break-even" point—beyond which any further use of inexpensive, loose-tolerance components will result in the penalty of excessive labor costs. Somewhere between excessive component costs and high labor costs is the region of optimum manufacturing costs. Computer simulation is an increasingly popular and useful means of finding that region.

In a large-scale system only the theoretical design of subcircuits that may require calibration is analyzed. With this selective approach the savings in time, labor and money are significant. Simulation shows not only how a combination of over-all component tolerances may affect the performance of a large number of systems. It also pinpoints actual or potential design problems.

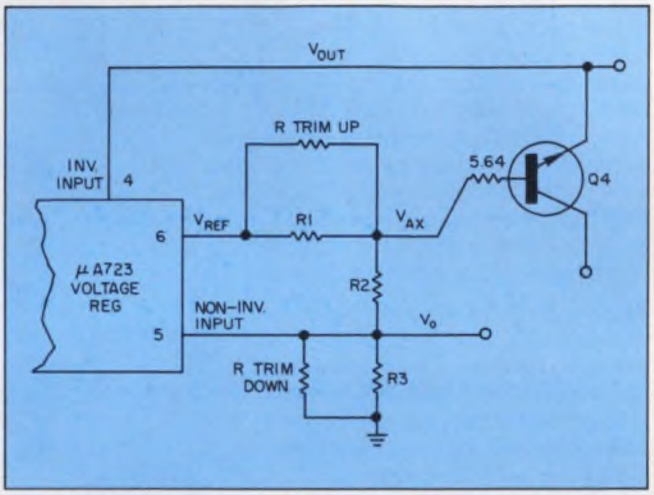
Two basic compromises further reduce the expense of running a simulation program:

1. The entire circuitry of the "black box" is not simulated. The circuit that may need calibration is isolated and that portion simulated as an independent entity.

2. There is no need for special "canned" simulation programs or any particular computer system. Any version of Fortran IV with a reasonably efficient pseudorandom number generator will do, and may be used on the many computers that have Fortran compilers—and on a variety of time-sharing services.

Use the Monte Carlo technique

The Monte Carlo simulation technique used isn't new. It is well known in engineering, and in other disciplines as well, but surprisingly, not much has been done in the area of manufacturing, where the pay-off for simulation can be very high.

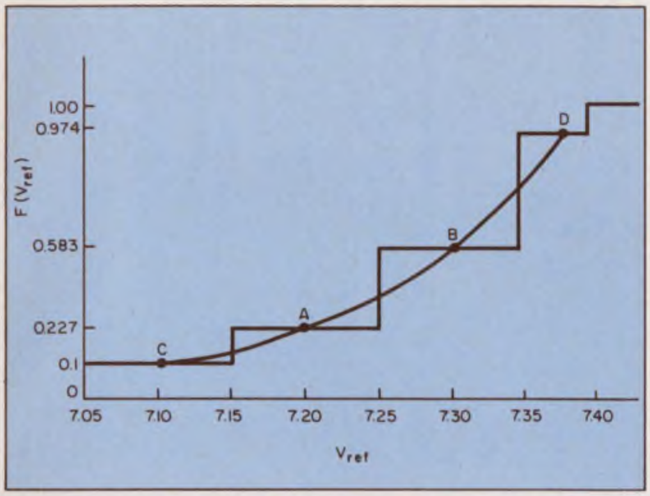


1. **Voltage regulator develops +5 V** output and an auxiliary voltage, V_{ax}, for undervoltage protection. A Monte Carlo computer simulation finds the best cost tradeoff between increased component tolerances and the need for individual calibration.

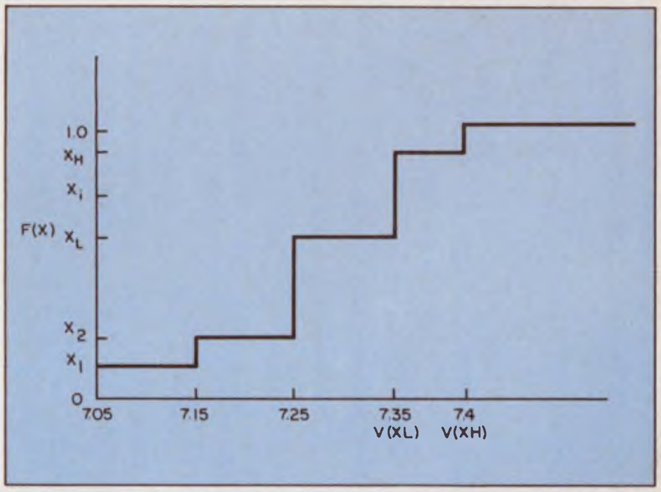
In order to simulate, the relevant and realistic parameter distribution of the circuit components must be known. Unfortunately, manufacturers' data sheets don't give complete and detailed density functions, so the user must collect his own data and generate the required density distributions. With these inputs, and with a pseudorandom number generator, a Monte Carlo program can be run.

Let's illustrate the selective simulation approach with the portion of a voltage regulator shown in Fig. 1. The circuit has two outputs: V_{out}, the +5 V supply, and V_{nx}, and auxiliary voltage to control undervoltage protection circuitry. Our objective is to select resistor values and tolerance so that the majority of the circuits will yield V_{out} within +5 ±0.06 V. At the same time, we want a V_{ax} high enough to turn on Q_1 and trigger undervoltage protection when V_{out} falls below 4.35 V. And, we want to do this without trimming every circuit individually.

Eli A. Sheffer, Supervisory Engineer, Hazeltine Corp., Greenlawn, NY 11740.



2. **Cumulative probability distribution curve** of the value of the reference voltage output from a large sample of μA 723 regulators.



3. **A random number, F(X),** determines the corresponding value of the reference voltage, V_{REF}, used in a simulation run.

In Fig. 1, a divider across the reference voltage from the voltage regulator, μA723, determines both outputs:

$$V_{out} = V_{REF} \cdot \frac{R_3}{R_1 + R_2 + R_3}$$
$$V_{ax} = V_{REF} \cdot \frac{R_2 + R_3}{R_1 + R_2 + R_3}\ . \qquad (1)$$

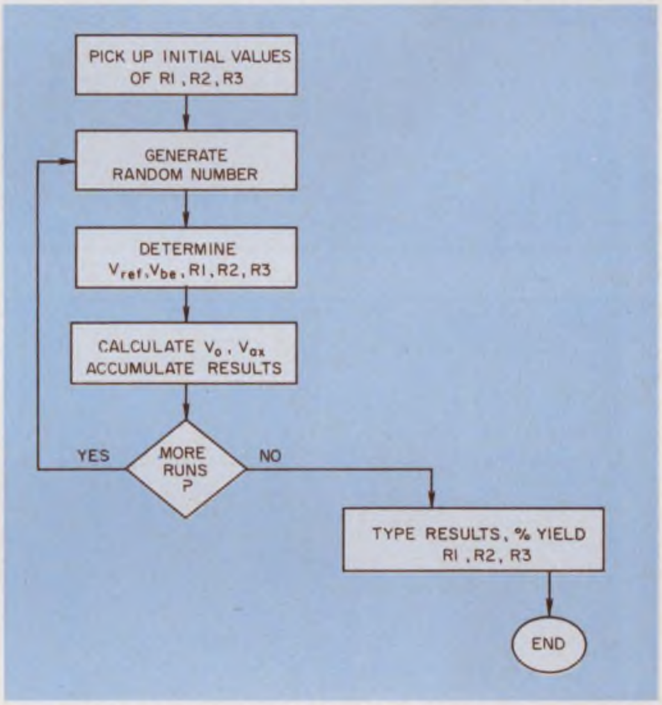
Also, the base-emitter drop, V_{BE}, of Q_4, determines the value of V_{ax} at which the transistor conducts.

Specify parameter distributions

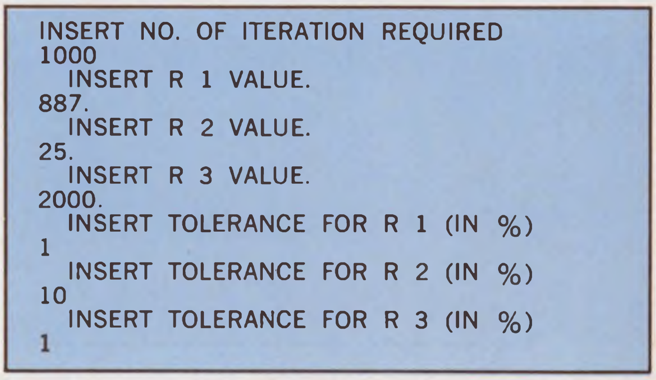
The next step is to specify the distributions of the three resistors and the two voltages, V_{REF}, from the IC, and the transistor V_{BE}. R_1 and R_3 are nominally 1%, R_2 5%, and we assume a uniform distribution throughout the tolerance range. The V_{BE} distribution is bell-shaped, with a mean value of 0.57 V and a standard deviation of 0.05 V. The V_{REF} distribution was derived from measurements on a statistically valid system of μA723 ICs and is discussed further below.

The Monte Carlo technique allows selection of nominal component and voltage values such that actual values will fall in the portion of the cumulative distribution curve where suitable values have a high probability. In Fig. 2 the cumulative distribution curve of V_{REF} is plotted against the probability function, $F(V_{REF})$. The slope from A to B is steeper than from C to A, indicating the probability of a higher concentration in the range from 7.2 to 7.3 than from 7.1 to 7.2 V. Thus, in simulation more values will be picked randomly in the first interval.

The cumulative distribution is constructed from sample measurements and consequently is noncontinuous. To find the V_{REF} corresponding to the random number generated, a linear inter-

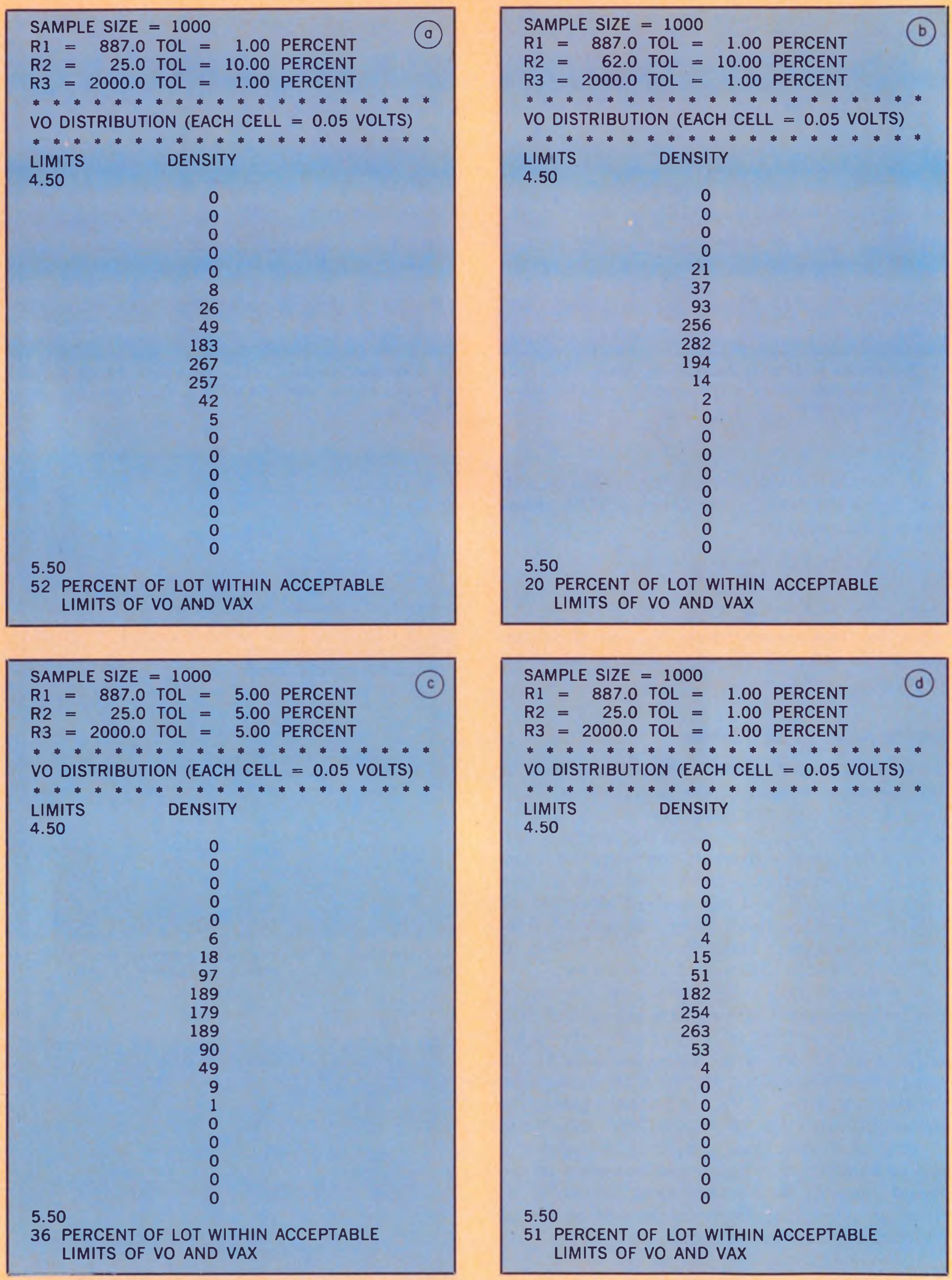


4. **Flow chart of the computer program** for the Monte Carlo simulation of a voltage regulator subcircuit.



```
INSERT NO. OF ITERATION REQUIRED
1000
  INSERT R 1 VALUE.
887.
  INSERT R 2 VALUE.
25.
  INSERT R 3 VALUE.
2000.
  INSERT TOLERANCE FOR R 1 (IN %)
1
  INSERT TOLERANCE FOR R 2 (IN %)
10
  INSERT TOLERANCE FOR R 3 (IN %)
1
```

5. **Typical user entries** of resistor values and tolerances for a voltage regulator subcircuit simulation run.



```
SAMPLE SIZE = 1000                              (a)
R1 =   887.0 TOL =   1.00 PERCENT
R2 =    25.0 TOL =  10.00 PERCENT
R3 =  2000.0 TOL =   1.00 PERCENT
* * * * * * * * * * * * * * * * * * * *
VO DISTRIBUTION (EACH CELL = 0.05 VOLTS)
* * * * * * * * * * * * * * * * * * * *
LIMITS          DENSITY
4.50
                    0
                    0
                    0
                    0
                    0
                    8
                   26
                   49
                  183
                  267
                  257
                   42
                    5
                    0
                    0
                    0
                    0
                    0
                    0
                    0
5.50
52 PERCENT OF LOT WITHIN ACCEPTABLE
   LIMITS OF VO AND VAX
```

```
SAMPLE SIZE = 1000                              (b)
R1 =   887.0 TOL =   1.00 PERCENT
R2 =    62.0 TOL =  10.00 PERCENT
R3 =  2000.0 TOL =   1.00 PERCENT
* * * * * * * * * * * * * * * * * * * *
VO DISTRIBUTION (EACH CELL = 0.05 VOLTS)
* * * * * * * * * * * * * * * * * * * *
LIMITS          DENSITY
4.50
                    0
                    0
                    0
                    0
                   21
                   37
                   93
                  256
                  282
                  194
                   14
                    2
                    0
                    0
                    0
                    0
                    0
                    0
                    0
                    0
5.50
20 PERCENT OF LOT WITHIN ACCEPTABLE
   LIMITS OF VO AND VAX
```

```
SAMPLE SIZE = 1000                              (c)
R1 =   887.0 TOL =   5.00 PERCENT
R2 =    25.0 TOL =   5.00 PERCENT
R3 =  2000.0 TOL =   5.00 PERCENT
* * * * * * * * * * * * * * * * * * * *
VO DISTRIBUTION (EACH CELL = 0.05 VOLTS)
* * * * * * * * * * * * * * * * * * * *
LIMITS          DENSITY
4.50
                    0
                    0
                    0
                    0
                    0
                    6
                   18
                   97
                  189
                  179
                  189
                   90
                   49
                    9
                    1
                    0
                    0
                    0
                    0
                    0
5.50
36 PERCENT OF LOT WITHIN ACCEPTABLE
   LIMITS OF VO AND VAX
```

```
SAMPLE SIZE = 1000                              (d)
R1 =   887.0 TOL =   1.00 PERCENT
R2 =    25.0 TOL =   1.00 PERCENT
R3 =  2000.0 TOL =   1.00 PERCENT
* * * * * * * * * * * * * * * * * * * *
VO DISTRIBUTION (EACH CELL = 0.05 VOLTS)
* * * * * * * * * * * * * * * * * * * *
LIMITS          DENSITY
4.50
                    0
                    0
                    0
                    0
                    0
                    4
                   15
                   51
                  182
                  254
                  263
                   53
                    4
                    0
                    0
                    0
                    0
                    0
                    0
                    0
5.50
51 PERCENT OF LOT WITHIN ACCEPTABLE
   LIMITS OF VO AND VAX
```

6. **The results of four simulation runs** on the voltage regulator. 52% of the production run, at best, will be in tolerance without calibration (a). Changing the value of R_2 reduces yield by 32% (b). Looser tolerances for R_1 and R_3 show an expected reduction in yield (c). A tighter tolerance for R_2 shows no improvement (d).

Typical program for simulation of voltage regulator

```
SAMP.F4
C ***PROGRAM FOR THE SIMULATION OF VOLTAGE REGULATOR ***
C *** AS OF AUG. 1,1975 ***
C ***
C ***
C *** ARAY-CONTAIN VALUE OF VREF DIST. (DISCRETE STEPS) ***
C *** ANOMI- "        "     " R1,R2,R3   NOMINAL VALUES ***
C *** ALIM-  "   CUMULATIVE PROBABILITY DIST. POINTS FOR VREF ***
C *** AVBE-  "      "          "         "    "    "   VBE **
C *** VBE- CONTAIN VALUE OF VBE DIST.(DISCRETE STEPS) ***
      DIMENSION ANOMI(3),R(3),IRSLT(20),ARAY(6),ALIM(6),TOL(3)
      DIMENSION VBE(7),AVBE(7)
      DATA (ARAY(I),I=1,6)/6.95,7.05,7.15,7.25,7.35,7.4/
      DATA (ALIM(I),I=1,6)/0.0,0.1,0.227,0.583,0.974,1.0/
      DATA (VBE(I),I=1,7)/0.37,0.42,0.52,0.57,0.62,0.67,0.72/
      DATA (AVBE(I),I=1,7)/0.0,0.023,0.159,0.5,0.841,0.977,1.0/
C *** INITIALIZATION ***
 2    DO 4 JJ=1,20
 4    IRSLT(JJ)=0
C *** ACCEPT USER NOMINAL AND TOL. OF PARAMETERS & NO. OF ITERATIONS ***
      TYPE 60
      ACCEPT 50,N
      DO 30 IN=1,3
      TYPE 40,IN
 30   ACCEPT 51,ANOMI(IN)
      DO 31 IN=1,3
      TYPE 70,IN
 31   ACCEPT 51,TOL(IN)
C  *** RUN SIMULATION FOR N ITERATION ***
      DO 1 II=1,N
C *** GENERATE TRIPLET (R1,R2,R3) ***
      DO 19 KK=1,3
      RNDOM=RAN(5)
      HILI=ANOMI(KK)+(ANOMI(KK)*TOL(KK)/100.)
      ALOLI=ANOMI(KK)-(ANOMI(KK)*TOL(KK)/100.)
 19   R(KK)=RNDOM*(HILI-ALOLI)+ALOLI
      RNDOM=RAN(5)
C *** DETERMINE INTERVAL I FOR VREF ***
      DO 13 I=1,6
      IF(RNDOM .LT. ALIM(I)) GO TO 11
 13   CONTINUE
C *** THROUGH LINEAR INTERPOLATION DETERMINE VREF ***
 11   VREF=ARAY(I-1)+0.1*(RNDOM-ALIM(I-1))/(ALIM(I)-ALIM(I-1))
C *** CALCULATE VO & VAX FOR THIS ITERATION ***
      VO=(VREF*R(3))/(R(1)+R(2)+R(3))
      VAX= VREF*(R(2)+R(3))/(R(1)+R(2)+R(3))
C *** VO DETERMINES CELL NO. ***
      CELL=(VO-4.50)/0.05
      K=INT(CELL)+1
      IF(K .GT. 20 .OR. K .LT. 1) GO TO 3
C *** ARRAY IRSLT CONTAIN DISTRIBUTION OF VO VALUES ***
C *** DETERMINE INTERVAL NU FOR VBE ***
      RNDOM=RAN(5)
      DO 32 NU=1,7
      IF(RNDOM .LT. AVBE(NU)) GO TO 33
 32   CONTINUE
C *** THROUGH LINEAR INTERPOLATION DETERMINE VBE ***
 33   VBEX=VBE(NU-1)+0.05*(RNDOM-AVBE(NU-1))/(AVBE(NU)-AVBE(NU-1))
      IF(VAX  .LT.( 4.35+VBEX)) GO TO 1
      IRSLT(K)=IRSLT(K)+1
 1    CONTINUE
C *** ACCUMULATE TOTAL COUNT OF VO IN THE REQUESTED RANGE ***
C *** CALCULATE PERCENTAGE OF VO FALLING INSIDE RANGE **
      ITOT=100*(IRSLT(10)+IRSLT(11))/N
C  *** DISPLAY DIST. OF VO ***
      TYPE 100,N,(ANOMI(J),TOL(J),J=1,3)
      DO 9 L=1,20
 9    TYPE 5,IRSLT(L)
      TYPE 41
      TYPE 14,ITOT
      TYPE 80
      ACCEPT 73,USER
      IF(USER .EQ. 'YES') GO TO 2
      GO TO 6
 3    PAUSE'VO OUT OF RANGE OF INTEREST'
 5    FORMAT(13X,I6)
 14   FORMAT(///2X,I6,2X,'PERCENT OF LOT WITHIN ACCEPTABLE LIMITS
     1 OF VO AND VAX'//)
 40   FORMAT(//2X,'INSERT R',I2,' VALUE.')
 41   FORMAT(2X,'5.50'/)
 50   FORMAT(I6)
 51   FORMAT(F9.0)
 60   FORMAT(/2X,'INSERT NO. OF ITERATION REQUIRED')
 70   FORMAT(/2X,'INSERT TOLERANCE FOR R',I2,'(IN %)')
 73  FORMAT(A5)
 80   FORMAT(//2X,'IF YOU WANT ANOTHER RUN ,TYPE "YES",OTHERWISE <CR>')
 100  FORMAT(/2X,'SAMPLE SIZE=',I6//2X,'R1=',F7.1,2X,'TOL='
     1,F9.2,2X,'PERCENT'/2X,'R2=',F7.1,2X,'TOL=',F9.2,2X,'PERCENT'/
     22X,'R3=',F7.1,2X,'TOL=',F9.2,2X,'PERCENT'/
     32X,43('*')/2X,'VO DISTRIBUTION',2X,'(EACH CELL=0.05',2X,
     4'VOLTS)'/2X,43('*')/2X,'LIMITS',5X,'DENSITY'/2X,'4.50')
 6    CALL EXIT
      END
```

polation is performed, which slightly reduces the over-all accuracy of the simulation.

The random number generator is the mechanism determining the value of the parameter from a given distribution, generating numbers in the range .00 to 1.0 in pseudorandom fashion. Any time a random number is generated, the corresponding value of V_{REF} may be determined from Fig. 3. Random numbers correspond to the vertical axis. A horizontal line is drawn at the number generated to the cumulative distribution curve, picking up the relevant interval of V_{REF}. Thus, in Fig. 3, the random number X_I falls between X_L and X_H, corresponding to the interval between 7.25 and 7.35 V. The value of V_{REF} corresponding to the random number drawn, X_I for example, is:

$$V_{REF} = V(X_{LI}) + (0.1)\frac{X_I - X_{LI}}{X_{HI} - X_{LI}}, \qquad (2)$$

where X_{LI} = Lowest value of F(X) in the interval I.

X_{HI} = Highest value of F(X) in the interval I.

X_I = Value picked by the random number generator.

V_{BE} and the resistors can be picked from their corresponding distributions in the same way. The values of V_{REF}, R_1, R_2 and R_3 are inserted in Eq. 1, and V_{out} and V_{ax} are calculated. For a successful trial, $V_{out} = 5.0 \pm 0.06$ V and $V_{ax} - V_{BE}$ is greater than 4.35 V. This process may be repeated as often as desired. V_{out} and V_{ax} distribution plots will be the indication of the over-all subcircuit performance. In this example simulation, by selecting the optimum nominal values for the triplet of R_1, R_2 and R_3, reduced the number of units requiring calibration from 80% to 48%.

Fig. 4 shows a flow chart for an interactive Fortran IV program on a DEC-10 machine for iteration of values for the resistor set. In practice, the designer interacts with the program and has the option of changing the values and/or the tolerances of the circuit parameters. Fig. 5 shows how the user enters the input parameters and tolerances.

The results of four sample printouts for V_{out} are shown in Fig. 6. In (a), with the resistor values and tolerances used, 52% of the circuits—at best—will pass the test without calibration. In (b), R_2 has been increased from 25 to 62 ohms, and the yield has decreased from 52% to 20%. In (c) the tolerance on R_1 and R_3 has been changed from 1% to 5%; on R_2 from 10% to 5%. The yield, as expected, drops to 36%. But, tightening the tolerance on R_2 to 1% does not increase the yield.

The Fortran IV program shown was written specifically for the circuit discussed. With some modification, it can also be used to simulate a variety of other circuits. ■■

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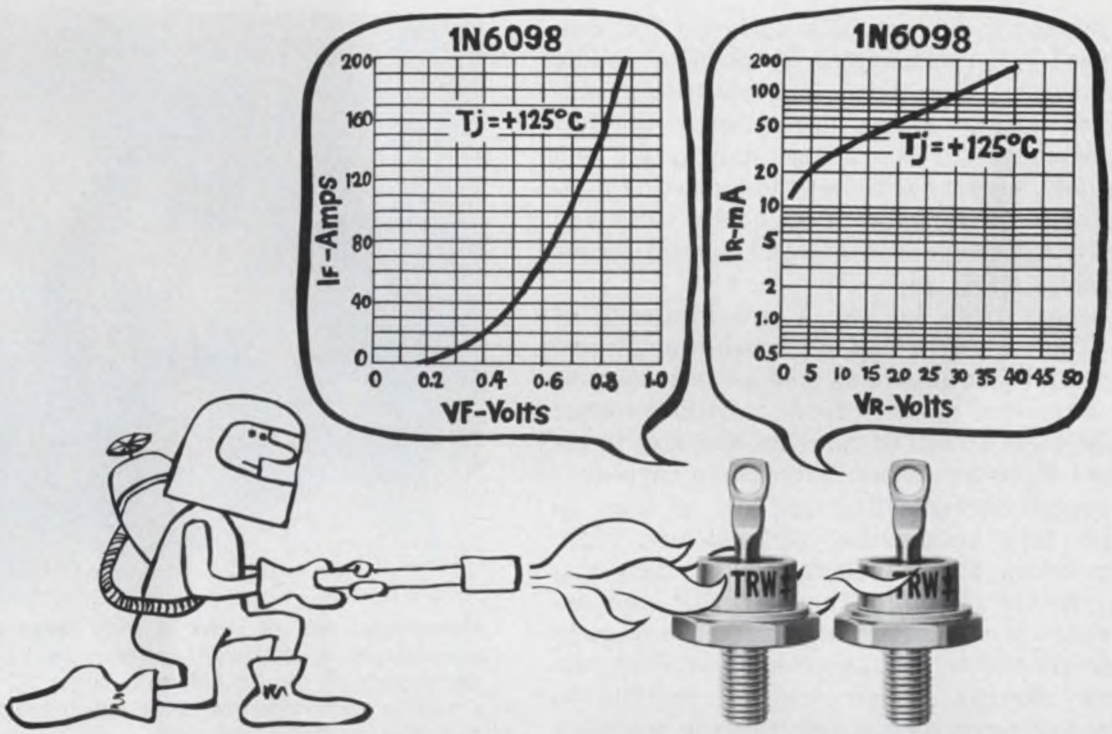

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The drive motor of a servo or start/stop system determines to a great extent the system's dynamic response. Low inertia/inductance motors allow high-performance designs.

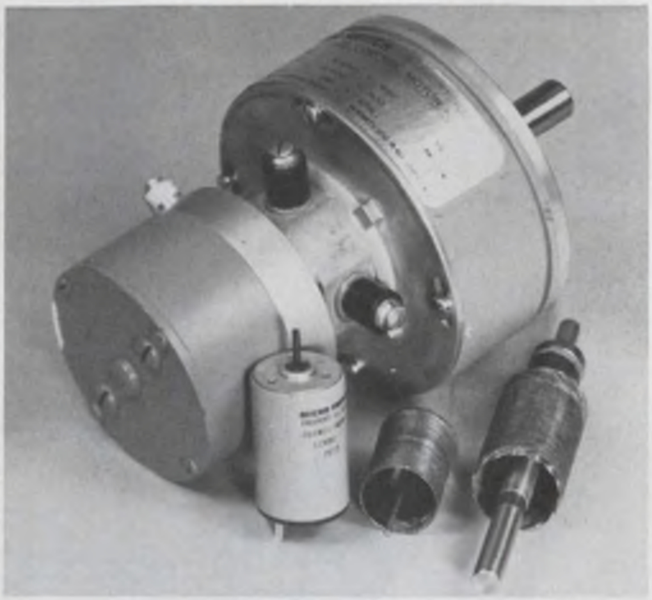
Many motors are specially designed for constant-speed operation—record players, audio tape recorders, chart drives and electromechanical timing devices. But a large class of applications, including servo systems, must start and stop rapidly, operate with very low starting voltages, provide a high torque-to-inertia ratio and preferably linear speed-torque and current-torque relationships (Fig. 1).

The linear plots in Fig. 1 are idealized, of course. They ignore a motor's brush-bearing-and windage—friction losses, as well as armature reaction. Armature reaction tends to reduce torque output at high armature currents and also to reduce the torque-per-ampere increase in current.

High-speed incrementing systems as used in computer tape transports, card readers, high-speed printers and numerically controlled machines, require motors with good start-stop dynamic characteristics. Of particular advantage in such use are the dc, permanent-magnet field, hollow-rotor designs.[1] Their special construction provides low rotor inertia and thus the desirably high torque-to-inertia ratio needed for rapid acceleration and deceleration.

A hollow-shelled armature winding forms a self-supporting cylindrical shell, or basket that contains no iron, but rotates about a stationary iron core. Such a shell design results in an armature inertia that is 10 times lower than so-called low-inertia disc designs and 100 times lower than traditional iron-core designs. Also, the armature inductance is 1000 times lower than in iron-core motors.

This type of motor is particularly suited for high-gain, wide-bandwidth servo systems, and cases where motors must be directly coupled to the load. Acceleration from dead stop to 3900 rpm in less than one millisecond and within only 5 degrees of shaft rotation is not unusual, because of the very high torque-to-inertia ratios that are possible. There is no cogging, and motor size is less than in ordinary wound-rotor motors of the same output.



