IC performance is improving with new and better fabrication techniques. Advances in double diffusion, ion implants and the polysilicon process are increasing digital-chip speeds and circuit density. Dielectric isolation cuts cross-talk to a minimum in linear circuitry. For details of the latest IC technology, turn to page 42.
Only Bourns is qualified to all 18...

A medal to Bourns from Bourns — slightly arrogant, but well deserved. We examined all competitive Mil-Spec Trimmer capabilities and found that no one even came close to the sheer number of approvals we’ve achieved...eighteen in all! And they’re manufactured with the same dedication to quality, service and value that has made Bourns Number One in trimmers for twenty-five years!

**WIREWOUND**

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<tr>
<th>Style</th>
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**CERMET**

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<td>RJ32</td>
<td>C.F</td>
<td></td>
<td>5/8 long DIP</td>
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...and at a new level of reliability

Not only did we invent the trimming potentiometer in 1952, but we’re reinventing it all the time. Patented design innovations incorporated into our Mil-Spec line have brought a new level of reliability unequalled in the industry.

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HEWLETT PACKARD

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SSR UPDATE

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- 800 volts peak blocking voltage for high overvoltage transient immunity
- 480VRMS output voltage rating for reliable 3-phase switching
- 200V/μSec min. off-state dv/dt rating
- Steady state load current ratings up to 40 Amps

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B. 611 Series* 10, 15, 25 and 40A (to 600V peak) Optically isolated, zero voltage turn-on. Dual purpose screw/quick disconnect terminals.

C. 675 Series* Low profile (0.5" max) pc board SSRs. Output rating 3A up to 600V peak. Optically isolated, zero voltage turn-on.

D. 671 Series I/O Converter Modules. Special purpose SSRs for use in programmable controllers, machine tool controls, etc. Mounting panel available.

E. SerenDIP Series* TO-116 DIP package. Output rating 1A/280VRMS. Logic compatible 3 & to 10VDC input.

F. 970 Series MOVs High voltage transient suppressors designed specifically for use with all Teledyne AC SSRs.

*UL recognized/CSA certified
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86 Design high-performance processors with bipolar bit slices. With on-chip cycle times of 45 ns, the Series-3000 units let you build fast, flexible processors.
98 Trace FET bias curves on any oscilloscope, and save extensive computation time. A simple curve tracer can be made with relatively few parts.
100 Need a PIN-diode attenuator? An improved circuit provides a constant characteristic impedance, logarithmic control and temperature compensation.
111 International Technology

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115 Discrete Semiconductors: Fast fall-time power transistors handle large secondary breakdown energy.
118 Modules & Subassemblies: 24-channel, 8-bit a/d converter comes in just two 32-pin DIPs.
124 Data Processing: Superplotter draws dashed lines in four colors, doubles as printer with five type fonts.
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Cover: Cover designed by Art Director Bill Kelly.
24 bits of D to A from AMD.
Three new 8-bit monolithic digital-to-analog converters from Advanced Micro Devices: the AmDAC-08, Am1508 and SSS1508A. They're all MIL-STD-883 for free, and more. Look:

<table>
<thead>
<tr>
<th></th>
<th>Non-Linearity</th>
<th>Max Over Opr.</th>
<th>Settling Time</th>
<th>Resolution</th>
<th>Available</th>
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<td></td>
<td>135ns (max)</td>
<td>8 bits</td>
<td>NOW</td>
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<tr>
<td>Am1508</td>
<td>.19%</td>
<td></td>
<td>300ns (typ)</td>
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<td>NOW</td>
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<td>.19%</td>
<td></td>
<td>250ns (typ)</td>
<td>8 bits</td>
<td>NOW</td>
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And soon, there'll be even more members of this family. Call or write Advanced Micro Devices and ask for the Linear Integrated Circuits Data Book. No home should be without one.

Advanced Micro Devices
Bipolar LSI. N-Channel, silicon gate MOS. Low-power Schottky. Multiple technologies: One product: excellence.
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Abbott's hermetically sealed power supplies have run this gauntlet many times. Each and every unit is subjected to rigid quality control procedures and extensive testing at our factory to insure that it will pass the most important test — your gauntlet.

Please see pages 1836-1848 of your 1976-77 EEM (ELECTRON ENGINEERS MASTER Catalog) or pages 676-682 Volume 2 of your 1976-77 GOLD BOOK for information on Abbott Modules.

Send for our new 60 page catalog.

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We have openings at our home office in Rochelle Park, NJ. Call Mike Elphick at (201) 843-0550.

New but misleading

In our new-product article on Figaro Engineering’s semiconductor gas sensor (ED No. 1, Jan. 4, 1977, p. 162) we goofed when we said: “The gas sensor is claimed to be the first and only UL-approved detector of natural and propane gas.” What we should have said was “The gas sensor is the heart of Craft-Alarm, the first and only UL-approved detector of natural or propane gas.”

Boosting R&D output is a matter of opinions

Al Cookson’s timely comments on boosting R&D output (ED No. 25, Dec. 6, 1976, p. 100) were very refreshing and directly to the point.

Hopefully, Mr. Cookson will not object if I add an additional facet that has always been of special interest to me. Information retrieval is an often neglected, but valuable, tool for boosting R&D output, in addition to reducing unnecessary engineering time and expense. Mr. Cookson perhaps intended this as a specific for accomplishing point no. 2 of his list of “fundamentals.” However, I feel that this area is so important that it bears emphasizing.

It has been my personal experience over more than 27 years of patent practice that engineers, when assigned a new project, just can’t wait to grab a pencil and draw a line. Rarely do they make an effort to determine whether the same or similar lines have been drawn previously.

However, many company technical libraries, as well as conveniently located public libraries, have excellent collections of textbooks and trade periodicals readily available for examining the general state of the art. Lately, terminals for “online” information retrieval have also become readily accessible.

Many companies have internal patent departments with large collections of prior art. Very often, in limited fields, these collections may be more extensive than references available in the U.S. Patent Office Search Room. A visit to the patent department soon after a project is initiated should be a company must.

Arnold J. Eriessen
Manager
Patent Law Dept.
Allen-Bradley Co.
1201 S. Second St.
Milwaukee, WI 53204

Al Cookson’s ideas on boosting R&D output represent the narrow view of a large corporation clearly dedicated to marginally improving its existing products and perpetuating its older technologies.

His suggestion to beware of transient inventors and promoters of inventions is oblivious to the fact that half of the significant (continued on page 14)
If you assemble panels - use the number one team - AMP Action Pins with ECONOMATE Components.

Reliability goes up.
Costs go down.
Because the AMP Action Pin has a spring-section concept which eliminates broaching, rupturing, distortion, tearing, and damage to plated-thru walls.

That means fewer rejects.

The Action Pin concept not only provides .025" sq. I/O posts but comes in connector configurations such as contacts for card-edge applications, as well as SEM/NAFI blade-and-receptacle contacts. A unique feature of the connector housings is that they simply snap on after the contacts are inserted. This not only provides repairability but offers the opportunity of real estate savings.

Whatever your needs, AMP ECONOMATE components featuring Action Pins have been fully tested to give you extreme reliability in the most critical environments.

You can cut costs even more with AMP high production equipment which can insert up to 10,000 Action Pins an hour.

In coming to AMP you can be assured we will support you on the production line, in quality control, in sampling for prototypes and by working with you to aid future designs. Professional engineers deserve support—at AMP our international reputation has been built on providing it.

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For laboratory, production line or maintenance applications, the Model 1801 will meet most requirements for sensitivity, ruggedness and dependability. With the Model 1801 you can watch oscillator adjustments, monitor RF and audio frequencies precisely, do fast production testing, check critical countdown chains, calibrate signal generators and check CB frequencies.

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Specified accuracy better than 10PPM, 0-50° C. Maximum aging rate 10PPM/year.

The 1801 is compatible with prescalers that will extend its usability into the UHF range.

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B&K Precision
MODEL 1801, $240

MHz display of 3.579548 MHz input (AUTO mode)

KHz display of overflow of 3.579548 MHz input (1SEC mode)

B&K Precision
PRODUCTS OF DYNASCAN

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Now, analog output is just this simple.

You no longer need to assemble D/A converters, address decoders and interface logic to obtain analog output from your microprocessor-based systems. Burr-Brown has solved the problem completely—for most of today's popular microprocessors—with 32-pin DIP's that provide two analog output channels each and look like memory to your CPU.

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For analog input applications, you can combine one channel of an MP10 or MP11 with a few external components and use the microprocessor to perform the logic of a successive approximation A/D converter. The second channel continues to function as an analog output.

Both the MP10 and MP11 provide ±10V outputs with 8-bit resolution and throughput accuracy better than ±0.4% of full scale range. With a price of just $99 (100's), it just doesn't make sense to design your own analog I/O solutions. Send for details today. Write or call Burr-Brown, International Airport Industrial Park, Tucson, Arizona 85734. Phone (602) 294-1431.

If you're attending Electro '77, see us in Booths 2824-26.

Leaders in microcomputer I/O.

CIRCLE NUMBER 8
A WEALTH OF WIDGETS RIDES AGAIN.

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In today's ad, we continue the legacy with a new product line and a few wrinkles on some old favorites.

THE EVER POPULAR TO-3

If you're in the market for TO-3 power transistors, we can show you how to get top quality, fast delivery and good prices with a single phone call. Fairchild produces over 200 of the most popular JEDEC and house numbers. Ranging from 2 to 50 amps for transistors and 2 to 20 amps for Darlington. With VCEOs up to 350 volts. And extensive NPN and PNP capability. Tack on the most competitive pricing in the business and you've got a pretty good reason to call Fairchild next time you get lonesome for a good TO-3.

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Nobody loves a slow switch. That's why you'll never get one from Fairchild. Our switching transistors exceed JEDEC specs for speed and E5/15 across the board. And our board is pretty broad. We not only make a complete line of our own switches, but we also offer some of the most popular 2N JEDEC devices in the industry. We're offering spec-for-spec equivalents, but with more margin for performance.

Do yourself a favor. Take a look at our top-of-the-line 2N6251. Then compare it with anybody else's top-of-the-line switch. Ten times out of ten, Fairchild performance is going to come out on top.

YOU'VE SEEN THE PACKAGE, NOW READ THE BOOK.

We recently introduced a second-generation TO-92 package for Small Signal transistors. Offering the tightest AQLs in the industry. Such as .4% on DC electricals, .65% mechanical and .04% on opens and shorts. Plus die surface passivation for improved moisture resistance and scratch protection.

All this is made possible by a revolutionary Fairchild process called TWN. Now we've written a brochure about the wonders of TWN and how it makes our new TO-92 the most reliable package ever developed. Drop us a line and we'll send you a brochure.
GETTING ON THE RF BANDWAGON.

Who says Fairchild is low man on the RF totem pole? We just introduced a broad range of RF devices, including the Fairchild proprietary FTR series. Giving you such crowd-pleasing specs as: Guaranteed AGC limits, Higher FT, Lower capacitance. And a completely redesigned lead frame. Shielded. With TWN processing.

Our line looks like this:

<table>
<thead>
<tr>
<th>Device</th>
<th>Primary Application</th>
<th>Features</th>
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<tbody>
<tr>
<td>FTR118</td>
<td>Forward AGC IF Amplifier</td>
<td>PG = 29 dB(TYP) @ 45 MHz; NF = 2.8 dB(TYP) @ 245 MHz; Cb = 0.2 pF(TYP)</td>
</tr>
<tr>
<td>FTR129</td>
<td>Low Noise RF Amplifier/Mixer</td>
<td>PG = 25 dB(TYP) @ 200 MHz; NF = 2.5 dB(TYP) @ 200 MHz; Cb = 0.27 pF(TYP)</td>
</tr>
<tr>
<td>FTR129A</td>
<td>Common Base Oscillator to 1 GHz</td>
<td>fT = 1000 MHz(TYP); rbC = 4.5 ps(TYP); Crb = 0.60 pF(MIN) — 0.90 pF(MAX)</td>
</tr>
<tr>
<td>FTT158</td>
<td>Low Noise Forward AGC Amplifier</td>
<td>PG = 25 dB(TYP) @ 200 MHz; Cb = 0.25 pF(TYP)</td>
</tr>
<tr>
<td>FTR168</td>
<td>Low Noise Common Base AGC Amplifier</td>
<td>PG = 18 dB(TYP) @ 200 MHz; NF = 2.8 dB(TYP) @ 200 MHz; Cce = 0.12 pF(TYP)</td>
</tr>
<tr>
<td>FTR174</td>
<td>VHF/UHF Common Base Oscillator</td>
<td>fT = 1000 MHz(TYP); Crb = 0.35 pF(MIN) — 0.65 pF(MAX)</td>
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We’re also second-sourcing 18 of the most popular industry standards.

MPH502 MPH10 MPH20 MPH32 MPH540 MPH547
MPH07  MPH11 MPH24 MPH34 MPH542 MPH568A
MPH508 MPH19 MPH30 MPH511 MPH546 MPH569A

All in all, you can’t get better RF performance anywhere else.

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If you need some high current transistors you can really kick around, you’ve come to the right place. We make a line of tough transistors that provide up to 50 amps of current in complementary pairs. They’re just what you need for a wide range of rugged industrial applications.

The only thing easygoing about these devices is the price we get for them. Take a close look at the 1-99 prices listed here. You’ll find they average about 18% below our competition.

If you think these prices are appealing, wait till you see what we can do for you on large quantity orders.

AND NOW A WORD FROM OUR SPONSOR.

We’d sure like to load you up with facts and figures about our entire line of power and signal transistors. Especially any of the little devils that particularly strike your fancy. Write or call for our transistor selection package or contact your Fairchild sales office, distributor or representative today. Of course, the direct line at the bottom of this ad will get you a more immediate response.

Fairchild Camera and Instrument Corp., Transistor Products Group, 464 Ellis Street, Mountain View, California 94042.
Tel: (415)962-2094. TWX: 910-379-6435.
inventions that provide new technology and employment in this country are made by individuals outside big, established corporations.

His other suggestion against the brilliant invention shows the nearsightedness of his commitment to the short-term profit result and lack of motivation for serious innovation. In the last 14 years his company's standing for products honored is at the bottom of the list in a recent survey (Industrial Research, October, 1976, p. 24) — only for 2 out of 1400 products by 100 companies and even fewer from the output of companies much smaller in size.

As long as corporations keep putting their money into improvements of marginal products and neglecting the most prolific sources and goals of innovation, we will continue the waste accompanied by grand pronouncements of boosting R&D output with the management (whip) approach.

Let's face it: With Al Cookson's point of view we will wind up having large corporations with super-efficient R&D managements but with increasingly marginal and inefficient products. He could save a good portion of his R&D budget by running down to the Patent Office and looking over the most recent inventions and innovations by individual inventors that may fill his bill. Or he can consider hiring individual inventors or small business firms engaged in R&D to obtain the biggest bang for his buck.

James Constant
RCS Associates, Inc.
1603 Danbury Dr.
Claremont, CA 91711

I would not have given much thought to Al Cookson's article had it been titled "... Boosting D Output." However, the implication that his thoughts should be followed by R&D managers is erroneous. This is not the way to run a true R&D "railroad."

Al Cookson's management philosophy does not apply to the management of basic research, applied research, or even advanced development. Had he been at Bell Laboratories instead of Jack Morton we would not have had the transistor today, or had he been at the Office of Scientific Research and Development instead of Vannevar Bush, we would have lost World War II.

Unfortunately, the article does not show the efficiency of ITT's R&D. It would be interesting to speculate what that efficiency would be if Mr. Cookson used a more enlightened and holistic management philosophy.

The 2% of gross sales that ITT invests in R&D cannot compare with Hewlett-Packard's 9.4%. Business Week's criterion that high-technology companies spend more than 5% excludes ITT from this league — probably due to, or because of, its management philosophy.

Remember what happened to the railroads, because management did not realize that they were in the transportation-system business, and did not know what "research" meant.

J. S. Zumbado
Electronics Engineer and Student of R&D Management
15505 Norman Dr.
Darnestown, MD 20760

Mr. Cookson replies

I would only like to quote from a recent article by Jenkin Lloyd Jones, Editor of the Tulsa Tribune: "As I have grown older, I have become more and more intrigued with what works, and this is a very unsettling form of inquiry for much of what ought to work doesn't and much of what shouldn't work does." We at ITT have honed our R&D management approach for many years and it works for us. In 15 years (1960 to 1975), our sales have grown by 1400% ($800-million to $11,400 million) and our net income by 1300% ($30-million to $400-million).

Although we have made many acquisitions, a substantial percentage of this growth has been internally generated and dependent on successful R&D. However, in a field as difficult and complex as R&D management, there fortunately exists a great range of competitive philosophies that are constantly being tried by good companies.
The Intecolor 8001 CRT.  
Buy One or Buy One Hundred.  
Just $1495.*

That's the price tag we'll put on the Intecolor 8001 if you place your order right now for 100 or more units. $1495. That's also the price we'll give you on a one-shot cash basis on an Intecolor 8001 CRT evaluation unit. Now, we'll never get rich with a price structure like that, but we look at it this way. That price is an investment in your future. We know that once you get your hands on the Intecolor 8001, once you see what it can do, you'll be back for more.

And it's because you'll be getting an Intelligent, 8-Color CRT that'll outperform any CRT on the market on a dollar for dollar and character for character basis. And it's complete. You won't have to lay out more cash for a keyboard, or 8080 CPU, or any of the standard features you'd expect to find on a good color CRT. It'll be ready to go. You can put it to work as a stand-alone CRT, incorporate it into your present system, or use it to upgrade the CRT's in the systems you're currently marketing. Whatever your application, it'll work for you.