Hollow-rotor motors cover a wide range of styles and sizes—from a flashlight-battery-sized cassette drive motor such as the 26 EM, to a larger 33 VM unit with a built-in tachometer to drive speed-servo capstans in computer magnetic-tape units.

In Fig. 1, current-curve B, which originates at zero, represents an idealized condition that neglects static friction, i.e. the torque needed to start the motor. Curve A, the more practical case, when extended to the torque axis intersects the axis at a value equal to this static-friction loss.

Defining motor characteristics curves

The speed curve for a given terminal voltage, V_T, intersects the speed axis at the no-load speed of the motor; extending the curve to intersect the loss-torque line provides a higher speed value close to the theoretical no-load speed, if no friction is present. At this speed the back emf of the motor equals the input-terminal voltage.

At zero speed the motor provides the stalled-torque output, T_{stall}, and the motor draws a stalled current that is limited only by its terminal resistance, R_T, where

$$I_S = V_T/R_T.$$

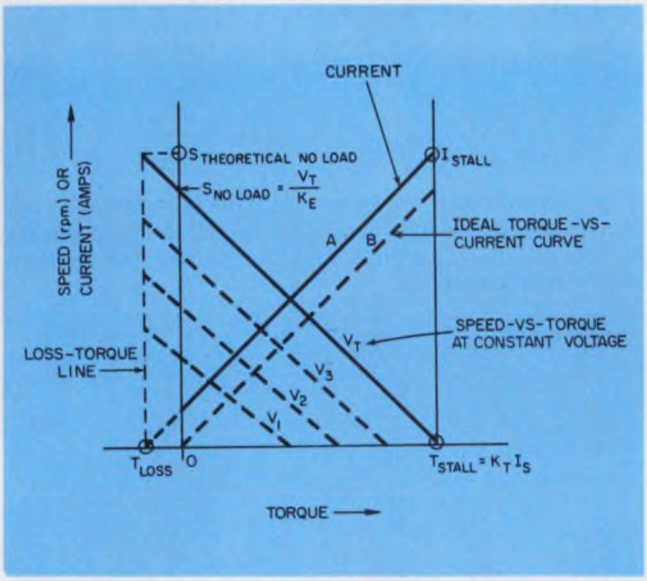
John Mazurkiewicz, Applications Engineer, Micro-Switch Div. of Honeywell, Freeport, IL 61032.

A linear relationship between torque and armature current is approximately true for the motors under consideration. A torque constant, K_T, can then be defined as

$$K_T \cong \frac{\Delta T}{\Delta I} \cong \frac{T_{stall} + T_{loss}}{I_s} \qquad (1)$$

In terms of a motor's construction and physical characteristics, the electrical equation for stall torque is

$$T_{stall} = N\phi I_s \frac{BpK}{A}; \qquad (2)$$



1. **The speed-torque and current-torque characteristics curves** of hollow-rotor motors are only approximately linear. These relationships are idealized into straight lines to simplify calculations and allow easy solution of the dynamic-response equations.

where N = number of turns per coil
ϕ = flux per pole
I_s = stalled current
B = number of commutator bars
P = number of poles
A = number of armature paths
K = constant for unit conversion.

For simplicity, let us assume that $T_{loss} = 5\%\ T_{stall}$; therefore

$$K_T \cong \frac{1.05\, T_{stall}}{I_s}. \qquad (3)$$

Combining Eqs. 2 and 3 and neglecting the 5% loss factor, we obtain

$$K_T = \frac{N\phi BpK}{A}. \qquad (4)$$

Since a motor's armature turns in a magnetic field, it also generates a back emf,

$$V = \frac{SN\phi pB}{A}, \qquad (5)$$

from which a voltage constant can be defined as

$$K_E = \frac{\Delta V}{\Delta S}, \qquad (6)$$

where S is the speed of the rotor in krpm. When we combine Eqs. 4, 5 and 6, K_T and K_E are related as follows:

$$K_E\ (V/krpm) = 0.74\, K_T\ (oz\text{-}in/A).$$

Thus, K_T automatically determines K_E, or vice versa. And in Fig. 1

$$S_{no\ load} = \frac{V_T}{K_E}. \qquad (7)$$

In general, the type of motors we are considering—dc motors with fixed-field permanent-magnet excitation—can be represented by the electrical equivalent diagram Fig. 2. From the diagram, we can derive the simple differential equation,

$$V_T = K_E S + I_a R_T + L \frac{dI_a}{dt}, \qquad (8)$$

where I_a is the armature current. Because of the hollow-rotor motor's extremely low inductance, Eq. 8 can be reduced to

$$V_T = K_E S + I_a R_T \qquad (9)$$

and

$$S = [V_T - I_a R_T]/K_E \qquad (10)$$

Note that the slopes of the speed-torque lines can be expressed by

$$\frac{R_T}{K_E K_T} = \frac{S_{no\ load}}{T_{stall}}, \qquad (11)$$

which is constant for all applied terminal voltages; thus a series of parallel straight-line speed torque curves for different terminal voltages, together with the single torque-current curve (Fig. 1) can fully describe the steady-state characteristics of the low-inductance, low-inertia motor.

Analyzing transient behavior

The transient performance of a motor may be analyzed in terms of motor speed and acceleration. However, the analysis undertaken for a system is dependent on whether a constant voltage or a constant current supply is applied to the motor.

When a constant voltage is applied to a motor, as the motor's speed increases, the back emf generated by the motor increases also and opposes the applied voltage to reduce the motor's current. The result is reduced acceleration as the motor speeds up. This can be precisely seen by solving the equation

$$T = J\alpha + K_D S + T_F + T_L, \qquad (12)$$

where T = output torque (oz-in)
J = system inertia (oz-in-s^2)
α = shaft acceleration (rad/s^2)
K_D = viscous damping (oz-in/krpm)
S = speed (krpm)
T_F = friction torque (oz-in)
T_L = load torque (oz-in)

From Eq. 11 and Fig. 1

$$S = S_{no\ load} - \frac{TR_T}{K_E K_T}, \qquad (13)$$

$$= \frac{V_T}{K_E} - \frac{TR_T}{K_E K_T},$$

and

$$T = \left[\frac{V_T}{K_E} - S \right] \frac{K_E K_T}{R_T}, \qquad (14)$$

Then Eq. 12, which is a differential equation, since $\alpha = d^2\theta/dt$ and $S = d\theta/dt$, can be written as

$$\left[\frac{JR_T}{K_E K_T} \right] \alpha + S = \frac{V_T}{K_E}, \qquad (15)$$

where θ is shaft angular displacement. Also, T_F and K_D are assumed to be negligible, and there is no load on the motor so only the motor's inertia is included in J.

A solution in terms of the motor constants yields

$$S = \frac{V_T}{K_E}\left(1 - e^{-\frac{K_T K_E}{JR_T} t} \right) \qquad (16)$$

The exponent in Eq. 16 contains the motor's mechanical time constant $\tau_m = JR_T/K_T K_E$, used by servo designers use for determining the responsiveness of a system. A more precise transient analysis would include also the electrical time constant of the motor $\tau_e = L/R_T$, but for the high-performance motors under discussion, $\tau_m >> \tau_e$; the electrical time constant is considered negligible.

Note that when time, t, in Eq. 16 becomes large, S approaches the steady-state, no-load-speed value, V_T/K_E, calculated in Eq. 7. In one mechanical time constant equal to $JR_T/K_T K_E$, the motor accelerates to 63.2% of its final speed (Fig. 3), after the application of a fixed voltage.

Substitute Eq. 14 into Eq. 12, but this time, consider the motor to be loaded with a load, T_L; thus $J = J_m + J_L$). Also retain the terms T_F and K_D. The result is

$$K_T \frac{V_T}{R_T} - \left[K_D + \frac{K_T K_E}{R_T} \right] S - T_F - T_L = J\alpha. \qquad (17)$$

Now solve this differential equation for speed and obtain

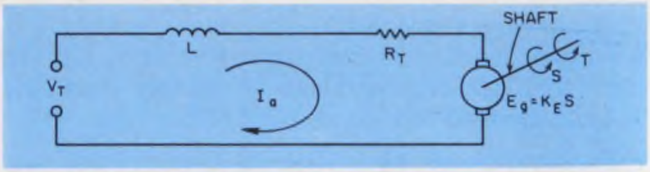
$$S = \frac{K_T \frac{V_T}{R_T} - T_F - T_L}{K_D + \frac{K_T K_E}{R_T}} \left[1 - e^{\frac{-R_T K_D - K_T K_E}{R_T J} t} \right] \qquad (18)$$

The denominator term $K_D + K_T K_E/R_T$ consists of two parts. The first term a damping constant-accounts for all friction losses that are velocity-dependent, such as losses that result from short-circuited conductors undergoing commutation in a leakage magnetic field, and losses from the friction of grease in the bearings. The second term results from damping caused by the back emf of the motor. However, in practical cases the relative magnitudes of these terms are such that

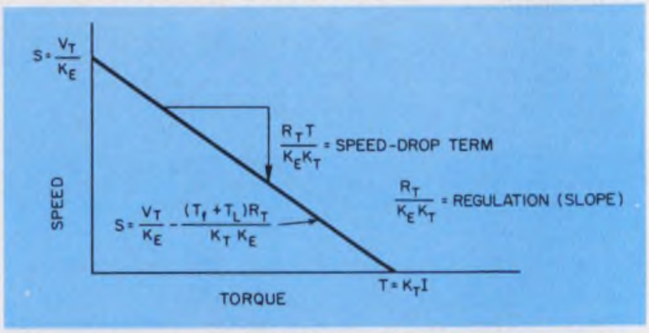
$$K_D << \frac{K_T K_E}{R_T}. \qquad (19)$$

As a result, the speed approaches

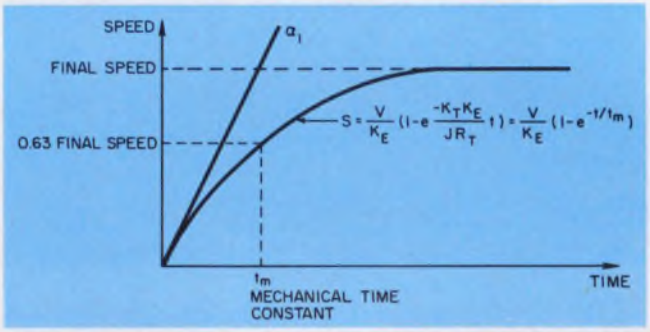
$$S = \left(\frac{V_T}{K_E} - \frac{(T_F + T_L) R_T}{K_T K_E} \right) \left[1 - e^{\frac{K_T K_E}{JR_T} t} \right] \qquad (20)$$



2. **An equivalent electrical circuit of a motor** helps in setting up and solving the dynamic-response characteristics of servo systems.



3. **A hollow-rotor motor's mechanical inertia,** even though comparatively small, still overshadows the effects of the rotor's inductance and determines the motor's acceleration capability.



4. **The slope of the speed-torque line** is determined by the motor's torque/current constant, K_T; its voltage/speed constant, $_E$, and its terminal resistance, R_T.

Note that the first term, V_T/K_E, yields the approximate steady-state speed at no load (Eq 16). The second term is known as the "speed-drop" term, and the coefficient, $R_T/K_T K_E$ is motor regulation (Fig. 4).

To solve for acceleration, differentiate Eq. 18 and obtain the result

$$\alpha = \frac{-K_T V_T - T_F R_T - T_L R_T}{JR_T} \left[e^{\frac{-R_T K_D - K_T K_E}{JR_T} t} \right] \qquad (21)$$

If the motor is driven from a constant-current source with current I_a, a solution of Eq. 12, is

$$S = \frac{K_T I_a - T_F - T_L}{K_D} \left[e^{\frac{-K_D}{J} t} \right], \qquad (22)$$

and the acceleration is

$$\alpha = \frac{K_T I_a - T_F - T_L}{J} \left[e^{\frac{-K_D}{J} t} \right] \qquad (23)$$

A typical hollow-rotor motor system might have the following specifications:

$K_T = 6$ oz-in/A,
$K_D = 0.01$ oz-in-s/rad,

$K_E = 0.0424$ V-s/rad,
$R_T = 0.8\ \Omega$
J (total) $= 0.0008$ oz-in-s^2.

To simplify a comparison of constant-voltage vs constant-current operation, assume T_F and T_L are negligible.

Then if $V_T = 16$ V, from Eq. 21, the acceleration when a constant voltage is applied to a motor becomes

$$\alpha_v = 150 \times 10^3 e^{-400t}, \qquad (24)$$

and Eq. 23 for constant current with $I_a = 20$ A during acceleration, becomes

$$\alpha_I = 150 \times 10^3 e^{12.5t}. \qquad (25)$$

A short tabulation of numerical solutions of the exponents of Eqs. 24 and 25—

t (sec)	e^{-400t}	$e^{-12.5t}$
0.001	0.660	0.99
0.01	0.016	0.89
0.1	4.2×10^{-18}	0.30

—reveals clearly that acceleration in the constant-voltage case drops very rapidly—even as little as 0.01 s after starting. However, in the constant-current case, acceleration remains substantially constant during the critical first few milliseconds after start.

Therefore, the initial acceleration for constant-current operation, with negligible T_F and T_L, can be written as

$$\alpha_I = \frac{K_T I_a}{J}. \qquad (26)$$

Note that acceleration is directly proportional to current for small time intervals. Also, motor resistance is absent from the speed formula, Eq. 22; thus speed is independent of motor resistance. A system that uses a constant-current driving source eliminates the effects of changes in motor resistance. Motor resistance changes can result from temperature variations and brush and commutator wear.

Pulse-width control is unsuitable

Pulse-width-modulated drive systems are often used to control motor speed and acceleration. Because the drive transistors operate in a saturated mode in pulse-width systems, the transistors dissipate less power for a given output and the system can operate at high efficiencies. However, with responsive low-inertia motors, the pulsed power may produce a ripple in the motor's output. And in a velocity servo system, the ripple is made worse, since it tends to be amplified.

Of course, a servo with a narrow amplifier bandwidth or with ripple filtering would reduce this undesirable condition, but it would also reduce the rapid-response capability of the servo system and defeat the high-response capability desired with low-inertia motors.

In addition, such undesirable speed variations cause excess motor heating and make precise speed control difficult. Speed ripple would create ripple in the tachometer output of a servo. This ripple looks like speed errors in the system and would cause a large amount of current switching when the system attempts to correct. Audible noise, excessive heating and even burn-out of the amplifier, motor or power supply could result.

Negative feedback in a servo system, if allowed to form torsional-resonance loops, will cause instability. As a signal flows around a servo-system loop, it encounters delays caused by motor inertia, filters, amplifier response, inductance, shaft wind-up, etc. If at any given frequency these delays result in a phase shift of 180 degrees and a net loop power gain exists, the system will become unstable and tend to oscillate.

The solution to this problem lies in identification of the delay elements and control of the over-all-system frequency response to that gain is much less than unity at 180-degree phase-shift frequencies.

In any mechanical system, torsional resonance can occur when two or more masses are connected by a common shaft. A high-performance motor, its associated tachometer and a load can be represented by three inertial masses connected by shafts. The shaft's inertia is generally considered negligible, but they supply the spring-constant of the resonant system.

To solve the high-order differential equation of even a simplified equivalent-circuit of such a mechanical system is a difficult task. Thus, experimental methods are often used to determine resonance frequencies and instability conditions.

In practice, the conditions can be very complex. The inertias of the loads, motor rotor and tachometer; their relative location; the length, diameter and material of the connecting shafts, couples and gears; and the friction and backlash in a system—all affect stability and are difficult to include in a mathematical model.

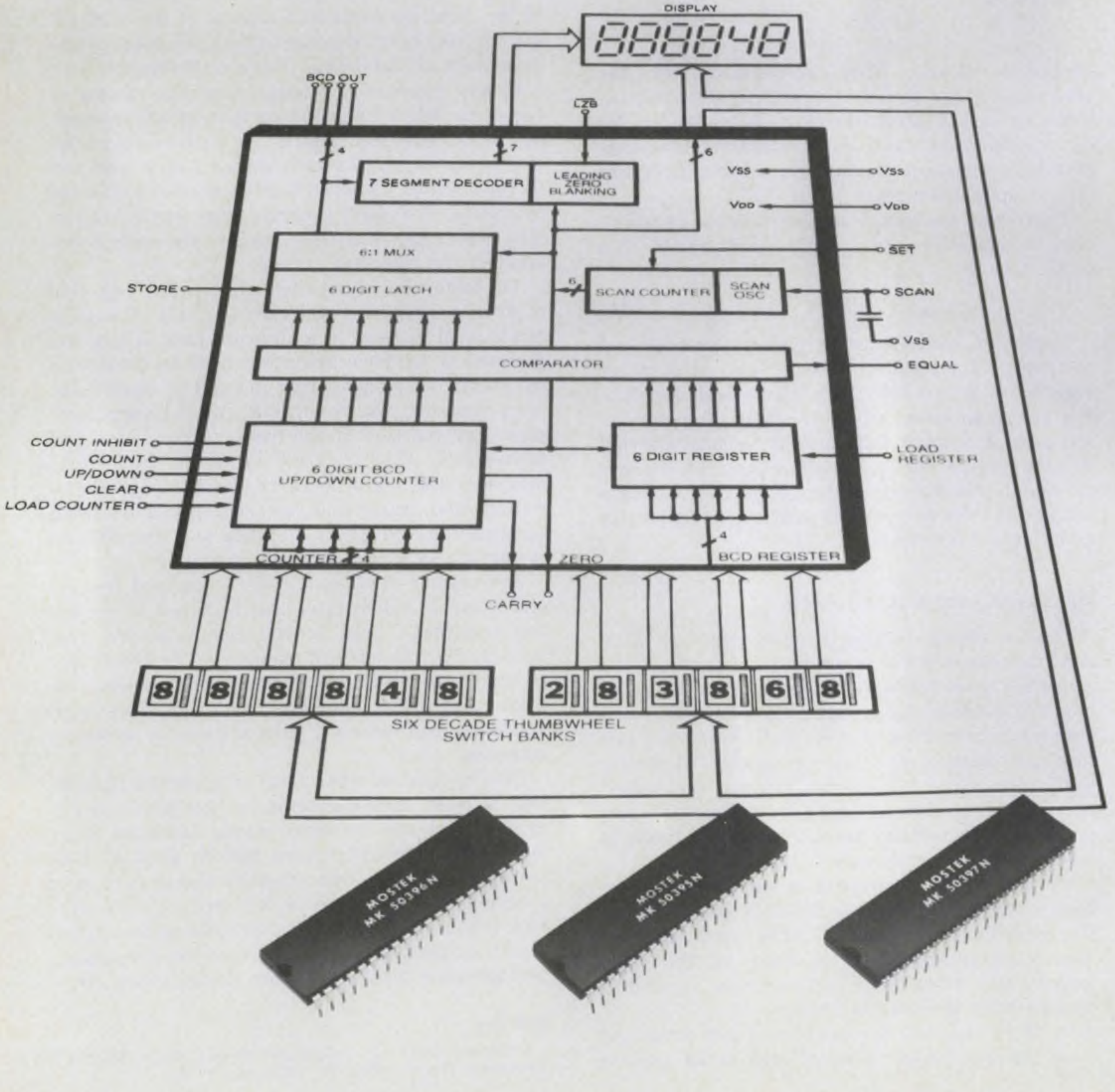
A resonant frequency can be damped in several ways. A notch filter can be tuned to reduce the amplifier's gain in the region of the frequency. Or, the rate of change of feedback can be limited to reduce the over-all system frequency below that of the resonant frequency. This later approach can severely compromise a system's response.

But no matter what type of system stabilization is used, high-performance, low-power drive applications can be more easily achieved with low-inertia, low-inductance motors such as hollow-rotor motors. And whether the system is a simple open-loop drive or a complex servo system, low-inertia and low-inductance motors allow the attainment of a higher level of rapid-response performance than most other motor types. ■■

Reference

1. Mazurkiewcz, J., "Consider Hollow-Rotor Motors," *Electronic Design*, May 24, 1975, pp. 76-79.

MOSTEK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COUNTERS

Application ideas are proving their versatility.

From a Continuous Rate-Indicating Thermometer to a Robot Parking Attendant the wide range of applications submitted in our "I Need Help Counting" contest revealed a hint of the versatility we designed into our MK 50395 counter circuit. We received so many quality designs, in fact, we awarded more prizes than anticipated. Here's a sampling of the innovative designs entered:

Digital Pulse Generator
Digital Delayed Oscilloscope Trigger
Simulated Counting at Frequencies above 100 MHz
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MOSTEK has expanded its counter series to include two new circuits which count various increments of time, the MK 50396 and MK 50397.

Circuit Count Capability

MK 50395	Counts to 999999
MK 50396	Counts time to 99 hrs., 59 min., 59 sec.
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Whether you're developing a new system or making improvements, MOSTEK's counter series can offer significant cost savings and improved efficiency.

Never has one circuit had so much counting capability.

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- **Comparator Function.** The six-decade register is constantly compared to the state of the six-decade counter and when the register and the counter have the same content, an EQUAL signal is generated.
- **Leading Zero Blanking.** The seven-segment decoder incorporates a leading-zero blanking circuit which can be disabled by an external signal.
- **BCD and Seven-Segment Output.** BCD and seven-segment data output provided. The MK 50395, 6 and 7 interface directly with standard CMOS logic and features single power supply operation, Schmitt-trigger on the count input, look-ahead carry or borrow and direct segment drive.

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CIRCLE NUMBER 59

Voltage-to-current converter built with few components

With a minimum component count (two op amps and five resistors), the circuit in Fig. 1 converts voltage signals in the range of 0 to 10 V to a current output in the range of 4 to 20 mA.

To understand the operation of the circuit, first consider the Off/Set switch open. The noninverting input of the 72558 op amp, because it is strapped to the output terminal, forces the summing junction, S, to follow the output voltage, V_L. Therefore,

$$I_L = -\frac{V_i}{R_3}\left(\frac{R_2R_3}{R_1R_4}\right) + \frac{V_L}{R_3}\left(\frac{R_2R_3}{R_1R_4} - 1\right). \quad (1)$$

The circuit becomes a perfect voltage-controlled current source, if the load current depends only on the input voltage, V_i, and not also on the load voltage, V_L. Make the coefficient of V_L in Eq. 1 equal to zero by setting

$$R_2R_3 = R_1R_4.$$

Then the load current is given by the simple expression

$$I_L = -V_i/R_3.$$

The load-current offset of 4 mA is obtained by closing the Off/Set switch to resistance R_o. The expression for load current then becomes

$$I_L =$$

$$-\frac{R_2}{R_1}\left(\frac{V_o}{R_o} + \frac{V_i}{R_1}\right) + \frac{V_L}{R_3}\left[\frac{R_2R_3}{R_4}\left(\frac{1}{R_o} + \frac{1}{R_1}\right) - 1\right]. \quad (2)$$

Now if

$$R_2R_3 = R_4\frac{R_oR_1}{R_o + R_1} \quad (3)$$

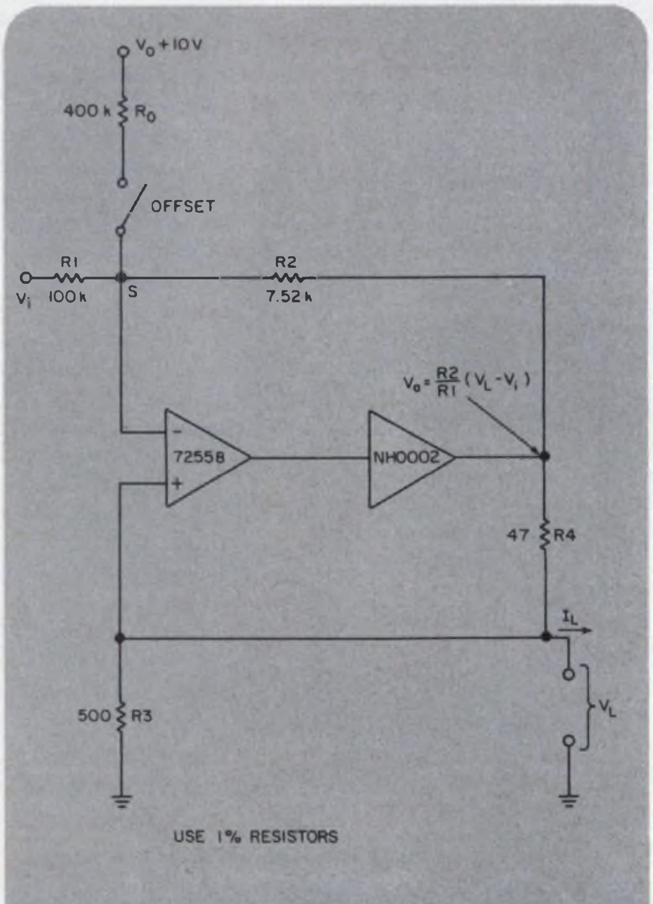
the expression for the load current reduces to

$$I_L = \frac{1}{R_3}\left(\frac{V_oR_1}{R_o + R_1} + \frac{V_iR_o}{R_o + R_1}\right) \quad (4)$$

If we set $(R_o + R_1)/R_1 = 5$ to correspond to the ratio 20 mA/4 mA when $V_i = 10$ V and 0 V, respectively, then $R_3 = 500\ \Omega$. The resistance R_1 should be high (100 kΩ) to ensure a high input impedance and R_4 should be low (47 Ω) to limit the voltage excursions of point V_a. Finally, R_2 is determined from the balance condition of Eq. 3.

D. G. van Niekerk and G. J. Kühn, Automation Div., National Electrical Engineering Research Institute, P.O. Box 395, Pretoria 0001, South Africa.

CIRCLE No. 311



Simple resistor relationships determine the transformation factor and output-current offset in this voltage-to-current converter.

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CIRCLE NUMBER 60

Power-down circuits allow three-state operation with some CMOS drivers

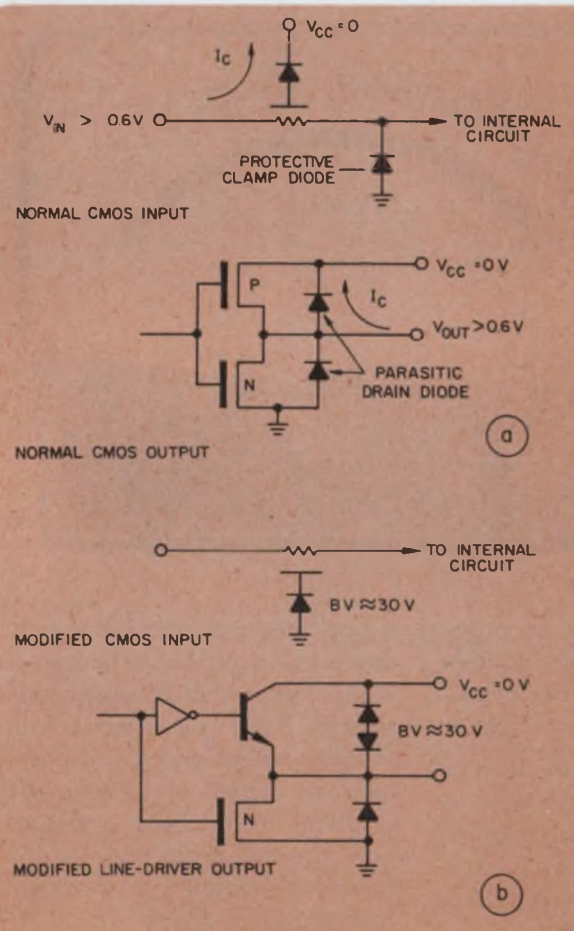
Three-state line drivers allow easy use of databussing architecture with microprocessors and with many other devices that "talk" to each other over bus lines. But few three-state line drivers are available.

Most ordinary CMOS drivers can't be used, because diode clamps protect their inputs, and the outputs have parasitic drain diodes (Fig. 1a). If V_{cc} is grounded, a parasitic p-channel diode would clamp any input signal to 0.6 V.
greater than 0.6 V; the input protection diode would clamp any input signal to 0.6 V.

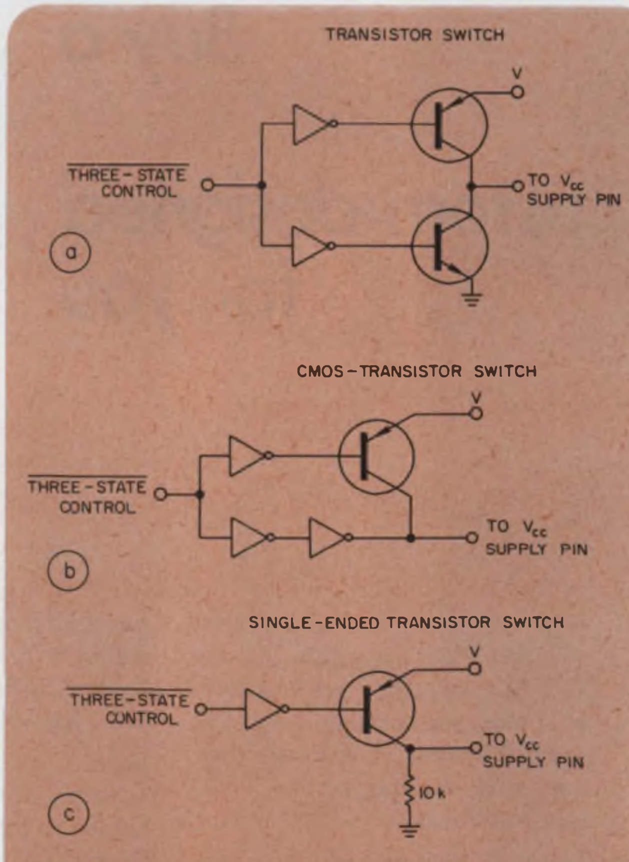
However, with types MM78C29 and MM78C30 CMOS line drivers, the inputs and outputs both go to high-impedance states when powered down (their V_{cc} terminals are brought to ground). These drivers have modified input protective diodes, and they use a high-voltage npn transistor in the output complementing circuit (Fig. 1b). With over 30-V breakdown limits, these CMOS drivers are amply protected in TTL circuits.

In the ON state, it's important to keep resistance between the line-driver circuit and the supply line as low as possible to minimize voltage variations at the driver's supply pin as its current varies. This minimizes cross-talk problems. A push-pull switch such as in Fig. 2a can be used to power down the line driver. Another version uses a CMOS inverter to replace the npn transistor (Fig. 2b). A single-ended configuration (Fig. 2c) is simpler and still effective; but it dissipates dc power.

Gerald Buurma, Design Engineer, National Semiconductor Corp., 2900 Semiconductor Dr., Santa Clara, CA 95051. CIRCLE NO. 312



1. **In ordinary CMOS drivers** an input-protection diode clamps any input signal greater than 0.6 V, if the supply pin is brought to ground. Also parasitic p-channel diodes clamp the output signal.