But if your needs call for a more sophisticated CRT, a CRT that'll give you higher-level functions — no problem. We'll be glad to work with you to help you come up with an options package to fit your requirements. Like additional RAM to 32K, Roll, Background Color, Light pens, Graphics, 48 Line X 80 Characters/Line and up to 64 Special Graphics Characters. You define your needs, and we'll give you the capabilities to get the job done. It's that simple.

But if you'd like to see for yourself, look over our rep list on the adjacent page and ask the rep in your area for a demonstration. Whatever your application, he can show you the right Intecolor 8001 CRT at just the right price.
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. We don’t think you’ll mind.

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ACROSS THE DESK

(continued from page 14)

large and small. In this free, highly competitive society, the optimum approach will succeed in time and its proponents will prosper.

Misplaced Caption Dept.

Sorry. That’s “Samson and Two Philistines,” by an unknown sculptor after Michelangelo. It hangs in the Frick Collection in New York City.

Full DACs are here

We were wrong in saying that single-chip conversion circuits, complete with reference, ladder network and output amplifier, were just emerging (ED No. 1, Jan. 4, 1977, p. 36). In fact, though many engineers prefer conversion chips without a built-in reference (so that, for example, several converters can share a common reference or a d/a converter can be used as a multiplying DAC), complete monolithic converters have been available for many years. The Precision Monolithics monoDAC-01, for example, a full 6-bit, single-chip DAC, was introduced in 1970. A 10-bit DAC, the monoDAC-02, was introduced in 1972. Both have internal reference and output op amp on chip.
AUGAT ANNOUNCES THE PC BREAKTHRU OF THE DECADE

The card you’re looking at is an ordinary printed wiring board with an extraordinary difference. There’s not a solder joint anywhere. Every component is plugged into place.

It’s this simple: Augat has invented a way to turn plated-through holes into plug-in sockets.

Think what that means: all the benefits of component plugability with no need for sockets or the headaches of soldering. You get socketed components with card spacing as low as .400".

And the cost? Less than the total soldered cost of typical inexpensive sockets.

Intriguing, yes? So is the way it works. At the heart of our new method, (which we call the Augat Holtite™ system), is a special adaptation of the long-proven, beryllium copper precision contact that we’ve turned out by the billions over the past decade for reliable component lead interconnections.

You simply insert the contacts into your plated-through holes, press them into place...

Augat contacts, magnified 7X...

and just like that you’ve got a component “socket” built right into your board. It’s that simple.

Another thing you’ll like: switching to our new Holtite system is totally painless. You continue to use the same artwork, drill tapes and process specs. Simply drill the holes to the recommended diameter.

As to mass loading the contacts into your boards, that’s easy too. We lease you a machine that does it automatically at a rate of 30,000 contacts an hour, which includes pressing them into place using a standard hydraulic press.

We’re confident our Holtite system is going to revolutionize PC component socketing, and we invite you to be a part of it.

To get started, order one of our Holtite prototyping kits (for $94.50) from your Augat distributor, or from us. It has everything you need (1,200 contacts, tools, instructions and test report) to try out our idea firsthand on your own boards. Give it a whirl — this week!

Order Kit No.
398-HK-001

Augat Inc., 33 Perry Avenue, P.O. Box 779, Attleboro, Mass. 02703. Tel. (617) 222-2202.

AUGAT®

Augat interconnection products, Isotronic microcircuit packaging, and Alco subminiature switches.

CIRCLE NUMBER 14
One source of ROMs overshadows all others

If you want 8K and 16K ROMs from the most skilled volume producer in the world, there's just one place to go.

Electronic Arrays pioneered the technology of MOS ROMs seven years ago. Introduced the world's first big 16K ROM over three years ago. Has now delivered 22 billion bits of ROM with over 1800 different mask programs to more than 400 customers worldwide. And every month we deliver another billion bits or more—in 18 different models including the popular 8316E ROM and the 2708 EPROM.

At other semiconductor companies, ROMs are only one of dozens of diverse products competing for attention. At EA, ROMs are the very heart of our business. So your order for ROMs receives the highest priority. You can expect very rapid delivery. And very low prices—because we've learned to fine-tune our production process to a peak of efficiency.

Price and delivery are excellent for another reason too. We make everything from the mask to the final package in house. There are no subcontractors to boost the cost or delay delivery.

So next time you need ROMs come to ROM COUNTRY: Electronic Arrays, 550 East Middlefield Road, Mountain View, Calif. 94043. Phone us on our toll-free WATS line (800) 227-9962 or our regular line (415) 964-4321.

In Europe you can reach us at Aalsmeer, The Netherlands 02977-23722. In the Far East, at Tokyo (03) 591-5241.

ROM COUNTRY
Tracing signatures finds faults on µP boards

To track down faults on printed-circuit (PC) boards containing microprocessors, two firms have come up with similar approaches. Both borrow the cyclic-redundancy-check (CRC) technique from digital communications. This method, which guarantees error-free digital communications, has been refined into what John Fluke Mfg. Co. Inc.’s Trendar subsidiary calls “merged sequencing” and Hewlett-Packard Co. dubs “signature analysis.”

Cyclic-redundancy checks are applied by feeding a digital data stream through a shift register that has feedback taps. The feedback signals are applied to a modulo-2 summing network at the input to the shift register. Since the transmission is coded, the resulting sum is known; but an error in the transmission causes an error in the sum, and can be detected.

In PC-board testing, a known data stream is fed into the circuit’s input and a shift-register measurement made at each node of a known-good board. A signature is yielded for each point on the board in much the same way as feeding an analog signal into an analog PC board, under fixed conditions, yields a repeatable waveform at each node on the board. By tracing faulty signatures back through a board, as in tracing erroneous waveforms through a troubleshooting tree, a technician can locate the faulty node precisely.

Merged sequencing is incorporated in Trendar’s new automatic board tester, the Model 3040A, which the firm calls the first low-cost system designed specifically for boards containing microprocessors. The system, which is priced from $60,000 to $95,000 depending on options, drives a board under test with pseudorandom data streams at rates up to 5 MHz. To test the microprocessor itself, which requires data in the proper syntax and cannot employ pseudorandom signals, user-defined test sequences can be processed at rates up to 1.5 million input words per second.

These bit patterns are used in go/no-go board testing. If the board fails, the test-system operator is directed to probe individual nodes. The tester determines the signature at that node. If the signature does not match the stored known-good signature, the tester directs the operator to probe nodes further back on that signal path to determine the point at which the fault first appears.

Earlier Trendar testers used a similar troubleshooting-tree approach to isolate faults, but simply counted transitions at each node. The more sophisticated merged sequencing measurement is more apt to find errors, says Don Allen, vice-president of marketing at Trendar, adding: “Transition counting approaches the error-detecting quality of CRC, but doesn’t reach it.”

Regardless of the subtlety of the fault, signature analysis yields a 99.998% certainty of spotting a faulty bit stream, according to Hans Nadig, project manager at HP’s Santa Clara division. To help engineers apply the technique, HP has introduced the Model 5004A signature analyzer, a $990 instrument designed for field-service as well as laboratory use.

The signature analyzer is applied to manual troubleshooting much like the Trendar automatic system for fault isolation.

One major difference is in HP’s readout: a nonstandard hexadecimal character set (0123456789AC-FHPU) is compatible with seven-segment displays and avoids the difficulty of differentiating between the 6 and the b of the usual notation (0123456789AbcdEF).

The only difficulty with signature analysis, notes Nadig, is that the product must be designed from the beginning with testability and signature analysis in mind. “From my experience, retrofitting to employ signature analysis into existing equipment doesn’t work,” says Nadig. When a product is in development, it is simpler to incorporate the necessary data-stream generators into the software and provide a means for breaking feedback loops to prevent a fault from disturbing properly functioning nodes.

Novel rotary printer prints 2200 characters/s

Weighing only 3 lb and with just nine moving parts, a printer is still able to bang out 2200 characters per second because of its unusual rotary printing mechanism.

The unique and simple device, introduced by SCI Systems, Inc., Huntsville, AL, doesn’t take up too much space—4 x 5 x 9 in. But even so, it can print 136-column computer data with standard 10-character/in. spacings. A 5 x 7 dot matrix is used to form characters, and print resolution is 70 lines/in.

The rotary-design printer consists of three main elements: a drive unit, a 400-ft roll of paper, and a printhead, which is the one replaceable part—but has a life exceeding 25-million characters. One small dc motor drives all elements of the printer: it belt-drives a central shaft, which supports both a code wheel at the rear of the drive unit, and the printhead at the front. A single-paper-feed roller is driven from the shaft through a
Wang small business computer line expanded

"To double the range of its current small Series 2200 business computer line," Wang Laboratories, Lowell, MA, has introduced the first minidiskette-based desktop computer for small business, the PCS II; two larger computers, the WCS/25 and the WCS/40; and new interactive terminals, printers, IBM-compatible diskettes, multiplexers and communications controllers.

Besides minidiskettes, the expanded line makes extensive use of microprocessors, a new terminal-access method (TAM) and "mini-front-end" capabilities that permit intelligence sharing by multiple terminals in the WCS/25 and WCS/40.

A self-contained unit, the PCS II includes a large 1024-character CRT screen; a typewriter-like keyboard with separate numeric keypad and 32 special-function keys for data entry and control. Its high-speed processor has two memories, and the 8 kbytes of user-available memory is expandable to 32 kbytes.

In its basic configuration, the WCS/25 includes a Series 2200 processor with 24 kbytes of user memory and 42.5 kbytes of read-only operating system memory to store Wang's extended BASIC language interpreter. It also features two diskette storage devices, a 120-characters/s printer, a Model 2236 MXC μP-based "mini-front end" controller, and three Model 2236 interactive terminals.

The WCS/40 is built to meet higher volume and more stringent form-filling and form-processing requirements than the WCS/25.

A fully equipped PCS II, including a high-speed printer, costs about $9100. A typical WCS/25 is priced at under $30,000, and a WCS/40, at $48,550.

CIRCLE NO. 319

Electric power may come from thermal noise

A long-unwanted phenomenon of electronics stands a good chance of becoming a useful energy producer — thermal noise voltages generated in resistors by elevated temperatures. To produce electrical power, a system based on this innovation will take the form of a thin, flat plate that theoretically can produce about 500 W per square meter of surface exposed to a hot sun.

Proposed by inventor Joseph Yater of Energy Unlimited, Lincoln, MA, the new energy-producing concept was the only one designated suitable for funding by the National Bureau of Standards out of more than 4000 ideas examined. With a $40,000 grant from the Energy Research & Development Administration, Yater is proceeding with the initial stages of development.

There are three components, Yater explained to ELECTRONIC DESIGN. One is a planar, insulating substrate that holds the other two key elements. On the upper, or hot side, resistors are exposed to either the sun or another heat source. On the bottom side, planar diodes rectify the noise voltages produced by the resistors. The resistors are connected in series, the diodes in series-parallel.

The key to system operation is the fact that the noise voltages due to the thermal agitation of electrons in the resistors cover a band of frequencies up to 1 THz (=10^{12} Hz). These voltage fluctuations are coupled to the diodes through the capacitance formed by the resistor-insulator-diode sandwich structure.

News Briefs

Soon to be added to the growing list of μP-based-computer suppliers is Heath Co. of Benton Harbor, MI. Parts of the extensive product line Heath plans to offer are said to be coming from the Digital Equipment Corp. catalog. And both Heath, by far the leading supplier of electronic kits, and the Maynard, MA, minicomputer maker have clamped tight security on their product plans. Introduction appears to be set for August at the Personal Computing '77 Consumer Trade Fair in Atlantic City, NJ.

The first of its PIC 1650 single-chip microcomputers should be shipped by General Instrument Corp.'s Microelectronics Division in Hicksville, NY, within the next few weeks. The 1650 (see ED 23, November 11, 1976, p. 38) is expected to sell for $6 to 7 in moderate volume and less than $5 in large quantities. Delivery quotes are about 90 days, including ROM mask-making time.
The end of the incandescents.

The end of the incandescents is in sight. Our Brite-Lite® LED lamps outlast them by an average of 10X. When the incandescents were all you could get, there was no choice. Now, you’ve got Brite-Lites. The brightest ideas in LED lamps, yet.

Brite-Lites offer proven solid-state reliability with an average life of more than 100,000 hours and minimal power requirements. Brite-Lites are available in red, green, and amber. In your choice of current/voltage combinations with current limiting resistors from 1.6 to 20 volts — 10 to 30 milliamps. In a wide range of packages from convenient snap-ins to space-saving T² Lites.

With all of their limitations, incandescents are much less practical than LED lamps. Now is the time to brighten up your next panel or printed circuit board project with Brite-Lites. The brightest LED lamps in the business. Our fast delivery won’t hold you up either. All you have to do is call or write, today. Join the thousands who’ve seen why the end of the incandescents is just the beginning for Brite-Lites by Data Display Products.

The brightest LED lamps in the business.
Are you getting the technology you need in RF linear power?

Transistor die metalization, 3300 magnification.

Conventionally-etched die metalization. Etched scalloping in metal fingers produces current crowding and resultant failure through metal migration.

TRW etchless gold die metalization. Exact finger definition holds original design values intact, eliminates current crowding and metal migration.

A small thing? Not when you consider how current crowding can blow a good product design. This time/temperature defect in RF power transistors and hybrids is normally not exposed until failures occur in the field. • Spend a minute thinking about what TRW’s gold metalized power devices could do for the reliability of your next design, and then look over our linear chart on the following page.
You get it all in every TRW RF linear power device.

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Aren't they worth checking out? Use this coupon, or call Warren Gould at (213) 679-4561 for complete specs and samples of TRW RF discretes and hybrids—milliwatts to kilowatts, 1 MHz to 4 GHz. When it comes to RF linear, we're ready to help.
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The industry’s broadest line to meet commercial, industrial and military requirements...including everything from the most stripped-down wirewound to glass-enclosed metal film.

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Space-saving SIP and DIP models, including the first DIP qualified to MIL-R-83401. Very competitive prices plus one-week delivery from stock.

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Dale’s low profile 700 Series and single turn 100 Series (3/8” square) interchange with all popular competitive models and give you performance advantages in a wide choice of pin spacings.

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Expanded production makes Dale a major supplier of roll-coated chokes. And, we're gaining steady acceptance as a source of filter inductors and low power laminated transformers.

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Get excellent price and delivery on .156” edgeboards and 2-piece rack and panel styles plus board interchangeability with a wide range of other styles.

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Dale offers overvoltage protection for everything from lightning to transients within a circuit. Exclusive patented design with Mil. qualification.

CRYSTALS
Our newest line. Includes compact, low-cost clock oscillators for DIP applications plus temperature compensated oscillators, voltage controlled oscillators and a broad range of filter designs.

It's a fact. Dale has more of the discretes you need. More standard parts from a strong distributor network ...more capability to meet your special needs...more of the quality you’ve come to expect from Dale. It adds up to more mileage for your efforts and your budget when you call your man who sells Dale.
Users and manufacturers don’t speak the same \( \mu P \) language

“We’re fed up with trying to master a new language every time another manufacturer develops a microprocessor.”

That’s what many users were saying at a panel discussion on standardizing low-end microprocessors at the 1977 International Solid-State Circuits Conference in Philadelphia. Attendees let loose their ire at the \( \mu P \) manufacturers, who did little more than describe their available processors.

If anything, the lack of standardization from vendor to vendor was thrown into the limelight.

Those who attended another panel discussion on high-performance microprocessors were not as upset with the lack of standardization. But the vendors, who in the past would let the proverbial cat out of the bag, revealed little in the way of upcoming products.

Within low-end product families most vendors offer compatibility from model to model. For example, Joel Cyprus of Texas Instruments (Dallas, TX), Gordon Smith of Rockwell (Anaheim, CA) and George Reyling of National Semiconductor (Santa Clara, CA) discussed their companies TMS-1000, PPS-4 and COPS Series, respectively. But, there is no easy way to switch from one series to another, protested irate users, adding that a “universal” development language is needed, which can be shared by everyone.

By using a pseudo-NMOS structure instead of normal CMOS design, engineers at Bell Laboratories managed to reduce the complexity and size of the gate logic in their 8-bit CMOS microprocessor.

This universal language the users proposed should be supported by all low-cost-\( \mu P \) vendors so that any program developed can be easily converted into the specific op code for the \( \mu P \) selected. But the vendors disagreed and stressed the inefficiency of the final op code.

According to the manufacturers, the user doesn’t want compatibility so badly that he’s going to sacrifice performance in the \( \mu P \) chip to get it. It’s too early to talk about a standardized instruction set, claimed both Smith, Manager of Systems and Logic Design at Rockwell and Claude Alleaume, Director of \( \mu P \) Engineering at Fairchild (Mountain View, CA), “Each one of the machines developed by now has a very unique history and has its own place,” continued Alleaume.

In the meantime, manufacturers are still “hard at work” developing new low-cost processors so that users can extract the optimum dollar/performance tradeoffs.

Intel (Santa Clara, CA) has opted for a new language set in its 8035/8048/8748 series of one-chip microcomputers, pointed out Henry Blume, Program Manager for the 8048. The 8748, when announced late last year, was a revolutionary design—not only did it contain a microprocessor with over 90 instructions but 1024 bytes of ultraviolet-erasable programmable read-only memory (UV EPROM)—all on a single chip.

Texas Instruments is going a different route, said Joel Cyprus, who is Manager of Systems and

What's better than one \( \mu P \) on a chip? Why two, of course. Combining both a bit and byte-oriented processor on a single chip, Intel has been able to make programmable controllers from the same basic chip.

The following editors contributed to this report: Dave Bursky, Andy Santoni, Stanley Runyon and Jim McDermott.
Here's how Data General's NOVA 3/D system stacks up against the competition.

The facts speak for themselves. For $37,610, Data General's new NOVA 3/D gives you more system, software and support than any comparable computer. And we deliver in 60 days.