2. **Low ON resistance to the positive supply is desirable** to minimize channel cross-talk in line drivers. Saturated transistor switches power-up CMOS line drivers for normal operation or power-down for the high-impedance third state.

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CIRCLE NUMBER 61

A simple battery charger for gel cells detects full charge and switches to float

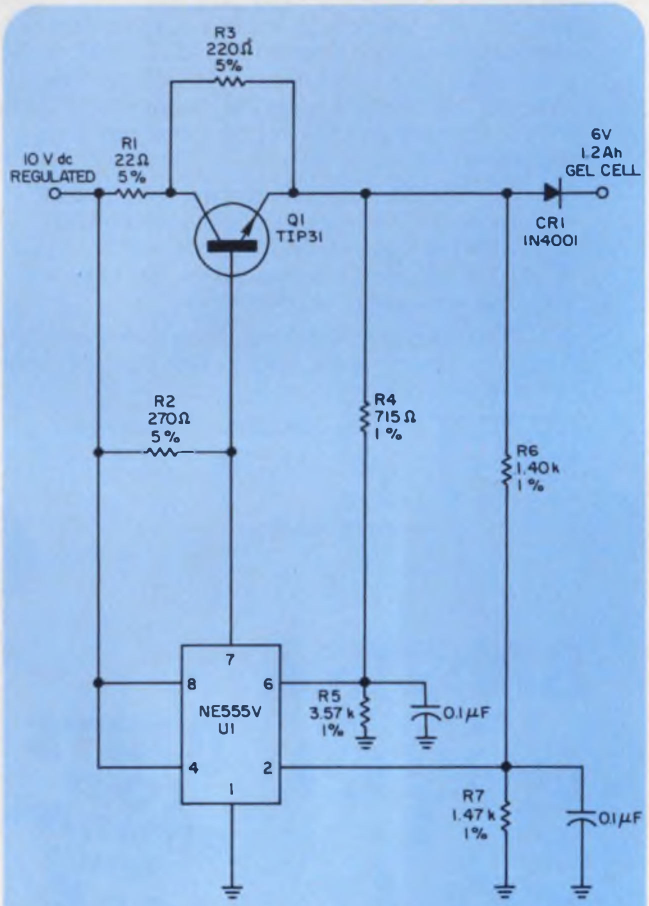
A gel-cell battery charger can be built with a 555 timer at a considerable parts saving over similar circuits. A cell should be charged at a current not exceeding 20% of its rated capacity until a specified terminal voltage is reached. The charging current must then be reduced to approximately 1% of the rated capacity of the battery to maintain the battery in a float condition.

The circuit in the figure meets these charging conditions for a 6-V, 1.2-Ah system. For this battery, the charge current should be equal to or less than 240 mA and the float-charge current should be approximately 12 mA. When the battery is fully charged it exhibits a terminal voltage of 7.2 V and a float voltage of 6.8 V.

The two comparators in the 555 detect both the need for charging and the fully charged condition. The timer's internal flip/flop and npn discharging transistor drive an external transistor, Q_1. Transistor Q_1 switches the charge current from its maximum value (limited by R_1) to the float value (limited by R_1 + R_3). Resistors R_4 and R_5 set the trip point for detecting a fully charged battery; resistors R_6 and R_7 set the trip points for detecting a partially discharged battery. Diode D_1 disconnects the charging circuit from the battery when the 10-V regulated-input source is removed.

Paul Kranz, Products Manager, and John Seger, Associate Engineer, Dytron Inc., 241 Crescent St., Waltham, MA 02154.

CIRCLE NO. 313



This battery charger for a 6-V gel cell automatically detects the full-charge state and switches to a float-charge condition—from 240 mA to 12 mA.

IFD Winner of March 15, 1976
John Okolowicz, Senior Electrical Engineer, Honeywell Inc., 1100 Virginia Dr., Fort Washington, PA 19034. His idea "Automotive charging regulator gives overvoltage and undervoltage warnings" has been voted the Most Valuable of Issue Award.
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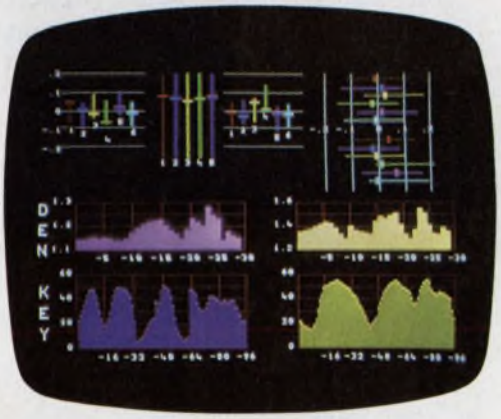

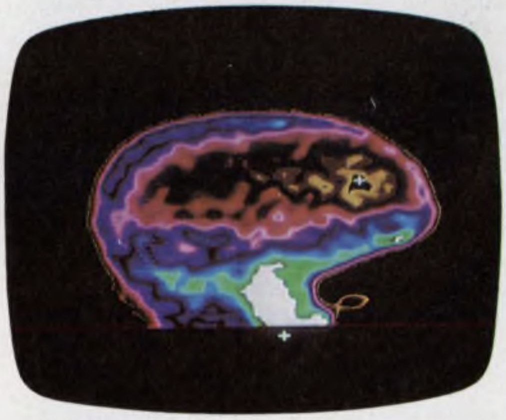

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CIRCLE NUMBER 62

Design Decision

Super-high g_m input stage sums currents to make precision modular instrumentation amp

A novel design of a modular instrumentation amplifier, developed by Datel Systems of Canton, MA, permits the construction of small, bipolar-input, discrete-component modules that rival the performance of more costly rack-mounted amplifiers.

The desired specifications—such as input offset current drift of 20 pA/°C, offset voltage drifts of only 0.25 μV/°C, gains from 1 to 1000 and CMRRs of 114 dB that are flat to 700 Hz—ruled out many of the conventional methods, such as the triple op-amp scheme of Fig. 1.

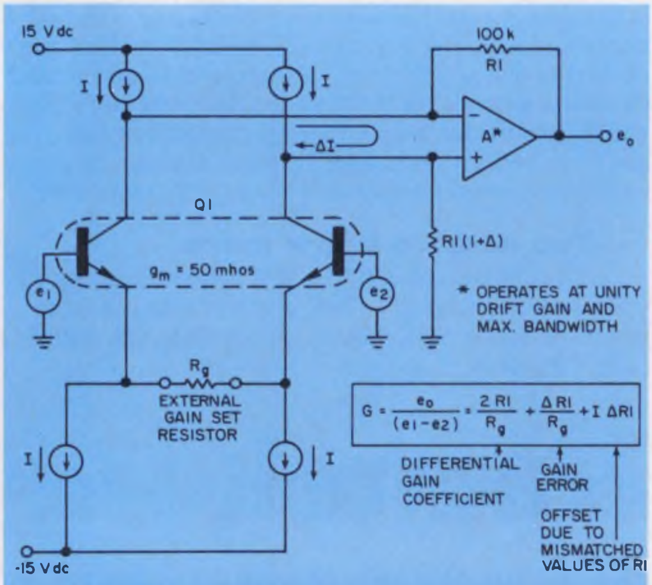
The approach chosen by Datel lets the CMRR and gain be determined by a wideband bipolar input stage that makes use of a "super-high" matched g_m instead of critical resistor matching (Fig. 2). The output stage also operates in a wideband mode and produces no common-mode error voltage due to resistor mismatch, but only an offset that can be calibrated.

The input stage of Datel's circuit contains a differential gain block, represented simply by Q_{1a} and Q_{1b}. These transistors have a transconductance of 50 mhos, and they represent a tightly matched, high-gain differential circuit. The current output of this stage drives an op amp that is connected as a differential current-to-voltage converter. When operated with 100% feedback, the amplifier has the desirable features of unity drift gain (unlike A_3 of Fig. 1 which has a minimum drift gain of 2) and maximum available bandwidth.

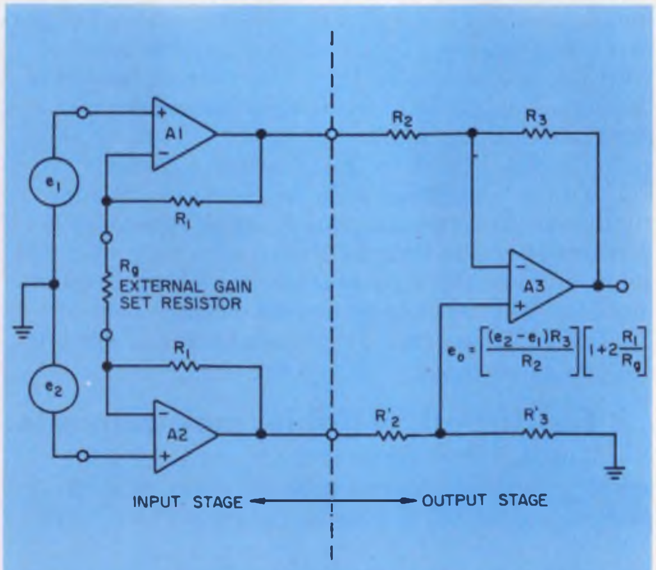
Only two nominally equal resistances, R_1 and R_1 $(1 + \Delta)$, are required. Any mismatch between them produces an output offset—not a common-mode error—and can be nulled out. The extremely high transconductance of the input stage provides three important advantages:

1. It permits the ratio of two passive components (R_1/R_g) to define accurately the differential gain equation, and it eliminates changing transistor parameters as possible error sources.
2. It permits close control of the static and dynamic behavior of the amplifier.
3. It lets you use standard value resistors to set gain values externally.

All the capability formerly available in many rack-mounted units can now be put into 1.5 × 1.5 × 0.375-in. modules at a fraction of the cost—less than $100 for the best unit.



1. **The CMRR of the common three op-amp instrumentation amplifier circuit** relies on resistor and op-amp matching. A unity differential-gain setting is impossible.



2. **The high differential transconductance input stage** converts resistor mismatch effects into an offset. This permits differential gains of less than one to be used.

The other place in town to get the Am2900 from the first supplier with software to support it.

Now there's another place in town for the 2900 Family of microcomputer components. Raytheon has immediately available the Am2901 4-bit Microprocessor Slice and the Am2909 Microprogram Sequencer.

The 2901 is the fastest, most powerful LS microprocessor in the world. With its cycle-saving two-address architecture, the Am2901's speed can't be touched. The 2909 can branch anywhere in memory, perform sub-routines, then return with up to four levels of sub-routine nesting. Together, the 2901 and 2909 are the most in-demand components in the Series. And the start of our big 2900 Family. Bus transceivers, look-ahead carry generators, registers, PROM's and RAM's are soon to come from Raytheon.

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For complete details, contact your local distributor or Raytheon Company, Semiconductor Division, Dept. 2900, 350 Ellis Street, Mountain View, CA 94042; (415) 968-9211.

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CIRCLE NUMBER 63

Novel display chips use magneto-optics

A novel display combines the storage properties of magnetic bubbles with magneto-optic effects produced using polarized filters.

Prototype display chips developed by Mullard Research Laboratories have a 10 × 10 bubble matrix. These chips have displayed alphanumeric characters using a 7 × 5 matrix format of 10 μm bubbles.

The display chip is similar to the conventional bubble memory. The chip has a thin layer of magnetic material overlayed with a pattern of permalloy elements that control the generation, propagation and annihilation of bubbles. The display chip is illuminated from behind with linearly polarized light. The light after passing through the chip, goes through a second polarized filter that has a different polarization axis.

Because the light passing through magnetized areas of the chip undergoes Faraday rotation, a color contrast between the bubbles and the space around them is produced. The contrast obtained is higher than that of other two-color displays, and the colors are varied by changing the polarized filters.

The display, like the bubble memory, is non-volatile. Also, it is current-driven at low voltage. Another advantage is that only two connections to the chip are required for display of any size.

A major limitation of the display is its tiny size. It must be viewed through a magnifying eyepiece.

Further work is aimed at developing a 100 × 100 matrix chip that operates at 10 kHz, takes 1 s to build up a picture. The chip would be only about 4-mm^2 in area; but Mullard claims data written on the chip would be clearly visible using a × 10 eyepiece.

Graphics device allows wide range of operations

The use of both light-pen and cursor controls allows a wide range of interactive-graphics operations to be carried out on a computer-controlled graphics device developed at the Science Research Council's Rutherford Laboratory at Didcot, Oxford, England.

The graphics system, called ASPECT, has stored graphics data. This enables pictures to be scaled, moved linearly or rotated in two and three dimensions in real time. A picture processor gives immediate response to operator signals.

The scaling, lateral movement, and rotation capabilities work directly from the digitally-stored file of coordinates describing a three-dimensional structure. An operator, using tracker-ball input devices, can zoom in on any portion of the display.

Other features of ASPECT include an alphanumeric character generator and a vector generator for supplying lines between any two specified points.

New technique plots carrier concentration

A technique to obtain a continuous automatic plot of carrier concentration versus depth in a semiconductor, has been developed at the Research Laboratories of the British Post Office.

The key to the method is the formation of a Schottky barrier between the semiconductor and an electrolyte. A depletion layer is formed within the semiconductor. Then the capacitance-voltage behavior of the layer is used to determine the carrier concentration. Integrating the electrolyte's dissolution current yields the depth at which the carrier concentration is being measured.

The concentrated electrolyte is conductive enough to behave like a metal, thus giving rise to a Schottky barrier such as is formed at the metal/semiconductor interface. When the junction is reverse-biased a depletion layer is formed. Its width is obtained by measuring the junction capacitance.

If the barrier potential is modulated, the junction capacitance and depletion layer width are also modulated; and the ionized impurity concentration can be found from the relationship $N_D - N_A = KdV$. Here, K is a material constant and $N_D - N_A$, the difference between the donor and acceptor concentrations, is the required carrier concentration (assuming an n-type material).

A potential-barrier height of 1.5 V is maintained across the depletion region and a 100 mV, 30 Hz modulation is superimposed on the 1.5 V. The junction capacitance is measured using a 50 mV, 3 kHz test signal.

Analog processing of the modulation signal yields W_D and log $(N_D - N_A)$. The depth of material removed by anodic dissolution is equated to the integrated dissolution current plus W_D.

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CIRCLE NUMBER 64

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Model 5740, 7-digit, 100 MHz Multifunction Counter/Timer. $295*

Quality you can count on. Data Precision's Model 5740 is a 7-digit, 100 MHz Timer/Counter; a superb laboratory quality instrument.

Data Precision built the 5740 to be exceptionally versatile. It measures frequency, period, period average, elapsed time and total events with the kind of accuracy, sensitivity, and upper frequency capability generally found only in higher priced units.

Consider: 10 mV RMS sinewave to 20 MHz. 50 mV RMS at 100 MHz. That's excellent sensitivity in anyone's book. And this sensitivity is a minimum specification (not a typical) allowing lock-in measurements from even extremely weak signals. The 100 MHz bandwidth means the 5740 handles everything from subaudio to VHF. Seven, not six digit resolution, means 0.1 Hertz resolution at 1 MHz, 1 part in 10 million in period measurements, with the decimal point always automatically correct.

Want even more? A low-cost optional BCD output provides printer and/or computer/system compatibility while providing counter status timing and control/ signals as well as reading and decimal-point data. And an optional remote start/stop control makes this a most flexible elapsed time indicator.

The 5740 Multifunction Counter/Timer. Its quality, versatility and value are unmistakable. And it comes with something no one else gives you: Data Precision dependability.

For complete information or a demonstration contact your local Data Precision representative or Data Precision Corporation, Audubon Road, Wakefield, MA 01880, USA, (617) 246-1600. TELEX (0650) 949341.

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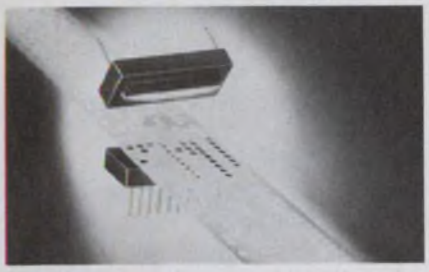
CIRCLE NUMBER 65

New Products

Infrared LED light bars read tapes and cards



Opto Technology Inc., 1001 E. Touhy Ave., Des Plaines, IL 60018. (312) 724-2800.

An infrared LED Light Bar is a packaged array of solid-state LEDs. A reverse-voltage blocking diode is included. The Bars are complete and ready to use. Minimum to maximum light level is externally adjusted by user. The units are available in standard 1-in. nine-channel-reader packages. Custom lengths are available to user specifications.

CIRCLE NO. 320

Power Darlingtons rated for a 200-C junction temp

Lambda Electronics, 515 Broad Hollow Rd., Melville, NY 11746. (516) 694-4200. $2.42 to $4.60 (100 up); stock.

Power-Darlington assemblies in three new power levels—100, 150 and 225 W—allow power supply designers to use fewer components, to increase reliability, to save 40% on material costs and to reduce assembly labor, according to Lambda. These transistors are the only 200-C operating-junction-temperature Darlington power transistors in the industry. They all are true-hermetic sealed. The 100 and 150-W versions are resistance-welded units; the 225-W units are solder constructed. All are continuous-duty rated, have a low thermal resistance (0.67 C/W) and are 100% tested for second-breakdown current and leakage-current stability at a 200-C junction temperature. Current gain is 1000 at a collector current of 4, through 10 A.

CIRCLE NO. 321

Avalanche photodiodes have diverse properties

RCA Solid State Div., Route 202, Somerville, NJ 08876. (201) 685-6423. $159: C30817; $200: C30872, $40: C30884, $97: C30895 (unit qty).

Three new silicon avalanche photodiodes, the C30817, C30884 and C30895, are supplied in low-profile TO-5 packages and have useful photosensitive areas of about 0.5 mm². A fourth—the C-30872—is a large-area photodiode; its useful photosensitive area is about 7 mm². This diode is supplied in a low-profile TO-8 package. The C30817 and C30872 are intended for use in general-purpose applications. They have a useful spectral range extending from about 400 to 1100 nm and rise and fall times of typically 2 ns. The C30884 has very high modulation capability, up to 400 MHz, and typical rise and fall times of 1 ns. Its spectral range is from 400 to 1100 nm. The C30895 is optimized for high responsivity and low noise at 1060 nm. Its spectral range extends from about 700 to 1100 nm. Rise and fall times are typically 2 ns. This device is designed for use in adverse environments.

CIRCLE NO. 322

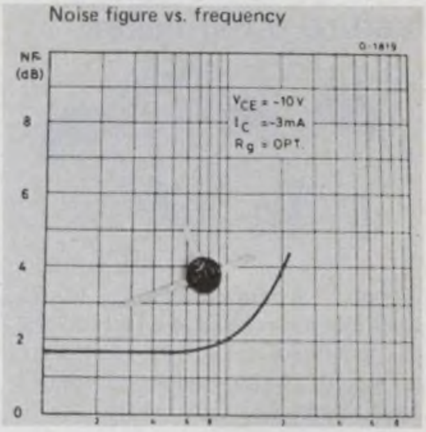
Green LED chips brighten watch displays

Xciton Corp., Shaker Park, 5 Hemlock St., Latham, NY 12110. (518) 783-7726. $2 (1000 up); stock to 2 wks.

Xciton's green monolithic watch chips, designated CXC-120G, used in numeric watch displays are two-to-five times brighter than previously available green digits. The displays are constructed with nine chip segments and each chip is a 0.097 × 0.060-in. bar. A companion chip, the CXC-121G, measures 0.088 × 0.045 in. Both are optimized for unmagnified viewing and rated at 100-mcd output with a 10-mA drive. The peak output wavelength is 565 nm and typical forward voltage is 1.9 V at 10 mA.

CIRCLE NO. 323

Rf silicon transistor provides low noise


Noise figure vs. frequency

SGS-ATES Semiconductor Corp., 435 Newtonville Ave., Newtonville, MA 02160. (617) 969-1610. $6 (1-9); stock.

BFT95 is a new 5-GHz silicon pnp transistor with extremely low noise (2 dB at 1 GHz) intended for high-volume rf applications such as antenna amplifiers, cable TV and up-converter tuners. The device is constructed with Planox silicon-nitride technology to minimize parasitic capacitances in a common-emitter configuration. It's mounted in the SGS-ATES T-plastic package, which uses a copper-alloy frame to withstand high current and thus achieve a better cross-modulation level. Forward-transmission gain is 10 dB at 1 GHz and the intermodulation intercept point with optimum biasing is +23 dBm.

CIRCLE NO. 324

Monolithic duals receive MIL approval

Teledyne Semiconductor, 1300 Terra Bella Ave., Mountain View, CA 94043. (415) 968-9241.

Military qualification for the monolithic 2N2919 and 2N2920 dual npn bipolar transistors are believed to be the first granted for these devices, according to Teledyne. Single-chip monolithic construction significantly improves matching and tracking when compared with two-chip units. Manufacturing economies also allow lower prices (not given), especially on the types requiring extra processing (JTX and JTXV), says Teledyne.

CIRCLE NO. 325

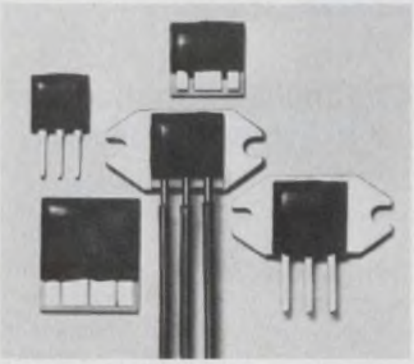
Solid-state indicators feature three colors

Chicago Miniature Lamp Works, 4433 N. Ravenswood Ave., Chicago, IL 60640. (312) 784-1020. $1.15 to $1.40: 6340; $0.60 to $0.80: 6080 (1000 up).

The new Ultralite series of solid-state indicators is available in red, amber and green in attractive chromed housings. The series is available in two sizes: a large 6340 series, featuring a 0.4-dia spot, and an economical 6080 series, featuring a 0.2-dia spot. The units provide up to 13 mcd (red, 6340 series) output. Power ratings include 5-V, 40-mA resistored and 2-V nonresistored styles as standards with 6-in. wire leads or solder/faston terminals.

CIRCLE NO. 326

Caseless SCRs and triacs 40% lower in cost



Unitrode Corp., 580 Pleasant St., Watertown, MA 02172. (617) 926-0404. $0.52 to $10 (1000 up); 3 to 4 wks.

Unitrode's ChipStrate line of SCRs and triacs now include ratings to 800 V and a wide range of new packaging options. The basic line covers 3-to-55 A ratings and consists of glassivated solderable power chips mounted on alumina or beryllia ceramic substrates having solderable terminal pads. The substrate package is smaller and up to 40% lower in cost than conventional stud or pressfit devices.

CIRCLE NO. 327

Switching power-supply transistors go plastic

Motorola Semiconductor Products, Inc., P.O. Box 20294, Phoenix, AZ 85036. (602) 244-3465. $0.75: MJE13002, $0.95: MJE13003 (250-999).

Motorola introduces its switchmode power transistor in plastic TO-126 packages. First in this planned series of plastic-packaged introductions are the MJE13002 and MJE13003 devices rated 1.5 A with a 600/700-V blocking voltage. The devices in the plastic packages are significantly lower in price than equivalent metal-packaged devices. For circuits requiring very fast turn-off time, at 100-C operation, critical parameters include a complete inductive-load switching matrix for collector currents ranging from 0.5 to 1.5 A, and a reverse-biased SOA for various turn-off voltages.

CIRCLE NO. 328

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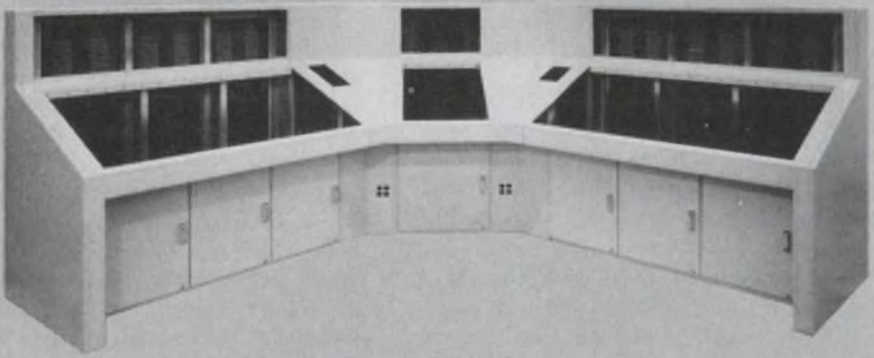

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CIRCLE NUMBER 67

Power Darlingtons give greater power gain

Motorola Semiconductor Products Inc., P.O. Box 20294, Phoenix, AZ 85036. (602) 244-3465. $6.25: MJ-10000. $7.75: MJ10001 (250-999).

MJ10000/MJ10001—first in a series of switchmode power Darlington transistors—are part of a high-voltage, high-speed series for use in switching power supplies and other inductive circuits where fall time is critical. The Darlingtons provide up to 10 times the power gain of conventional, single-transistor, switchmode devices, according to Motorola.

CIRCLE NO. 329

High-efficiency diodes protect transistors

Unitrode Corp., 580 Pleasant St., Watertown, MA 02172, (617) 926-0404. $1.10: 50-V leaded units, $14.55: 500-V, DO-5 (1000 up); Stock.

High-efficiency industrial power rectifiers for use as commutating or "catch" diodes in switching regulators protect transistors from excessive switching losses, second breakdown and voltage stress. Their low V_f (typically 0.7 V under maximum operating conditions) and fast t_{rr} (typically 30 ns) make them equally suitable for high-frequency power supplies, telecommunications systems, dc motors and high-current off-line switching circuits. They are available in fused-in-glass axial-leaded bodies and DO-4, DO-5 and TO-3 packages with output current from 2 to 70 A and voltages to 500 V. The thermal resistances of the DO-4, DO-5 and TO-3 are typically 1.6, 0.6, and 0.8 °C/W, respectively.

CIRCLE NO. 330

Darlington array operates with C/PMOS

Sprague Electric Co., 347 Marshall St., North Adams, MA 01267. (413) 664-4411.

A new high-current, high-voltage Darlington array, Type ULN-2004A, has been designed with series input resistors chosen to allow operation directly from CMOS or PMOS outputs that use supply voltages of 6 to 15 V. The input current is less than that of the Type ULN-2003A, while the input voltage is less than that required by the ULN-2002A.

CIRCLE NO. 331

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51-353-112	3	125	13	70	70
51-320-023	1	240	24	70	70

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CIRCLE NUMBER 68

Miniature relay features low profile

Guardian Electric Manufacturing Co., 1550 W. Carroll Ave., Chicago, IL 60607. (312) 243-1100.

A low-profile miniature relay, Series 1475 DC, with a choice of either an SPDT or DPDT contact assembly features contacts with multiple-convoluted contacting surfaces. The contacts are rated from dry-circuit to 10-A ac-resistive loads depending on voltage. For use on PC boards with 0.6-in. spacing between boards, the relay's terminals have a standard 0.1-in. grid spacing. The unit's sealed housing allows wave or hand soldering to 650 F without contact contamination or other damage. The case made of a glass-filled thermoset polyester is highly resistant to flux solvents.

CIRCLE NO. 332

Cermet trimmer offered with bushing mounting

Spectrol Electronics Corp., 17070 E. Gale Ave., City of Industry, CA 91745. (213) 964-6565. $1.70 (100 up).

The new bushing-mount option to Spectrol's 3/4-in., Model 43, multiturn cermet-trimmer line is available in any of the common three-pin configurations. All units in this 20-turn trimmer line feature a T-slider block design and brush contacts that provide improved settability and stability as well as improved CRV and RT tolerance, according to Spectrol. The rectangular units have a low profile and stand only 1/4-in. above the board. They are resistant to shock and vibration per MIL-R-22097 and come in a sealed case that permits board washing.

CIRCLE NO. 333

Transient protectors handle 1-joule surges

Dale Electronics Inc., P.O. Box 609, Columbus, NE 68601. (605) 665-9301.

An expanded series of PCB-mounted transient protectors for low-voltage dc circuits, the LVP Series, now provides 10 standard models with preset clamping voltages from 6.2 to 51 V dc. The units have a shunt capacity of 15 μF, nanosecond reaction times and operate over a temperature range of −55 to 85 C. These 1-joule units withstand power surges from 5000 W peak for a duration of 0.1 μs to 40 W peak for a pulse duration of 10 ms. Physical size is 5/8-in. high with case diameters ranging from 0.651 to 0.932 in.

CIRCLE NO. 334

Small dc motors provide tach output

Siemens Corp., 186 Wood Ave. South Iselin, NJ 08830. (201) 494-1000. $30 (1000 up).

A subfractional-horsepower motor, the 1AD4002, is supplied with a commutator circuit on a PC board that has two inputs for dc power and one tachometer signal output that allows speed regulation within 1%. Also speed is controllable externally. Available windings can meet customer requirements over a range of 4.4 to 30 V dc up to 10,000 rpm and for a stall torque of 2.9 oz-in. and continuous-running torque of 1 oz-in. The motor can be used either for gradual speed-change applications or accurate repeatable steps.

CIRCLE NO. 335

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Accepts Most Devices . . .
Even "Bicentennial" Versions!

Even "Bicentennial" lead patterns offer no real challenge to the unique flexibility of TEXTOOL's standard GRID ZIP socket series.

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Simple mechanical action, characteristic of all TEXTOOL zero insertion pressure sockets, allows a user to literally "drop" a device into the GRID ZIP's funnel entries which guide the leads to socket contacts. Then, simply flip a lever to test or age. Another flip of the lever allows extraction of the device with zero contact pressure, thus virtually eliminating mechanical rejects caused by bent or distorted device leads.

Regardless of device configurations — TO's, DIP's, platform and even "Bicentennial" — the versatile GRID ZIP socket accepts them all! If desired, several devices may be mounted in a single GRID ZIP for burn-in, or a single device may be inserted for hand test.