Any way you look at it, it all stacks up in your favor. For more information and our brochure, call or fill out and return the coupon.

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CIRCLE NUMBER 18
Applications. “We currently offer the TMS-1000 series of PMOS microcomputers and will soon introduce an NMOS equivalent of the TMS-1000 called the TMS-2000, which will be instruction-compatible but offer better speed performance.”

By year’s end, an all-in-one 16-bit microcomputer will be introduced as well. Dubbed the 9940, it will use a subset of the TMS-9900 instruction set and have onboard ROM, RAM and I/O capability, but will not be expandable.

Owen Williams, Motorola’s Manager of Systems and Marketing (Austin, TX), unveiled plans for two more μPs by the end of 1977. The 6801, an all-in-one 8-bit processor, will contain ROM, RAM, timer, clock and I/O on a single chip and be 6800-instruction-compatible. Also on the way is a μP called the 6802, which will contain 128 bytes of RAM and a clock and be 6800 instruction compatible.

There are hidden standards, too

Even though there is no apparent effort to standardize language, most of the manufacturers’ approaches are similar, said Howard Raphael, Product Manager for Intel. All of them are interested in the same features—I/O, high integration, low cost, and so on.

The same situation exists for the high-performance microprocessors—many of the μPs offer similar features although every company uses a different software set. But the panel discussions on high-performance processors revolved around several technology developments—such as device scaling, integrated-injection logic design, 5-V EPROM design, CMOS-on-sapphire and closed-loop CMOS—as well as a few new architectural and circuit designs.

For instance, Hewlett-Packard of Palo Alto, CA, has crammed a 16-bit CMOS microprocessor into a chip only 34 mm². By taking full advantage of CMOS-on-sapphire to cut capacitance losses, the processor can operate at a 6.7-MHz clock rate and dissipate only 0.5 W (with a 12-V supply). However, this μP can’t be purchased by itself—it’s designed for controller applications within HP instruments and computer equipment.

RCA, Somerville, NJ, in research funded by a government contract, found a way to reduce the size of the CMOS transistor cell and increase speed by eliminating the guardband usually needed between n and p-channel devices. The closed CMOS logic is self-guardbanding and the transistor capacitance is low. As a result, dynamic circuits can offer five times the speed of standard CMOS. Used in the company’s 1802 μP, the C-L design packs transistors in a 238 × 172-mil chip.

By going to a pseudo-NMOS design, Bell Laboratories’ designers in Murray Hill, NJ, can pack 7000 devices in a 220 × 230-mil CMOS chip. Noncomplementary structures for certain portions of the logic result in a processor with the functional density of NMOS but with the power dissipation and noise margins approaching CMOS.

Exploiting its Isoplanar version of integrated injection logic (IPL), Fairchild has developed a 40-pin 16-bit μP that executes the same instruction set as the Nova 1200 series of minicomputers. Called the 9440, the chip measures only 182 × 189 mils and can operate from a 5-V supply and a 1-V, 180-mA current source. One unusual feature of the 9440 is its 4-bit accumulator—instead of performing a full 16-bit operation like all other processors, it does four consecutive 4-bit operations. This method reduces the general logic functions.

Getting “the mostest into the leastest,” Intel has pushed device density to 0.41 devices per square mil—about four times that of its original 8080 μP. On a chip measuring 218 × 244 mils, the company has managed to pack 22,000 transistors in the form of two processors. Designed to be microprogrammed at the mask level, the dual processor circuit can thus be made to perform floppy-disc control, synchronous data-link control, or any other function.

The basic chip has a byte-oriented processor with 46 instructions, a 1.25-μs execution time, and almost 7000 bits of control-store program space. Also on the chip is a bit-oriented processor, with 3300 bits of control-store memory.

Another circuit planned by Intel is a CRT controller, also based on the dual processor chip. Based on its recently developed 5-V EPROM technology, Intel will soon release a user-programmable, universal I/O circuit, the 8741/8041. The programmable circuit is expected to hold 1024 bytes of UV EPROM like the 8748, and take only 2.5 μs to execute instructions. And by the end of this year, further circuit development should increase transistor density to 30,000 devices on a 200 mil² chip.

Other μP peripheral circuits, such as a/d and d/a converters, are also getting some new twists. For instance, Precision Monolithics of Santa Clara, CA, described a novel converter trim technique, that quickly zaps diodes in current sources under computer control instead of doing time-consuming laser trimming of deposited resistors. (See “First Monolithic 12-bit DAC,” ELECTRONIC DESIGN, No. 4, Feb. 15, 1977, p. 34).
PMI announces the new 108A.

Do you want to know the real inside story of our new 108A/308A precision low power op amp? Here it is, without names in order to protect our customer. Fact is, this customer came to us and asked if we could make some 108A's that met 108A specs. We tried and couldn't. But we found out why nobody else could, either; it was simply designed wrong.

So we redesigned it as a 108A. Corrected the unbalance which caused the high $TC_{V_{OS}}$. Gave it our zener zap treatment. Plus ion implantation. And the kind of pricing high volume production parts deserve.

Result? Check with your distributor. He has 108A's on his shelf right now. And they work. Up to MIL-M-38510/101D-04 specs. Processed to MIL-STD-883A Level B. $V_{OS} \leq 0.5mV$ Max.; $TC_{V_{OS}} \leq 5\mu V/^{\circ}C$ Max.

Just ask for it by name: PMI's new 108A/308A. The one that works.

It works.
MOS memory performance matches bipolar in medium-speed range

The relentless pursuit of bipolar speed by MOS memories continues. But even though today's MOS memories match last year's bipolar speeds, the bipolar circuits are getting even faster. In fact, one bipolar RAM described in a paper at the International Solid State Circuits Conference accesses in only 7.5 ns. However, MOS devices maintain their leads in high density and low power dissipation.

MOS and bipolar memories are really in a race at the medium-speed range (100-ns access time) according to Andrew Varadi, Director of Engineering for memory components at National Semiconductor (Santa Clara, CA). A MOS RAM from National is close in performance to medium-speed bipolar RAMs built with I-L technology, claims Varadi, adding that MOS circuit performs almost every function of the I-L circuit.

Scaling improves density

One of the methods now commonly used to increase memory density and performance is scaling. By shrinking the size of each device on a chip while keeping constant size ratios between gate, source and drain areas, the operating speed of the device can be increased and more memory locations fitted on the same-size chip. "In both the MOS and bipolar areas, there is a significant amount of scaling and shrinking going on," says Varadi, adding that "speed, die size, yield—everything is in favor of scaling."

Taking advantage of device scaling, Intel (Santa Clara, CA) has improved the access time of its 4-k static RAM. An n-channel MOS device, the memory has a typical access time of 45 ns, about 30% better than other available MOS RAMs. (At the 1976 conference, Intel described a 70-ns, 1-k MOS RAM.)

"Reducing the physical parameters of the MOS device by a fixed scaling factor increases circuit density and performance while decreasing active circuit power," notes Intel's Richard D. Pashley. The advanced technology uses polysilicon gate lengths under 4 μ and a gate-oxide thickness less than 1000 A.

The speed-power product, commonly used as a figure of merit, is 1 pJ (for the 4-k RAM) using an 11-stage ring oscillator with stage fanout of 3. In comparison, a conventional 6-μ gate, NMOS circuit has a speed-power product of 4 pJ.

Hold that ECL RAM

But no MOS RAM can match the access time of a 1-k ECL RAM developed by Nippon Telephone and Telegraph and Fujitsu Ltd. in Japan. With a typical access time of 7.5 ns, it's twice as fast as even the fastest ECL RAM previously reported. The Japanese memory consists of four blocks, each 256 words by 1 bit. Each block can be selected independently by four block-select terminals, so the device can be configured as 256 words by 4 bits or 1024 words by 1 bit.

Typical operating power is 832 mW for the ECL RAM and 500 mW for the Intel 4-k MOS part. But while these numbers may sound comfortably small, they may be too high for large systems that pack many memory chips on a single board.

A 4-k static RAM built with CMOS technology is aimed at such high-density applications. Designed by Tokyo Shibaura Electric Co. Ltd. of Japan, the circuit has a speed-power product of 10 nJ—a fraction of an NMOS RAM's. Since the standby current of the Toshiba part is a minute 0.1 μA—comparable to a battery's natural discharge current—battery backup systems should be easy to set up.

In the NMOS area, Mostek (Carrollton, TX) design engineer Vernon McKenny described a 4-k static RAM that features an operating power of 80 mW and operates from a single 5-V power supply. "Historically, 5-V static MOS RAMs have been slow, or have had high operating power and high standby power," says McKenny.

The Mostek 4104, on the other hand, has a typical access time of 150 ns and standby power of 8 mW, in addition to its low operating power. And the device operates from a 5-V ±10% supply. "The relatively small chip size (136 x 184 mil) and the extremely low standby power are obtained by the use of a new type of static cell in the matrix and dynamic circuit techniques in the clock generators, row and column decoders, and output buffers," notes McKenny.

Another Mostek RAM, designed for high-density applications, packs 16 kbits into 27,700 mil. This dynamic RAM is organized as 16 words by 1 bit—the same as all other 16-k RAMs. It can access a word in 150 ns and is housed in a standard 16-pin package. Seven address bits are multiplexed, and all clocks and other inputs are TTL-compatible.

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Comparison of memory technologies

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<th>Magnetic bubble</th>
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<tr>
<td>Storage (kilobits)</td>
<td>16</td>
<td>65</td>
<td>100</td>
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<td>1 to 10 ms</td>
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<tr>
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<tr>
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<td>0.25 to 0.4</td>
<td>0.2 to 0.3</td>
</tr>
</tbody>
</table>

scribed at the conference is a 4-k I-L design from Fairchild Camera and Instrument Corp., Mountain View, CA. Fully static, the memory is organized as 4-k × 1 and uses a walled-emitter Isoplanar process to obtain small memory-cell and chip size, as well as high speed. ECL techniques are used for internal circuitry to produce a typical access time of 35 ns and a current consumption of 185 mA at 5 V.

“Another figure of merit—access time × chip size × power dissipation—is considerably better for bipolar devices than for MOS devices. But the two technologies are converging,” according to Thomas A. Longo, vice-president and chief technical officer at Fairchild. “The cross-over point, if the trend continues, is in the 1980s,” he says.

L. W. Wu, manager of design engineering at Amdahl (Santa Clara, CA), looks at costs through the eyes of a user. “As we see it, there’s a doubling of memory density every two years, which allows the system designers to develop a product at lower cost.” But even as Mostek’s senior staff engineer Paul Schroeder notes that the trend has been toward quadrupling the size of memory every three years, he cautions: “We probably will not see that kind of growth continuing ad infinitum.

“We’re now at a point where there is very little density to gain just from reducing cell size,” Schroeder adds. “But there are still some things that could conceivably be done to get us to the next level of integration. I’m not necessarily suggesting that any of these are practical or are going to work out, though.”

Room for improvements

Schroeder points to three possible avenues for improvement.

■ One is to use fault-tolerant techniques in designing memory devices so that wafers that have dies where some bits aren’t functioning can be used in systems nevertheless.

■ Another possibility is to go to different computer architectures, which would allow high-density CCDs to be used for low-cost virtual storage.

■ A third alternative is to restore historical growth patterns through scaling, among other techniques. “If that is the route by which semiconductor memories develop further, it may turn out that there is some justification for a 32-k RAM,” says Schroeder. “There might be a sufficiently wide time window in which it’s the economical configuration.”

A 92,160-bit CCD memory tolerates faults in single-memory cells because any of the 36 blocks like this one can be disconnected from the circuit, leaving only good cells in operation.

A 92,160-bit CCD serial memory developed by Honeywell Information Systems (Phoenix, AZ) uses the first approach suggested by Schroeder. The memory is divided into 36 blocks, each containing 2560 bits of storage. Each block can be connected into the system via a laser link-burning test system that zaps shorting links at the wafer-probe level. Thus, only a small part of the device is lost due to a single bit failure—not the entire memory.

A 256-k CCD memory will be available by 1980, predicts Fairchild’s Longo. And Mark Guldry, manager of MOS-CCD memory design at Fairchild, notes that since the CCD structure is somewhat simpler than that of MOS RAMs, “the CCD memory can be somewhat denser,” and its price per bit potentially lower.

Just a few years ago, CCDs were referred to as “gap-filler technology,” recalls Al F. Tasch, branch head for advanced memory technology at Texas Instruments Inc. (Dallas, TX). But as CCD performance and chip size come closer to that of MOS RAMs (see table), Tasch predicts that CCDs find greater application in computer systems for virtual memory as well as for operating-system storage.

An while CCDs will never replace RAMs, in the view of Thomas L. Pafl, vice-president for research at Intersil Inc. (Cupertino, CA), they will find use in such applications as buffer storage in time-shared systems.
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Monolithic Memories

CIRCLE NUMBER 21

Electronic Design 7, March 29, 1977
Ultra-high-speed logic—more than just a promise in LSI

The 10-year-old promise of subnanosecond ICs may finally be kept—and with lower power consumption and larger scales of integration than ever before. Among the more impressive advances reported at the International Solid State Circuits Conference were bipolar ICs with propagation delays under 100 ps, 4-GHz GaAs MESFET ICs and a “masterslice” LSI circuit targeted at subnanosecond, random-logic applications.

Although high-speed ICs have been around for some time, high cost and a voracious power appetite have kept such chips prohibitive for high-volume applications. A new bipolar process—called Elevated Electrode IC (EEIC)—may change all that.

Elevated structure raises speed

Described by Tetsushi Sakai of Musashino Electrical Communication Laboratory, Tokyo, Japan, the EEIC process produces elevated electrodes (emitter and collector) from arsenic-doped polycrystalline silicon (P-Si). All interconnections and electrodes are formed without fine lithography or etching.

The elevated structure is processed to form an overhanging edge, which separates the P-Si from the lower level. When the metallization is applied, the various evaporated metals are isolated from each other by the shadowed area under the overhanging edge.

The high performance made possible with EEIC was demonstrated by an experimental, 16-stage ring oscillator and an 8-bit arithmetic and logic unit (ALU). In a low-power configuration, the oscillator shows a blazing propagation delay of only 102 ps and a minuscule power-delay product of 0.075 pJ.

An even higher-speed version clocks in at 85 ps and 0.187 pJ, respectively.

The ALU illustrated the high packing density also possible with EEIC: 180 gates are integrated within an area of $1.6 \times 1.0 \text{ mm}^2$—twice the density possible with conventional ICs. Observed propagation delay is 260 ps per gate.

Another way to build ultrafast logic is with GaAs MESFETs—a rising star in the world of microwave power devices. The advantages of GaAs for high-speed and, possibly, low-power logic circuits, were outlined at the conference.

From microwaves to logic

A 4-GHz frequency-divider IC may offer enormous potential for designers of frequency counters and other instruments. Described by Rory Van Tuyl of Hewlett-Packard Laboratories in Palo Alto, CA, the divider is made up of master-slave flip-flops and operates with sinusoidal inputs down to dc. However, the input sensitivity drops sharply with increasing frequencies above 3 GHz. And at 4 GHz, a rather large 3 V pk-pk input is needed in a 50-Ω system. But no problem exists for high-impedance uses.

The present MSI density capability of GaAs MESFET technology, explained Van Tuyl, is obtained at 25 to 30% yields—at least for a gated prescaler built with three of the frequency dividers. The future, according to Van Tuyl, should bring 6-to-8-GHz counting circuits as well as more complex chips that consume less power. The current divider chip measures $440 \times 400 \mu\text{m}$ and dissipates 160 mW.
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When you look at it that way, one thing becomes obvious. The cost of owning a multimeter is a lot more important than the price.

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A twist on the "usual" GaAs MESFET logic was reported by Hajime Ishikawa of Fujitsu Laboratories, Kawasaki, Japan. A 13-stage ring oscillator was built with normally-off FETs, instead of the usual normally-on approach. As a result, power-speed products as low as 0.026 pJ and propagation delays as low as 280 ps were obtained—but not simultaneously.

Keep it off to keep it fast

Compared with normally-on logic, the "off" technique dissipates one-hundredth the power—and even more drastic reductions are expected, claimed Ishikawa, as design and fabrication are refined. In fact, packing density as high as 800 gates/mm² may be achievable.

The key to fabricating normally-off MESFETs is to control the threshold voltage, $V_T$. Reported $V_T$ is 0.1 V, with a logic swing of 0.6 V, noise margins of 0.27 V and 0.06 V, an active-region dc gain of 2.5 and a $V_{PD}$ of 1.2 V. Some attendees doubted the validity of the noise-margin specifications, and the ensuing discussion failed to resolve the question.

When asked about the possibility of LSI MESFETs, Ishikawa responded that the cost of GaAs would be the limiting parameter, and LSI products wouldn't appear for another five years. But the importance of building circuits in LSI to reach high-volume markets was underscored by Walter Braeckelmann of Siemens AG in Munich, West Germany, who told of a bipolar "masterslice" LSI. Composed of ECL circuitry arranged in a complex, cell-based logic array, the LSI chip provides up to 700 gate functions at average speed-power products of 2.5 pJ per gate.

Instead of basic logic gates, the masterslice builds up logic with extensive series gating and complex functions. Each cell—the smallest repetitive part of the LSI chip—consists of 38 transistors and 16 resistors, which can be connected by various intracell wirings to arrive at different complex cell types.

Two basic layouts, with either 24 or 36 cells, have been built, with respective chip sizes of 36 and 28 mm². Up to 700 gate functions are possible with the 36-cell array, and 500 with the 24 cell. Typical performance levels for delay and power consumption are 0.5 ns, 9 mW for an OR/NOR gate (with one gate function), and 0.8 ns, 11 mW for a 4-bit multiplexer (with seven gate functions). Typical logic swing is 400 mV. Previous masterslices consisted of basic gates, and had a speed-power product of 17 pJ and 100 or 200 gates per chip.

In the Siemens design, intracell wiring is laid out just once. Internal gates are connected with LSI pins through level shifters to obtain high noise immunity, compatibility with standard ECL and outputs that can drive 50-Ω lines. The shifters can also perform logic functions or even act as latches in some cases.

Approximately 25% of the area of the 24-cell slice is occupied by the logic cells, another 25% by the intercell wiring, and 16% by the pads. The remaining real estate (24%) holds the supply lines and level shifters. Of the chip's 64 pads, 58 are used for logic, 6 for power. A special 64-pin ceramic package holds the LSI chip, and the package's thermal resistance is 20°C K/W at 3 m/s of forced air flow.

**Better I-L coming soon**

Speed and chip size, as well as getting more on the chip, dominated many of the sessions. For example, in the session on LSI technology, Tich T. Dao of Signetics, Sunnyvale, CA, showed how threshold I-L can save area over conventional I-L designs.

Present technology makes multi-level logic possible, and Dao described a deskewing FIFO that sets flags to indicate the one-quarter, one-half and three-quarter-full conditions.

The conditions are derived by enumeration of the ONEs in a 16-bit control register. For example, the one-quarter-full condition is true if four or more consecutive bits in the register are ONE. To indicate such a condition with conventional two-level circuitry requires 13 AND gates—much more than threshold I-L.

Although I-L is used mostly for linear ICs, a new fabrication approach outlined by Stanford University's Roderick Davies pushes I-L switching speed to better than 10 ns at 100 μW per gate—to three times faster than existing I-L processes.

**Digitial I-L foretold**

The new technique—termed Poly I-L—gains its advantages from an improved doping profile of the npn transistors and from formed polyepitaxy diodes acting as clamps or antisaturation devices.

The speed premium of Poly I-L is gained without increasing standard IC-process complexity too much, and without degrading linear-circuit capability or losing compatibility with low-speed, micropower I-L. What's more, such benefits open new doors to the construction of complex analog and digital functions on a single monolithic chip—a topic of considerable interest today.
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Fabrication and circuit progress leads to better microwave devices

Both the power output and frequency range of microwave devices have improved significantly this past year. One reason is better device fabrication technology. Another is the development of improved interfacing and matching circuitry. Not surprisingly, these key advances highlighted the microwave sessions at the International Solid State Circuits Conference. Chief among the developments discussed were:

- A 12-W, 4-GHz transistor amplifier with a new type of self-aligned bipolar structure.
- A bipolar transistor that uses state-of-the-art interfacing techniques to give a 7-dB CW power gain at 5 GHz and 5-W output.
- Deep-diffused, low-loss p-i-n diodes with breakdown voltages greater than 1500 V which can handle 5-kW peak power in a microwave phase shifter.
- A fixed-tuned Trapatt amplifier that is insensitive to diode parameter variations such as junction capacitance and breakdown voltage.
- A gallium-arsenide FET satellite communications receiver that provides a 60-dB gain with a maximum noise figure of 3.7 dB.

Bipolar amp gives 12 W at 4 GHz

A three-stage amplifier that relies on transistors made with a new kind of self-aligned bipolar structure delivers a high rf-power output using a 20-V-dc supply. The 12 W of rf is due to the improved high-frequency performance of the bipolar transistors and a well-designed power-combining circuitry, according to the amplifier's developers, Nippon Electric of Japan.

Seven transistors, each capable of delivering 3 W at 4.2 GHz are used in the three-stage amplifier. Transistor gain is 5 dB, with a 17% power-added efficiency in a common-base configuration.

The transistors are fabricated with polysilicon-emitter fingers that have an overhang cross section. The emitter structure is formed on the base region by employing a differential etching rate between the undoped polysilicon on top and the arsenic-doped polysilicon of the lower layers.

Output capacitance is decreased as a result of very narrow spacing between the emitter and base metallic contacts. These contacts are formed with a relatively simple alignment procedure, which consists of applying metallization after the polysilicon eaves are formed. Also, the parasitic MOS capacitance associated with the bonding pads is reduced by introducing a porous silicon dioxide layer about 2.5 μm thick beneath the bonding-pad metallization.

Each transistor assembly in the amplifier contains microstrip input and output-matching networks. The latter are connected to the power-combiner/divider of a double-section 3-dB quarter-wave hybrid.

One of the major advantages of the transistor's construction is the low junction operating temperature—below 120 C at a 50-C ambient.

Parallel cells give 5-W output

State-of-the-art input and output matching techniques are employed in a 5-GHz bipolar transistor developed by TRW (Lawndale, CA). In the transistor the outputs of six transistor cells are combined to deliver a total of 5 W. Applications for such devices abound in transmitter amplifiers for troposcatter communications, satellite communications systems and phased-array radars.

The transistor assembly's gain and stability are improved by two techniques. First, a reactive component in the output current at the common-mode base device is minimized by returning the collector-shunt inductor directly to the base bonding pad. Second, gain and stability are further increased by double-bonding to return the base more directly to ground.

The blocking capacitor for the collector shunt is placed as close as possible to the transistor chips. Not only does this reduce losses in the collector circuit, but also lowers the VSWR that the remainder of the circuit must tune out.

To further reduce losses at the internal-to-external circuit interface, the collector-matching network resides entirely on the substrate. The input circuit is a minimum-loss, low-pass network that permits maximum transfer of drive power while maintaining an acceptable input match. Over-all thermal resistance is reduced by spacing the six transistor cells widely apart.

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Electronic Design 7, March 29, 1977
### Microwave device performance and applications

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<td>➊ to ➋ above  ➋ Above  ➋ Poor performance repeatability</td>
<td>➋ above  ➋ Poor performance repeatability</td>
</tr>
</tbody>
</table>

A 3.13-GHz amplifier that can withstand variations in Trapatt-diode junction capacitance and breakdown voltage has been developed at the Hughes Research Center (Torrance, CA). The insensitivity of the amplifier voltage to diode parameter variations makes it particularly useful in applications requiring many of these devices, such as phased-array radar systems.

The twin-diode stagger-tuned amplifier produces more than 260-W peak power at 25% efficiency, report Hughes researchers. Several lots of mesa Trapatt diodes, with junction capacitances ranging from 5 to 16 pF and breakdown voltages from 65 to 95 V, have been operated in this amplifier without having to be retuned. Most of the diodes tested produce power-added efficiencies of at least 20% and power gains from 4 to 9 dB.

The amplifier's design is based on the bandpass impedance-transforming characteristics of a pair of coupled lines. To achieve high efficiency, fundamental mode extraction is also employed. The amplifier itself consists of a multiple-section bias filter, a pair of open-ended coupled lines about one-quarter wavelength long, and an SMA output connector.

**GaAs FETs make satellite receiver**

By using all gallium-arsenide FET active elements, the communications-satellite transponder receiver from RCA Ltd. in Montreal, Canada satisfies the stringent requirements of gain linearity and noise figure imposed on these high-performance systems. This FET receiver has a 60-dB gain with a 0.5-dB flatness over a 5.295-to-6.425-GHz input bandwidth and a 3.7-to-4.2-GHz output bandwidth. At the worst point in the band, the gain slope is 0.01 dB/MHz, and the noise figure is 3.7 dB. But the noise decreases to as low as 3.3 dB at the band center.

In the receiver, an input isolator is followed by a 6-GHz, two-stage low-noise GaAs FET amplifier whose output is fed to a 6/4-GHz mixer. The mixer has an over-all gain of 1 dB with a 9.8-dBm, 2.225-GHz local oscillator signal applied to the mixer-FET drain.

---

Electronic Design 7, March 29, 1977
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I²L and CMOS battle for lead as IC-technology race heats up

Monolithic IC technologies are expanding simultaneously on a broad number of semiconductor fronts. Rival chip fabricators are outlining each other by creating smaller chips with ever increasing numbers of integrated elements. These in turn provide such performance features as lower power, higher operating speeds, improved temperature characteristics and lower noise. Where the fabricators are unable to accomplish these goals with processing—diffusion, ion implantation, dielectric isolation—they rely on the ingenuity of their chip-circuit designers to overcome performance obstacles.

I²L is coming up fast

Probably the fastest moving technology today is I²L. The processing difficulties, which made this bipolar technology’s potential uncertain just two years ago, have been licked, and I²L is becoming useful for applications ranging broadly from wristwatches to microprocessors.

Not only does I²L give better packing density than MOS, but it provides better performance as well. And it’s giving MOS—its leading competitor—substantial competition in low-power devices.

I²L watch-circuit density has improved in the past few months. A watch-chip can now be fabricated on 20,000 mil² or less—a trend that will continue, according to Dean Tooless, vice president of engineering for Texas Instruments’ Semiconductor Group.

The I²L watch chips are optimized to consume minimal power. In LED watches the I²L power drain is the same as that of CMOS, about 5 μA at 3 V.

In some respects, I²L is even better than CMOS for LED watches, which need a 5-mA display-drive capability. Because I²L is a bipolar technology, bipolar transistor drivers can be put onto the I²L chip efficiently to get this capability.

But for an equivalent CMOS chip, the drivers—consequently the chip—are necessarily larger because of higher losses. (However, where the application doesn’t require a high current capability, CMOS is a good solution.)

Another advantage of I²L over CMOS is its ability to operate with a single 1.5-V battery, down to 1-V supply voltage. CMOS is more difficult to fabricate for these low voltages because it requires threshold voltages of less than 1 V.

High-performance I²L technology is tailored to applications that benefit from the inherent low power but require logic switching speeds close to or exceeding standard TTL. An example is TI’s 16-bit I²L 9900 microprocessor.

For this technology, propagation delay is about 20 ns at 100 μW per gate. A 5000-equivalent-gate device has only 0.5-W dissipation. Indications are that the present 20-ns technology can be reduced to 5- to 10-ns for complex logic functions.

Advances in I²L circuit density are being made at Motorola and Fairchild Semiconductor. Several Motorola custom I²L chips have gates in the 500-to-1000-gate complexity.

“Three years ago,” says Joe Brendel, manager of linear design operations, “we had only 70-to-100-gate complexity.”

Another version is I²L

Fairchild Semiconductor is using its version of I²L—isoplanar integrated injection logic (I²L)—for logic, memories and a new 16-bit “micromini” processor.

“We get greater densities per chip with I²L than with MOS technology,” says Thomas A. Longo, vice president and chief technical officer. “An I²L chip is about 60% the size of an isoplanar n-channel chip of equivalent density. For example, our 9408 microprogrammed sequencer chip, which is used with the four-bit slice microprocessors, is about 12,000 mil² and has a 1000-gate complexity.

“Another example, our recently announced 4-k dynamic memory, has 4096 bits on a 12,000-mil² chip. And we can shrink it even further. Also, it has a single 5-V supply, two supplies less than the number needed for MOS RAMs.”

After being hit hard as a technology during the recent recession,

Jim McDermott
Eastern Editor

Electronic Design 7, March 29, 1977
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CIRCLE NUMBER 26
CMOS is now making a strong recovery. JEDEC standards were established in 1976 for the first and new B-series of CMOS parts.

CMOS technology expanding

Significant CMOS advances are being made by RCA in watch chips, automotive control functions, and CB frequency synthesizers. To better compete against established watch chip suppliers like TI, National, AMI and Fairchild, RCA developed the low-voltage aluminum-gate process (LoVAG), a proprietary CMOS technology that is considerably simpler than the self-aligned silicon gate approach. According to RCA, the company is following a defect-density-tolerable approach both in the masks and in the process line—and moving ahead quickly.

"In the first LoVAG generation, the chips had about 5800 transistor equivalents on a 28,900-mil² chip," says Jerry Beckman, director of COSMOS at RCA. "The second generation has a device count of over 10,000 per chip. The latest design philosophy uses dynamic logic on one-half of the chip and static on the other to attain more circuit density."

Acquiring bipolar versatility

Originally developed for low-power digital circuitry, CMOS is now being tailored for a variety of strictly linear circuits as well as for chips containing both linear and digital devices. "You can make any analog function using today's CMOS technology," says Dave Bingham, engineering manager of Intersil's industrial timing group. "This includes op amps, other amplifiers, current or voltage sources, and signal conditioners."

"Intersil and probably the rest of the industry are capitalizing on CMOS silicon and metal gate technologies for combining both analog and digital signal processing on a single chip."

"Using circuit-design tricks," Bingham continues, "we can achieve, in CMOS, almost anything you can do in bipolar. But we can't get quite as high a speed, nor can we get the close match of bipolar."

"For example, we can operate CMOS counters at 20 MHz, where a low power Schottky process will go up to 70 or 80 MHz. We can match CMOS transistors better than 10 mV whereas bipolars can be matched within 2 mV."

A 3-1/2-digit multimeter CMOS chip has just been completed by Intersil with "everything on it," according to Bingham. It provides noise performance down in the 10-μV range, draws lower current and has smaller chip size than has been achieved to date in any other technology.

"We can even go into high power applications with CMOS," Bingham adds. "For example, we have products under development that can drive large LED displays requiring several hundred mA per digit, directly from the chip."

Linear and digital technologies are combined in this high-density variable-slope delta modulator by Motorola. A linear-compatible I-L process used in the digital portions of the chip reduces chip size by 5 to 1.

Semiconductor manufacturers are also improving on the ability to combine both bipolar and MOSFET devices on the same chip. For example, while dual op amps using the BIFET technology have been around for some time, TI has just announced the first quad version.

The technology advance was achieved, according to TI, with a thorough understanding of processing—particularly ion implantation—and clever chip circuitry.

Motorola is achieving linear-digital circuit compatibility through a variety of fabrication techniques such as low-power Schottky I-L technology, laser trimming, ion implanting, dielectric isolation and linear-compatible I-L circuitry.

While I-L and CMOS developments are taking the spotlight on the IC-technology stage, there are a number of other competing technologies making important contributions in different device areas.

Double-layer polysilicon process

One of the older technologies that has aided the development of the new 16-k RAMs is the double-layer polycrystalline silicon (poly-silicon) process.

"With this technology," says Derrell Coker, Mostek's applications manager for memory products, "we're able to build a 16-k dynamic RAM, like the MK 4116, with a chip size of less than 27,000 mil²—essentially the same size as its 4-k predecessor, which was fabricated with the single-level polysilicon process.

The double-level polysilicon process isn't new; it's been around as standard technology for CCDs. But it offers advantages for the new 16-k RAM products. Coker explains:

"The latest generation of 4-k RAMs are designed with n-channel silicon-gate processes. They use a single-transistor storage cell made up of a pass transistor and an associated storage capacitor.

In the 4-k RAMs these elements occupy individual areas. But with the double-layer polysilicon process, one is mounted over the other, so that area-wise it looks like one component instead of two."

Access times of the MK 4116 range from 350 ns to less than 150, depending upon its mode of operation in a microprocessor system.

Advanced fabrication and IC circuit-design techniques have smashed speed barriers for static NMOS RAMs. A new 4-k × 1 RAM in pilot production at Intel, the 2147, has a typical access time of 45 ns. Announced by Intel at the International Solid State Circuits Conference, the RAM achieves its speed not through new technology but by scaling down the physical dimensions of on-chip devices and providing on-chip substrate biasing. The RAM operates from a single 5-V supply.

The 2147 approach beats both I-L and CMOS on performance, Intel claims. But static 1-k RAMs with speeds equal to or better than..."
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the 2147 have been reported for VMOS devices.

**VMOS makes fast ROMs**

Vertical MOS (VMOS) is one of the newer technologies with great promise for high-speed, high-density logic and memories as well as for linear devices like high-power, high-frequency amplifiers. Unlike conventional planar MOS, with the source, gate and drain on the surface of the chip, the VMOS structure looks like an inverted pyramid etched into the chip.

In the VMOS structure the source is on top and the drain—like the collector of a bipolar transistor—is on the bottom. The gate is formed on the sides of the V-shaped notch between the source and drain. Current flows from the source to the drain along the sides of the notch.

A 16-k, 5-V static ROM made with this process has been demonstrated by American Microsystems. The 16-k device occupies a chip somewhat less than 17,000 mil—marked contrast to standard n-channel ROMs, which occupy an additional 5000 mil.

Because of the device structure, capacitance between the drain and the source is substantially reduced over conventional MOS cells. The result is an access time of 50 ns or less.

In general, however, this type ROM has a limitation. Because all its memory cells share a common source element, the substrate of the chips, independent control of each memory cell is complicated.

A new VMOS-cell structure, reported at the Solid State Circuits Conference by American Microsystems designers, is suitable for a ROM, an EPROM or a dynamic RAM. All cells have the same topology and surface area (0.36 mil²). Each cell consists of a 6 µ x 6-µ VMOS transistor at the intersection of orthogonal gate and drain conductor stripes. Die size for a prototype 1-k static VMOS RAM is 81 x 125 mil. Access time, at 75 C and 4.75 V, is 45 ns.

The advantages of VMOS technology have also been applied by Siliconix designers to rf power FETs operating in the 200-1000-MHz region. "We’re in production with 2-A devices at 100 V that can dissipate up to 35 W," says Gary Hess. "Applications range from high-speed switches to communications amplifiers.”

Fabricated on a chip together with zener protection, these amplifiers have under 10-ns on-off times.

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**Programmable ROMs improving**

Several different technological advances are being made in a specialized, but diverse area of mem-
ories: programmable ROMs. For example, the first CMOS PROM with fused silicon links has just been announced by Harris Semiconductor. It was developed to provide programmable CMOS memories for microprocessor use.

UV-erasable PROM (EPROM) technology has taken two steps forward at Intel with the an-
ouncement of two new devices. One, the 2716, is a 16-kbit EPROM that uses a single 5-V supply. The other is the 8748, a single-chip 8-bit, 5-V microcomputer with an 8-k EPROM built into the chip.