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CIRCLE NUMBER 69

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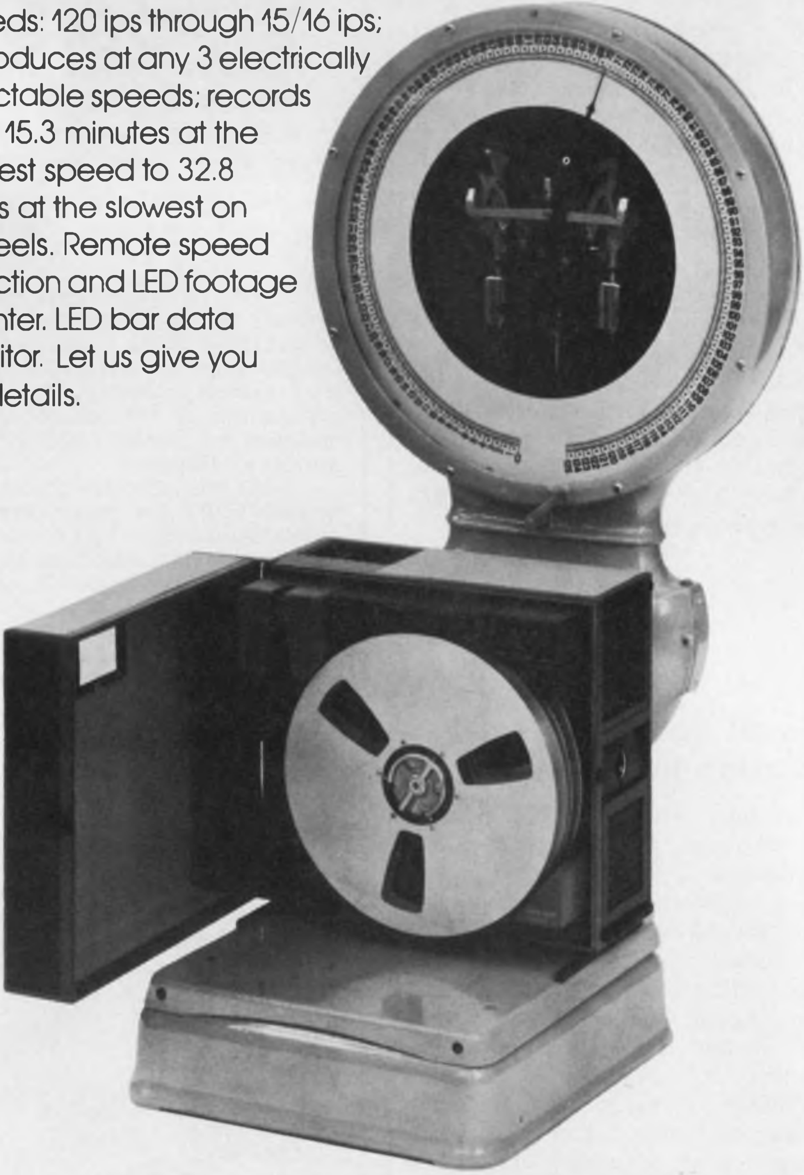

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CIRCLE NUMBER 70

Low-profile switch set by thumb or screwdriver

EECO, 1441 E. Chestnut Ave. Santa Ana, CA 92701. (714) 835-6000. $2: BCD (1000 up); 4 wks.

A low-profile stripswitch, the 2500 series, features a 0.3-in.-high design that enables mounting on PC cards racked at 0.5-in. intervals. The switch can be mounted by hand, wave or flow soldering; vertically or horizontally; and on both sides of a board. No mounting hardware is required. Single modules snap together to form a multistation switch of any desired length. This feature allows the mixing of different codes within one unit. Snaps may be cut off when switches are used in a single-station application. Available models offer thumbwheel or screwdriver setting, and legends on the top or side. Stops are available. Codes include 10-position BCD, BCD complement only, BCD with complement, decimal, + and −, not-true bits.

CIRCLE NO. 336

Photoelectric control resists interference

Micro Switch, Div. of Honeywell, 11 W. Spring St., Freeport, IL 61032. (815) 232-1122. $210; (unit qty).

A photoelectric control penetrates dust, frost, rain, paper or canvas and is immune to high ambient light. The MLS5A can scan 250 ft in clear air and is highly resistant to shock and vibration, according to the Honeywell division. The twin-unit is solid-state controlled and uses high-intensity LED pulsing. Because the emitter transmits a specific pulsed frequency and color, to which the receiver is specially "tuned," the unit is largely unaffected by interfering signals. Indicators at the rear of the emitter and receiving units instantly indicate proper operation and alignment. The units are only 3.25-in. high. The control can provide 20 operations/second and requires 12 to 18 V dc. A 24-V-dc model also is available.

CIRCLE NO. 337

Scott-T Xformer comes in small package

Magnetico, Inc., 182 Morris Ave., Holtsville, NY 11742. (516) 654-1166. $18 (100 up); stock to 4 wks.

A new driver Scott-T transformer, Part Number 12945, offers a low profile to allow close board-to-board spacing and small size to allow dense board packaging. Size is only 3/4 × 1-1/2 × 7/16 in. With a 400-Hz resolver and input at 6 V rms, the output will drive an 11.8-V line-to-line synchro, equivalent to a 300-Ω load. Accuracy, stability and ground isolation are provided for the life of the system. Other features include an input impedance of 500 Ω, an angular accuracy of 5 arc-minutes. Operation is over the temperature range −55 to 125 C.

CIRCLE NO. 338

Automobile fuses receive new look

Littelfuse, Inc., 800 E. Northwest Highway, Des Plaines, IL 60016. (312) 824-1188.

The first major change in American automotive fuses in six decades provides a marked upgrading in the reliability of electrical-circuit protection for car owners, according to Littelfuse. The new Autofuse line replaces traditional glass-cartridge fuses in 1977 GM full-sized Buick, Cadillac, Chevrolet Oldsmobile and Pontiac cars. The fuses are small plug-in units made of only two components, an element/terminal combination protected by a tough plastic housing. Glass fuses, however, contain as many as six different piece parts. Autofuses provide large easy-to-read amperage numerals on top of each fuse for easy servicing.

CIRCLE NO. 339

Trigger transformers isolate SCRs

Dale Electronics, Inc., East Highway 50, Yankton, SD 57078. (605) 665-9301. From $0.88; (100 up).

Low-cost, low-profile SCR isolation trigger transformers, designated PT50, have an above-board height of only 0.625 in., but have pin-spacing and performance that make them interchangeable with Sprague 11Z and Dale PT20 models. Other dimensions are a 0.75-in. length and .625-in. width. The unit is designed to transfer high-amplitude or long-duration pulses without saturation. Models are available with primary inductance values from 200 to 500 μH with turns ratios of 1:1, 2:1 and 5:1. The transformer is designed to operate at 240 V ac, 60 Hz over a temperature range of −55 to 105 C.

CIRCLE NO. 340

FREE Fiber Optics Catalog

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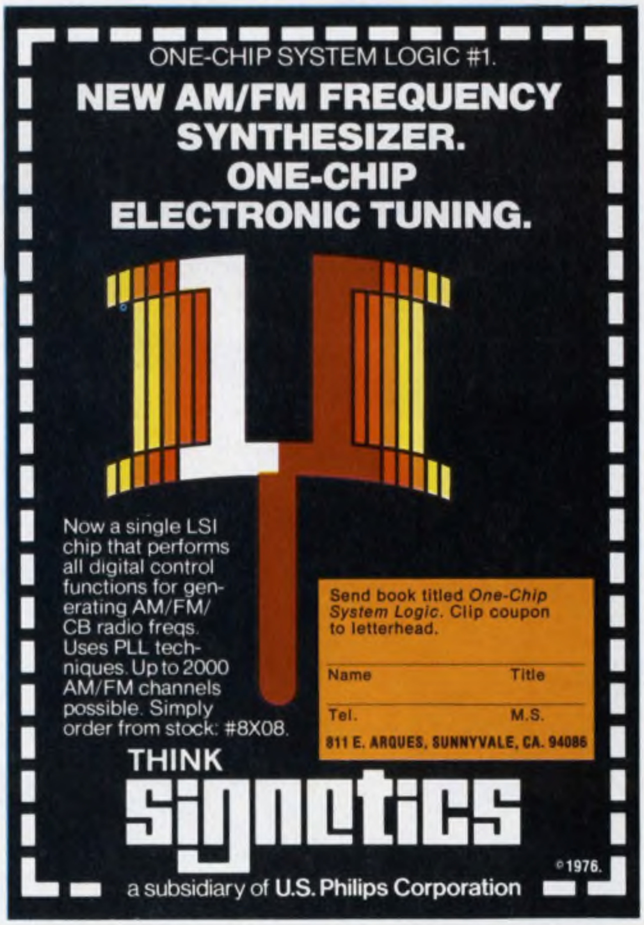
CIRCLE NUMBER 71



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CIRCLE NUMBER 72

PM hysterises clutch repeats torque to 1%

Vernitech, 300 Marcus Blvd., Deer Park, NY 11729. (516) 586-5100. 6 to 8 wks.

A new industrial permanent-magnet hysterises clutch, the PMC series, has been designed for repeatable torque and long life. These units can make equipment comply with OSHA safety regulations; as a fail-safe device it can protect other expensive components. In the 1.5-in.-dia frame size, torque is factory adjustable up to 8.5 oz-in., which can be held within 10% from unit to unit for speeds up to 10,000 rpm. Torque repeatability of a unit can be maintained within ±1%. The operating temperautre range is −65 to 260 F.

CIRCLE NO. 341

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The 33311B OEM Microwave Switch

- DC to 18 GHz with 1.4 SWR, 0.8 dB loss and useable to 24 GHz.
- 90 dB isolation, ±.03 dB repeatability at 10^6 switchings, ungated port terminated in 50 ohms.
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CIRCLE NUMBER 73

Proximity switch senses industrial objects

Eldec Corp., 16700 13th Ave. W., Lynnwood, WA 98036. (206) 743-1313. $125 (small qty); 30 days.

A new industrial long-range proximity switch, the Model 8-275, senses steel targets up to 1 in. away. The unit features a LED that indicates each time the target is sensed. The sensing range for nonferrous metals is 0.50 in. Equipped with a steel-conduit fitting for easy installation, the self-contained sensor operates on 115 V ac or 15 to 24 V dc, and it interfaces directly to control logic or relays. Specifications include a 2500 cpm switching rate, approximately 2-ms response time, no warm-up time, momentary short-circuit protection, a 40-to-180-F operating-temperature range and an environmentally sealed aluminum case. The unit weighs 0.39 lb.

CIRCLE NO. 342

Mushroom switch for emergency operation

Alco Electronic Products, Inc., 1551 Osgood St., North Andover, MA 01845. (617) 685-4371. $18 to $21.85 (1-9).

A series of "mushroom" switches for use in security and emergency applications features an exceptionally large button that measures 3-1/2-in. diameter, colored in red to act as an alert. Two operative modes are provided—momentary push and side to side wobble. Each switch comes mounted in a gray polyester box, which contains a choice of either a NO, NO/NC or dual NO/NC contact block, all rated at 10 A, 300 V ac.

CIRCLE NO. 343

INTEGRATED CIRCUITS

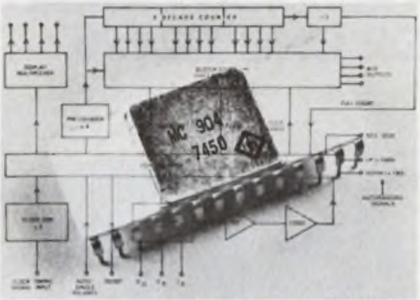
Multiplying CMOS d/a has 12-bit resolution

Analog Devices, P.O. Box 280, Route 1 Industrial Park, Norwood, MA 02062. (617) 329-4700. From $8 (100-up); stock.

A CMOS multiplying d/a conveter, the AD7531, has 12-bit resolution and 8, 9, or 10-bit linearity. The unit operates from a single, 5-to-15-V supply and dissipates only 20 mW, including the ladder network. The differential-nonlinearity tempco of 2 ppm of FSR/°C, maximum, and gain-error tempco of 10 ppm of FSR/°C, maximum, provide excellent stability over the 0-to-75-C operating range. The output-current settling time of the unit is 500 ns to 0.05%, worst case. The AD7531 is housed in either a plastic or ceramic 18-pin DIP.

CIRCLE NO. 344

DVM on a chip delivers multiplexed BCD outputs

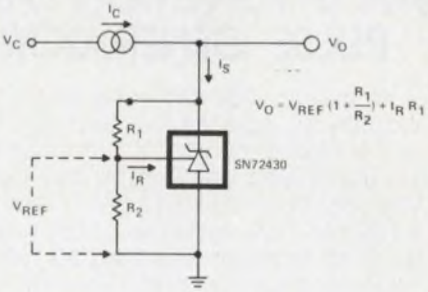


Integrated Photomatrix Inc., 1101 Bristol Rd., Mountainside, NJ 07092. (201) 233-7700. $16 (100-up); stock.

The MC904 DVM IC can drastically reduce the number of components needed to build a meter. It contains both analog and digital functions on a single MOS chip. The IC contains automatic clamping for a stable zero point, has a cycle time of 100 ms for a full count and 300 ms per conversion, and input ranges from ±199.9 mV to ±199.9 V. The circuit delivers a multiplexed BCD signal so that the user can optimize the display driver.

CIRCLE NO. 345

Two resistors program shunt regulator



Texas Instruments, P.O. Box 5012, MS/84, Dallas, TX 75222. (214) 238-3527. See text; stock.

The SN72430, a three-terminal shunt regulator, can be set to any output voltage between 3 and 30 V with two resistors. The programmable regulator is temperature compensated and can handle shunt currents of 100 mA, maximum. It can work with input currents as low as 500 μA and its temperature coefficient is ±50 ppm/°C. The SN72430 is available in a TO-92 plastic package and costs $0.73 in 100-piece lots, or in eight-pin ceramic DIPs at $1.81 in the same quantities.

CIRCLE NO. 346

Low cost, high performance 3A SPDT relay really saves PC board space

Mounts on .69" centers... satisfies thousands of application needs

Where size and space are important, the Series 27 relay can be just the low cost answer you've been looking for. It provides 3 amps of switching in a 0.526" cube and mounts on .69" centers, assuring high density PC board mounting. The cost is $1.05 each in 1,000 piece lots for 3, 6 and 12V dc units ...slightly higher for 24V dc.

You'll find the Series 27 relay suitable for hundreds of control applications. For instance: timing controls; gas pilot light controls; anti-theft devices for CB radios; automotive controls; emergency lighting equipment; and medical equipment, to name a few.

The relay has a 450 mW pick-up sensitivity (180 mW available). Contact rating is 3A res @ 28V dc. 120V ac. Contact resistance is 0.10 ohm.

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CIRCLE NUMBER 75

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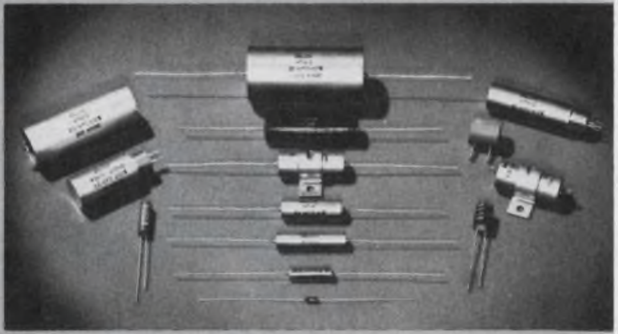

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DF at 25°C and 1 kHz (%)	0.05	0.1
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Dielectric Absorption (%)	<0.05	<0.05
IR (Ohms)	$>1 \times 10^{12}$	$>1 \times 10^{11}$

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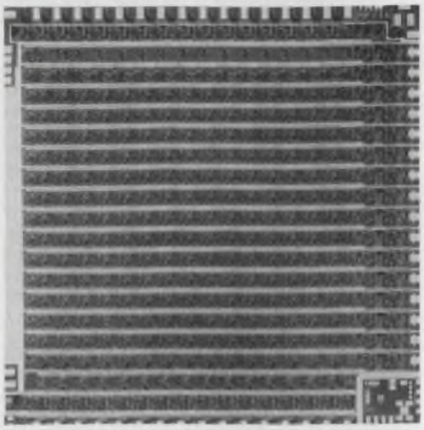
CIRCLE NUMBER 77

Multiply 16-bit numbers in 300 ns



TRW, One Space Park, Redondo Beach, CA 90278. (213) 536-1500. $250; end of year.

A single-chip 16-bit bipolar multiplier can generate a 32-bit data word every 300 ns. Inputs and outputs are fully TTL compatible, and the outputs have three-state control. A single 5-V power supply is used. Emitter-follower logic (EFL) is employed internally. Total power consumption is 5.1 W. The multiplier comes in a 64-pin hermetic flat package and operates over a case temperature range from −40 to +100 C.

INQUIRE DIRECT

See the Microprocessor Design section for microprocessors and related products.

Telephone-tone encoder uses simple keyboard

Intersil, 10900 N. Tantau Ave., Cupertino, CA 95014. (408) 996-5000. $4.10 (100-up); stock.

The ICM7206, 2 of 8 sine-wave tone encoder, delivers dual-tone signals and uses a single-contact-per-key keyboard. The circuit uses a 3.579545-MHz crystal as the base frequency and can operate from 3-to-6-V supplies. Tone drive levels are approximately −3 dBV into a 900-Ω termination. Skew between high and low tone groups is typically 2.5 dB without low-pass filtering. The circuit is housed in a 16-pin DIP.

CIRCLE NO. 348

Mini-on-a-board rivals speed of other μCs

Hewlett-Packard, 1501 Page Mill Rd., Palo Alto, CA 94304. (415) 493-1501. $1475; 2 wks.

The Model 2108K processor board runs as much as five times faster than LSI based microcomputers, according to the company. The board is identical to the one inside the HP 21MX series of minicomputers, and will execute 210 microinstructions. Connecting an optional ROM board ($350 in single qty.) to the 2108K enables the full instruction set of the 21MX to be emulated. Additionally, user generated programs may be stored in ROM and unique instruction sets may be generated. Because of its high speed the 2108K can control complex functions, such as handle array processing or be incorporated into a distributed computing network. The unit adds two 16-bit numbers in its internal registers in one 325-ns machine cycle.

CIRCLE NO. 349

Three low-cost desk calculators print

Unitrex of America, Inc., 689 Fifth Ave., New York, NY 10022. (212) 688-3400. 10PPM: $99.95; 12PPMR: $129.95; 14PPMD: $179.95.

Three desktop printing calculators, Models 10PPM, 12PPMR and 14PPMD, feature an impact printing head. All three units measure 9-1/2 × 11-1/4 × 3-1/2 in. and weigh 6 lb each. Other common characteristics include the ability to do chain or mixed calculations, reciprocal calculation, squaring and raising numbers to a power. In addition, they also share four addressable memory registers, an item count key, two-color ribbon, automatic percentage keys and a buffered keyboard. Model 10PPM has a 10-digit capacity and a non-add key. Model 12PPMR has 12-digit capacity, and an automatic square-root key. The combination printer, with display, Model 14PPMD, features 12-digit capacity, separate zero and triple zero keys and a selectable decimal point.

CIRCLE NO. 350

Digital data processor calculates equations

Aiken Industries, California Instruments Div., 5150 Convoy St., San Diego, CA 92111. (714) 279-8620. $1500; 30-60 days.

Called the CP70A, this unit accepts digital data from up to three separate sources and operates on this data according to equations stored in a plug-in EPROM. Each equation may include data derived from any one or all of the external sources as well as one or more constants stored in RAM. Front panel thumbwheel switches allow the user to select either from a standard or optional series of equations. The value of the constants may be changed via a front panel keyboard. Results of calculations are displayed on an 8-digit display containing both polarity and decimal. The readout may also show the value of constants programmed from the keyboard. The basic CP70A comes with up to eight standard equations, including such functions as addition, subtraction, multiplication, ratios, deviations.

CIRCLE NO. 351

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Rose Enclosures, made specifically for electronic use, culminate years of design, engineering and production experience. Extra high quality, precision-finished units provide functional protection, easy access, excellent esthetics. Available materials: Lexan, Aluminum, Polyester and ABS. Clear plastic covers with Lexan and ABS. A competitively-priced stock of Rose Enclosures is maintained in Belding, Mich. for immediate shipment. Contact us at (616) 794-0700.

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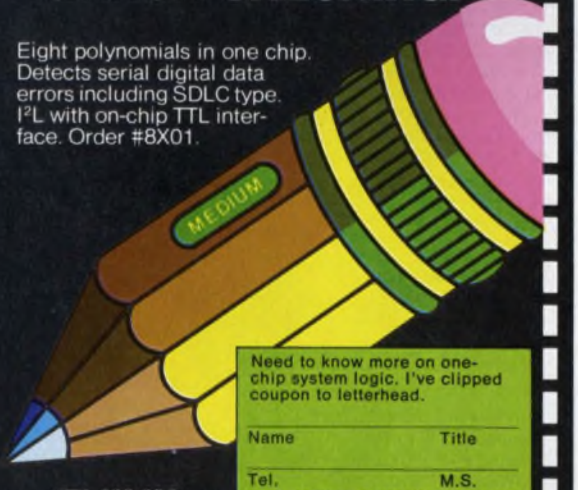
CIRCLE NUMBER 78

ONE-CHIP SYSTEM LOGIC #3

NEW CRC GENERATOR/CHECKER. ONE-CHIP ERROR-CHECKING.

Eight polynomials in one chip. Detects serial digital data errors including SDLC type. I²L with on-chip TTL interface. Order #8X01.



Need to know more on one-chip system logic. I've clipped coupon to letterhead.

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811 E. ARQUES, SUNNYVALE, CA. 94086

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CIRCLE NUMBER 79

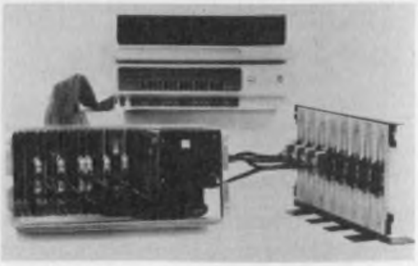
More disk storage available for System/3

IBM, General Systems Division, P.O. Box 2150, Atlanta, GA 30301. (404) 256-6797. $7845, $310 per mo; March, 1977.

The 5448 disk storage drive can be installed on IBM's System/3, Models 8 and 10. Added to an existing system already using the 5444 disk storage drive, this 9.8 Mbyte disk drive will provide total System-3 capacities of 14.7, 17.15 or 19.6 Mbyte. The 5448 has four fixed disks with eight recording surfaces. Access times average 126 ms at 1,500 rev/min. The 5448 transfers data at an effective rate of 199,000 bytes/s.

CIRCLE NO. 358

Sensor I/O subsystem controlled by computer



Data General, Southboro, MA 01772. (617) 485-9100. $5200; 64 lines.

An I/O subsystem called DG/DAC ties Data General computers to a wide variety of sensors, laboratory apparatus instruments and industrial control devices. The DG/DAC includes a wide selection of analog and digital I/O function modules, circuitry for dual computer configurations and an optional line controller. Modular design simplifies installation and subsequent alterations. Software support for the DG/DAC subsystem is provided by Data General's real-time operating systems. Thirteen types of printed-circuit I/O control cards handle a wide variety of analog and digital signals. Included in the selection is a series of high-speed analog-to-digital converters for accurate low-level analog inputs. Any combination of analog and digital signal lines can be mixed in the same subsystem chassis. Software support for the subsystem is provided by a library of device handlers and subroutines that control I/O transfers between user programs and sensor hardware or instrumentation.

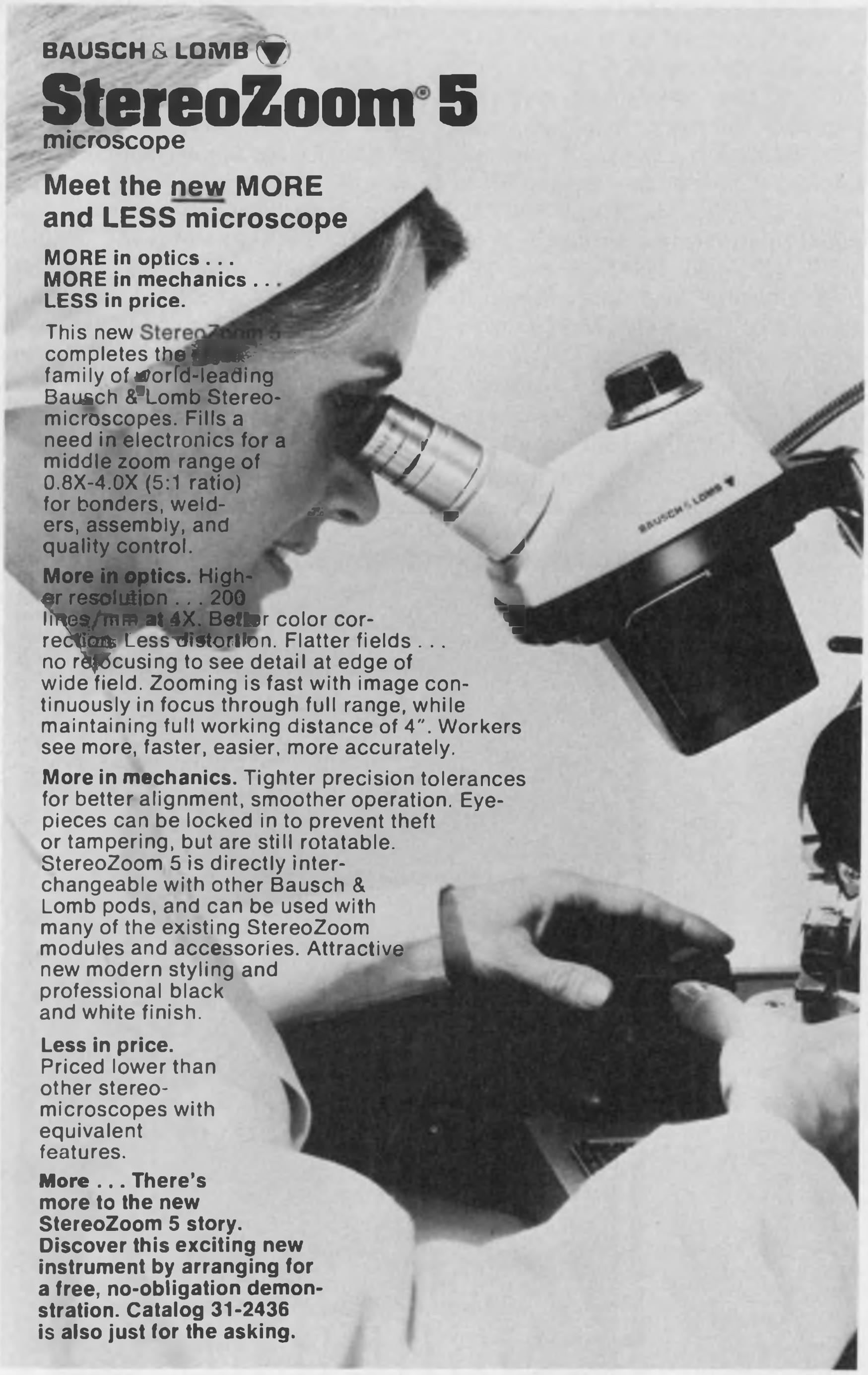
CIRCLE NO. 359

Plotter Controller connects to IBM's 5100

Houston Instrument, One Houston Sq., Austin, TX 78753. (512) 837-2820.

The Complot PTC-5 plotter controller allows the IBM 5100 portable computer to generate plots. The PTC-5 interfaces to the firm's DP-1, DP-3 or DP-7 digital plotters. A complete graphics system from IBM supports the PTC-5 with software similar to that used on IBM 370 computers.

CIRCLE NO. 360



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In Canada: Bausch & Lomb, Scientific Optical Products Division, 2001 Leslie St., Don Mills, Ont. M3B 2M3

CIRCLE NUMBER 81

200-MHz linear amp generates 200 W

Amplifier Research, 16 School House Rd., Souderton, PA 18964. (215) 723-8181. $7400; 45 days.

Model 200L broadband amplifier delivers 200 W of cw power at less than 1.0 dB-gain compression, from 1 to 200 MHz. A minimum 300 W of pulsed power is available at a 50% duty cycle with up to 500 W available at a 10% duty cycle. No special signal sources are required. The Model 200L can be driven to full output by any standard sweep generator or signal source capable of providing a 1-mW signal. An input attenuator allows the operator to vary the power output through a continuously adjustable 20-dB range. Flatness is ±1.5 dB over the entire frequency range. Harmonic distortion at 300 W is not less than 12 dB down for frequencies below 110 MHz and 25 dB down for frequencies above 110 MHz.

CIRCLE NO. 361

Antenna-position differences displayed

Trak Systems, 4722 Eisenhower Blvd., Tampa, FL 33614. (813) 884-1411. $3975; 120 days.

Model 6500-3 difference display provides visual indication of the differences between true position and designated antenna positions. Two pointers display azimuth and elevation differences from zero to ±10°. Also, correction of the angular error is enhanced; an on-target indicator displays the status of an on-target input line to alert the operator of any antenna-position error. The Model 6500-3 uses plug-in digital and analog circuits and nearly all of the intraconnections are wire-wrapped. A self-contained power supply system has overvoltage protection, short-circuit protection, and RFI line filtering.

CIRCLE NO. 362

Coax attenuators meet MIL spec

Weinschel Engineering, Gaithersburg, MD 20760. (301) 948-3434. $17 to $25; stock to 60 days.

The Model HF and L series of film-resistor coaxial attenuators achieve rated specifications under conditions defined by MIL-A-3933. The Model L units operate at dc to 2 GHz and are available with Type N, BNC, or TNC connectors (one male and one female). The Model HF attenuator operates at 2 to 10 GHz and is available only with Type N connectors. The Model L features attenuation values of 1 to 20 dB with maximum deviations of ±0.2 dB to 0.5 GHz, ±0.5 dB to 1.0 GHz, and ±0.75 dB to 2.0 GHz. Maximum VSWR is 1.20 with Type N connectors, and 1.25 with BNC and TNC connectors. Power rating is 1 W average. The Model HF attenuators are available in values of 3 to 20 dB with maximum deviations of ±10%. Maximum VSWR is 1.35 to 1.4, and power is rated as 5 W average. All units operate over the −20-to-70-C temperature range.

CIRCLE NO. 363

NOW–A FAIL-SAFE SOLID-STATE RELAY

A unique combination of dv/dt snubber, fusible-link protection, and an overdesigned triac makes the new optically-coupled Heinemann SSRs fail-safe. Now, the worst thing that can happen to your system in the event of relay failure is the simple need to replace the relay. That's a lot better than having to reprogram your entire control sequence, isn't it?

We make our new SSRs for either zero-voltage or non-zero-voltage switching, and both types are rated for maximum ac load currents of 5A or 10A. Any control voltage from 3Vdc to 32Vdc; all models compatible with TTL, DTL, and CMOS logic.

And you have a choice of solder-pin, quick-on, and screw terminals.

Talk with Bob Kusek (609-882-4800) or write for further information. Heinemann Electric Company, Brunswick Pike, Trenton, NJ 08602.