The 8748 is the reprogrammable version of the recently introduced 8048 single-chip device. The 2716 is a new double-layer, polysilicon n-channel MOS device and a third-generation EPROM.

Electrically alterable ROM (EAROM) technology hasn’t been standing still either. New devices have been developed jointly by both NCR Microelectronics and General Instrument. One part is an 8-k bit device, while the second is a 4-k bit unit that is, for the first time, word-alterable.

The latest GI EAROMs have been speeded up. For example, the ER3401’s erase time is only 10 ms, well down from 100 ms for earlier versions. “And we’ve reduced the write time to 1 ms whereas the fastest previous EAROM was 10 ms,” says Brian Cayton, General Instrument’s memory-product man-
ger. Access time has been re-
duced to under 1 µs from a previous best of 2 µs.

Electronic Design 7, March 29, 1977
Here Comes the Biggest Discrete News Since Plastic Power!
Here Comes Motorola
TO-220 Silicon Power!

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Electronics Design 7, March 29, 1977
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MOTOROLA Semiconductors

50  ELECTRONIC DESIGN 7, March 29, 1977
How to operate your MPUs at 2x their rated power... or 1/2 their case temperature.

Unique new Micro-Clip heat sinks permit MPU operation in much hotter environments

Time was when microprocessors posed no thermal problems for designers. That's because earlier MPUs required very little power — up to 250 mw or maybe ½ watt at most. Then, too, designers usually spec'd only one to a circuit board. Surrounded by plenty of air, the lonely MPU did its job without generating much heat. So nobody worried much about heat dissipation.

Today's reality: serious MPU thermal problems

Today, designers are spec'ing many MPUs on the same board. And these boards often must operate in military-type environments where ambient temperatures reach 71°C. Also, today's MPUs do more and, therefore, generate much more heat than earlier models. For example, they often function as both the arithmetic logic unit and the control section of a computer. These factors combine to cause serious thermal problems. Coping with these problems has become an increasingly important part of a circuit designer's job.

IERC finds efficient solution

To solve growing MPU thermal problems, IERC recently introduced its two-piece "Micro-Clip" series of heat dissipators. These units adjust to fit all double DIP, CMOS, MOS-FET, and microprocessor packages within the 20- to 40-pin range.

As the adjacent drawing shows, the Micro-Clip's unique spring-finger design lets the dissipator make good, solid contact with both the top and bottom of the MPU, assuring efficient heat transfer from case to dissipator. Tests show these units dissipate up to 100 percent more heat than conventional glued-down devices.

Staggered-finger design also assures more efficient heat dissipation

Micro-Clip series dissipators capitalize on IERC's patented staggered finger design. Heat radiates to the ambient, never transfers from one finger to another. In forced air modes, the staggered fingers maximize turbulence, further increasing heat transfer efficiency. Three finger heights are available — ¼ in., ½ in., and ¾ in. — to meet varying space and dissipation requirements. Micro-Clip dissipators weigh only 4 grams and require only .6 in.² more board space than the IC device itself. So board densities and spacing between rows of, for example, double DIPs and CMOSs are unaffected.

Stocking problems greatly reduced

Designed to (1) meet an infinite number of application needs and (2) fit an entire range of package sizes, Micro-Clip dissipators greatly simplify a user's stocking problems. This benefit appeals especially to companies with high-volume manufacturing operations.

Easy to attach

Only two screws or rivets or dots of thermally conductive epoxy are needed to fasten Micro-Clip dissipators securely into position. Mounting Micro-Clip units to MPUs already mounted to boards requires no disassembly.

To learn more about how IERC's Micro-Clip series can help you solve your heat dissipation problems, write or call today. Ask for Bulletin 186. International Electronic Research Corporation/A subsidiary of Dynamics Corporation of America/ 135 West Magnolia Blvd., Burbank, California 91502 • (213) 849-2481.

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CIRCLE NUMBER 33
Navy ships to be protected from missile attacks

Next year 284 Navy surface ships will begin to be outfitted by Raytheon Corp. with a new electronic warfare (EW) suite, the AN/SLQ-32 (V). It will protect them against incoming missiles by detecting and jamming enemy radar.

The new EW suite replaces current manually operated systems based on vintage-mid-1950s vacuum-tube technology, and uses computer control for instant response. It will be installed on small amphibious and auxiliary craft, medium-size combatants such as destroyers and frigates, and cruisers and large amphibious and auxiliary vessels. First installation is planned for May, 1978 on a Navy destroyer (DD 973), with all the ships to be outfitted by the end of 1981. Cost before inflation is estimated at $180 million.

In a head-to-head prototype competition known as the Design to Price Electronic Warfare Suite (DPEWS), Raytheon was declared the winner over Hughes Aircraft. A four-year contract is due to be awarded in April after a meeting of the Defense Systems Acquisition Review Council (DSARC).

Exxon will use RCA Satcoms for off-shore platforms

Despite objections from competing communication-satellite-system operators, the Federal Communications Commission has approved Exxon’s request to put portable satellite receivers on its off-shore oil rigs to use the RCA Satcom system. The 4.5 m antennas, which use band-edge frequencies of the share-spectrum allocation, will be mounted on platforms in the Gulf of Mexico, the Atlantic and Pacific Oceans, and off the Alaskan coasts to warn of approaching storms as well as provide a two-way data link.

Comsat General and Western Union had objected on the grounds that the Exxon application was essentially maritime, their MARISAT system should provide the service. ITT and AT&T filed similar protests. However, FCC ruled that since the Exxon stations are mobile, they are exempt from any restrictions imposed on temporary-fixed stations in terrestrial-fixed radio services.

Navy prefers Michigan for Seafarer ELF system site

Public hearings on the Navy’s proposed Seafarer system for extremely-low-frequency (ELF) communications with submerged submarines are scheduled to run all during April in Michigan, Nevada and New Mexico. But the Navy has made it clear that its favored site is on Michigan’s Upper Peninsula.
Although the hearings are required before the final environmental-impact statement can be written and a site chosen, the Navy’s preliminary statement concludes that the most cost-effective site would be near K. I. Sawyer Air Force Base, just south of Marquette, MI. Total system costs there (including receivers in the submarines and the first 10 years of operation) are put at $593-million, and at $837-million for an alternate site at Nellis Air Force Base in Nebraska and $718-million at White Sands Missile Range in New Mexico.

Further, nearly global coverage would be provided by the Michigan site because of the nonconductivity of the rock strata there, the Navy believes, while the New Mexico site would cover only the adjacent waters around North America and the Nevada site slightly more.

The system operates in an FM mode at a center frequency of 76 Hz and an estimated data rate of 10 bits/min., which is considered adequate for communicating with submerged nuclear submarines. The Navy proposes to build five transmitters at the Michigan site and install 2400 miles of buried antenna cable in segments over a 4000-square-mile area.

FAA research aimed at air-traffic control in 1990s

The Federal Aviation Administration’s $85-million engineering, research and development (ER&D) request for the new fiscal year is a down payment on an air-traffic control system for the 1990s, FAA Administrator Dr. John McLucas told the House Transportation Subcommittee.

Introducing a new technology into the air-traffic system requires 15 to 20 years from concept formulation to field implementation, he said, although some of the results will be felt sooner. Technical programs in ER&D include conflict alert, air-traffic-delay reduction, wind-shear-and-microwave landing systems.

“High-priority” has been given by the FAA to implementing a conflict-alert capability at en route centers, as well as to minimum-safe-altitude warning systems, according to McLucas.

The wind-shear problem is being studied by testing detection devices at Washington, DC’s Dulles and Chicago’s O’Hare airports, as well as by evaluating an anemometer-based system. Possible solutions to air-traffic delay problems include developing a wake-vortex advisory system, which will allow reduction of the longitudinal separation requirements, and a discrete-address beacon system as well as an airport-surface-traffic control system to allow more aircraft to operate in the same traffic areas.

Capital Capsules: A next-generation multi-spectral scanner, the thematic mapper, will be built for NASA’s Landsat-D by the same company that built the multi-spectral scanner in the current Landsat program: Hughes Aircraft. An object-plane linear scanner, the instrument will provide one more channel of imaging (six) and better resolution (30 m to 80 m) than the current scanner. It was chosen over a TRW candidate using an image-plane linear scanner from Perkin-Elmer. The Landsat-D is due to be launched in 1981. . . . The Pentagon has increased the single-pulse power output of rare-gas halide lasers operating in the ultraviolet and visible spectra from 1 joule to more than 350 joules over the past year as part of its High Energy Laser (HEL) weapons program. Efficiency was only 10%, however. In the coming year, research will be focused on scaling up the output of hydrogen-fluoride chemical lasers operating in the infrared spectra (2.7 μm).
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SwitchTron Power Transistors

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* TO-61/II VERSIONS ALSO AVAILABLE
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To get your 27L08s fast, or for more data on the 27L08, 27L08, and 4700, call your TI distributor. Or write Texas Instruments, P. O. Box 1443, M/S 669-27L08, Houston, Texas 77001.

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CIRCLE NUMBER 36
DELCO'S NEW 25-AMPERE HIGH VOLTAGE DARLINGTONS WITH THE SPEED AND ENERGY CAPABILITY YOU ASKED FOR.

Good news for motor speed control designers who have expressed a need to upgrade horsepower ratings. The 25-ampere gain of these new Darlington's permits increased horsepower ratings of existing AC motor speed control systems and a reduction in paralleling in new designs. However, grouping of t_on is available for current sharing in designs with parallel Darlington's. A speed-up diode is built into the DTS-4074 and DTS-4075 permitting data sheet typicals of 1.0 μs. Drive circuit techniques involving I_B2 ≥ 2 A and a Baker clamp produce t_on typicals in the 0.4-0.6 μs range for the DTS-4066, DTS-4067, DTS-4074, and DTS-4075.

Our experience with tolerances, faults, transients, and start-stall conditions in most systems convinces us that these Darlington's have the right trade-off between speed and peak power handling capability. Note the greater than 10 kVA region of the reverse bias safe operating graph. All this, and you still get Delco's traditional solid copper TO-3 hermetic package that has a conservative 0.75°C/W thermal resistance.

These Darlington's are already in high volume production and are available on distributor shelves. Prices, applications literature, and data sheets from your nearest Delco sales office or Delco distributor can complete the story on these new Darlington's.

Features of Delco's new DTS-4066, 4067, 4074, 4075 Darlington's:

- Upgrade existing motor speed control horsepower ratings.
- Reduce need for paralleling in new systems.
- Offer switching speed improvements over our earlier types.
- Achieve greater than 10 kVA peak power dissipation.
- Available with t_on grouping.
- Delco hermetic copper package with 0.75°C/W.
- Currently in high volume production.

<table>
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<th>Type</th>
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TYPICAL SWITCHING

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<td>1.0μs</td>
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**CIRCLE NUMBER 40**

**DELCO ELECTRONICS**

Division of General Motors
Kokomo, Indiana

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**Electronic Design** 7, March 29, 1977
Vactec serves manufacturers of a wide range of modern electronic products. Pictured are a few examples. All these devices are both made and sold by Vactec, including complete lines of LDR's (photoconductive cells, CdS and CdSe); silicon solar cells, as well as silicon high speed and blue enhanced cells; NPN phototransistors and darlington; opto-couplers (LED/LDR, lamp/LDR and neon/LDR); selenium photovoltaic cells; silicon photodiodes, blue enhanced and PIN; and custom C-MOS and bipolar IC’s. Write for technical bulletins on the types that suit your requirements. Or send your application, and Vactec will recommend the right cell for the job.
MOS μP or bipolar slice?  It's more than a matter of speed

MOS μP or bipolar bit slice? What are the trade-offs? Which is best, speediest, lowest in build cost, or most flexible for your application?

"Speed is the place to start," says Peter Alfke of Fairchild Semiconductor. "As manager of applications engineering for digital products, I deal with both sides, the MOS F8 and the bipolar Macrologic.

"You usually have a certain amount of execution time available. If you have enough time and memory, the F8 or the 8080 or the 6800 can do any job. But if you have to do a multiply in 6 μs, every μP is too slow by a factor of 100 or so."

But Steve Herrick of Computer Linguistics warns:

"The computing-speed criterion fools people. You may not have a computing-rate constraint at all, yet have to do bit-slice because of the need for large files on-line. Why? Because floppies can't handle really big jobs. If hard disc is necessary, you simply have to go to a faster machine than MOS."

Herrick, the President of the Colonie, NY, software firm, also likes the emulation capability of the bit-slice approach. "When a hardware manufacturer changes instruction sets or just discontinues a line of hardware, you don't want to throw out a 20-man-year software

(continued on page 64)

Swap the 8080 CPU for a Z80 without changing boards

Don't replace the entire CPU card in an Altair, Imsai or any other Altair-bus-compatible microcomputer. To change the CPU from the 8080 to a Z80 simply plug the Z80-80 piggy-back card into the 8080's socket, and a cable into the 8212's vacated socket.

A system monitor on paper tape comes with the board, as well as a Z80 manual. The board costs $159.95, and delivery is from stock.

library. By building new bit-slice hardware that uses the old instruction set you can keep it and continue to use it.”

“But the moment you consider bit-slice, you’re talking 30 to 50 chips,” says Alfke. “You’re leaving the realm of a $20 solution with a μP. True, your bit-slice approach gives you a new degree of freedom, a more efficient, more dedicated, and more specialized solution.

“If you can possibly do your job with a MOS μP, do it,” Alfke advises. “In a bit-slice design, if you can avoid the insanity of inventing your own instruction set, do that,” he adds, acknowledging that bit-slice microcoding lets you use existing supported instruction sets, and does not force anyone to create “orphan” command sets. “Bipolar and supported instruction sets come together in our 9440,” notes Alfke. “It’s a Nova for a lot less money but without the support hand-holding.”

The Transitron 1601 slated for 1978 has its own fixed instruction set, too (see ED Microprocessor Design, March 1, 1977, page 41), along with fast bipolar hardware.

“The advantages of both—the fixed instruction set of the μP, plus the speed of bipolar—are merged in bipolar μCs like our 8X300,” Joe Conway of Signetics Applications observes. “The 8X300 is very good for fast controllers. In 250 ns, it can take in pieces of data, massage them, and dump them back out. But if you have to really crunch numbers, a bit-slice gives you much more—we don’t have the register architecture for top speed arithmetic.”

“All these different approaches have their place,” notes Dave Uimari, LSI product manager at Raytheon Semiconductor. “But a big factor often forgotten is the number of units you are going to build. If you can write development costs off over a long run of finished systems, you’ll be able to take your choice—lots more throughput for the same build cost, or much lower unit cost for a given performance level.

“We plot the whole thing out for the design engineers we work with,” Uimari adds, pointing to a volume-versus-performance chart (see figure). “All boundaries on the chart are in motion as new technologies develop; but you need an overview of five solutions to know which ones can apply to your problem. The bipolar μCs showed up just recently in the very middle, where four other approaches all used to compete. Everything is moving upward and to the left, and eating up territory that once belonged to the minis alone. Bit slices like our 2901 are in the "bipolar components" group. They’re moving the same way, as hardware speeds go up and as development aids like our RAYASM microcode assembler cut the basic development costs.”

---

**Jumbo ROM offers 32-k storage for PPS systems**

Able to cut the package count in PPS processing systems, the A66XX, a 32-k ROM, offers 4 k × 8 of program storage. The ROM is believed by Rockwell to be the largest unit on the market.

Two main features of the ROM are dynamic address decoding and device-select circuitry. Up to 16 ROM circuits can be selected directly with the device’s 12 address and four chip-select inputs, and memory easily expanded through normal or “virtual” bank switching. The virtual mode permits simple switching-command arrangements.

The 32-k ROM, which consists of a 156 × 242 mil chip housed in Rockwell’s standard 42-pin plastic package, is designed as a direct replacement for the smaller capacity A52XX and A05XX ROMs. Price for the ROM depends on pattern and quantity but is approximately $23 in 1000-unit lots.

Rockwell International, 3310 Miraloma Ave., P.O. Box 3669, Anaheim, CA 92803. (714) 632-8111.
Keyboard and display round out μC evaluation kit

Available in kit form, the MEK6800D2 microcomputer evaluation system even includes a keyboard and a display. When assembled, the system is a fully functional microcomputer based on the 6800 μP.

The MEK6800D2 consists of two boards—the microcomputer module (9.75 x 8.3 in.) and a keyboard/display module (10 x 6.25 in.) that includes an audio cassette interface designed to accept data recorded according to the tape interface known as the "Kansas City Standard."

Six 7-segment LED readouts on the keyboard module display the four-digit hex address and the two-digit data. The keyboard has all hexadecimal keys plus eight additional command keys. The μC module also contains a 6800, a JBug-monitor ROM, three 6810 RAMs, two 6820 P1As, a 6850 ACIA and a 6871B clock. In addition, the system can be expanded on a breadboard area with up to twelve 16-pin ICs and two 24-pin DIPs.

The price is $235, less power supply and cassette recorder. Delivery is from stock. Motorola, 3501 Ed Bluestein Blvd., Austin, TX 78721. (512) 928-2600.

CIRCLE NO. 502

Time-sharing software available for 2900 development

Developed to generate microinstructions for use with the Am2900, the AMDASM software system is available worldwide through Computer Science Corporation’s Infonet Service. Written by Advanced Micro Devices, the program provides software assistance and documentation for writing and modifying microprograms and generating tapes for PROM programmers.

AMDASM includes a framework for a common language, automatic accounting information and billing control. Budget limits, character-rate option and batch rates make AMDASM cost-competitive with in-house software.

Documentation currently available explains how to interact with AMDASM to microprogram all control signals and memory. Variable instruction set microprogramming makes field service and system enhancements easy, since they require only additional data in the microprogram memory.

Advanced Micro Devices, 901 Thompson Pl., Sunnyvale, CA 94086. Elliot Sopkin (408) 732-2400.