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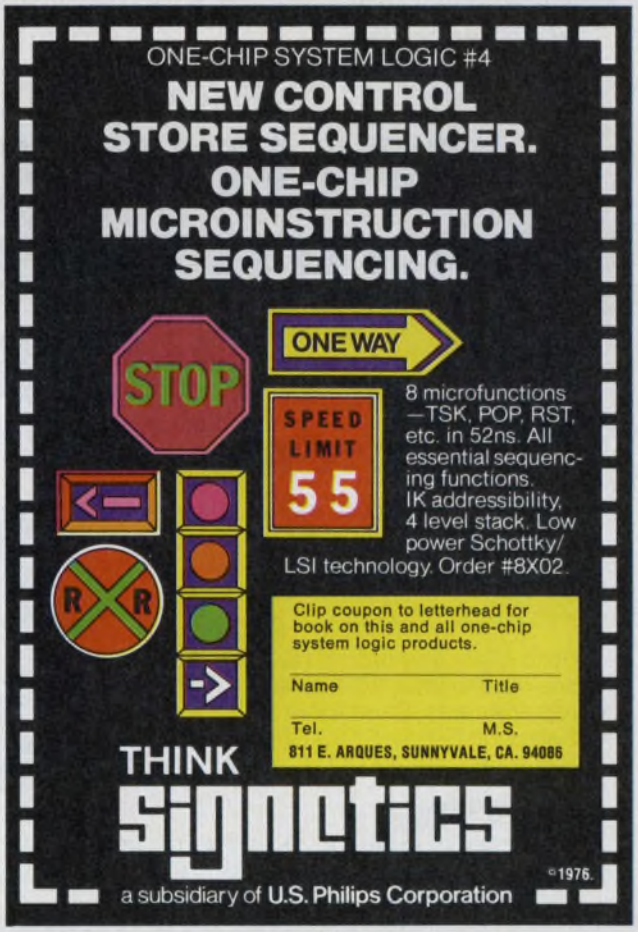
CIRCLE NUMBER 82



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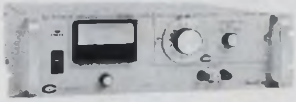
CIRCLE NUMBER 84

GENERATE
CORRECT AND CONTROL
AMPLITUDE
FREQUENCY



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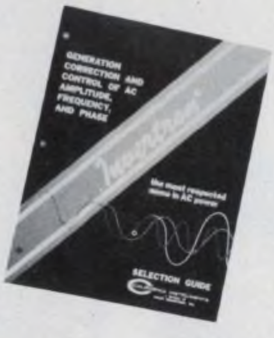

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See EEM Pages
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CIRCLE NUMBER 85

Attenuators are remotely programmable

Kay Elemetrics, 12 Maple Ave., Pine Brook, NJ 07058. (201) 227-2000. $250; 2-4 wks.

Two models of controlled, continuously variable and programmable attenuators are suitable for remote operation and have no moving parts. Model 2000 and 2100 can be used as an rf switch with high turnoff ratio or as control elements in a leveler to produce flat output for signal sources. Specs include a frequency range of 2 to 500 MHz, attenuation range of 0 to above 76 dB and insertion loss of 6 dB max.

CIRCLE NO. 364

Interference filters speed measurements

Melles Griot, 3006 Enterprise St., Costa Mesa, CA 92626. (714) 556-8200. $450 to $795 per set; stock.

Interference-filter sets allow rapid measurement of spectral irradiance distribution and spectral response. Each filter comes with its spectrophotometer curve. Ten different filter sets consist of 7-to-13 elements each. Seven are equally spaced bandpass and variable bandpass sets. Bandpasses of 10, 40 and 80 nm are available in the visible spectrum. Also, three color-process sets may be used in television, photography, printing and for inspection.

CIRCLE NO. 365

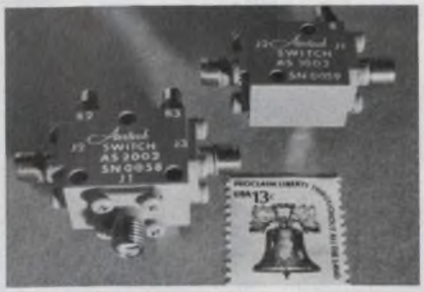
Amp modules handle 800 mW

TRW RF Semiconductors, 14520 Aviation Blvd., Lawndale, CA 90260. (213) 678-4561. $35 to $55.

Hybrid amplifier modules for general-purpose use feature rise times of 5 to 10 ns and have power ratings to 800 mW. Three lines are available: CA 2800, for 10 to 400 MHz with 17-dB gain; CA 2810, for 10 to 350 MHz with 33-dB gain; and CA 2818, for 5 to 150 MHz and 18-dB gain. The new amplifiers use thin-film techniques.

CIRCLE NO. 366

Miniature PIN switches operate in 15 ns



Aertech Industries, 825 Stewart Dr., Sunnyvale, CA 94086. (408) 732-0880. AS1002, $135; AS2002, $240; 30-45 days.

PIN diode switches offer 15-ns switching speed over the complete 2-to-18-GHz frequency range. Model AS2002 single pole, double throw provides 2.7-dB maximum insertion loss with 55-dB minimum iolation at 18 GHz. It occupies only 1/3 in^3. Model AS1002 single pole, single throw provides 2.0-dB maximum insertion loss and 45-dB minimum isolation at 18 GHz. It occupies only 1/4 in^3.

CIRCLE NO. 367

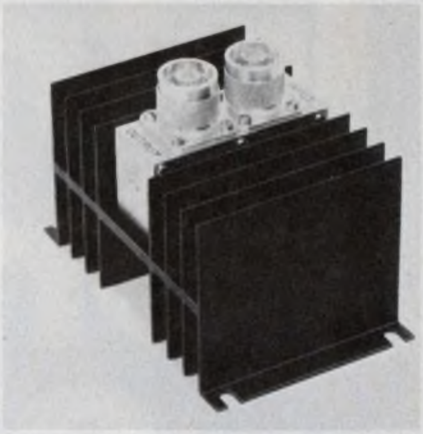
Uhf bandpass filter has 1.5% BW

Frequency Engineering Laboratories, Farmingdale, NJ 07727. (201) 938-9221. $1245 (5-9); 6 wks.

A two-channel uhf bandpass filter for space or airborne environments uses WR51-size equivalents in each of the five-pole sections of the filter. The result is a flat 1.5% bandwidth at 560 MHz, maximum insertion loss of 4.0 dB, and VSWR of 1.3 max. Rejection bandwidth is 25 MHz at −30 dB, with the first spurious response occurring above 20 GHz. The 1-lb. unit has been assigned P/N 10EE185900. Other units having bandwidths as great as 40%, with up to 15 sections, and covering ranges from low rf to X-band, are included in this evanescent-mode filter series.

CIRCLE NO. 368

Coax attenuator handles 5 kW peak



Sage Laboratories, 3 Huron Dr., Natick, MA 01760. (617) 653-0844. $150; 45 days.

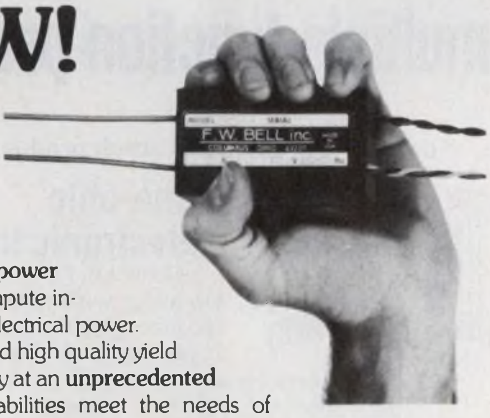
FA2015 coaxial attenuator covers dc to 2 GHz and features small size and high power handling capability. Attenuation is 10 ±0.5 dB, and is flat within ±0.1 dB. Power handling capability is 5 kW peak and 50 W average. VSWR is 1.2:1 max. Model FA2015 measures only 2-5/8 × 1-1/4 × 1 in., excluding the connectors.

CIRCLE NO. 369

New Transducer modules

measure electric power

NEW!



These **new power transducers** compute instantaneous ac electrical power. Simple design and high quality yield excellent reliability at an **unprecedented price.** New capabilities meet the needs of hundreds of previously difficult or uneconomical applications. These include, ±0.50% accuracy, **50 Hz to 10 kHz** frequency range, one and three phase operation, accurate operation with non-sinusoidal waveforms, better than ±0.25% power factor influence and a 100μs response time.

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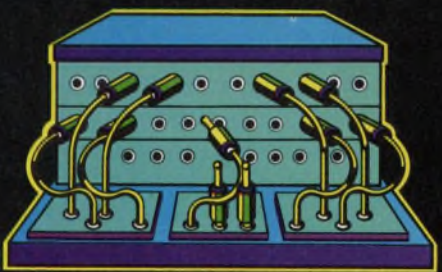
CIRCLE NUMBER 86

ONE-CHIP SYSTEM LOGIC #5

NEW
8-BIT INTERPRETER.
ONE-CHIP
CONTROLLER.



Finally, bipolar fixed instruction microcontroller on a single chip. Eliminates up to 150 SSI and MSI packages. Advanced Schottky LSI technology. 250 nanoseconds instruction cycle time. 8 powerful instructions. Order #8X300.

Coupon attached to my letterhead for *One-Chip System Logic* book.

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CIRCLE NUMBER 87

Introducing One-Chip System Logic.

You get one-chip solutions to multiple-function problems!

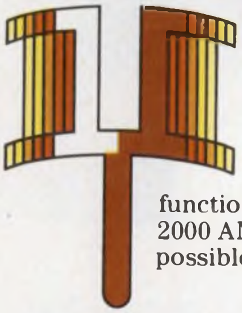
Until now, when you wanted high-performance, you had to pay the high price. When you wanted low price, your performance options were limited.

That's exactly why Signetics has developed its line of "One-Chip System Logic" LSI products. To give you the best of both worlds. You get multiple functions on one chip. Great to build your own designs around. Great to upgrade from TTL and Schottky SSI and MSI. Great to save you time, hassle, board space, and reduce associated logic for overall lower systems cost.

"One-Chip System Logic" incorporated high-performance I²L and LS technologies and interfaces with TTL. The key is Signetics ¼ inch die capability which allows design and production of sophisticated LS building blocks.

System logic is one of the many LSI product families offered by Signetics including the MOS 2650 and bipolar 3000 series microprocessor.

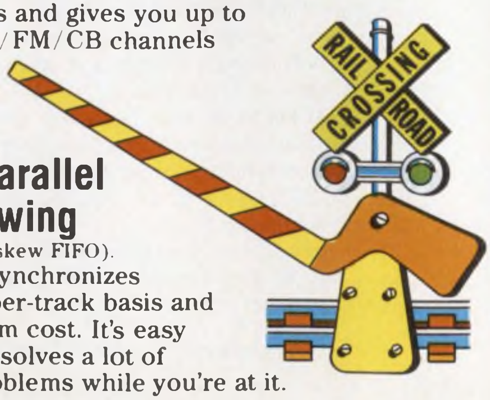
Now, here are Signetics stock products



① One-chip electronic tuning

(#8X08 AM/FM Frequency Synthesizer).

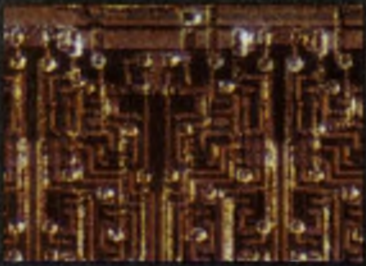
Do away with mechanical tuning and frequency generation forever. It performs all digital control functions and gives you up to 2000 AM/FM/CB channels possible.



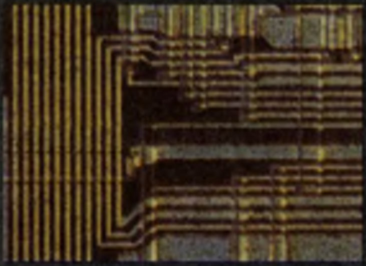
② One-chip parallel data deskewing

(#8X03 & 8X04 Deskew FIFO).

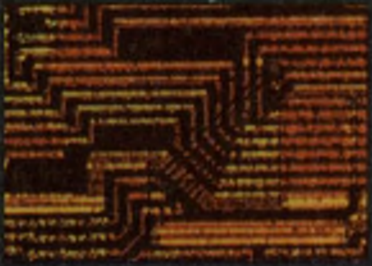
Now, one chip synchronizes parallel data on a per-track basis and offers lowest system cost. It's easy to design with and solves a lot of multiple circuit problems while you're at it.



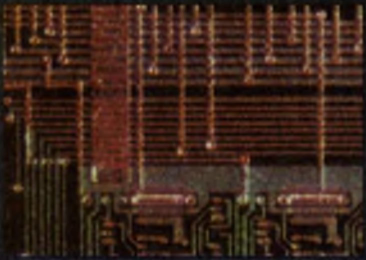
1. New AM/FM Frequency Synthesizer. 8X08



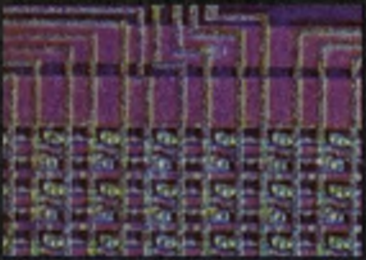
2. New Deskew FIFO. 8X03/04



3. New CRC Generator/Checker. 8X01



4. New Control Store Sequencer. 8X02



5. New 8 Bit Interpreter. 8X300

6. Your 1977 Solutions.

The only logical way to improve performance and save on systems cost.

③ One-chip error-checking

(#8X01 CRC Generator/Checker).

Eight polynomials for error detection of serial digital data. Detects SDLC type remainder. Easy-to-work with at an easier-to-live-with lower systems cost.

④ One-chip microinstruction sequencing

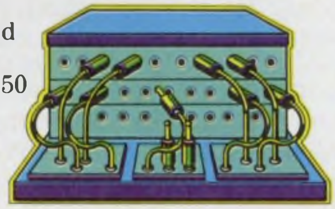
(#8X02 Control Store Sequencer).

You get 8 functions — everything you need for most efficient microprogramming. With low power Schottky LSI technology, 28 pin DIP with 1024 word addressability, and more.

⑤ One-chip central controlling

(#8X300 8 Bit Interpreter)

Control oriented bipolar fixed instruction microprocessor on one LSI chip. Eliminates up to 150 discrete SSI/MSI chips. You get easy programming and fast processing — 250ns instruction cycle time.



⑥ One-chip to solve your future needs.

Signetics has written a whole book detailing all of the instock standard products with a future products preview of "One-Chip System Logic." It shows you how Signetics is more responsive to your exact mixture of requirements. It includes a function/requirement questionnaire: tell us what you want us to develop as standard product in the system logic family for your next application. Read the book and send us the card.

Attach this to your letterhead for fast response.

- ☐ Send me the whole book titled "One-Chip System Logic — Multiple Functions on One-Chip Now and in the Future."
- ☐ I have lots of questions. Please call me.
- ☐ Have a Field Applications Engineer make an appointment soon.

My application is ____________

Name ____________ Title ____________

Telephone ____________ Mail Stop ____________

THINK Signetics

811 E. Arques Ave., Sunnyvale, Ca. 94086

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CIRCLE NUMBER 88

Lab power supply adjusts itself for constant power

Hewlett-Packard, 1501 Page Mill Rd., Palo Alto, CA 94304. (415) 493-1501. See text.

Sandwiched between the constant-current and constant-voltage modes in Hewlett-Packard's new laboratory power supply is another, more unusual mode—one that can be termed constant wattage or power.

HP calls the Model 6002A an extended-range supply, however, rather than a constant-power unit, because the 6002 delivers a full 200 W over a 20 to 50-V output.

The output voltage is continuously adjustable from zero, and the maximum current is automatically controlled to stay within the power boundary. Or you can turn up the output current, from zero to 10 A, and the supply adjusts the voltage level accordingly.

If you'd like your calculator, computer or other controller to do the adjusting digitally, an option makes the HP 6002 one of the first supplies to offer the new standard interface bus (variously called the HP-IB, IEEE-488, ANSI MC1.1, universal bus or interface).

Switches included with the bus option allow either HP-IB or local front-panel control of voltage or current. When you operate the supply below 10 V, a programmable range improves resolution by a factor of ten.

Perhaps the only other supply on the market that offers an "extended" range (using an entirely different method than the HP) is the Uniply "universal" power source, from Power Designs, Westbury, NY. The patented Uniply has been around for many years, apparently without competition in its operating principle.

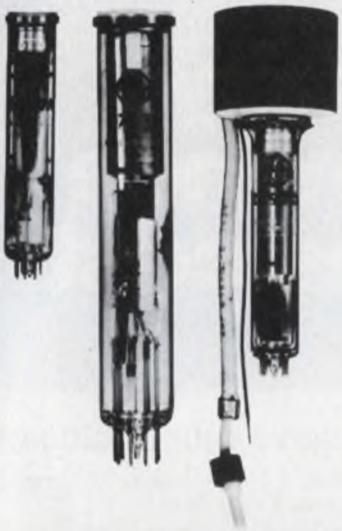
In operation, the Power Designs' source automatically ranges, or selects—from a number of internal unregulated sources, power transistors and control circuits—the combination that satisfies both the panel settings and the load demand, with minimum losses.

The highest-power unit in the Uniply series is the Model 6150, a $350 lab supply that can deliver 0 to 6 V at 15 A or 0 to 15 V at 7.5 A, and so on, to a top level of 60 V at 2 A.

Price of the HP 6002A—which also offers a number of other features, status indicators and protection capabilities—is $800. The HP-IB option costs another $350. Delivery is stock to 30 days.

For Hewlett-Packard **CIRCLE NO. 370**
For Power Designs **CIRCLE NO. 357**

LEADER IN IMAGING DEVICES



General Electric offers you a wide selection of high-quality imaging devices for a wide variety of surveillance, monitoring and display applications.

These GE imaging devices also offer:

- The right resolution and sensitivity for your specific needs!
- Prices lower than you normally expect!
- Ease of application combined with traditional GE expertise, quality and economy!
- Rugged construction!

For more detailed information, circle the Reader Service Card number below or contact: General Electric Company, Imaging Devices Operation (360-22), Room 301, Building 7, Electronics Park, Syracuse, N. Y. 13201 (phone 315-456-3300).

GENERAL ELECTRIC

CIRCLE NUMBER 90

They're gonna make you a star.

In just a very short while, we'll be giving static RAM users the same thing we've already given dynamic RAM users.

The fastest MOS device on the market.

Using the same super technology that gave you the world's first 150ns 4K dynamic RAM, we'll soon be giving you the μPD410 series of 4K static RAMs with speeds down to 100ns.

So right now you can start designing products where that kind of speed at that kind of density can really help make you a star.

For your present applications, we'll also have slower versions you'll want to use right away.

In addition to access times down to 100ns, our n-channel silicon gate 4K x 1 static RAMs will also feature cycle times down to 200ns, 12 μW/bit maximum standby power, three-state output, proven cross-coupled Flip-Flop storage cell structure to eliminate soft errors and the need for refresh circuitry.

And they'll be pin compatible with the industry standard 22-pin dynamic part.

The μPD410 series of 4K static RAMS.

For people into terminals, add-on memories, mainframes, and minis, it's quite a coming attraction.

NEC Microcomputers, Inc.,
Five Militia Drive, Lexington,
MA 02173. 617-862-6410.

NEC microcomputers, inc.

(Data sheets now at reps and distributors.)

REPS: East – C & D Sales 301-296-4306, Contact Sales 617-273-1520, Trionic Assoc. 516-466-2300; South – Merino Sales 214-233-6002, Perrott Assoc. 305-792-2211, 305-275-1132, 813-585-3327, Wolffs Sales Serv. 919-781-0164; Midwest – K-MAR Eng. & Sales 816-763-5385, McFadden Sales 614-221-3363, R.C. Nordstrom 313-559-7373, 616-429-8560, R.F. Specialists 312-698-2044; West – Mike Duffy Assoc. 303-934-7392, Electronic Component Marketing 714-524-9899, 714-295-6122, 213-340-1745, Summit Sales 602-994-4587, Trident Assoc. 408-734-5900, Tri-Tronix 505-265-8409, 206-454-0940; Canada – R.F.Q. Ltd. 416-626-1445, 514-626-8324 DISTRIBUTORS: Century Electronics, Diplomat (Chicopee Falls, Woodbury, Mount Laurel, Little Falls, Newport Beach, Clearwater, Dayton, Elk Grove Village, Farmington, Minneapolis, St. Louis, Salt Lake City, Sunnyvale), G.S. Marshall (Sunnyvale), Harvey Electronics (Lexington, Norwalk, Woodbury, Fairfield), Intermark (Santa Ana, San Diego, Sunnyvale, Seattle), Lionex Corporation, Mirco Electronics, R-M Electronics, Semiconductor Specialists, Technico.

Our 4K RAM
our 4K RAM.

is faster than

Our fast 4K RAM.

Model No.	Access Time	Read/Write Cycle Time	Read/Modify/Write Cycle Time
MM5270 (18-pin)	200 ns	400 ns	580 ns
MM5271* (18-pin)	250 ns	400 ns	560 ns
MM5280 (22-pin)	200 ns	400 ns	520 ns
MM5281* (22-pin)	250 ns	400 ns	510 ns

*Chip enable is TTL compatible.

Our faster 4K RAM.

Model No.	Access Time	Read/Write Cycle Time	Read/Modify/Write Cycle Time
MM5270A (18-pin)	150 ns	300 ns	400 ns
MM5271A* (18-pin)	200 ns	300 ns	400 ns
MM5280A (22-pin)	150 ns	300 ns	370 ns
MM5281A* (22-pin)	200 ns	300 ns	370 ns

*Chip enable is TTL compatible.

ED719

National Semiconductor Corporation,
2900 Semiconductor Drive, Santa Clara, CA 95051

Gentlemen:
Kindly rush data sheets on your fast, and faster, 4K RAMs.

Name____________________Title__________

Company______________________________

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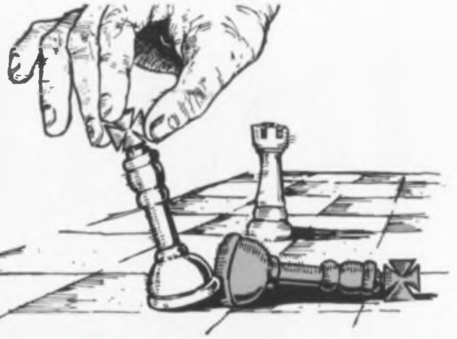
switch cost?

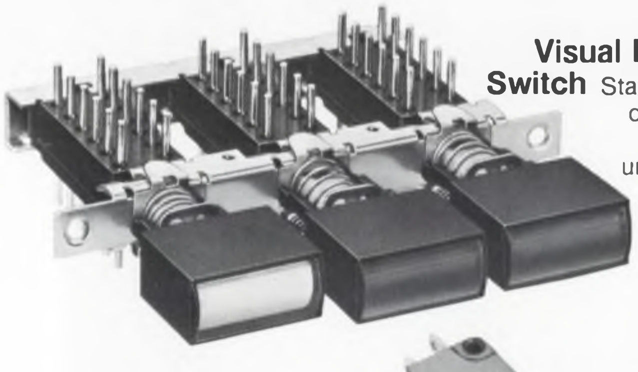


Check These Centralab Distributors For Three New Ways To Cut Switch Costs

The three new Centralab Pushbutton Switch products shown below are now available from Centralab Pushbutton Switch Distributors. They're low-cost money savers, and yet they offer the same high-quality features of all Centralab switches.

You can get these new products, custom assembled to your specifications, from our factory trained Distributor Switch Specialists.

Contact your Centralab Distributor, listed at the right, for complete details. Ask for a copy of Centralab's New Pushbutton Switch Catalog, Series No. 301.



Visual Display in a Non-Lighted Switch

Status indicator button adds visual display to non-lighted Centralab switches. The button, with a unique fluorescent display, uses reflected ambient light to indicate switch status. 6 display colors. Black or chrome plated buttons. 140° peripheral viewing angle.

5-amp Pushbutton Line Switch

UL listed for TV-5 rating: 120V, 5A, 78A peak inrush current. Accepts all Centralab button options.

Low-cost Lighted Pushbutton Switch

T-1¾, wedge base lamp brings cost down. New options increase harmonized panel aesthetics. Flat or recessed lenses. 8 lens colors. 15mm or 20mm spacing. Switch assemblies to 13 stations.

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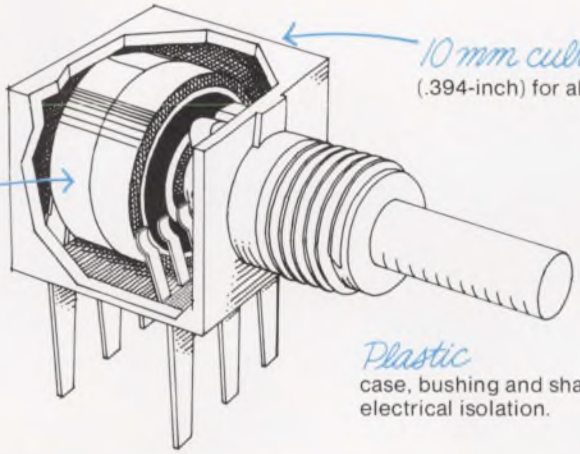
ISOSTAT LICENSED

CIRCLE NUMBER 151

The one variable the world can standardize on.

Our new Type M conductive plastic variable resistor is hard metric. A 10 mm cube that's tiny, flexible and rugged. The MINI-METRIC is the smallest dual pot available today. Manufactured in the United States, it's dimensioned the way the rest of the world thinks. Allen-Bradley has what you need; or, it can be ordered through our distributors. Ask for Publication 5239.

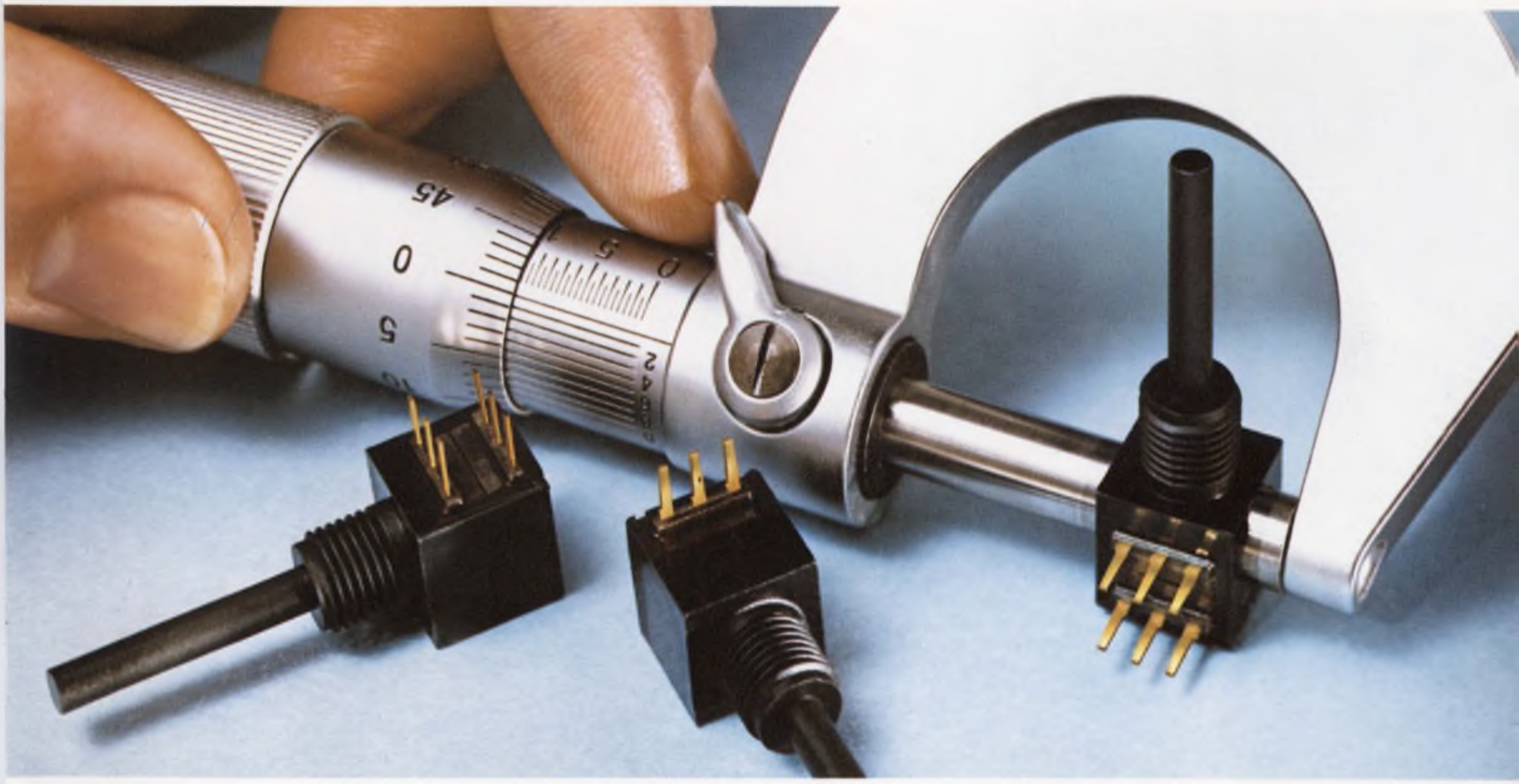


Choices
single or dual pot or pot/switch combinations

10 mm cube
(.394-inch) for all combinations.

100 ohms to 1 megohm
conductive plastic resistance elements, ±20% tolerance, standard resistance values conform to IEC.

Plastic
case, bushing and shaft for electrical isolation.



Quality in the best tradition.

ALLEN-BRADLEY
Milwaukee, Wisconsin 53204

EC131

CIRCLE NUMBER 152

Welcome to the family, little fella

Omron. 43 years old, and still building a family of relays, switches, and timers for every need.

Mind you, the control component *you* need may not be in the photograph. That's because this picture shows less than 5 percent of the components in our line. But it's more than likely that the "unique" device you're looking for is one which we've been making for a long time, and which we carry in stock.

Omron hasn't achieved a position of international leadership by sitting still. Since we began making control components in 1933, we've been carving out a reputation for excellence in engineering, manufacturing, and—above all—in serving you, the Omron customer. We're still adding new products all the

time, and we're providing faster delivery than ever thanks to our expanded distributor network.

To find out what Omron can do for you, contact your nearest Omron distributor or call us at (312) 885-9500. We think you'll want to welcome us as your components supplier... because no matter what little fella you're looking for, we can probably help you give him a home.

OMRON
a world leader in electronics since 1933

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CIRCLE NUMBER 153

New from Centralab…

CERBON™ TRIMMER RESISTORS

Affordable Stability… 300% More Stable Than Carbon… at a Carbon Trimmer Price!

Why pay more? With Centralab's new *CERBON* trimmers you get stability approaching cermet and at carbon prices …As little as 28¢ in distributor 1,000 quantities; as low as 10¢ in high volume orders.

The secret of *CERBON* superior performance? A totally new thick film resistor element, which combines both potentiometer and conventional thick film technologies, *plus* a heat stable ceramic substrate, *plus* a dual-tine contact spring, *plus* "Fluxgard" protection from dust and wave soldering contaminants. In short, a totally balanced electromechanical system.

Look at these benefits:
• TCR less than −400 ppm/°C. • CRV less than 2% of maximum resistance. • Rotational life exceeds 500 cycles. • Adjustability (typical)—0.05% of total voltage. • High overload capability—1 watt at 25°C ambient for 1,000 hours exhibits less than 2% cumulative resistance change. • Maximum stability in humid environment—Resistors exposed to an atmosphere of 40°C at 95% relative humidity for 300 hours return within four hours to +2.5% of their initial readings.