CIRCLE NO. 503

Control-store sequencer simplifies microprogramming

All random logic needed to do microprogram sequencing in bipolar μPs can be replaced by the 8X02, a control-store sequencer. This microprogrammed control section for computers, controllers and sequenced logic elements, combines with standard ROMs or PROMs to form a complete controller.

The 8X02 is a low-power Schottky device that can address up to 1 kword of microprogram expandable to any microprogram size by conventional paging techniques. External page registers, when provided, can be controlled either entirely or partially by the microprogram.

Compared with other available units, the 8X02 provides several advantages. The 1-k addressing capability is not available in other units, nor is the 8X02’s subroutine-nesting capability. The controller has a four-way stack-register file and offers conditional nesting

(continued on page 66)
MICROPROCESSOR DESIGN

(continued from page 65)

for branching to a subroutine or for handling interrupts automatically.

There are three control lines for the three-hit command code; control instructions include increment, test-and-skip, and conditional-branch-to-subroutine. One 8X02 cycle takes only 80 ns. The unit operates from a +5-V supply and consumes 1 W.

The control-store sequencer is housed in a 28-pin plastic DIP and costs $19.45 when purchased in 100-unit lots.

Signetics, 811 E. Arques Ave., Sunnyvale, CA 94086. (408) 739-7700.

CIRCLE NO. 504

Micromodule chassis and racks ease system development

Several Micromodule card cages and a power supply have been added by Motorola to support M6800-based equipment development. Two card cages are available: one with five card slots, the other with 10. Both cages have motherboards that are pin-compatible with all Micromodules and EXOrciser modules.

The available power supply delivers 15 A at +5 V dc, 2.5 A at +12 V dc, 1.5 A at −12 V dc and 0.1 A at 8 V ac. Short-circuit, overload and overvoltage protection are provided. A remote-voltage-sensing capability for the 5-V output can compensate for as much as a 0.5-V drop along the connecting leads. The supply requires a single-phase, 47-to-420-Hz input from 95 to 125 V or 205 to 250 V.

A bare chassis with five card slots costs $98 and a 10-slot unit costs $147. Card cages with power supplies and chassis built-in cost $610 and $660, respectively. Both fit 19-in. RETMA racks. By itself, the power supply costs $295. All units are available from stock.

Motorola Semiconductor Products, P.O. Box 20294, Phoenix, AZ 85036. (602) 244-6900.

CIRCLE NO. 505

Upgraded software permits easy program development

A substantially upgraded version of Imsai’s self-contained software-operating system for 8080-based machines is now available. The enhancements offer a package for developing medium-size assembly-language programs. Software features include a debugger with multiple dynamic and static breakpoints, number conversions, memory searches, an I/O-port control, a trace and hex arithmetic. There is enough symbol-table space for 8192 bytes. A facility for adding device drivers to support a wide variety of I/O devices is available (teletypewriter driver is included).

Programs may be loaded from industry-standard object paper tapes. The software resides in high-order memory locations so that it may reside with application programs and Basic. A line-editor routine is also included. A paper-tape listing of the program costs $40 and includes all source listings. Delivery is from stock.

Imsai, 14860 Wicks Blvd., San Leandro, CA 94577. (415) 483-2093.

CIRCLE NO. 506

Z80 microcomputer board fits into Intel MDS systems

A $10,000 investment may not be necessary when switching from an MDS-800 development system for 8080 μPs to a system that handles Z80s. The Z80 MDS microcomputer board from Relational Memory Systems can convert MDS-800 development systems into a system for Z80 programs for less than $1500.
The Z80 MDS board runs with ICE-80, ICE-30, ROM simulators and other Intel 8080 accessories. The board also provides a single-cycle capability via a switch mounted on the board. LEDs on the board indicate whether the Z80 MDS is accessing memory or I/O ports.

Two versions of an assembler program are supplied with the board. One is disc-based for users of the ISIS DOS system, and the other is a stand-alone, one-pass assembler that operates five times faster than Intel's stand-alone assembler. The complete μP board and software package costs $1490, and delivery takes 30 days.

Relational Memory Systems, 150 Saratoga Ave. 332, Santa Clara, CA 95050. James Kelley (408) 248-6356.

CIRCLE NO. 507

Microcomputer controller offers wide choice of options

A completely self-contained microcomputer family, dubbed the HT-1000, is designed specifically for control-systems applications. All units in the HT-1000 series can monitor or control up to 160 points as well as provide the user up to 24 function keys.

Input options for the system include ac signals, logic levels, switch contacts, dc voltages and resistance changes, while output options include solid-state relays up to 220 V at 40 A, SCR control and dc voltages. Data can be displayed on up to six 0.6-in.-high LED displays or as many as 18 LED lamps.

Each HT-1000 uses a 6502 μP and comes with its own power supply, which requires about 25 W. Typical size of the controller board is 8 × 8 in., and the operating temperature range 0 to 50 C. But wider ranges are available.

A typical HT-1000 system, which costs about $745 (in 100-unit lots and depending upon program complexity), may consist of eight logic-level or switch inputs, eight 115-V-ac, 1.5-A optically isolated relay outputs, eight LED indicators, a 16-key control panel, a three-digit numeric display, a power supply and a program.


CIRCLE NO. 508

Microcomputer card comes in tutorial & industrial models

Capable of being expanded into a full microcomputer, the Datac 1000 microprocessor card is available in both a tutorial version and an industrial model. The processor card, claimed by Datac Engineering to be the most adaptable card around, is based on the 6502 microprocessor.

The tutorial card carries the μP, 256 bytes of RAM, a one-bit serial output latch, eight data, eight address and nine control touch pads (used for data entry) and eight data and eight LED address indicators. On-board regulators permit operation from raw dc, and a single-cycle operating mode permits simple program debugging.

The expanded industrial version permits 16-bit addressing and has 1 kbyte of RAM sockets for 2 kbytes of UV PROM, a ROM containing I/O routines for a teletypewriter as well as a current loop or RS-232 interface, a cassette interface, two parallel I/O ports, and a bus structure that permits simple expansion.

Unique touch pads used by Datac facilitate data and address entry and permit faster bit-by-bit data entry than entry via conventional toggle or slide switches. Aside from the address and data-bus pads, controls are provided for halt, run, reset, single step, normal, (continued on page 68)
Microcomputer kits available for all experience levels

A series of inexpensive microcomputer kits has been designed to meet various needs—from the beginner's to the advanced engineer's. The kits in American Microsystems' EVK series are based on the 6800 \( \mu \)P and range in price from $133 to $765.

There are three kits: the EVK-99, 100 and 200—plus an assembled version of the 200 called the EVK-300. All come with 10.5 \( \times \) 12 in. PC boards with two 86-pin edge connectors, one for the \( \mu \)P bus lines and one for the I/O.

The EVK-99 is for beginners, and features 6800-family parts—one \( \mu \)P, four 128 \( \times \) 8 RAMs, one P1A, one 2-k \( \times \) 8 ROM and one ACIA. The mid-range kit, the EVK-100, costs $295 and contains all the EVK-99 parts plus enough TTL circuits to make a terminal-communication port.

For the weathered engineer the EVK-200 includes everything in the EVK-100, but also I/O interfaces, a serial RS-232 port, 1 k of RAM, 2 k of EPROM, an on-board programmer, a crystal clock and switch-selectable baud rates from 0 to 9600—all for $495. Its fully assembled version, the EVK-300, costs $765 and also includes four EPROMs and a paper tape containing a version of Tiny Basic.

American Microsystems, 3800 Homestead Rd., Santa Clara, CA 95051. Tom Eden (408) 246-0330.

Micro Capsules

A full 16-bit microcomputer on a single chip is currently in development by Texas Instruments, Dallas. The chip, dubbed the TMS 9940, will use a subset of TMS 9900 instruction set and have ROM, RAM, I/O and the processor all on a single chip. . . Containing ROM, RAM, timer, clock and \( \mu \)P on a single chip, the 6801 microcomputer will soon be released by Motorola, Austin, TX. Instructions will be compatible with the company's 6800 \( \mu \)P and the chip will hold 1024 bytes of ROM and 64 bytes of RAM. . . . Another combination processor/UV PROM will soon be available from Intel, Santa Clara, CA. The 8041/8741 as it will be called is intended for universal interface development and will have an instruction cycle time of 2.5 \( \mu \)s. On the 8741 will be 1024 bytes of UV EPROM and the 8041 is a pin-compatible mask-programmed version. . . . Look for some new software from National Semiconductor, Santa Clara, CA, to support the PACE and SC MP \( \mu \)Ps by mid-1977. For the PACE will be a 7-k ROM software package containing Basic and for the SC MP will be a full resident-assembler package.
When high Q and stable performance are a must, you can’t settle for a trimmer capacitor that is “almost right”. Only Voltronics, with its unique, patented, non-rotating piston, eliminates the problems of conventional capacitors. This totally unique principle is available in both glass and air units. The non-rotating piston provides ±1% linearity, and no chance of reversals—unlike rotating pistons, where linearity is limited to ±10% due to unavoidable turning eccentricity.

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Electronic Design 7, March 29, 1977  CIRCLE NUMBER 42
Electronic Design’s

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See LFE's complete line of process control instruments at booths 1634-1636, Electro77, April 19-21.

CIRCLE NUMBER 45

Electronic Design 7, March 29, 1977
The paper mountain

There’s an old tale about an executive who finally realized that his staff was drowning in paper, so he stormed in one day and ordered that all files be discarded. “But first,” he cautioned, “copy everything in triplicate.”

There’s less humor in the fact that Marks and Spencer, a powerful British chain store, saved almost a million pounds a year by slashing the amount of paper it produced. That was some years ago, when the pound was real money, worth $2.40 in American dollars—and dollars were real.

Somewhat sadder, at least for Franklin M. Jarman, was his ouster in January from the position of chief executive of Genesco because of what Business Week called “paperwork paralysis.” What’s worse, the poor fellow had his salary chopped from $285,000 to a mere $180,000.

Apparently, Jarman was a great believer in managing by computer printout—so much so that operations were often stalled by paperwork and red tape. Urgent decisions would frequently be postponed while Jarman demanded more analysis.

Jarman’s love for paper, coupled with less than excessive sensitivity to people (to make a point, he once gave each of his top executives a hangman’s noose), made it relatively easy for Genesco’s directors to strip him of corporate power.

But why should we worry about a billion-dollar clothing and retailing conglomerate? We’re in a different business and we don’t run our operations by paperwork. Or do we?

Many of us, fearful of making wrong engineering or business decisions, hesitate. We busy ourselves generating paper and analyzing reports. We conceal inaction behind paper screens, the mark of modern management.

Or we shuffle data till we find support for a preconceived conclusion. Or become slaves to our own creation, the digital computer. For who can argue with decisions based on computer analysis?

Perhaps that’s where it all will end. Maybe we’re destined to freeze as we climb yet another mountain of paper, hoping that the next mountain will provide answers we need before we can make a decision.

GEORGE ROSTKY
Editor-in-Chief
Microdata introduces a matrix printer that thinks.

A built-in microprocessor makes Microdata's new matrix printer the smartest buy in the industry.

It provides bidirectional printing and paper feed for full incremental plotting. It has extensive horizontal tabbing and computer programmable vertical forms control.

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Our new matrix printer is compatible with all industry standard RS-232-C or parallel interfaces and available for immediate delivery in 100 unit quantities at $1755. It's just one of a complete line of significant OEM peripherals built and backed by Microdata Corporation.

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It's the 48-pin IT-200 bench-top tester. The most flexible integrated circuit tester around. Handles virtually all digital devices. Now its flexibility stretches to MPU's. All it takes is our new special test head, which is compatible with all existing IT-200's.

IT-200 will perform DC parametric as well as functional testing via standard factory programs. It can also use an associated MPU instruction set to perform customer specified test routines.

Test the 6800 or the 8080, just to name two of the MPU's which the IT-200 can now handle. All this plus its original IC test versatility. The 100 kHz functional capability, coupled with a powerful DC parametric capability, allows testing of CMOS, NMOS, PMOS, ECL, and TTL devices of any complexity. The particularly powerful DC parametric test capacity provides current ranges from ±200 na to ±200 ma, and voltage ranges up to ±20V.

Check out the IT-200. You'll find the specs are truly in a class by themselves and the price is surprisingly low.

For more information on what IT-200 can do for you, write or call Cliff Small, Siemens Corporation, Measurement Systems Division, 3 Computer Drive, Cherry Hill, New Jersey 08034. (609) 424-2400.

SIEMENS
Your microcomputer's I/O software may well determine its over-all performance. And in real-time applications, I/O timing often means everything.

No matter how ingenious or efficient your microcomputer program, it will do you no good if you can't get the data into your machine and the answers out. That goes for a computer of any size, but input/output (I/O) is especially critical for microcomputers. Micros are most often used in real-time dedicated applications, converting inputs from sensors, keyboards, and meters of all kinds, to outputs that control machines, test equipment—even other computers.

While I/O software for general-purpose computers is contained in the operating system, for micros you usually have to write your own I/O routines as part of the applications programs. They are often the most critical part.

Your I/O routines must fit specific hardware interfaces. The hardware's job is to make a physical connection between the computer's data bus and the external data sources and destinations. Equally important, the hardware must translate electrical signal levels, synchronize signals, store data temporarily, and isolate the computer from unwanted data.

Most microcomputer systems have several I/O ports for interfacing devices such as keyboards, CRT terminals, printers, disc memories, tape units, instruments, control switches, indicator lights, and all kinds of data transducers. In a generalized I/O scheme (Fig. 1), the I/O data bus is isolated from the CPU data bus by a bi-directional bus driver. When properly addressed and enabled, any of the I/O ports may be used to route data to or from the CPU.

The control/status bus may be as simple as a single read/write line, or it may have several lines for "handshake," interrupt and timing functions. The complexity range of the address decoder/driver can be extreme—from a complicated multilevel decoder to nothing at all. The I/O ports themselves match the devices to be interfaced, but can usually be classed as parallel-in-put, parallel-output, serial-I/O, or multiple-bit discrete I/O ports.

Fig. 2 shows a simple 8-bit input port with three-state outputs. A simple 8-bit output port (Fig. 3) uses latches to store a byte from the bus until it can be accepted by an external device. More complex parallel I/O ports often use multiplexers and addressable latches to provide multi-

---

Robert W. Ulrickson, President, Logical Services Inc., 711 Stierlin Rd., Mountain View, CA 94043.
2. An 8-bit parallel-input port is essentially a multipole switch that connects the inputs with the data bus when the "enable" pulse occurs.

3. A simple 8-bit output port uses latches to store data from the bus. When the output device is ready to receive, the "enable" pulse makes the connection.

Marching to different drummers

I/O devices seldom operate at the same speed as the computer—so synchronizing the I/O, or timing, is usually required. This can be accomplished with control signals, software timing loops, hardware, or combinations of the three.

Status and control signals can direct the data transfers between the computer and the I/O device. In such I/O operations the computer waits for one or more status indicators to show that the device is ready before supplying control signals to actuate the transfer. These signals may be present in any order or combination. Some applications may require only one or the other.

Status and control signals provide a very flexible and reliable way to transfer data to and from the computer. When you are designing a computer I/O system, reserve some I/O ports for the timing and control signals that are required by your peripherals.

A software timing loop is a program section or subroutine that idles the computer for a fixed period of time. Such loops normally load a constant into a register and increment or decrement it until it reaches zero. The loop constant is chosen so that the loop terminates after a known period of time.

Selection of the loop timing constant depends greatly on the characteristics of your microcom-

(continued on next page)
4. The handshake dialog ensures proper signal flow between a "master" and a "slave" device. Usually the CPU is the master for output operations, and the I/O device for input operations.

5. Device-initiated and computer-initiated input operations are similar. In the first case, you simply leave out the light logic element.

puter. The value is affected by the machine cycle and system memory speeds, and the execution time of the instructions in the loop.

Remember that most timing loops are only approximations, and they are not suitable for applications requiring extremely precise timing. The total delay, \( t_\text{r} \), in a delay routine is given by the following equation:

\[
t_\text{r} = N \cdot t_\text{l} + t_\text{p}
\]

where \( N \) states how often the loop executes, \( t_\text{l} \) is the execution time for the loop, and \( t_\text{p} \) is the execution time of subroutine instructions not within the loop. With a delay routine you can vary the loop constant to generate pulses or repetitive waveforms of any duty cycle and pulse width.

Is your chip fast enough?

In some applications you will find that software alone is not fast enough to detect certain peripheral status signals. For example, an ASCII-encoded keyboard often shows a strobe pulse to indicate that a parallel character is ready. In many cases the strobe and the data signals make their quiescent-to-active transitions faster than the microprocessor can detect.

If you are using a typical microprocessor (2-MHz clock, no-wait memory), you will be hard pressed to reliably detect pulses shorter than 10 \( \mu \text{s} \). If the CPU is too slow to detect data, you need some additional hardware to widen the pulses. For instance, you use the short strobe pulse to trigger a monostable multivibrator. The multivibrator output can then be adjusted to a width the computer can detect, so you can then test the output of the one-shot just as you test any other pulse input. Or, you can gate the input signal into a latch and then test the latch output. Whenever it shows an active level, you know that the signal has occurred.

Slaves require handshakes

Before data can be transferred in most I/O operations, you need to make sure that the I/O device is ready. In some cases, you also want to
test after the transfer, to make sure that the I/O operation has been completed before initiating the next transfer. Such transfers are handshake-controlled.

The device that initiates the I/O transfer is called the master device, the device responding to the transfer is called the slave device. In most computer applications, the central processing unit (CPU) is the master for output operations and the I/O device is the master for input operations. Handshaking requires at least two separate I/O control lines in addition to the data lines (Fig. 4).