CERBON trimmers are offered in a resistance range of 1 K ohm to 1 megohm with a choice of standard PC terminal configurations. They fit universally accepted circuit board mounting patterns. And they're ready now for fast delivery in any quantity.

Write for complete technical data on Centralab's new *CERBON* trimmer resistors. Or call (915) 779-3961 for a free evaluation sample. Move up to *CERBON* and save!

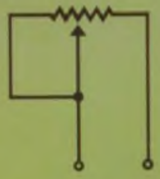
Knob colors available in white, blue, red and green for ease in assembly operations.

CENTRALAB
Electronics Division
GLOBE-UNION INC.
7158 MERCHANT AVENUE
EL PASO, TEXAS 79915

CIRCLE NUMBER 154

AVAILABLE CIRCUIT OPTIONS

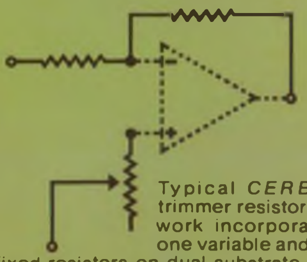
Thanks to their ceramic substrate, Centralab *CERBON* trimmers permit a variety of screen printed circuit options. Here are three typical circuits:



TERMINAL SHORTING

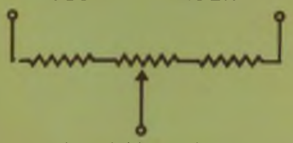
One of five electrical termination options available.

OPERATIONAL AMPLIFIER NETWORK



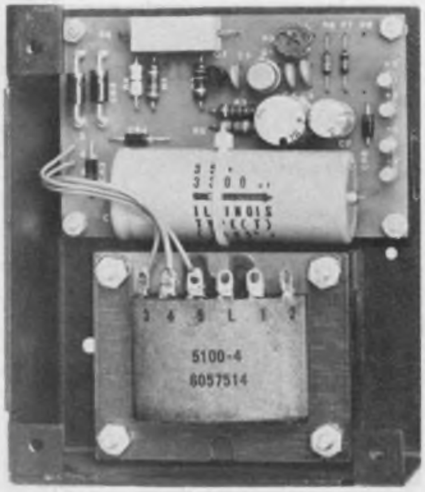
Typical *CERBON* trimmer resistor network incorporating one variable and two fixed resistors on dual substrate configuration.

VOLTAGE DIVIDER



Fixed and variable resistors can be ratio matched for precise values and to insure temperature tracking. Eliminates need for costly discrete resistor selection.

Modular supplies offer adjustable outputs



Century Electronics, 2688 S. La Cienega Blvd., Los Angeles, CA 90034. (213) 870-1083. Start at $23 (100); stock.

SA series is composed of 12 standard models of wide-range single-output modular dc power supplies. Designed with open-frame construction, the units are available in popular OEM voltages with up to 12-A load current. These standard units are offered in four continuously adjustable output voltage ranges for low, medium and high-current applications from 4.5 to 30 V dc. OVP and ac line fusing are optional. Specs include regulation of ±0.1% and output ripple of 0.01% rms typically.

CIRCLE NO. 371

Supplies "trained" for combat duty

ERA Transpac, 311 K East Park St., Dept. 1209, Moonachie, NJ 07074. (201) 641-3650. $385 to $890; stock-10 wks.

MS series are off-the-shelf MIL spec dc modular power supplies. Transformers are per MIL-T-27A, semiconductors are MIL-STD-701 or MIL-S-19500 preferred types. Tantalum foil capacitors per MIL-C-3965 are used throughout except in the filter sections of higher current types where MIL-C-62 military grade electrolytic capacitors are used. These units have been fully tested to meet the component, workmanship, and environmental requirements of MIL-E-4158, MIL-E-5400, MIL-E-16400, MIL-E-5272, MIL-T-21200.

CIRCLE NO. 372

CHECK DIGITAL IC'S FASTER THAN A SCOPE, SAFER THAN A VOLTMETER

You're looking at the most convenient and efficient way developed to check digital IC's: CSC's Logic Monitor. It speeds digital design and testing by accurately and automatically displaying static and dynamic logic states of DTL, TTL, HTL and CMOS DIP IC's. All in a compact, self-contained 16-pin circuit-powered unit.

Use it to effortlessly trace signals through counters, shift registers, gating networks, flip-flops, decoders . . . even entire systems made up of mixed logic families. It's a great way to cut minutes, even hours all along the line from design through debugging.

Nothing could be simpler: just clip it over any DIP IC up to 16 pins, and the Logic Monitor does the rest. Precision plastic guides and unique flexible web insure positive connections between non-corrosive nickel-silver contacts and IC leads. Each contact connects to a single "bit" detector with high-intensity LED readout, activated when the applied voltage exceeds a fixed 2V threshold. Logic "1" (high voltage) turns LED on; Logic "0" (low voltage or open circuit) keeps LED off. A power-seeking gate network automatically locates supply leads and feeds them to the Logic Monitor's internal circuitry.

Very clever. Very portable. Very effective. And very reasonable, at $84.95.* See the Logic Monitor at your CSC dealer, or write for our catalog and distributor list.

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*Manufacturer's suggested price. Prices and specifications subject to change without notice.

CIRCLE NUMBER 91

Dial-a-load makes testing easier

Transistor Devices, 85 Horsehill Rd., Cedar Knolls, NJ 07927. (201) 267-1900. $279; stock.

The DAL 50-15-100 electronic Dial-A-Load can handle 3 to 50 V at 0 to 15 A, with a maximum power rating of 100 W. Load current regulation is less than 0.05%/V, temperature coefficient is less than 0.03%/°C. Other maximums: line regulation 1%, ripple 0.1% rms. Overcurrent and overpower protection are standard. Turn-on time is approximately 20 ms and temperature rise is 35 C max.

CIRCLE NO. 373

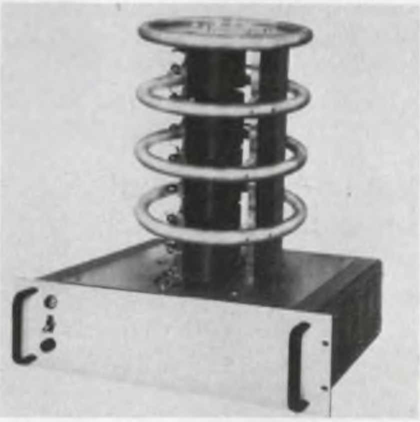
Switcher offers four outputs to 750 W

LH Research Inc., 1821 Langley Ave., Irvine, CA 92714. (714) 546-5279. $745; 4 wks.

A new switching regulated power supply offers up to four outputs totaling 750 W from a package that measures only 5.1 × 7 × 12.75 in. Primary output of the Model MM-440 is 5 V at 150 A. The second output can be any one of the following: 2 V at 12 A; 5 V at 12 A; 12 V at 10 A; 15 V at 10 A; 18 V at 8 A and 24 V at 5 A. Third and fourth voltage outputs can be one of a number of combinations.

CIRCLE NO. 374

HV supply adjusts continuously

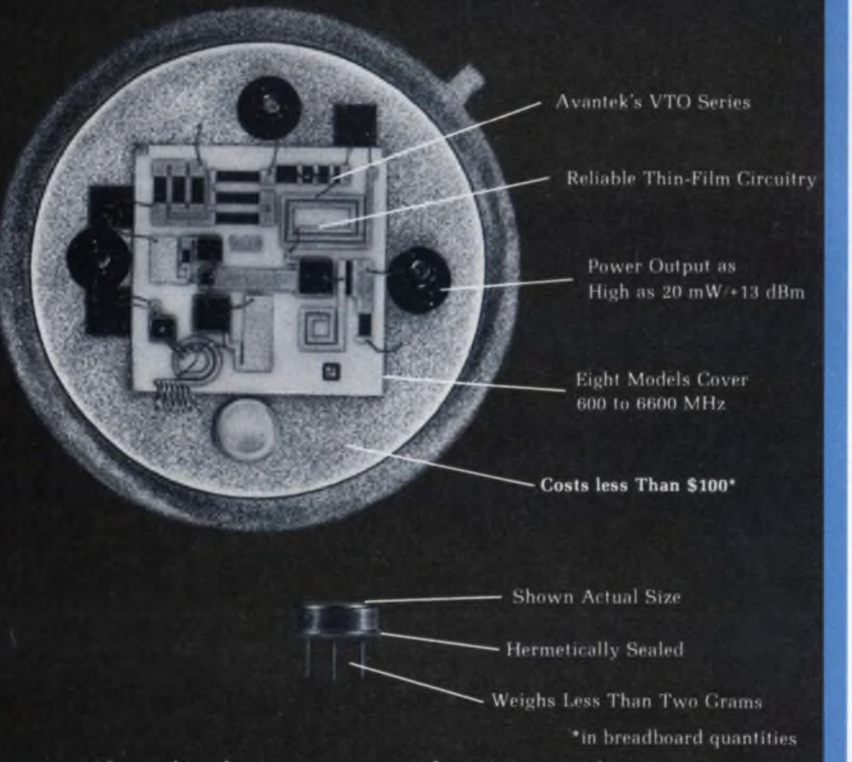


Spellman High-Voltage Electronics, 1930 Adee Ave., Bronx, NY 10469. (212) 671-0300. $7300; 8-12 wks.

Model UHR160P640 regulated dc power supply delivers a continuously adjustable output of 160 kV at 4 mA. The unit is fully protected from arc-over, short circuit and overload. Line regulation is 1% for a ±10% change in line voltage. Load regulation is 1% for a no-load to full-load variation. Ripple is 0.5% pk-pk. Input requirements are 208-V ac, 3 phase, 4 wire.

CIRCLE NO. 375

Anatomy of Value in a Voltage-Tuned Oscillator



If you're designing a synthesizer or other instrument, why worry about designing voltage-tuned oscillators? Avantek VTO's represent an outstanding value as a cost-effective alternative to in-house discrete designs. Contact Avantek for an applications brochure describing the VTO Series in detail.

Avantek
3175 Bowers Ave., Santa Clara CA 95051 Phone (408) 249-0700

CIRCLE NUMBER 92

High Efficiency

5-Volt, 10-AMP Power Supply

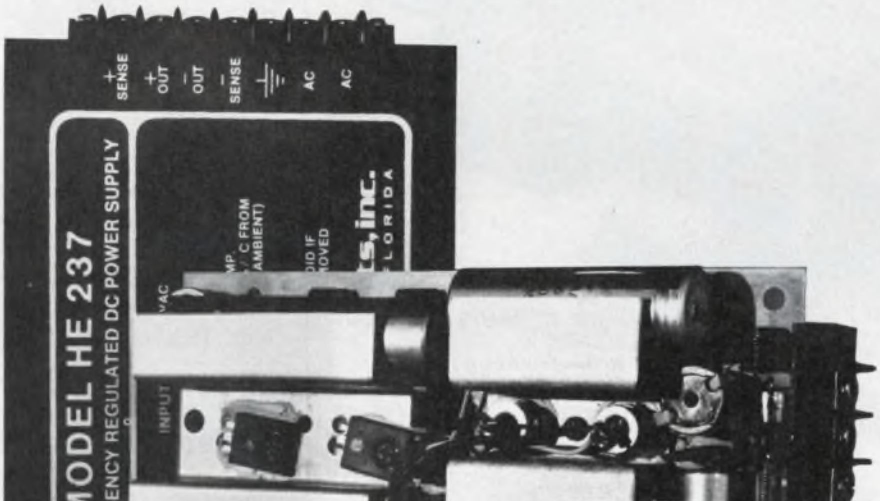
The Model HE237 Power Supply offers the design engineer, for the first time, a low cost, highly efficient alternative to the size, weight, and heat generation problems normally associated with series-pass regulated supplies. Using state-of-the-art switching techniques and CMOS logic, the HE237 achieves 75% efficiency, at a full load of 10 amps.

The HE237 has the "footprint" and mounting dimensions of the Lambda package size "B" supplies—a feature that allows the engineer to experiment with high efficiency techniques in existing designs. In new designs, the engineer can take advantage of the HE237's small size (6½" x 4½" x 1½") and light weight, (1.7 lbs).

The highly reliable HE237 Power Supply is short-circuit proof, contains over-voltage protection, and is backed by a full two year warranty.

Finally, the HE237 offers the design engineer considerable savings. It is available in both 115 and 230 VAC input models for just $195 . . . quantity, one.

Computer Products, inc.



1400 NW 70 Street, Fort Lauderdale, Florida 33309 • (305) 974-5500, TWX (510) 956-9895.

Distributors: Los Angeles 213-877-5518 / Albuquerque 505-255-2440

CIRCLE NUMBER 93

93

Tiny atomic oscillator boasts high stability

Efratom California, 3303 Harbor Blvd., Suite El, Costa Mesa, CA 92626. (714) 556-1620. $5340 (unit qty.); stock.

The FRK-HTO atomic oscillator operates from −54 to +65 C. Its 10-MHz sine-wave output maintains a longterm frequency stability of typically 1×10^{-11} per month and a short-term stability of better than 1×10^{-12} for 100 seconds averaging time. The FRK-HTO weighs 1.3 kilograms and measures 4 × 4 × 4.5 in. The unit's ruggedized design complies to MIL-STD-810C, procedure 1, for shock and vibration and MIL-T-5422F for 95% humidity operation.

CIRCLE NO. 376

You know our Capacitors, but have you seen our...

ALUMINUM FOIL TRANSFORMERS

If you're looking for an isolation or autotransformer with...

- Single or multiphase
- Reduced size and weight
- Higher temperature operation
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- Higher electrical efficiency, and better regulation

...then our aluminum foil transformer line could be your answer. Units are available in 50/60 Hz, 400 Hz and higher frequencies, in sealed, shell and open-frame versions, with ratings to 5000 VA and outputs through 500 volts. Or send us your requirements for a design and price proposal. Send for our transformer data sheet and technical bulletin today to Electrocube, 1710 So. Del Mar Ave., San Gabriel, CA 91776; (213) 573-3300.

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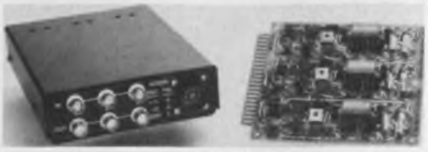
CIRCLE NUMBER 94

Triple low-pass filter available in four models



Fogg Systems Company, P.O. Box 22226, Denver, CO 80222. (303) 758-2979. See text.

The Model 126 programmable low-pass filter is three identical, unity-gain, differential-input filters. Each channel consists of an active two-pole Butterworth filter whose high-frequency 3-dB point is user programmed via a DIP switch on the 5.4 × 4.55 × 0.7 in. card. Four standard versions provide frequency ranges of 1 to 16 Hz, 10 to 160 Hz, 100 Hz to 1.6 kHz, and 500 Hz to 8 kHz. The high-frequency 3-dB point is easily set at any one of 16 frequencies within the range. Roll-off is 40 dB/decade for all units. Power supplies or batteries from ±2.7 to ±15 V dc can be used to power the Model 126. The full-scale input and output range is ±10 V with a ±15-V supply. The filter card costs $196 for the 10-to-160-Hz and 100-Hz-to-1.6-kHz models, $215 for the 500-Hz-to-8-kHz model and $225 for the 1-to-16-Hz version. Up to 17 cards can be packaged in a 7 × 19-in. card cage. Two metal enclosures are available. One provides BNC signal connectors and an MS power connector for $65. The other, priced at $20, provides a printed-circuit connector. Up to three of these enclosures can be mounted in a 1-3/4 × 19-in. panel slot. Delivery is 30 days.

CIRCLE NO. 377

Crystal oscillators span 1 Hz to 5 MHz

Accutronics, 628 North St., Geneva, IL 60134. (312) 232-2600. From $19.25; 6 wks.

The Series 162 crystal oscillator delivers a CMOS-compatible output an any fixed frequency from 1 Hz to 5 MHz. Typical operating current of the modular oscillator is less than 2 mA. Frequency stability of the output is ±0.001% over the standard 0-to 50-C operating range. Wider operating ranges are also available.

CIRCLE NO. 378

these two Panel Meters...
can become 93 different measuring instruments...

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Thermistor C or F	8 models
Offset and Scaled	4 models
Process Monitors	8 models

and the best part is...

You can change to any one of these models anytime. It is as simple as reprogramming the rear connector or adding one of DigiTec's exclusive adapters. Call or write for complete specifications.

These instruments are available under GSA Contract, GS-00S-27741.

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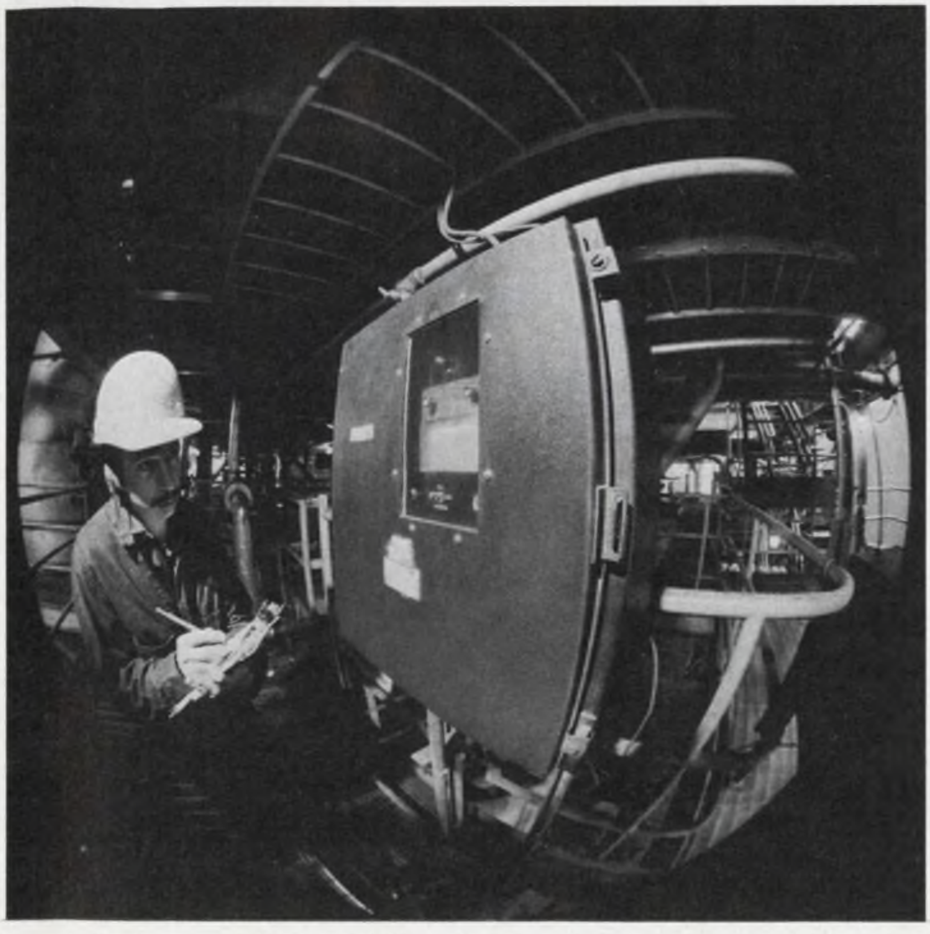
INFORMATION ONLY, CIRCLE 281

DEMONSTRATION ONLY, CIRCLE 282



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CIRCLE NUMBER 95

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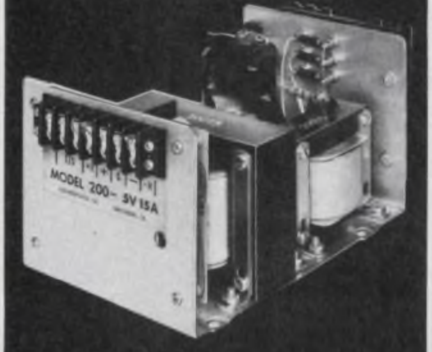
5V15A



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Singles and duals up to 200 Watts, 3 to 50 Volts.

SPECIFICATIONS

Size: 5 x 5.5 x 10.75 overall
Input: 105-125V, 47-420 Hz
Output: Any DC voltage 3 to 50
Regulation: Line — 0.005%
Load — 0.05%
Ripple: Less than 250 Microvolts
Temp: Operative —40 to +71°C
Storage —65 to +85°C
Coefficient —0.01%/°C Max.
Current Limiting: Fixed Foldback Type
Overvoltage: Optional

MODEL	VOLTS	AMPS
200-5	4.5-5.5	15.0
200-12	11.5-12.5	10.0
200-15	14.5-15.5	9.0
200-24	23.5-24.5	7.5
200-28	27.5-28.5	7.0
200-48	47.5-48.5	4.0
200-0505	± 4.5-5.5	7.0
200-1212	±11.5-12.5	5.0
200-1515	±14.5-15.5	4.5
200-2424	±23.5-24.5	3.5
200-2828	±27.5-28.5	3.5

ORDERING INFORMATION

SINGLE			DUAL		
Qty	Price	w/O.V.	Qty	Price	w/O.V.
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10-24	94	107	10-24	113	122
25-99	90	102	25-99	104	112

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CIRCLE NUMBER 97

S/d converter series tracks at 5760°/s

Computer Conversions Corp., 6 Dunton Ct., East Northport, NY 11731. (516) 261-3300. Less than $350 (prod. qty.); 4 wks.

The SDC410 series of synchro-to-digital converters can track input rates of up to 5760°/s with no added error. The modules convert synchro or resolver inputs of 11.8 or 90 V, 400 Hz, or 90 V, 60 Hz, into 10-bit, parallel-binary outputs that represent the angle with an accuracy of ±30 min. of arc. There is no accuracy degradation over the unit's operating temperature range, for ±10% amplitude and frequency variations and for ±5% power-supply variations. All units in the series measure 2.6 × 3.1 × 0.82 in. Typical operating requirements include a reference input of 26 or 115 V ac and supplies of +15 V at 65 mA, —15 V at 40 mA, and +5 V at 275 mA. Two operating temperature ranges are available: 0 to 70 or —55 to +85 C.

CIRCLE NO. 379

Two-tone decoder spans 832 to 2704 Hz

Solid-State Communications, 21060 Corsair Blvd., Hayward, CA 94545. (415) 785-4610. Under $90; stock.

The Model 221 two-tone sequential decoder is intended for mobile selective calling systems. The decoder accepts signal formats of 100 ms to 1 s per tone over frequency range of 832 to 2704 Hz. Operating frequencies can be changed in the field without special tools or instruments. Both latched and timed relay outputs are available to control the radio speaker, vehicle horn, or other external functions. The unit operates from a power source of 10 to 15 V dc and draws a 10-mA standby current over a temperature range of —30 to +75 C. The decoder comes in two configurations: The V221 self-contained dash-mount control head with a lighted reset switch and a call-horn-monitor switch or a board-only version, the Model 221-A.

CIRCLE NO. 380

Narrow-band notch filter has 50-dB attenuation

Frequency Devices, 25 Locust St., Haverhill, MA 01830. (617) 374-0761. $85 (1 to 9); stock.

The 585 series of narrowband notch filters have —3 dB and —50-dB bandwidths that conform with Bell System specifications. The units are three-pole-pair, stagger-tuned, band-reject active filters. They are packaged in plug-in modules that measure only 2 × 2 × 0.4 in. (50.8 × 50.8 × 10.1 mm). All models exhibit a passband gain of 0 ±0.3 dB, a constant input impedance of 20 kΩ, an offset voltage of less than ±5 mV, and an offset tempco of 50 μV/°C over their full operating temperature range of 0 to 70 C. All models provide rated specifications with ±15-V-dc power supplies but can be operated from power supplies ranging from ±5 to ±18 V dc. Output characteristics include a full power response to ±10 V at ±5 mA from dc to 10 kHz, and less than 50 μV of noise in a dc to 50 kHz bandwidth. Two standard models are available. Model 585-1 has 50 dB of attenuation from 995 to 1025 Hz to eliminate test tones, 1004-Hz holding tones and 1020-Hz tones that are often used for phase jitter measurements. Model 585-2 has 50 dB of attenuation from 2785 to 2815 Hz to eliminate the 2800-Hz holding tone that is commonly used in telephone system for line noise measurements.

CIRCLE NO. 381

High resolution v/f's deliver 100 kHz

SGR Corp., Neponset Valley Industrial Park, P.O. Box 391, Canton, MA 02021 (617) 828-7773. From $39 (unit qty.); stock.

The 500 series of 100-kHz voltage-to-frequency converters offers resolution of better than 16 bits. Six models are available, with overall accuracies from 11 to 13 bits. Full-scale errors range from a loose ±150 ppm/°C to a tight ±15 ppm/°C.

CIRCLE NO. 382

E-Z-MICRO HOOK ■ E-Z-MINI HOOK X100W AND XL1 ■ E-Z-MACRO HOOK XH AND XHL ■ E-Z-NAILCLIPS

E-Z-PROBES XP AND XPL ■ TEST LEADS AND JUMPERS ■ ADAPTORS

OUR NEW MICRO TROUBLE SHOOTER SOLVES YOUR IC TESTING PROBLEMS

The XM Micro Hook is designed for difficult IC test connections. Light weight (less than 1 gram) and Finger-eze Hypo Action permit direct hookup to delicate wires where weight and leverage may damage component. Fully insulated to a single contact point for true readings.

Construction: One-Piece Beryllium Copper, Gold-Plated Conductor and Hook, made for connections over leads up to .025" diameter. Durable Heat and Chemical Resistant Nylon Body. Stainless Steel Spring. Available preconnected to a wide variety of interface connectors.

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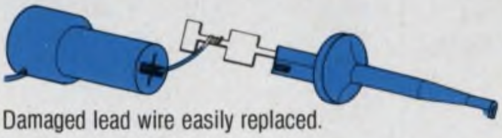
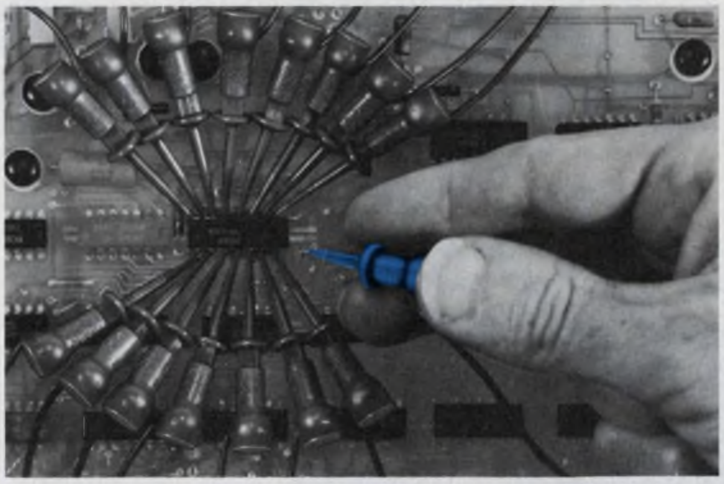
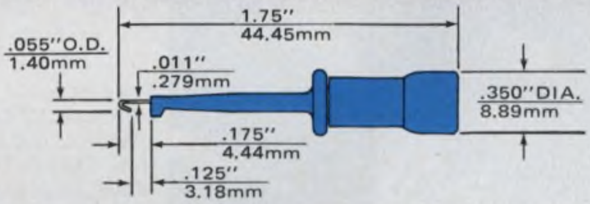


Damaged lead wire easily replaced.



MODEL XM SHOWN ACTUAL SIZE WITH HOOK EXTENDED.



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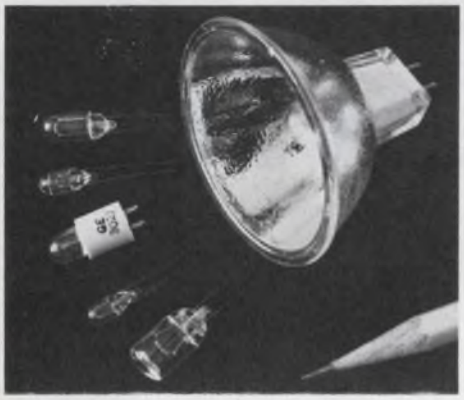
LSI computer systems, inc.

22 Cain Drive, Plainview, NY 11803 (516) 293-3850

CIRCLE NUMBER 99

Stay current with small lamp data from General Electric. It's free.

Check these 6 halogen cycle lamps GE has added to its low-voltage line.

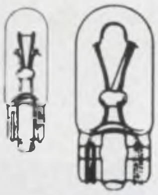


General Electric now offers over 27 halogen cycle lamps that pack high light output in small packages. (In addition, GE offers 8 sealed beam halogen lamps primarily for aircraft applications.) Bulb diameters range from 3/16" to 1/2". Lengths from .520" to 2.25". Voltages from 3.5 to 28. O.V. And candlepower from 2.15 cd up to 250 cd.

They're ideal for you if you're designing applications such as optical systems, instrumentation, illuminators, fiber optics, card readers, displays and aircraft navigation. A variety of terminals are offered.

For updated technical information circle the number below or write GE for Bulletin #3-5357.

These GE wedge base miniature lamps offer you savings in time, money and space.



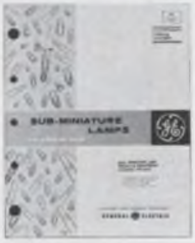
These lamps are ideal for applications such as indicators, markers and general illumination where space is at a premium. Their wedge-based construction makes them easy to insert and remove. They don't require bulky, complicated sockets. And because the filament is always positioned the same in relation to the base, you get consistent illumination from lamp to lamp.

You can choose from over 25 types of GE wedge base lamps. Voltages range from 6.3 V to 28 V. Candlepower from 0.03 to 12 cd. Bulb sizes range from subminiature at 6mm to a heavy-duty bulb at 15mm.

To send for updated wedge base lamp technical information, circle number below or write GE for Bulletin #3-5259.

These three free GE catalogs include important data changes that could affect your present design. Send for yours today.

#3-5169

June '75 Miniature lamp catalog features 40 pages and 500 data changes for complete 500-lamp line.

#3-6252R1

Feb. '75 Sub-miniature lamp catalog features 24 pages and 91 changes for more than 210 lamps.

#3-6254R

Dec. '74 Glow Lamp catalog features 8 pages and 50 changes for 83 Glow Lamp Indicator and Circuit Component lamps.

For up-to-date technical information on any of these items write: General Electric Company, Miniature Lamp Products Department #3382- L, Nela Park, Cleveland, Ohio 44112.

GENERAL ELECTRIC

CIRCLE NUMBER 101

Signal digitizer works with most transducers

Automated Industrial Measurements, P.O. Box 125, Wayland, MA 01778. (617) 653-8602. $325 (1 to 9); stock.

A general-purpose transducer digitizer and transmitter—the 1001—includes the interface circuitry for most transducers. The input circuitry is programmable for both gain and offset, as well as being fully isolated from ground. Common-mode signals of up to 2500 V can be handled. Specifications include a nonlinearity of 0.01%, a gain temperature coefficient of ±10 ppm/°C and a zero offset of ±1.5 μV/°C. Floating ±15-V power supplies are built into the digitizer so that additional signal conditioning circuits could be powered. The 1001 transmits the digitized signal over a twisted pair of wires (which are also the 24-V power supply leads) at a frequency that ranges from 0 to 1 MHz.