The master device makes the data available and initiates the transfer. The slave device then reads the data and sets the signal to indicate it has been received. The master device in turn resets the "transfer" signal, after which the slave device resets the "received" signal. Finally, the master device outputs the new data and re-initiates the cycle.

The handshake can be implemented in several ways. If the devices are fairly slow, the entire handshake can be accomplished by software. For faster devices you may need a combination of hardware and software logic.

A common variation of the basic handshake I/O: The master device outputs the control signal to the slave device as a strobe, and then reads the handshake signal as a latched input. This causes the slave to respond with a pulse after the data transfer is complete. Because it's no longer necessary for both the master and the slave to sense signal transitions, the interface becomes somewhat simpler.

Parallel or serial?

Data transfer through an I/O port must conform to the type of port used. Parallel data move through an I/O port in a single operation. Serial data require several operations to transfer the data, one bit at a time. Parallel-data transmission is usually faster and requires less programming—therefore, less memory—whereas serial transfer requires only one bit of I/O-port hardware. Both of these methods are commonly found in microcomputer systems.

Parallel-input operations can be initiated either by the input device or the computer. In a device-initiated input operation, the computer simply waits until the data are supplied by the input device. In a computer-initiated input operation, the computer sends a strobe signal to the input device, then waits for the device to supply the data. The computer-initiated operation is nearly identical to the device-initiated routine except that you need additional logic to tell the input device that a transfer is to be performed (Fig. 5).

At least two separate input ports are usually required by parallel-input operations. One input port contains the input data and the other, called a status input port, contains the signal(s) that indicate when the data are ready. Computer initiated transfers, on the other hand, require a control-output port that starts the transfer by transmitting transfer-initiation signals(s) that trigger the input device.

A single-status input port and a single-control output port can usually serve several different devices in turn. The correct bits for each device are selected from such a shared port by software.
masking and imaging techniques. It is important
that the data are sampled by the computer during
time periods when they are known to be valid.
Transferring parallel data out of the computer
is similar to transferring parallel data in. Either
the computer outputs the data, assuming that
the peripheral is always ready, or you must con-
trol the output with status tests and control sig-
als. The required program logic is very similar
to that controlling input operations.
First, check the status of the device to make
sure it is ready. Then place the data into a latch-
ed output port and send the control signals for
reading the data from the output port (Fig. 6).

10. The logic for an encoder is the reverse of the de-
coder logic. Subroutine ENCODE shifts successive bits
right instead of left.

A line printer is a typical parallel-output inter-
face and is controlled by the timing, control, and
data waveforms of Fig. 7. The “printer ready”
signal is HIGH whenever the printer is ready
to accept data from the computer. The data are
placed in the output port and the “print strobe”
signal is driven HIGH. The “printer ready” line
then goes LOW until the character is printed. As
long as “printer ready” is LOW the character in
the output port must remain stable.
The control logic for this interface (Fig. 8)
shows that after the read strobe has been issued,
the program exits without testing “printer ready.” This happens because the printer hard-
ware sets the “printer ready” signal LOW as
soon as the strobe is received. If several char-
acters are to be printed consecutively, you must
test for “printer ready” HIGH to make sure that
the previous character has been accepted before
sending out new data.

What’s your line?
Often microcomputers have to select one of a
group of data lines. For example, you may want
the system to input a number from lines 0
through 9 and activate or de-activate the device
attached to the selected line. This scheme is call-
ed a one-of-N decoder, because only one of N pos-
sible lines is selected for use.
To implement this algorithm, use the input
value as a loop-control variable and initialize the
output image to zeroes with a “1” in the least-
significant-bit position (Fig. 9). Count the loop
control variation down, shifting the output image
left by one bit position for each count, and put a zero in the least-significant bit. When the loop
terminates, the image has a “1” in the selected
bit position.
Now that you have the correct image, transfer
it to the correct control-output port. The number
of lines that can be decoded by the program logic
shown in Fig. 9 is virtually unlimited, but the
most common decoders are 1-of-8, 1-of-10, and
1-of-16. The computer requires enough output
ports to provide one control line for every legiti-
mate input value. Thus, a 1-of-16 decoder imple-
mented on an 8-bit microcomputer requires two
8-bit output ports.
The reverse operation is performed by a parallel encoder, whose input is a single active line; the output is that line's bit position (Fig. 10). First, clear a counter in a register or memory location. Then read the input port, and enter the main loop. The loop rotates the input data one position to the right, moving the data in the least significant bit into the carry flag. Since only one bit of the input port is active, the loop exits when that bit is found.

On every pass through the loop, the counter is incremented; when the loop exits, the counter contains the encoded value. This basic logic can be expanded to a large number of input lines, but the most common encoders have 8, 10 or 16 levels.

Hex your ASCII

Translating data from one form or number system into another form is a very common software operation for parallel I/O. Conversions from ASCII code to hexadecimal or BCD (and vice versa) are required to properly interface a microcomputer with a terminal or hard-copy printer device.

For an example of parallel-code conversion, consider a routine to translate parallel ASCII characters from a keyboard into hexadecimal numbers for arithmetic operations within the CPU. The input is an ASCII character code representing the hexadecimal numbers 0-9, A-F. These ASCII codes (in hexadecimal notation) are 30-39H, and 41-46H, respectively. The result of the operation will be a 4-bit hexadecimal number, 0-F.

Notice that the ASCII codes for 0-9 can be converted to their hexadecimal equivalents by merely removing the "3" in the most significant digit. This conversion can also be performed by subtracting hex 30 from the number (e.g., ASCII 0 = 30, and 30-30 = 0). The ASCII codes for A-F are each greater by 37H than their corresponding hexadecimal values. Therefore, if you subtract hex 37 from the ASCII code, the remainder should be the hex value represented by that code. For the A with an ASCII value of hex 41, you obtain 41 - 37 = 0A which is the correct value. You now have all the material needed to prepare a flow chart for this algorithm.

The test to ascertain that an ASCII character falls in the range 0-9 and A-F is more complex than the logic flow chart (Fig. 11) indicates. The ASCII character codes for 0-9 and A-F are not contiguous values. So, tests must be performed to eliminate all characters less than 30H, greater than 46H, or in the 39-40H range. Therefore implementing the general logic with assembly language will require several separate tests.

In serial I/O, precise timing is essential

The most common type of serial I/O device is the Universal Asynchronous Receiver/Transmitter (UART), commonly used to connect teletype-writers and other data terminals to a computer. The UART looks like a parallel port to the computer, but to the terminal device it presents a standard bit-serial signal with start bits, stop bits, data bits, and parity.

Serial data are transmitted as a sequence of individual bits. Since most modern computers operate on parallel data, serial I/O operations mainly convert data from serial to parallel on input and from parallel to serial on output. Normally, serial data are input and output using multiple input and output operations on a single bit of a parallel-I/O port.

Serial I/O operations require precise timing between the sending and receiving devices. Therefore, most serial I/O is performed by dedicated hardware that incorporates the necessary
timing and control logic.

In some applications, you can reduce system cost by replacing all or part of this logic with software. When you replace the critical timing hardware by software timing loops, such “software serial I/O” encounters all the problems that plague timing loops. Not all applications can tolerate that.

Although many serial data formats are used in various systems, all of them have certain common characteristics. Serial data consist of a start bit, the actual data, and a stop bit. Because serial devices usually cannot use strobes to indicate a “data ready” condition, a start bit is sent ahead of the data to indicate to the receiving device that a data transmission is beginning. After the start bit is received, the receiving device can process the input data. Several bits follow the transmitted data with error-detection information to verify the data’s validity, as well as stop bits(s) that set up the receiver to listen for the next data transmission.

In a general block diagram for a serial I/O system (Fig. 12), the data-detection block monitors the signal line and determines when a valid start bit has occurred. Then it sends the serial data stream to the serial-to-parallel block which outputs the parallel data. After receiving the stop bit, the data-detection block listens for a new start bit, which indicates the start of the next data transmission.

The output section of Fig. 12 works in reverse. After the parallel-to-serial conversion block receives a character, the data transmission block generates the start bit. The characters are then converted from parallel to serial and sent out one bit at a time, followed by the parity and stop bits. The timing module provides the critical timing which ensures that the data are placed on, or received from, the data line at the correct rate. When data bytes are sent and received at the same rate, the timing module is shared by the send and receive modules. If different data rates are required, both modules have separate timing generators.

The ASCII format exemplifies a serial-data transmission system because it is the most common of all serial data formats (Fig. 13). Each character consists of 11 data bits. The data line idles in the “mark” state.

The start bit is always in the “space” state, and the stop bit(s) always in the “mark” state. The data proper starts with the least significant bit and takes up seven slots. Parity bit and stop bit(s) complete the transmission of an ASCII character. The flow chart for an ASCII serial interface (Fig. 14) summarizes the receiving and transmitting sequence.

**Beware of false starts**

A serial ASCII data transmission begins with the start bit. The highest speed normally used with this character format is 960 characters/s. At this speed, the individual data bits are sent at a rate of approximately one bit every 100 μs. If you simply search for the presence of the transition from “mark” to “space,” you will detect the leading edge of the transition and you need very exact timing to ensure that the data bits are read at the right moment.

But external factors can produce noise or other-
16. Converting a serial character to hex requires that
the data bits be assembled in the proper sequence.
The least significant bit arrives first.

wise trick your computer into accepting a false
start. So, a double-test method is more reliable.
After the transition is detected, insert a delay
equal to one-half the start-bit time, then test
again. If at that time the signal doesn’t show a
start bit, ignore the false start and resume moni-
toring. If the start bit is still there, you can be
fairly sure of a valid start (Fig. 15). If sub-
sequently you wait one full bit time, you will sam-
ple the center of each data bit. The conversion
thus becomes much less susceptible to small varia-
tions in data frequency.

ASCII data arrive with the least significant
bit first. If you input and save the incoming bits
the right way, the input operation and serial-to-
parallel conversion can be accomplished at the
same time. Simply shift the partially accumulated
character right circularly, and mask-in the new
bit. After eight circular shifts, the character is
assembled in the correct order. Having waited
for the appropriate stop bit(s) to ensure data
synchronization, transfer the converted character
to the main program (Fig. 16).

Serial-data output is usually easier to realize
than serial-data input because generating the
start and stop bits is easier than detecting them.
In the case of serial-ASCII characters, simply
output the proper levels to the data port for fixed
periods of time. After the start bit is transmitted,
the character is shifted out one bit at a time, fol-
lowed by the stop bit (Fig. 17).

The standard rates for data interchange in the
serial ASCII data format are 10, 15, 30, 120, 240,
480, and 960 characters per second. These rates
are often expressed as the number of bits/s, or
baud rates. For the characters with seven data
bits per character, standard rates are 110, 150,
300, 1200, 2400, 4800, and 9600 baud. You can
adapt the general-purpose serial I/O routines to
any of these rates by adjusting the loop timing
for the critical timing loops. Solving the delay
equation for N, you obtain this equation:

$$N = \frac{t_d - t_m}{t_i}$$

where \(t_d\) and \(t_m\) are the actual execution times of
the machine code in your application. The result,
N, is the loop variable for the required delay.

Remember that serial data transfers are high-
ly time sensitive. So you must pay close attention
to time delays both in the hardware and the soft-
ware.

The program-initiated I/O operations describ-
ed so far merely scratch the surface of I/O soft-
ware. Others yet to be discussed include I/O soft-
ware for interrupts, real time I/O, scanned I/O,
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CIRCLE NUMBER 49
Design high-performance processors
with bipolar bit slices. With on-chip cycle times of 45 ns, the Series 3000 units let you build fast, flexible processors.

Designing high-performance processing systems is normally limited by available single-chip MOS and bipolar microprocessors. But with bipolar LSI elements like the Series 3000 bit slices,* you can build a complete microprogrammed digital processor that rivals many minicomputers.

Bit slices enable you to build a processor with any word length just by placing the “number-crunching” chips end to end and manipulating them with a single control circuit. The Series 3000 consists of two components—the 3001 microcontrol sequencer and the 3002 arithmetic and logic unit (ALU) processor (Fig. 1)—and is supported by virtually all TTL circuits (some directly related circuits are shown in Table 1). And since both the 3001 and 3002 have typical microcycle times of only 45 ns, rapid computations are possible.

The current level of integration possible with bipolar-Schottky technology has precluded the development of full submicrosecond microprocessors (8-bits and larger) on a single chip. However, by partitioning the processor system into three major blocks (Fig. 2) high-performance bipolar LSI circuits can be fabricated:

1. The processing section, containing the ALU, some general-purpose registers, an accumulator, special-purpose registers and status flags. This section provides all data-transfer paths, manipulates data in the ALU, generates status flags and provides some storage files.

2. The control section, consisting of a macroinstruction decode circuit, a control store, a test-brigde decode circuit and microprogram-sequencing logic. This block initiates memory and I/O operations, decodes microinstructions, controls the manipulation and transfer of data, tests status conditions and responds to interrupts.

3. The I/O and memory-interface section, containing mainly I/O ports, high-power bus driver

*For more on bit slices, see "A Primer on Bit-Slice Processors" by Dr. John Nemec, Gordon Sim and Brian Willis, Electronic Design, Feb. 1, 1977, p. 52.

Stephen Y. Lau, Manager, Bipolar MPU Development and Support, Signetics, 811 E. Arques Ave., Sunnyvale, CA 94086.
receivers and some temporary storage facilities. This block multiplexes data to the proper destination, provides bus interfacing and usually has temporary data latches for storage.

**Build outward from the processor**

Since all data manipulations are handled by the processor section, start the over-all processor design by taking a close look at the 3002 Central Processing Element (CPE). The CPE represents a complete 2-bit slice of a computer's data-processing section. The 3002 contains 11 general-purpose registers (R, to R, and a T register), one accumulator (AC), one memory-address register (MAR), one multifunction ALU and three-state address and data bus buffers (Fig. 3).

Each 3002 has five independent two-line buses and one seven-line microfunction input bus (F bus). Functions for each of the two-line buses are defined as follows:

1. Input M bus—transfers data from external memory.
2. Input I bus—transfers data from the I/O device.
3. Input K bus—functions as a microprogrammed mask.
4. Output A bus—acts as a memory-address bus and is fed by the MAR.
5. Output D bus—functions as a data bus and is fed by the AC.

The F bus accepts microprogram words and controls the internal operation of the CPE by selecting both the operands and the operation they will perform. As you can see from the list of commands given in Table 2, over 40 Boolean and binary operations are possible with the ALU built into the 3002.

**Table 1. Series 3000 hardware**

<table>
<thead>
<tr>
<th>Circuit function</th>
<th>Part number</th>
<th>100-up prices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bit-slice processor</td>
<td>N3002</td>
<td>$11.70 ceramic</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7.65 plastic</td>
</tr>
<tr>
<td>Microprogram controller</td>
<td>N3001</td>
<td>22.50</td>
</tr>
<tr>
<td>PROM 4 k, (512 x 8)</td>
<td>82S115</td>
<td>15.50</td>
</tr>
<tr>
<td>PROM 8-k (1 k x 8) bipolar</td>
<td>82S180/181</td>
<td>34.40</td>
</tr>
<tr>
<td>PROM 8-k (1 k x 8) UV erasable</td>
<td>82S2708</td>
<td>*</td>
</tr>
<tr>
<td>PROM, 16 k, (2 k x 8)</td>
<td>82S190/191</td>
<td>*</td>
</tr>
<tr>
<td>Field programmable gate array</td>
<td>82S102/103</td>
<td>7.00</td>
</tr>
<tr>
<td>Field-programmable logic array</td>
<td>82S100/101</td>
<td>16.00</td>
</tr>
<tr>
<td>Bus buffers and transceivers</td>
<td>Entire 8T</td>
<td></td>
</tr>
<tr>
<td>family, but specially:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8T26</td>
<td>2.40</td>
<td></td>
</tr>
<tr>
<td>8T28</td>
<td>2.40</td>
<td></td>
</tr>
<tr>
<td>8T31</td>
<td>3.00</td>
<td></td>
</tr>
<tr>
<td>8T32</td>
<td>3.00</td>
<td></td>
</tr>
<tr>
<td>8T95</td>
<td>1.25</td>
<td></td>
</tr>
<tr>
<td>8T96</td>
<td>1.25</td>
<td></td>
</tr>
<tr>
<td>Parity generator</td>
<td>74180</td>
<td>1.35</td>
</tr>
<tr>
<td>Carry look-ahead generator</td>
<td>74182</td>
<td>1.00</td>
</tr>
</tbody>
</table>

*To be announced

A 28-pin dual in-line package houses the CPE. Besides the seven F bus lines and the 10 lines for the five smaller buses, two lines are used for carry-propagate and carry-generate outputs (X and Y lines), one line is needed for the clock-timing input and two more for power-supply hook up. Of the six remaining lines, four provide additional control of the ALU and the other two enable or disable the three-state A and D buses.

The various I/O buses can be put to good use. For example, output buses A and D are often used to present address and data to the main memory during the same microcycle. This capability is a significant advantage over available 4-bit processors, which require two microcycles plus an extra address register to do the same job.

Another example that "flexes" the CPE's capabilities is a byte-swap operation, which connects the lowest eight bits of the D bus to the highest eight bits of the M bus and the highest eight bits of the D bus to the lowest eight bits of the M bus. The byte-swap operation requires just one microcycle on the 3002, but can require as many as four microcycles for other bit slices.

By employing inputs to the K bus as masks or constants, the CPE offers yet another advantage over other slices: Most of them require that the
mask or constant be loaded into an internal register—which requires an additional microcycle. But with its output bus, the CPE’s dedicated MAR permits simultaneous operations—such as presenting an address on the address bus and data on the data bus to the main memory—without external hardware or an extra microcycle.