CIRCLE NO. 383

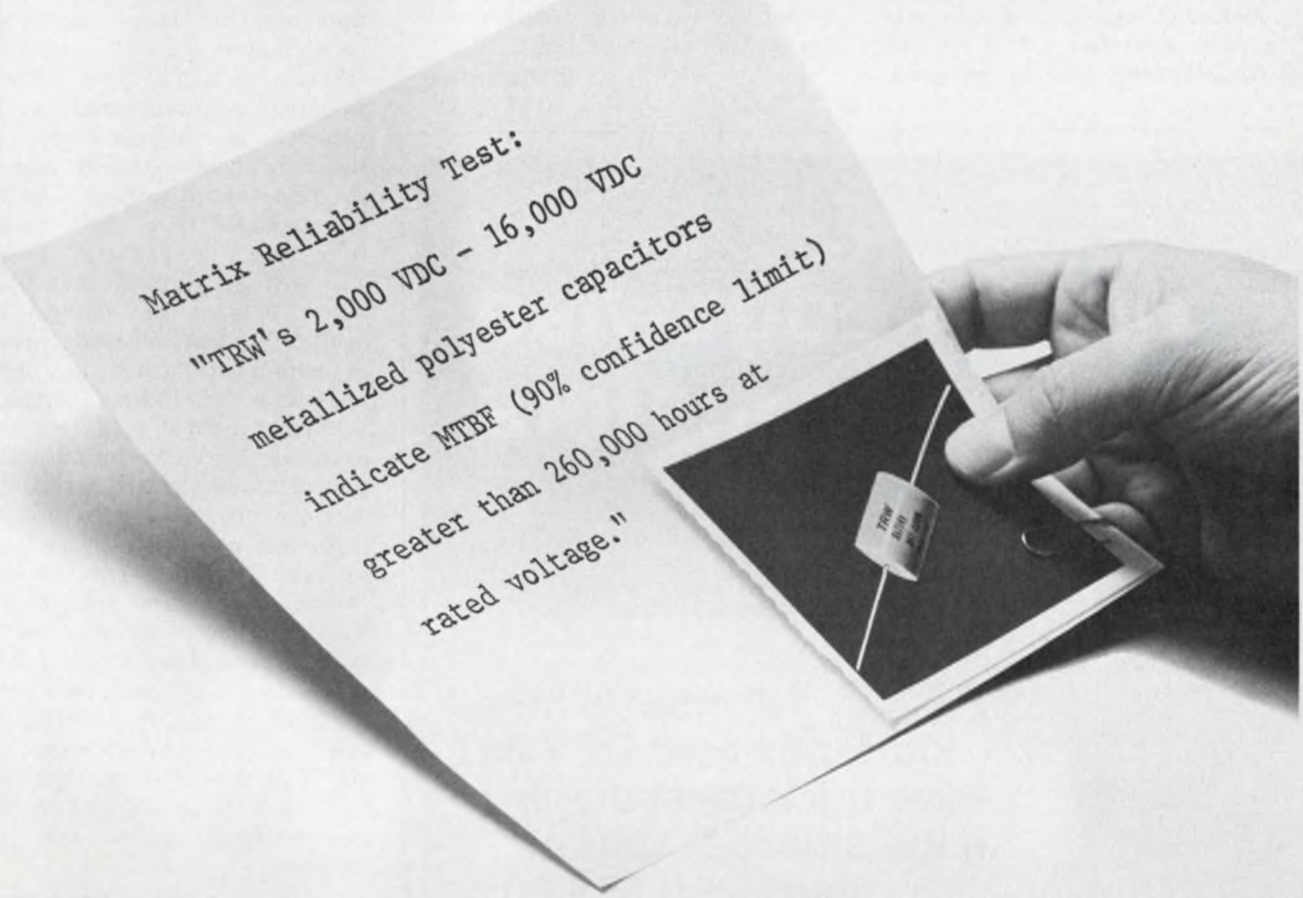
Power amps intended for digital resolver systems

Natel Engineering, 8954 Mason Ave., Canoga Park, CA 91306. (213) 882-9620. From $250 (prod qty); 4 wks.

Two solid-state power amplifiers, the PS-56 and PA-13, provide 56 and 13-W outputs, respectively. Both units have current-limiting and thermal-shutdown protection. The amplifiers are intended for operation with the company's DSC 5012 digital-to-resolver or r/d converters. The accuracy of the DSC 5012 converter is within four minutes and with either the PA-56 or PA-13 added, the accuracy is within 15 minutes under load. Both the converter and the amplifier are designed to MIL-E-5276C and E-5400.

CIRCLE NO. 384

Reliability test results:



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metallized polyester capacitors

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TRW's X675HV series is designed to meet the requirements of voltage multipliers and high voltage filters in high density, high voltage power supplies, instrumentation, data displays, pulse modulators and copiers.

They're smaller, lighter, self-healing and eliminate wet components which can bleed, crack and wreck a board.

The standard design is metallized polyester with axial leads, tape wrap and epoxy endfill case. Insulation resistance is 30,000 megohms x MFD and the dissipation factor is less than 1% at 1000 Hz.

The X675HV series can replace traditional dielectrics in many applications with substantial savings in size at comparable lower costs. *On quantity orders, modifications can be made to your specifications.*

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CIRCLE NUMBER 100

Phase-locking oscillator allows ±30 ppm range

Vectron, 121 Water St., Norwalk, CT 06854. (203) 853-4433. From $74 (100-up); 60 days.

The CO-233V voltage-controlled, crystal oscillator is intended for applications requiring phase locking. The deviation of ±30 ppm allows self-correcting to the specified center frequency without adjustment for a period of five years. The oscillator has a 0-to-50-C operating range and is available at any frequency in the 4-to-200-MHz range. An output of +7 dBm into 50 Ω is available. The oscillator can be purchased for either printed circuit-board mounting or chassis mounting.

CIRCLE NO. 385

Hybrid 12-bit DACs 2nd-source Burr-Brown

Micro Networks, 324 Clark St., Worcester, MA 01606. (617) 852-5400. 100-up prices: $18.50 (current outputs); $19:50 (voltage output); stock to 3 wks.

The DAC-80 series of 12-bit d/a converters is completely self-contained and includes internal reference supplies and output amplifiers (voltage models). The units are available in either binary or BCD versions, are pin-compatible with the Burr-Brown DAC-80 and meet the same specifications. The units are packaged in a glass, hermetically sealed 24-pin DIP package. The DAC-80 units are available in either current or voltage-output modes. The current-mode provides an output of 0 to 2 mA or ±1 mA with an output compliance voltage of ±2.5 V, max. In the voltage mode, the converter outputs are user selectable by external pin connections providing 0 to +5, 0 to +10, ±5, or ±10-V outputs. The voltage models, DAC-80-CBI-V (binary coded) and DAC-80-CCD-V (BCD coded), have a slew rate of 20 V/μs and settle to ±1/2 LSB in 3 μs for a full scale change. For a 1-LSB change, the settling time is 1.5 μs. The current output models, DAC-80-CBI-I and DAC-80-CCD-I, settle in 300 ns. All units operate from ±15-V and +5-V supplies.

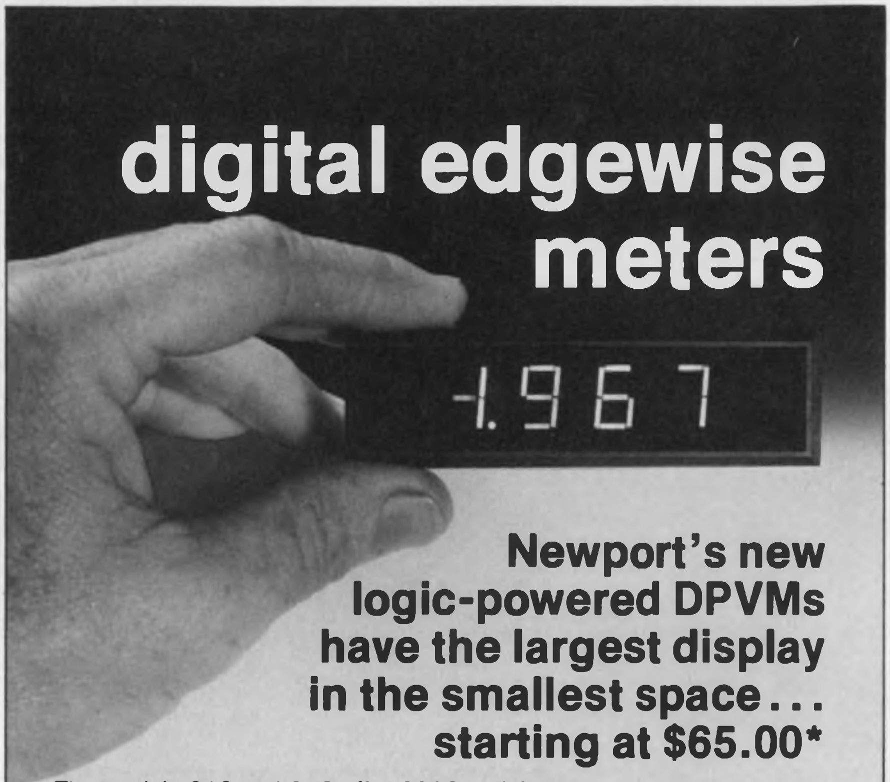
CIRCLE NO. 386

A/d converter series offers 3-state output

SGR Corp., Neponset Valley Industrial Park, P.O. Box 391, Canton, MA 02021. (617) 828-7773. From $69 (unit qty); stock to 30 days.

A series of microprocessor-compatible a/d converter modules has three-state outputs, 13-bit resolution and up to 13-bit accuracy. The 6100 series units use a multislope integration technique and also provide for automatic zero correction, have an overrange flag line and have internal references. The converters are housed in 2 × 3 × 0.4-in. encapsulated modules. The units accept bipolar input signals, provide two's-complement, binary outputs, and require +5 and ±15-V supplies.

CIRCLE NO. 387



digital edgewise meters

Newport's new logic-powered DPVMs have the largest display in the smallest space . . . starting at $65.00*

The models 213 and 216 offer 2000 and 6000 count capacity respectively. Four ranges of voltage are available for each unit. The DIN standard case and cut-out permits mounting without occupying precious front panel space. The depth, including the connector, is 71 mm.
Newport's DPVMs will replace your edgewise analog meter with bright 13mm (½ inch) LED digits easily read from a distance.
Low power consumption and low parts count, plus Newport's ten years experience, add up to real reliability you can count on.

*OEM quantities

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NEWPORT

CIRCLE NUMBER 102

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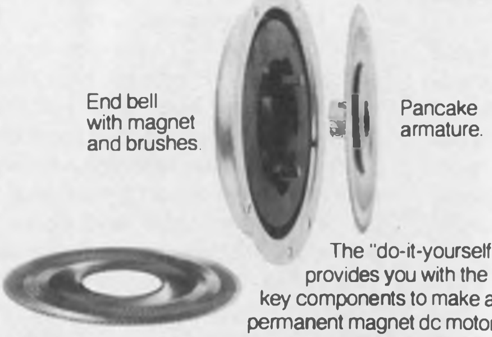
CIRCLE NUMBER 103

Do-it-yourself dc motor with Pancake armature.

No coupling. No bearings. No shaft. No front housing.



The "do-it-yourself" motor provides you with the minimum key components to make a permanent magnet dc motor an integral part of your product. You save the cost of couplings, motor shaft and bearings, mounting plate and motor enclosure parts, while reducing assembly and alignment costs.

We supply the unique Pancake armature to mount on your shaft and an end bell with magnet and brushes. Your load bearings serve as motor bearings. Your housing can be the flux return path. These motors are thinner than any other, so you can design more compactly than before.

Pulse torque capability is very high, typically 10 times continuous-duty ratings. With low armature inertia, response is extremely fast with smooth torque at speeds ranging from 0 to over 3000 rpm. Brush life up to 10,000 hours. Ratings: 1/25, 1/13 and 1/8 hp.

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CIRCLE NUMBER 104

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ED 38

Where the energy future is now

CIRCLE NUMBER 105

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Add 3-D to any X-Y display or oscilloscope for only $147.00 (basic DC-500 KHz system). The 6100 Series of 3-D Modules come with bandwidths from DC-500 KHz up to 5 MHz. The modules generate aerial and geometric perspective, 360° rotation, interposition, depth of focus, and binocular (stereo) depth cues.

The entire image is described by ±10V full-scale analog voltages.

Since the 6100 Series of 3-D Modules are analog by nature, it provides full compatibility with analog systems. When used with digital systems, the 6100 Series is placed at the CRT, X, Y inputs.

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CIRCLE NUMBER 106

Digital clock module just needs transformer

National Semiconductor, 2900 Semiconductor Dr., Santa Clara, CA 95051. (408) 732-500. From $10 (100-up); stock.

A miniaturized electronic digital clock movement is available with 0.5-in. high digits. The MA1002 series clock modules combine a MOS IC, a four-digit LED display, a power supply and associated components on a single PC board. Just add a transformer and switches to construct a pretested digital clock. Timekeeping may be done from inputs of either 50 or 60 Hz, depending on the model selected. Display formats of 12 or 24 hours are available. Direct, non-multiplexed drive for the LED display eliminates any possible rf interference.

CIRCLE NO. 388

Fast a/d converters have 8, 10 & 12-bit models

Teledyne Philbrick, Allied Dr. at Route 128, Dedham, MA 02026. (617) 329-1600. Unit qty prices: $256, $281, $264, $309 for models 4130, 31, 32 and 33, respc.; stock to 6 wks.

The 4130 family of 8, 10, and 12-bit binary output a/d converters has a maximum nonlinearity of ±1/2 LSB for 8 bits and ±1 LSB for 10 and 12 bits. Conversion rates of 1.33 MHz for 8 bits (Model 4130), 1 MHz for 10 bits (Model 4131), and 0.285 MHz (Model 4132) or 0.4 MHz (Model 4133) for 12 bits are guaranteed. Monotonic operation from 0 to +70 C is guaranteed for 8 and 10-bit units. The 12-bit devices are monotonic from 1 to 49 C. Stability over the full operating-temperature range results from a ±20 ppm/°C maximum full scale temperature coefficient, with offset stability a low ±15 ppm/°C for 8 and 10-bit units and ±10 ppm/°C maximum for 12 bits. In addition, the nonlinearity temperature coefficient is guaranteed to be ±10 ppm/°C maximum for up to 10 bits and ±5 ppm/°C maximum for 12 bits.

CIRCLE NO. 389

Temperature controller handles 4-A loads

Oven Industries, P.O. Box 229, Silver Spring Industrial Pk., Mechanicsburg, PA 17055. (717) 766-0721. From $29.50; stock.

Two series of 4-A temperature controllers—the 5C1 and 5CX—provide proportional control for heating elements. Both 120 and 230-V-ac models are available. The zero-voltage firing, proportional control circuitry is completely solid state to ensure maximum controller and heater life. An operating ambient temperature range of 0 to 50 C is compatible with most industrial applications. The TX and TP series sensors provide control temperature ranges from −65 to +550 C (−85 to +1000 F). Coarse and fine set temperature adjustments permit precise control of temperature settings.

CIRCLE NO. 390

Line integrity monitor can shut off equipment

Potter & Brumfield, Div. of AMF Inc., 1200 E. Broadway, Princeton, IN 47671. (812) 385-5251. $16 large qty.; 10 to 12 wks.

The CZS-01 ground line integrity monitor automatically disconnects electrical equipment from the line if an excessive potential difference develops between neutral and ground. If ground line resistance becomes high and sufficient fault current exists to develop an 8 to 15 V rms potential between neutral and ground, an internal relay will de-energize and open the power line. Likewise, if the ground line opens (resistance rises to approximately 1 MΩ or higher) the relay will de-energize. When the relay de-energizes, it will remain so even if proper ground-line conditions are restored. The CZS-01 must be reset by removing and reapplying power. Operating temperature range of the unit is 0 to +55 C, and termination is by 0.187-in. quick-connect solder lugs. The relay comes with DPDT contacts rated either 10 or 15 A at 120/240 V ac, 50/60 Hz. The unit measures 3.25 × 1.75 × 1.5 in. (the 240-V model has a maximum length of 3.35 in.).

CIRCLE NO. 391

Wire-wrapping kit eases breadboarding

Cambridge Thermionic Corp., 445 Concord Ave., Cambridge, MA 02138. (617) 491-5400. $14.95 (unit qty).

A wire-wrapping kit, Pt. No. 601-2542, contains all of the tools necessary to produce wrapped-wire breadboards. The package contains an 80-pin socket, a 16-pin discrete component adapter, an IC insertion/extraction tool, a wrapping tool and 30-gauge wire. The 80-pin socket accepts up to five 0.300-in.-wide packages and has a removable cover for easy pin replacement.

CIRCLE NO. 392

Fiberglass shelter protects equipment

Porta House, Portatronic Div., 717 Kevin Court, Oakland, CA 94621. (415) 638-0100. See text.

Portatronic fiberglass shelters protect electronic equipment in temperatures from −30 to +130° F. The prefabricated shelters are supplied with power distribution panels and fluorescent lighting. Louvres, fans, air conditioners, heaters, wireways and specialized equipment are optional extras. The insulating and support material consists of polyurethane foam 1.5 in. thick. One model weighs 2112 lb. and costs $3800 without optional equipment.

CIRCLE NO. 393

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In a hurry? EMC can shorten your need time with a computer-aided Design/Drafting Package for your new Wire-Wrap® IC Panel . . . Often within a week! And you're getting the unequalled NURL-LOC® terminal with 5 times the gripping surface that prevents twist and keeps your panel from warping. For fast action phone (401) 769-3800 or write Electronic Molding Corp., 96 Mill Street, Woonsocket, R.I. 02895.

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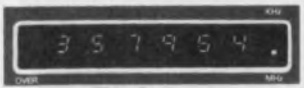
- Automatic ranging, 20 Hz to 40 MHz is guaranteed...readout to 60 MHz is typical
- TTL circuitry updates the six-digit display five times per second
- Resolution to 1 Hz obtained by suppressing digits above 1 MHz when switching to 1 SEC mode



MHz display of 3.579548 MHz input (AUTO mode)

KHz display of overflow of 3.579548 MHz input (1SEC mode)

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In Canada: Atlas Electronics, Toronto

CIRCLE NUMBER 109

Potting compound conducts heat well

Aremco Products, Inc., P.O. Box 429, Ossining, NY 10562. (914) 762-0685. $27.50 qt. (single qty).

Ceramacast 510 is a high-thermal-conductivity potting compound for encapsulating electronic components. The compound's high alumina content gives it a thermal conductivity of 25 BTU/hr/ft^2/in./°F. The material is inert (neither basic or acidic) and does not attack electrical windings. Ceramacast 510 has 7500-psi compressive strength, 1500-psi modulus of rupture, and a dielectric strength of 50 V/mil. The compound comes in powder form, and water must be added. The mixture is then poured in place and cured at 200 F.

CIRCLE NO. 541

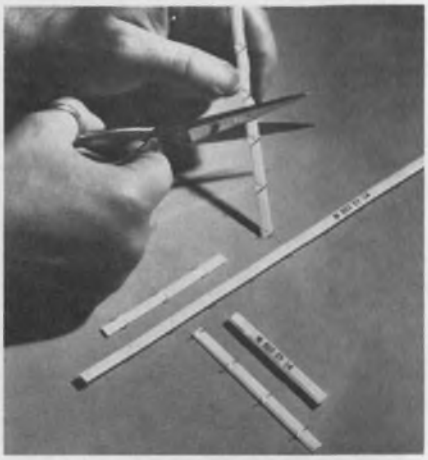
Fiber optic cables are useful up to 6600 ft

Galileo Electro-Optics Corp., Galileo Park, Sturbridge, MA 01518. (617) 347-9191. See text; stock to 90 days.

A line of five optical communication fibers, Galite Models 1000, 2000, 3000, 4000 and 5000, has been introduced. Each model is produced by a different process for optimum efficiency when used in specific lengths. Galite 1000 is recommended for use in applications of from 1 to 150 ft; Galite 2000, 150 to 250 ft; Galite 3000, 250 to 1100 ft; Galite 4000, 1100 to 3300 ft; and Galite 5000, 3300 to 6600 ft. The fibers may be sheathed in different jackets, depending on the intended use of the cable. All come jacketed in polyvinyl chloride or Tefzel, a special material produced by Du Pont. Types 3000, 4000 and 5000 also are available in a specially strengthened jacket. Standard cables have one or two strands, or bundles of 7 or 19 strands. Prices are per ft, in lengths of 1000 ft, with seven strands and a polyvinyl chloride jacket. Outside diameter for all types is 1.37 mm. Type 1000 costs 14¢; 2000, 28¢; 3000, 74¢; 4000, $1.05; and 5000, $2.10.

CIRCLE NO. 542

DIP power bus can be cut to length

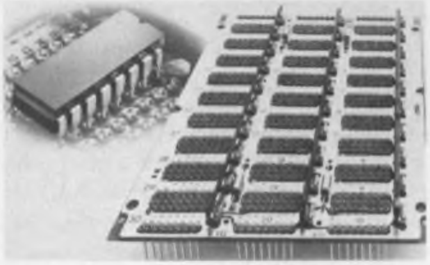


Rogers Corp.,.Chandler, AZ 85224. (602) 963-4584. $1.25 (100 up).

The Model M-822 EY-14 Mini/Bus strip can be trimmed to length by the user. The bus strip is mounted underneath 14 or 16-pin DIPs for power and ground distribution. Construction of the 9-in. bar permits cutting with a scissors to the required length.

CIRCLE NO. 543

Wrapped-wire socket board made for ECL ICs



EECO, 1441 E. Chestnut Ave., Santa Ana, CA 92701. (714) 835-6000. $100 (single qty) stock to 4 wks.

The Model 2D-ECL202 socket board will reduce noise problems that occur in some emitter-coupled logic applications. The board features four tantalum and 18 ceramic bypass capacitors, and has provision for mounting 12 additional capacitors. Three bus bars are used in the power distribution system. Power is prewired to all socket positions. The 2D-ECL202 can hold up to 30 16-pin, dual-in-line and 27 eight-pin, single-in-line packages. The board has dimensions of 5.06 × 4.14 in., and contains 0.370 in.-long posts for two-level wrapped-wire connections.

CIRCLE NO. 544

If you need a few custom ICs and can't afford them, call us.

When others quote you high prices for a few custom ICs, its because they treat them as a sideline. At Silicon Systems, custom ICs are our bread and butter. Especially modest quantity orders. Priced to compete with catalogue ICs.

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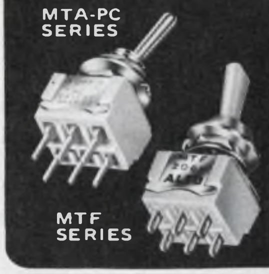
CIRCLE NUMBER 110

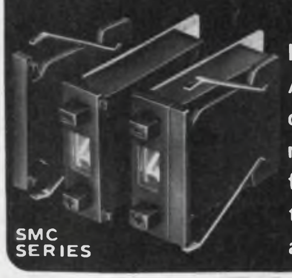
MINIATURE TOGGLES



Compare these premium features. MOLDED-IN TERMINALS eliminate epoxy seal. SOLID SILVER contacts with gold flash to retard oxidation. Anti-Push-In toggle. High torque bushing and many other features most suited for your needs. Rated 3A @ 250 VAC or 6A @ 125 VAC. Compare and find ALCOSWITCH your best buy!

CIRCLE NUMBER 111

BI-DIRECTIONAL PUSHBUTTON



Smallest size ever with large easy-to-read numerals. Occupies only 0.3 sq. in. of panel space, impractical with thumbwheels. Heavy gold plated contacts. Available in a variety of coded outputs (includes decimal) and mating accessories. Matte black finish. Detailed information on this and larger mating types available upon request.

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CIRCLE NUMBER 113

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M.S. Kennedy Corp.
Pickard Drive, Syracuse, New York 13211
Tel. 315-455-7077

CIRCLE NUMBER 114

Microcomputer controls wafer dicing saw

Micro Automation Inc., 3170 Coronado Dr., Santa Clara, CA 95051. (418) 988-2180.

Perhaps anticipating the era when computers will be self-reproducing, a new semiconductor-wafer dicing saw is controlled by a microcomputer. The Model 1000 programmed dicing saw cuts silicon wafers that have diameters of up to 5.25 in. The operator control panel has a 10-key numeric input keyboard, a program input group and an operating control group. To program for a particular wafer, the operator pushes the "program" key and enters the horizontal and vertical die dimensions in English or metric units. These are digitally displayed and entered into the machine. An internal microcomputer does the necessary calculations to profile the circular wafer. The operator mounts each wafer on a vacuum chuck and aligns it while observing through a microscope. When the wafer is properly aligned, the Cut pushbutton initializes dicing. The Model 1000 then completely saws the wafer at speeds up to 6 in./s. As the system will cut entirely through the wafer without causing microcracks or heat damage to the dice, no "breaking" is required after sawing.

CIRCLE NO. 546

Cable withstands high temperatures

Belden Corp., Electronic Div., 2000 S. Batavia Ave., Geneva, IL 60134. (312) 232-8900. 83¢/ft (1000 up).

The RV-1290 cable withstands 200 C temperatures indefinitely, and higher temperatures for short intervals. It is intended for fire alarm circuit wiring in buildings. Two 22-gauge solid copper conductors are insulated with teflon, wrapped in a high-temperature tape barrier and covered with a double outer jacket. The jacket is clear teflon placed over a red teflon underlayer. The RD-1290 is imprinted "Fire Alarm Service," spiralled between the jackets, making the cable quickly identifiable.

CIRCLE NO. 547

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E 108

CIRCLE NUMBER 115

Fastest pulse generator blazes at 1-GHz rep rate

Hewlett-Packard, 1501 Page Mill Rd., Palo Alto, CA 94304. (415) 493-1501. See text.

After the HP 8080 system hangs up its hat as the world's fastest pulse generator, don't be surprised if it shows up later in an entirely different guise. The modular system can be configured as a 1-GHz pulse generator or as a 300-MHz word generator.

Functional blocks build up a complete instrument in the 8080 system. For example, combine the 8091A repetition-rate generator with the delay-generator/frequency divider module (8092A) provides modules, and you've got a two-channel pulser with 1-GHz rep rate, 300-ps transition times and ±1.2-V output into 50 Ω.

The delay-generator/frequency-divider module (8092A) provides some interesting capabilities. With it, you can delay one channel with respect to the other. Or you can chop the rep rate of one channel in half, leaving the second channel alone.

The full and half-frequency outputs contain each of the four possible digital combinations of two bits. This means you can test dual-input logic without two separate, synchronized generators.

Delays can be set in 100-ps steps over a ±9.9-ns range, with LEDs showing you the selected separation.

Still another rep-rate generator, the 8081A, works up to 300 MHz. Either generator can act as the source for the 8080 system. But for word generation, 300 MHz is the maximum rate.

Frequencies are adjusted on the generators with an eight-position range switch and a three-turn pot for fine control.

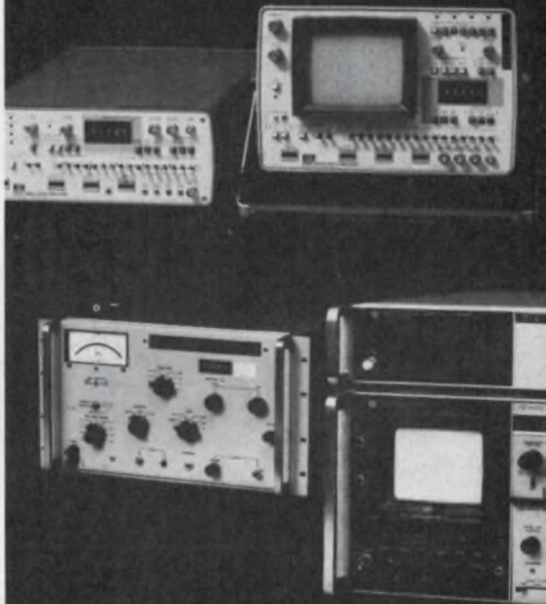
To put together a word generator, use the 8084A half-width module, together with the 300-MHz source and output-amplifier module. The 8084A generates a 16, 32 or 64-bit serial word in RZ or NRZ format.

You load the pattern you want

(continued on page 162)

CIRCLE NUMBER 116 ▶

Break your analyzer bottleneck



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CIRCLE NUMBER 117

Use it for its connections, or use it for its pull.

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A P has a Super-Grip™ Clip for any DIP.

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TC-16	.3 in.	923700	$ 4.75
TC-16LSI	.5/.6 in.	923702	$ 8.95
TC-18	.3 in.	923703	$10.00
TC-20	.3 in.	923704	$11.55
TC-22	.4 in.	923705	$11.55
TC-24	.5/.6 in.	923714	$13.85
TC-28	.5/.6 in.	923718	$15.25
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CIRCLE NUMBER 118

(continued from page 161)

into the 8084A's memory with pushbuttons, and you can display the contents on LEDs, 16 bits at a time, with a "fetch" pushbutton.

Both the pulse and word generators deliver outputs in various selectable modes. In the gating mode, you can produce a pulse burst; in the gated-cycle mode, an external or manual command starts and stops the data.

Other modes let you choose continuous recycling or single-word outputs, synchronization to an external source, and more.

Signals from the pulse or word generator (or delay unit) go to one or more output amplifiers before reaching the outside world. The amplifiers condition the waveforms for 50-Ω operation, let you adjust output amplitudes and offsets for ECL, TTL or other logic, and perform other tasks.

In the two-channel system, independent controls provide individual adjustment of each channel for amplitude and offset.

How much does all this cost? The 1-GHz pulser with delay and two output channels sells for $9615, the 300-MHz word generator for $4920. Delivery takes 6 weeks.

CIRCLE NO. 548

New line debuts: counters, timers, more

Data Tech, 2700 S. Fairview Rd., Santa Ana, CA 92704. (714) 546-7160. $675 to $1225.

Included in a new series of instruments are digital universal counter timers, digital frequency counters and an automatic AM/FM modulation meter. The outstanding advantage offered by these instruments is a new LSI device containing the equivalent of 5000 components on a single chip. Standard features include RFI shielding enclosures, LED readout, 10-mV sensitivity, automatic gain control input circuitry, $\pm 3 \times 10^{-7}$/month crystal stability.

CIRCLE NO. 549

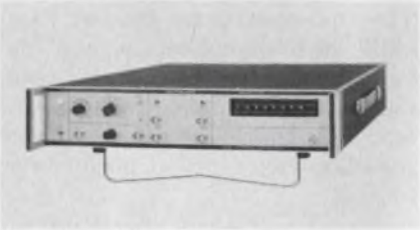
Logic monitor clips on DIPs

Continental Specialties, 44 Kendall St., Box 1942, New Haven, CT 06509. (203) 624-3103. $125.

Logic Monitor 2 digital test instrument offers a fully isolated power supply and selectable trigger threshold that matches the precise characteristics of the logic family under test. The LM-2 consists of two units: a connector/display unit, which clips over the IC and a power-supply module. The unit checks out the static and dynamic states of DIP ICs of up to 16 pins.

CIRCLE NO. 550

Unit lets you set delays in 10-ns steps



Eldorado Instruments, 2495 Estand Way, Pleasant Hill, CA 94523. (415) 682-2100. $1950; 90 days.

Model 670 10-ns time delay generator provides 10-ns resolution delay steps with 100-ps accuracy, over a range from 10 to 999,999,990 ns. A unique feature is a "period mode" in which the pulse repetition rate is determined by the selected delay and is therefore highly accurate. Since a dual-channel option is available, it is possible to have both the pulse rate and a delayed pulse digitally selected (in 10-ns steps) with 100-ps accuracy.

CIRCLE NO. 551

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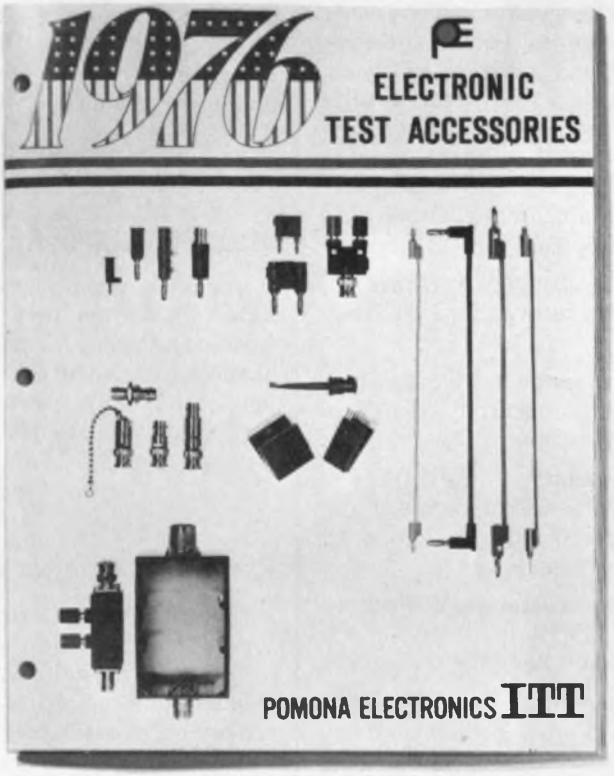

This new General Catalog is our latest family portrait. In the past twenty-five years (1976 is our Silver Anniversary year) it has grown from a handful of items to almost 500 products for the electronics industry.

Our catalog has grown to 76 pages for 1976, and we are introducing 65 new items this year. It describes and illustrates every member of our family. You're bound to find the solution to your testing problem with one or more of these quality products.

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CIRCLE NUMBER 119

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Resistance values . . . from 1K to 1 meg at 25°C . . . also miniature discs and rods of 100 ohms to 1 meg at 25°C are available.

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Low-cost series . . . three inexpensive probes to answer many requirements.

Catalog TP-739
. . . gives details on 23 probe styles and ordering information. Circle reader service card.

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Thermistor Division
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CIRCLE NUMBER 121

Application Notes

Contrast techniques

"Contrast Enhancement of Glow Discharge Displays" describes several alternative methods of contrast enhancement. Charts and drawings are included. Burroughs, Plainfield, NJ

CIRCLE NO. 552

Remote multiplexing

Written for designers of data-acquisition systems, a six-page application note, "Remote Multiplexing," points out the advantages of multiplexing and digital transmission over, both direct wiring and analog transmission. Burr-Brown, Tucson, AZ.

CIRCLE NO. 553

Magnetic shielding

Complete magnetic and physical data, application notes and fabrication methods of a new magnetic shielding material are given in an application note. Perfection Mica, Magnetic Shield Div., Bensenville, IL

CIRCLE NO. 554

Ceramic capacitors

"The ABC's of Ceramic Capacitors" describes the various types of ceramic capacitors, shows the construction of the most popular types and discusses their applications. Sprague Electric, North Adams, MA

CIRCLE NO. 555

Calculator interfaces

Two application summaries describe a pair of interface systems for the HP 9825 desktop programmable calculator. Included in the summary are descriptions of HP 9825/IB operation, additional capabilities through the General and Extended I/O ROMs, the interrupt device and a list of 25 HP-IB compatible instruments. Hewlett-Packard, Palo Alto, CA

CIRCLE NO. 556

Bulletin Board

RCA Electro-Optics and Devices has increased prices from 2 to 50% on many of its **phototubes, imaging devices, display devices and tube sockets.**

CIRCLE NO. 557

Mostek has lowered prices for its **F8 μC evaluation package (Survival Kit)** to $147 from $197 unassembled (MK 79001) and to $185 from $250 assembled (MK 79002).

CIRCLE NO. 558

Diablo has begun shipping **serial printers Models 1345, 1355 and the 1355 WP word processing unit.** The company has reduced the price of the 1345 model to $1300, and the 1355, a 55-cps printer is $1230 (100). Basic price of the 1355 WP is $1500.

CIRCLE NO. 559

Dionics has developed a line of low-cost multivalue **MOS capacitor chips** designed specifically for manufacturers of LED and LCD digital watches.

CIRCLE NO. 560

The Optoelectronics Div. of Fairchild has announced a new development in **optical coupler technology** that doubles the guaranteed minimum isolation voltage for all device types at no increase in cost.

CIRCLE NO. 561

Crydom Div. of International Rectifier has cut prices averaging 30% for its line of **120 and 240-V miniature solid-state relays.**

CIRCLE NO. 562

Honeywell's Materials Requirements Planning (MRP) software package operates on a "net-change" processing basis for reduced computer run time and current information. It is intended for use with Honeywell's Level 66 large-scale computer system.

CIRCLE NO. 563

for design engineers

new fhp motor ...and control catalog

Just published! An expanded catalog covering more than 325 stock Bodine fractional horsepower motors, gearmotors, plus controls. Helps you select and match the right motor and control for your application.

Twenty pages, 75 illustrations, tables and drawings (all drawings decimalized). Includes 14 new gearmotors, adjustable speed/torque drive systems. Optional and accessory parts for motor controls fully tabulated. Also a performance chart on K-2 motors . . . covers normal slip, high slip and synchronous motors. Ask for Catalog S-5.

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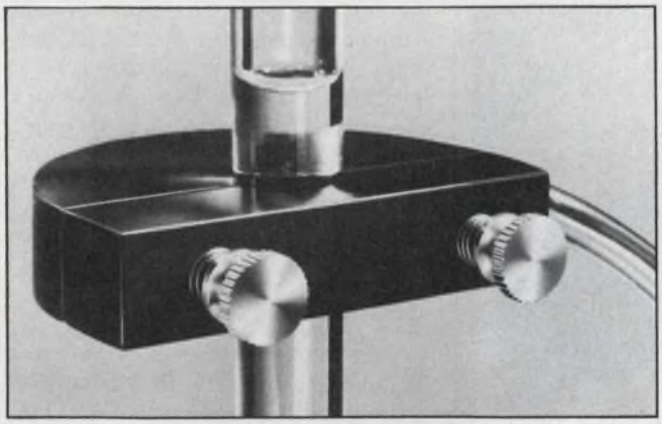
Bodine Electric Co., 2500 West Bradley Pl., Chicago, Ill. 60618

CIRCLE NUMBER 122



Liquid Level Detection from the outside looking in

This new Sight Glass Skanner will detect the level of virtually any liquid including water. It senses the capillary edge of the liquid with a positioning accuracy of ± .003 inch. The unit easily clamps around the outside of a sight glass by means of tension springs for easy repositioning. The skanner's photoelectric sensor is compatible with the full range of standard Skan-A-Matic amplifiers and controls. 3 day shipment. **SEND FOR MORE INFORMATION**

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CIRCLE NUMBER 123

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Evaluation Samples

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CIRCLE NO. 564

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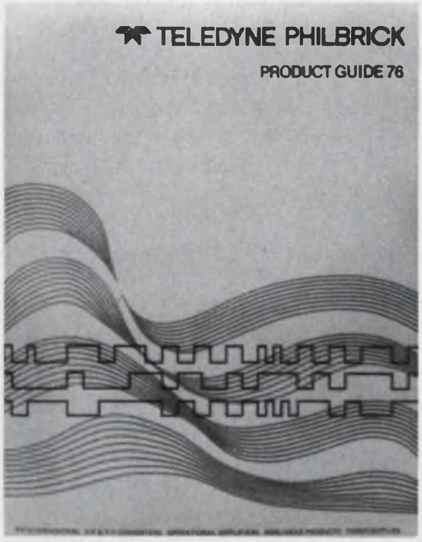
New Literature



TELEDYNE PHILBRICK
PRODUCT GUIDE 76

Microcircuits, modules

Presented in data-sheet format, a 192-page catalog contains specifications, hook-up, packaging and applications for hundreds of electronic microcircuits and modules. Teledyne Philbrick, Dedham, MA

CIRCLE NO. 568

PM speed/torque systems

PM drive systems and accessories are featured in a 20-page catalog. Bodine Electric, Chicago, IL

CIRCLE NO. 569

Adhesives

Silicone and epoxy adhesives for electronic and industrial applications are covered in a 13-page catalog. Transene, Rowley, MA

CIRCLE NO. 570

8-bit microprocessor

"Using an 8-bit Microprocessor" is a comprehensive 170-page examination of the Intel 8080. Flowcharting and programming techniques are explained by solving typical problems. It is written from the viewpoint of the noncomputer oriented professional. No previous μP or computer experience is assumed. Cost: $13.95 including postage and handling. Technitrol, 1952 E. Allegheny Ave., Philadelphia, PA 19134.

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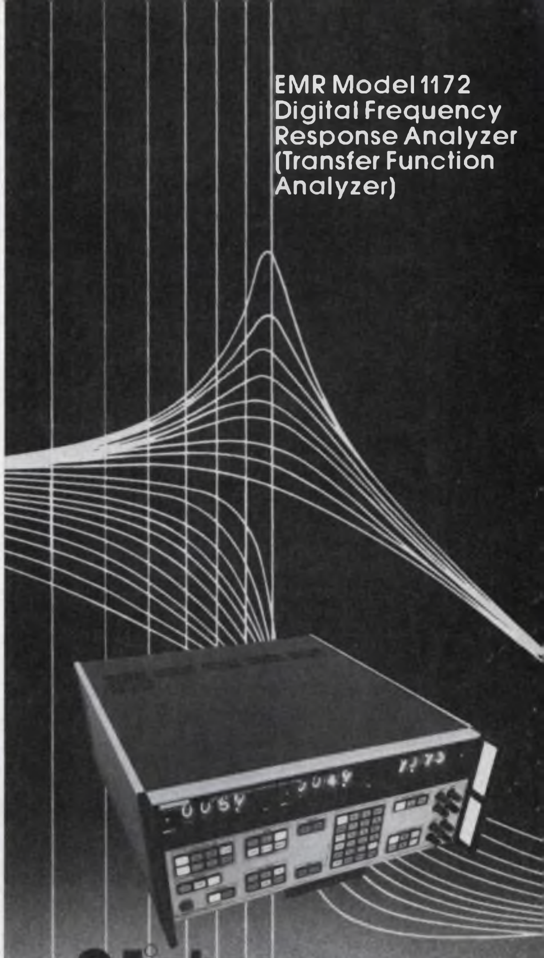

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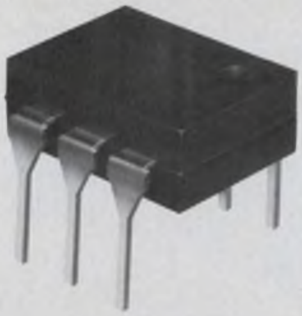

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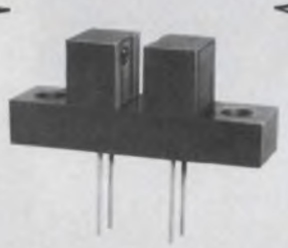

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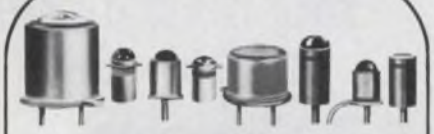

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CIRCLE NO. 574

Bridges, rectifiers

"Devices for Use in Power Supply Applications," an eight-page guide, features silicon bridges and standard rectifiers. N.A.E., Semiconductors, West Lynn, MA

CIRCLE NO. 575

OEM power supplies

How to select standard single and triple-output switching-regulated power supplies in the 110-to-600-W range is covered in a 20-page catalog. Hewlett-Packard Rockaway NJ Div., Palo Alto, CA

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Capacitors

Pictures, prints and full dimensions of film capacitors are presented in a 28-page catalog. Paktron Div., Illinois Tool Works, Vienna, VA

CIRCLE NO. 577

Resistors

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Motor starter

Technical data and performance curves of Posistor solid-state motor starters are given in a two-page data sheet. Murata, Rockmart, GA

CIRCLE NO. 579

Instrumentation

The top articles in the latest edition of "News from Rohde & Schwarz" deal with diplomatic radio networks, rotatable lightweight log-periodic antennas for shortwave working and the latest plug-ins for the insertion-signal generator SPZF. Rohde & Schwarz, D-8000 Munchen 80.

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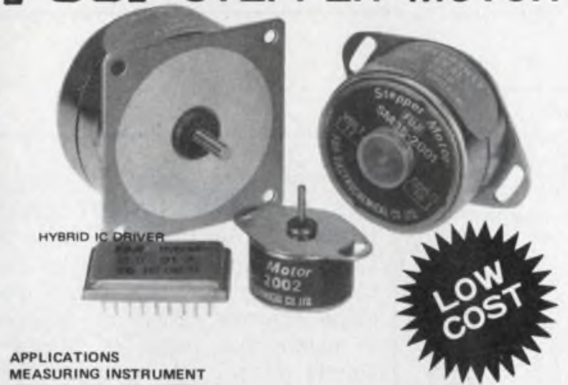

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SM40-2001	18	165
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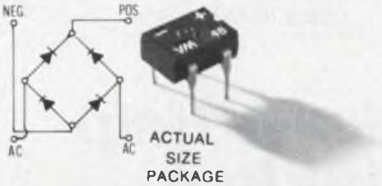

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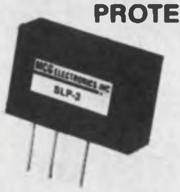

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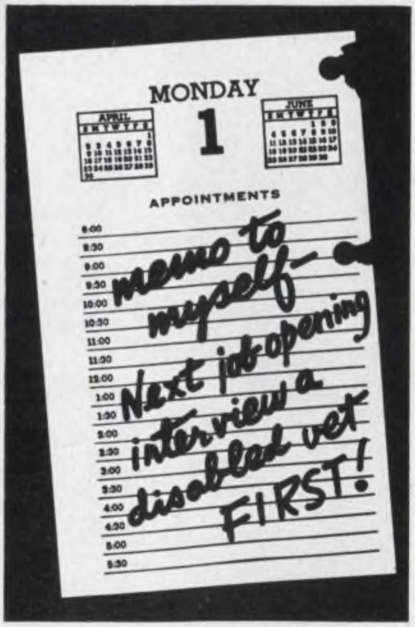

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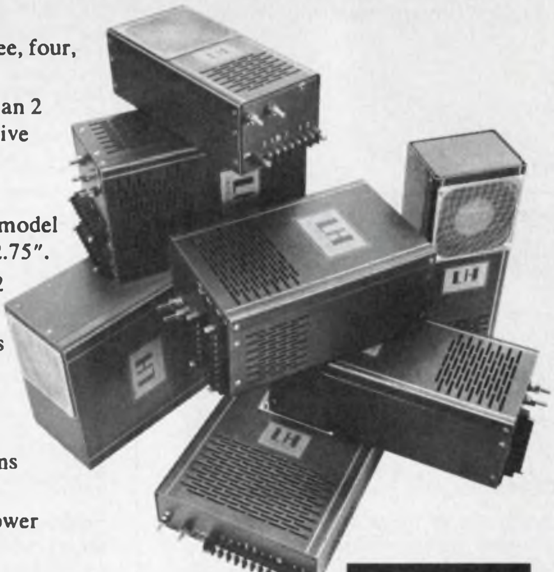

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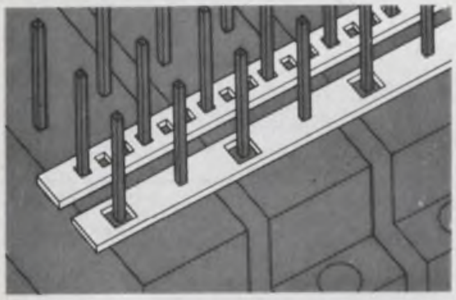
MINIATURE CAPACITORS 181



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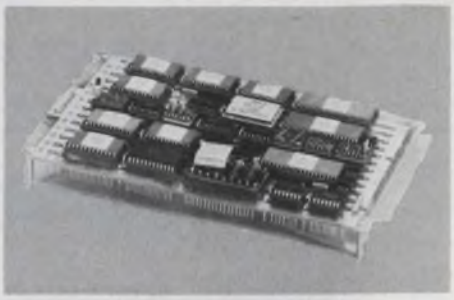

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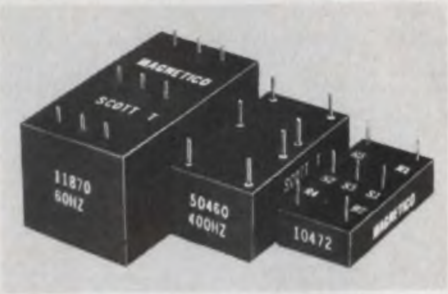
ASSEMBLER SIMULATOR 186



Scott T Transformer. 11870: 60HZ, 90v, L-L in. 1.1x2.1x1.1. 50460: 400 HZ, 90v, L-L in. 7/8x1-5/8x11/16. 50642: 400HZ, 11.8v, L-L in. 7/8x5/8-11/16. 10472: 400-HZ, 11.8v, L-L in. 3/4x1-1/2x3/8. All with 6v RMS sine & cosine output. MAGNETICO, INC., 182 Morris Ave., Holtsville, N.Y. 11742 516-654-1166.

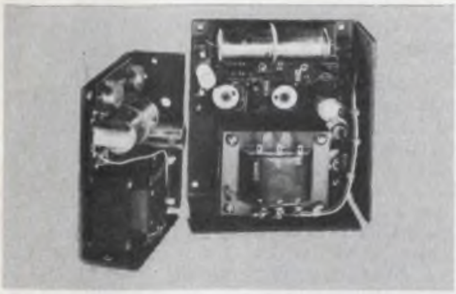
TRANSFORMER 187

Basic Electricity & Basic Electronics by Van Valkenburgh, Nooger & Neville, Inc. Derived from the COMMON-CORE Training Program initially developed for the U.S. Navy. Thorough, comprehensive coverage. Available in separate paperbacks or cloth volume. Write for FREE brochure. Hayden Book Co., Inc., 50 Essex St., Rochelle Pk, N.J. 07662 (201) 843-0550.

TRAINING TEXT 188

'LYTIC CAPACITORS WITH AN OPTION. Type 32D Compulytic® Aluminum Electrolytic Capacitors, designed for power supply applications, give you the option of securing more capacitance in a given case size with the Type 32DX version or of obtaining lower ESR and higher ripple current capability in Type 32DR. Sprague Electric Co., 347 Marshall St., No. Adams Ma. 01247 (413) 664-4411.

CYLINDRICAL 'LYTIC CAPACITORS 189



New "Slim Line" Industry Standard DC Supplies offer narrow silhouette interchangeability with other makes. Competitively priced, the SPS 32/42 are fully rated from 47 to 440Hz, 115/230Vac ±10% inputs. Nom. outputs are 5, 12, 15 and 24/28Vdc at 3.0, 1.8, 1.6 and 1.2/0.9A(max) for the SPS 32; and, 6.0, 3.5, 3.0 and 2.3/1.8A(max) for the SPS 42. Vdc adj. to ±10%. For data, prices and local distr: Standard Power, Inc., 1400 So Village Way, Santa Ana, CA 92705 (714) 558-8512, or in east: (516) 420-0944.

DC POWER SUPPLIES 190

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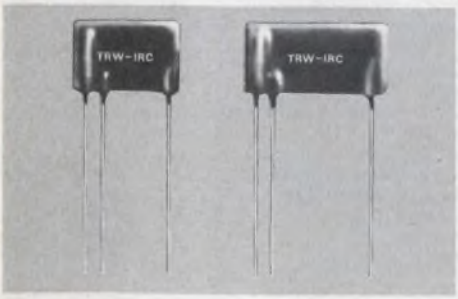
ELECTRONIC SURPLUS CATALOG 191



Thick-Film High Voltage Dividers are the latest line of high-voltage resistors from TRW. Each device consists of a high-voltage thick-film resistor circuit deposited on a high alumina ceramic substrate. The circuit can be encapsulated in a high-temperature epoxy coating with printed circuit leads or it can be made as a substrate for customer assembly into an integral high-voltage function. Available in various sizes and configurations. TRW/IRC Resistors, 401 N. Broad St., Phila, Pa. 19108. (215) 922-8900.

HIGH VOLTAGE RESISTORS 192

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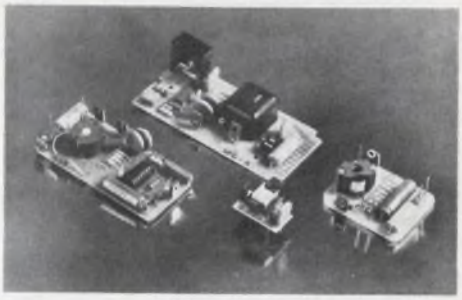
3M DATA CARTRIDGE RECORDER 193

The **PMK04** is a portable off-line terminal tester. It can be used with your system up to exercise serial ASCII terminals such as Digital's VT50/52 CRT's, LA 30/36 terminals and other teleprinters and CRT's using 20 MA current loop or EIA interfaces. Priced at a low of $1425 per unit with discounts available. Digital Equipment Corporation, Customer Spares, Parker Street, Maynard, MA 01754

TERMINAL TESTER 194

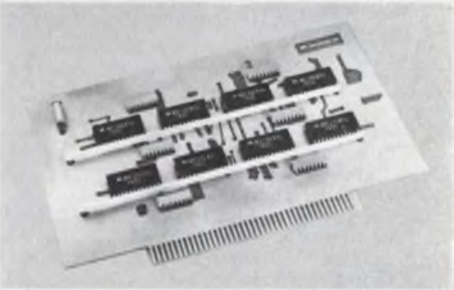
RECORDS ACCELERATION AND SHOCK Low cost, sensitive Accelograph™ simultaneously monitors and premanently records acceleration and low frequency shock in all directions within a given plane. No power or electronics needed. Stylus traces acceleration on replaceable recording disc that can be resurfaced in field. Ranges of 1-50G. Ideal for shipping containers to record abuse in transit, monitor dynamic vehicle tests. Humphrey, Inc., 9212 Balboa Ave., San Diego, CA 92123. (714) 565-6631

SHOCK RECORDER 195



Activate gas discharge readouts! Custom designed and produced DC-to-DC power supplies to activate gas discharge displays, or for other applications. Regulation I/O options, packaging (encapsulated, aluminum shell or open frame), size and configuration, heat dissipation, mounting (PC board pins, edge connectors), etc., can be tailored to meet individual specifications. Price and delivery discussed after specifications are submitted. Endicott Coil Co., Inc., 31 Charlotte Street, Binghamton, N.Y. 13905 (607) 797-1263.

CUSTOM DESIGNED POWER SUPPLIES 196



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MINI/BUS 197

Overcurrent Protector, manual reset eliminates fuse replacement. Convenient panel mounting. 19 fractional ratings from 0.1 to 5 amp. Other models up to 400 amp. Trip-free and fool-proof, UL and CSA approved. High quality, low cost $1.33 ea. in 1000 lots. E-T-A Products Co. of America, 7400 N. Croname Rd., Chicago, Ill. 60648. Tel: (312) 647-8303. Telex: 253780.

CIRCUIT BREAKER 198

Advertiser's Index

**Advertisers in non-U.S. edition*

TWO-MINUTE QUIZ.

There are two major electronics directories to assist engineer/specifiers in doing their jobs. How do they rate in a head-to-head editorial comparison?

1. "Which provides the greater number of product headings in its Product Category?"

   GOLD BOOK has 5182. EEM has 3335.

2. "Which furnishes the greater number of pages in its Product Directory?"

   GOLD BOOK has 542. EEM has 255.

3. "Which provides more pages in the Trade Name Directory?"

   GOLD BOOK has 33. EEM has 24.

4. "Which supplies the greater number of pages in the Manufacturers Directory?"

   GOLD BOOK has 397. EEM has 338.

5. "Which furnishes the larger number of manufacturers?"

   GOLD BOOK has 6771. EEM has 3300.

What more need be said, except to ask one additional question:

6. "Which leads in circulation in the increasingly important foreign market?

   GOLD BOOK has 13,000. EEM has zero.

On top of all this, GOLD BOOK rates are lower than EEM rates by far!

ELECTRONIC DESIGN'S GOLD BOOK WORKS WORLDWIDE!

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Product Index

Information Retrieval Service. New Products, Evaluation Samples (ES), Design Aids (DA), Application Notes (AN), and New Literature (NL) in this issue are listed here with page and Information Retrieval numbers. Reader requests will be promptly processed by computer and mailed to the manufacturer within three days.

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Laser Beam Digital Watch

Never press another button, day or night, with America's first digital watch that glows in the dark.

Announcing Sensor's new Laser 220—the first really new innovation in digital watch technology.

Would you do this with your solid-state watch? Of course not. Most solid-state watches require care and pampering but not the Sensor. You can dunk it, drop it and abuse it without fear during its unprecedented five-year parts and labor warranty.

It's ingenious, it's simple and it makes every other digital watch obsolete. Scientists have perfected a digital watch with a self-contained automatic light source—a major scientific breakthrough.

SELF-CONTAINED LIGHT SOURCE

The Laser 220 uses laser beams and advanced display technology in its manufacture. A glass ampoule charged with tritium and phosphor is hermetically sealed by a laser beam. The ampoule is then placed behind the new Sensor CDR (crystal diffusion reflection) display.

The high-contrast CDR display shows the time constantly—in sunlight or normal room light. But, when the room lights dim, the self-contained tritium light source automatically compensates for the absence of light, glows brightly, and illuminates the display.

No matter when you wear your watch—day or night—just a glance will give you the correct time. There's no button to press, no special viewing angle required, and most important, you don't need two hands to read the time.

Replace the battery yourself by just opening the battery compartment with a penny. Free batteries are provided whenever you need them during the five-year warranty.

A WORRY-FREE WATCH

Solid-state watches pose their own problems. They're fragile, they must be pampered, and they require frequent service. Not the Laser 220. Here are just five common solid-state watch problems you can forget about with this advanced space-age timepiece:

1. Forget about batteries The Laser 220 is powered by a single EverReady battery that will actually last years without replacement—even if you keep the 220 in complete darkness. In fact, JS&A will supply you with the few batteries you need, free of charge, during the next five years. To change the battery, you simply unscrew the battery compartment at the back with a penny and replace the battery yourself.

2. Forget about water Take a shower or go swimming. The Laser 220 is so water-resistant that it withstands depths of up to 100 feet.

3. Forget about shocks A three-foot drop onto a solid hardwood floor or a sudden jar. Sensor's solid case construction, dual-strata crystal, and cushioned quartz timing circuit make it one of the most rugged solid-state quartz watches ever produced.

4. Forget about service The Laser 220 has an unprecedented five-year parts and labor warranty. Each watch goes through weeks of aging, testing and quality control before assembly and final inspection. Service should never be required. Even the laser-sealed light source should last more than 25 years with normal use. But if it should require service anytime during the five year warranty period, we will pick up your Sensor, at your door, and send you a loaner watch while yours is repaired—all at our expense.

5. Forget about changing technology The Sensor Laser 220 is so far ahead of every other watch in durability and technology that the watch you buy today, will still be years ahead of all others.

THE ULTIMATE ACHIEVEMENT

Other manufacturers have devised unique ways to produce a watch you can read at a glance. The new $300 LED Pulsar requires a snap of the wrist to turn on the display, but the Pulsar cannot be read in sunlight. The new $400 Longine's Gemini combines both an LED and liquid crystal display. (Press a button at night for the LED display, and view it easily in sunlight with the liquid crystal display.) But you must still press a button to read the time. All these applications of existing technology still fail to produce the ultimate digital watch: one you can read under all light conditions without using two hands. Until the introduction of the Sensor.

PLENTY OF ADVANCED FUNCTIONS

Sensor's five time functions give you everything you really need in a solid-state watch. Your watch displays the hours and minutes constantly, with no button to press. But depress the function button and the month and the date appear. Depress the button again and the seconds appear. To quickly set the time, insert a ball-point pen into the recessed time-control switch on the side. It's just that easy.

Sensor's accuracy is unparalleled. All solid-state digitals use a quartz crystal. So does the Sensor. But crystals change frequency from aging and shock. And to reset them, the watch case must be opened and an airtight seal broken which may affect the performance. In the Sensor, the crystal is first aged before it is installed, and secondly, it is actually cushioned in the case to absorb tremendous shock. The quartz crystal can also be adjusted through the battery compartment without opening the case. In short, your watch should be accurate to within 5 seconds per month and maintain that accuracy for years without adjustment and without ever opening the watch case.

The new exclusive laser-sealed tritium and phosphor light source is a thin solid-state tube that automatically illuminates the display when the lights dim.

STANDING BEHIND A PRODUCT

JS&A is America's largest single source of digital watches and other space-age products. We have selected the Sensor Laser 220 as the most advanced American-made, solid-state timepiece ever produced. And we put our company and its full resources behind that selection. JS&A will warranty the Sensor (even the batteries) for five full years. We'll even send you a loaner watch to use while your watch is being repaired should it ever require repair. And Sensor's advanced technology guarantees that your digital watch will be years ahead of any other watch at any price.

Wear the Laser 220 for one full month. If you are not convinced that it is the most rugged, precise, dependable and the finest quality solid-state digital watch **in the world**, return it for a prompt and courteous refund. We're just that proud of it.

To order your Sensor, credit card buyers may simply call our toll-free number below or mail us a check in the amount indicated below plus $2.50 for postage, insurance and handling. (Illinois residents add 5% sales tax.) We urge you, however, to act promptly and reserve your Laser 220 today.

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TIP 29B	RCA 29B	TIP 31B	RCA 31B	TIP 41B	RCA 41B	DTS 413	RCA 413
TIP 29C	RCA 29C	TIP 31C	RCA 31C	TIP 41C	RCA 41C	DTS 423	RCA 423
						DTS 431	RCA 431
TIP 30	RCA 30	TIP 32	RCA 32	TIP 42	RCA 42		
TIP 30A	RCA 30A	TIP 32A	RCA 32A	TIP 42A	RCA 42A		
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