Several of the 3002 CPEs can be cascaded to form a processor of any word length by parallelizing all the control signals and cascading the X and Y lines so that carries and borrows will proceed normally. Even readily available circuits such as the 74S182 look-ahead carry generator can speed up the addition process (Fig. 4).

Manipulate the CPE with the controller

To operate all the control signals necessary to manipulate the processor formed from cascaded CPEs, the 3001 Microprogram Control Unit (MCU) keeps track of the sequence in which microinstructions are accessed. Microinstructions are, of course, the codes stored in ROM, PROM or RAM that determine the operations performed by the CPE and any other support circuits. Inside the MCU (Fig. 5) is an address-control section that provides a 9-bit output to address up to 512 words of control program. For additional addressing capability, you can use external registers, controlled by the MCU.

In addition to the 9-bit address output, the MCU has a 4-bit program latch, 2 flag registers, 11 jump commands, 8 flag-control commands and buffers on all output lines for three-state operation. Simple decoding is possible with a two-dimensional addressing scheme for the microprogram memory which separates the nine address lines into MA₈ to MA₁ for columns and MA₀ to MA₁ for rows. The microprogram memory can be expanded if necessary by adding a page-control flip-flop (Fig. 6).

Control of the MCU is exercised by microinstructions applied to the AC₉ to AC₁ lines and the FC₉ to FC₁ lines. These two control buses define a group of jump/test functions that create the next microinstruction address. Table 3 outlines how and what each of the jump/test functions performs, while Table 4 describes the eight flag-control capabilities of the 3001. The next address logic permits the MCU to unconditionally jump anywhere within a particular row or column but not anywhere within the 16 × 32 matrix. For any location contained in the matrix, the next address can be selected from a fixed subset of microprogram addresses.

Lines FC₉ to FC₁ enable the MCU to save the carry output of the CPE and control the carry input to it. Two flags, called the C flag and the Z flag, and a simple latch called the F latch indicate the current state of the CPE array’s carry-output line. Combined with the carry and shift logic of the CPE, the MCU’s flag logic can perform shift/rotate and arithmetic functions.

There are two special instruction buses on the MCU: the primary instruction bus, PX₉ to PX₁, and the secondary instruction bus, SX₉ to SX₁. The primary bus holds data that are tested by a JPX instruction to determine the next microprogram address. Secondary bus data are loaded into a four-bit PR latch and when PX-bus data are being tested, simultaneously appear at inputs to the next-address logic section. During a subsequent cycle, the contents of the PR latch may be tested by the JPR, JLL or JRL commands (see Table 3) to determine the next microprogram address. Information held in the PR latch can determine any of 16 possible branch addresses, while the latch outputs, PR₁ to PR₀, help to either modify microinstructions at the outputs of the microprogram memory or provide additional control lines.

Loading information into the MCU is controlled by the load (LD) line. If the line is active-high at the rising edge of the clock, the data on the PX and SX buses are loaded into the microprogram-address register and the M bit is set to 0. Since the interrupt-strobe enable of the MCU permits priority-interrupt control circuits to override the selected next-row address from the MCU, the MCU is forced to a new address.

Control the controller with memory

The microprogram memory addressed by lines MA₈ to MA₁ can be formed from many of the commonly available RAMs, ROMs or PROMs that have cycle times of 50 ns or longer. A circuit like the 82S115, a 512-word × 8-bit bipolar fusible-link PROM, will fit the bill. The 82S115 even has on-chip output latches that can be used as a
microinstruction register. With this extra register, pipelined operations can be performed with very little extra hardware.

Even programmable logic arrays can be used as MCU microprogram storage or decoder elements. A unit such as the 82S100/101 FPLA can be used to decode microinstructions by classes. These arrays offer up to 48 product terms (AND terms) and eight product function outputs. Each output can be programmed for either true active-high or true active-low; the true state of the output functions is controlled by an OR matrix.

For buffering data and instructions while they move around with a system, multiple-bit transceiver circuits, such as the 8T31, 32 and 33, provide buffering and on-board storage latches for up to eight bits of data. Many other devices offer two, four or six I/O buffers in single DIPs. Commonly used circuits include the 8T26A and 8T28 4-bit, three-state transceivers and the 8T95 to 8T98 6-bit, three-state buffers.

Developing the microprogram code to be stored
in the control memory is usually the most difficult part of the entire bit-slice processor design. First, let's establish two basic definitions: A microinstruction is the smallest instruction the MCU-CPE combination can perform. A macroinstruction represents a sequence of microinstructions that will be performed when the macroinstruction is requested.

Basically, the microinstruction (microword) consists of a number of control fields that handle the following functions:
1. Initiate main-memory operations.
2. Initiate I/O operations.
3. Decode instructions.
4. Control data transfers.
5. Test machine status.
6. Respond to processing interrupts.
7. Sequence addresses.

After all possible and necessary control functions are defined, the microword can be structured. For example, look at the structuring of a 32-bit microword in Fig. 7a. Split into many small groups of bits (called fields), the word can do many jobs at the same time.

Often user-defined macroinstructions are employed to call forth a sequence of microwords. Basically however, a macroinstruction is set up in a manner similar to a microinstruction. A typical 16-bit macroinstruction can be broken into five basic fields (Fig. 7b). To start with, the word might consist of two 2-bit, address-mode control bits, two bits for the source operand (AMS) and two for the destination operand (AMD). Two 3-bit fields can define the source register (RS) and the destination register (RD), which are then used in conjunction with the AMS and AMD fields to define where the source operand (data) is and where to put it (address). The other six bits are used for an operation code that defines the desired functions.

**Define the controller macroinstructions**

For an example of a macroinstruction, consider the command, Move Word. If AMS is set so that the source operand (the word to be moved) is in the location specified by RS, and AMD is set so that the destination address is formed by add-
<table>
<thead>
<tr>
<th>Mnemonic Definition</th>
<th>Description and diagrammatic explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>JCC</td>
<td>Jump in current column</td>
</tr>
<tr>
<td>AC&lt;sub&gt;.&lt;i&gt;j&lt;/i&gt; to AC&lt;sub&gt;.&lt;i&gt;k&lt;/i&gt; are used to select 1 of 32 row addresses in the current column. specified by MA&lt;sub&gt;.&lt;i&gt;j&lt;/i&gt; to MA&lt;sub&gt;.&lt;i&gt;k&lt;/i&gt; as the next address.</td>
<td></td>
</tr>
<tr>
<td>Function</td>
<td>Next row</td>
</tr>
<tr>
<td>AC&lt;sub&gt;.&lt;i&gt;j&lt;/i&gt; 5 4 3 2 1 0</td>
<td>MA&lt;sub&gt;.&lt;i&gt;j&lt;/i&gt; 7 6 5 4</td>
</tr>
<tr>
<td>0 0 d&lt;sub&gt;.&lt;i&gt;j&lt;/i&gt; d&lt;sub&gt;.&lt;i&gt;k&lt;/i&gt; d&lt;sub&gt;.&lt;i&gt;j&lt;/i&gt; d&lt;sub&gt;.&lt;i&gt;k&lt;/i&gt; d&lt;sub&gt;.&lt;i&gt;j&lt;/i&gt; d&lt;sub&gt;.&lt;i&gt;k&lt;/i&gt; m&lt;sub&gt;.&lt;i&gt;j&lt;/i&gt; m&lt;sub&gt;.&lt;i&gt;k&lt;/i&gt; m&lt;sub&gt;.&lt;i&gt;j&lt;/i&gt; m&lt;sub&gt;.&lt;i&gt;k&lt;/i&gt;</td>
<td></td>
</tr>
<tr>
<td>JZR</td>
<td>Jump to zero row</td>
</tr>
<tr>
<td>AC&lt;sub&gt;.&lt;i&gt;j&lt;/i&gt; to AC&lt;sub&gt;.&lt;i&gt;k&lt;/i&gt; are used to select 1 of 16 column address in row 0. as the next address. *See Note</td>
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<tr>
<td>Function</td>
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<tr>
<td>AC&lt;sub&gt;.&lt;i&gt;j&lt;/i&gt; 5 4 3 2 1 0</td>
<td>MA&lt;sub&gt;.&lt;i&gt;j&lt;/i&gt; 7 6 5 4</td>
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<tr>
<td>0 1 0 d&lt;sub&gt;.&lt;i&gt;j&lt;/i&gt; d&lt;sub&gt;.&lt;i&gt;k&lt;/i&gt; d&lt;sub&gt;.&lt;i&gt;j&lt;/i&gt; d&lt;sub&gt;.&lt;i&gt;k&lt;/i&gt; m&lt;sub&gt;.&lt;i&gt;j&lt;/i&gt; m&lt;sub&gt;.&lt;i&gt;k&lt;/i&gt; m&lt;sub&gt;.&lt;i&gt;j&lt;/i&gt; m&lt;sub&gt;.&lt;i&gt;k&lt;/i&gt; d&lt;sub&gt;.&lt;i&gt;j&lt;/i&gt; d&lt;sub&gt;.&lt;i&gt;k&lt;/i&gt;</td>
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<td>JCR</td>
<td>Jump in current row</td>
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<td>AC&lt;sub&gt;.&lt;i&gt;j&lt;/i&gt; to AC&lt;sub&gt;.&lt;i&gt;k&lt;/i&gt; are used to select 1 of 16 addresses in the current row, specified by MA&lt;sub&gt;.&lt;i&gt;j&lt;/i&gt; to MA&lt;sub&gt;.&lt;i&gt;k&lt;/i&gt; as the next address.</td>
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<tr>
<td>Function</td>
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<tr>
<td>AC&lt;sub&gt;.&lt;i&gt;j&lt;/i&gt; 5 4 3 2 1 0</td>
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<td>JCE</td>
<td>Jump in current column/row group enable PR-latch outputs</td>
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<td>AC&lt;sub&gt;.&lt;i&gt;j&lt;/i&gt; to AC&lt;sub&gt;.&lt;i&gt;k&lt;/i&gt; are used to select 1 of 8 row addresses in the current row group, specified by MA&lt;sub&gt;.&lt;i&gt;j&lt;/i&gt; and MA&lt;sub&gt;.&lt;i&gt;k&lt;/i&gt; as the next row address. The current column is specified by MA&lt;sub&gt;.&lt;i&gt;j&lt;/i&gt; to MA&lt;sub&gt;.&lt;i&gt;k&lt;/i&gt;. The PR-latch outputs are asynchronously enabled.</td>
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<td>JPR</td>
<td>Jump/test PR-latch</td>
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<td>AC&lt;sub&gt;.&lt;i&gt;j&lt;/i&gt; to AC&lt;sub&gt;.&lt;i&gt;k&lt;/i&gt; are used to select 1 of 8 row addresses in the current row group, specified by MA&lt;sub&gt;.&lt;i&gt;j&lt;/i&gt; and MA&lt;sub&gt;.&lt;i&gt;k&lt;/i&gt; as the next row address. The four PR-latch bits are used to select 1 of 16 possible column addresses as the next column address.</td>
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<td>Function</td>
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<td>JLL</td>
<td>Jump/test left-most PR-latch bits</td>
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<td></td>
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<td>AC&lt;sub&gt;.&lt;i&gt;j&lt;/i&gt; 5 4 3 2 1 0</td>
<td>MA&lt;sub&gt;.&lt;i&gt;j&lt;/i&gt; 7 6 5 4</td>
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<td>1 1 0 1 d&lt;sub&gt;.&lt;i&gt;j&lt;/i&gt; d&lt;sub&gt;.&lt;i&gt;k&lt;/i&gt; d&lt;sub&gt;.&lt;i&gt;j&lt;/i&gt; d&lt;sub&gt;.&lt;i&gt;k&lt;/i&gt; m&lt;sub&gt;.&lt;i&gt;j&lt;/i&gt; m&lt;sub&gt;.&lt;i&gt;k&lt;/i&gt; m&lt;sub&gt;.&lt;i&gt;j&lt;/i&gt; m&lt;sub&gt;.&lt;i&gt;k&lt;/i&gt; d&lt;sub&gt;.&lt;i&gt;j&lt;/i&gt; d&lt;sub&gt;.&lt;i&gt;k&lt;/i&gt;</td>
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Note: When d<sub>.<i>j</i> d<sub>.<i>k</i> d<sub>.<i>j</i> d<sub>.<i>k</i> = 1111, the ISE signal will be active. This signal can be used to communicate with the interrupt priority logic or some other type of logic.
Table 4. Flag controls for MCU

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<th>Flag input control functions (C, Z)</th>
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<td>STC</td>
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<tr>
<td>HCZ</td>
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</table>

6. If more than 512 words of microprogram memory are needed, the address bus of the 3001 can be expanded by adding an extra flip-flop for paging.

7. By making the microword as long as necessary, every control function you will ever want can be given its own field (a). A macroinstruction word can also be divided into fields (b), which must be decoded further into microinstructions.
8. Using a high-level Micro Assembler to turn mnemonic microword listings into executable code can cut the time required to develop and assemble microcode. Available

on time-sharing, the Micro Assembler developed by Signetics handles mnemonics, symbols and delimiters to simplify microcode generation.

ing the register contents specified by RD to the controller's base address, the sequence of operations performed by microinstructions (the microprogram) goes like this:

1. Fetch macroinstruction and update program counter.
2. Decode macroinstruction into classes with PLA or ROM.
3. Form destination address.
4. Form source operand address.
5. Execute transfer.
6. Allow for interrupts at end of execution.

In the mnemonics of the Series 3000 processors, the sequence of operations goes as follows:

1. AC=JCC; FC=HCZ, FF0; F=LM1
2. AC=JPX; FC=HCZ, FF0; F=ACM
3. PC=ACCUM, PC; AC=JRC; FC=HCZ, FF0; F=ILR
4. RD+ACCUM→RD, ACCUM; AC=JPR; FC=HCZ; FF0; F=ALR
5. RS→ACCUM; AC=JCR; FC=HCZ, FF0; F=JLR
6. AC=JZR; FC=HCZ, FF0; F=LM1

Of course, writing such programs requires that

you carefully structure exactly what you want the machine to do. But some program development aids will help you prepare microprograms for the Series 3000 processors. A Micro Assembler program from Signetics can translate a microprogram written in symbolic assembly language into executable binary form. Thus, microprogram commands can be expressed with mnemonics, symbols and delimiters (Fig. 8).

The Micro Assembler helps you keep track of all branch points by automatically assigning a physical address for each symbolic label. After the microprogram is assembled, it can be loaded directly into the appropriate PROMs or RAMs for execution. The Micro Assembler is available either on NCSS time-sharing networks or in purchasable form.

When debugging an assembled program, you can often employ a ROM simulator to temporarily hold the program. A ROM simulator is basically a read write memory configured to appear just like a particular type of ROM or PROM. However, unlike ROMs or PROMs, you can alter specific bits in the ROM simulator's memory.

Electronic Design 7, March 29, 1977
9. Building a memory-error logging and reporting subsystem is similar to designing a small computer. The only major difference is that no macroword decoding is necessary—the panel switches define every operation.

Now that you’ve become familiar with the important aspects of the Series 3000 bit slices, let’s step through a short design example of an 8-bit intelligent controller called a memory-error logging and reporting subsystem (MELRS). Look for the following attributes in the MELRS:

1. The subsystem is totally independent of its host system, a machine such as an IBM 370/168.

2. The MELRS logs single-bit and/or double-bit errors, and has a capacity for logging up to 51 errors that can be associated with 51 specific addresses of the host system. Each error may be monitored for occurrence up to 256 times at the scanning rate of the MELRS. The syndrome bits (or parity bits) associated with each error can also be logged. Logging proceeds until all log space is occupied; an indicator lights when it is full.

3. All error status reports in the log are displayed on hexadecimal displays. The error count can be used to judge the seriousness of a particular memory error.

4. The MELRS has two reporting modes: (a) single-step, in which errors are reported one at a time, and (b) auto-step, in which error data are displayed every 0.5 s with internally programmed delay routines. Once all errors have been shown, the display can be terminated by deactivating the execute switch.

5. A feature is included to stop the MELRS each time an error is detected and displayed. No logging will take place, and a manual reset will restart the MELRS.

6. Another mode not only permits an error to be detected and displayed, but also logged into the next available space if it is a new error. If an error is already logged, its associated count is updated.

7. A log-reset control clears all log memory, including all 3002 CPE registers.

Basically, the MELRS subsystem resembles a simple computer, as shown in Fig. 9. The design,
11. Flow-charting the machine's operation before the program is written is a must. Since there are many decision points, the MELRS flow chart gets to be very complex.

12. The random-access memory needed to hold the log data must be grouped into blocks of five bytes for each error file. Three bytes are needed for the system address, one for the parity and one for the error-count.

However, differs from a typical computer structure in that it has no macroinstruction set to execute. Instead, the subsystem responds to commands from the activated front-panel switches that load instructions directly into the 3001.

The processing section consists of four 3002 slices cascaded to form 8-bit data and address paths. Internal registers in the 3002 are assigned different functions, as defined in Fig. 10. A single 3001 stores and decodes the function-select commands. The control program is stored in four PROMs to provide a 512-word × 32-bit memory, whose format is similar to the control word shown in Fig. 7a. A flow chart describing the entire machine's operation is shown in Fig. 11.

All commands come from the front panel and all inputs of loggable data (addresses, parity bits, and so on) come from the host system. An error signal generated by the host system indicates when information on the address and data buses should be latched and subsequently processed.

The log consists of two 2606-1 RAMs, connected to look like 256 words × 8 bits and organized as shown in Fig. 12. Five bytes of storage space are reserved for each error: three bytes for the host system address, one byte for the parity bits and one for the error count.
COMING
JUNE 7
Electronic Design's
MAJOR SEMI-ANNUAL
COMPUTER REPORT

The most intensive editorial coverage of computers that Electronic Design has ever attempted is scheduled for June 7. The semi-annual COMPUTER REPORT will feature emerging standards for semiconductor memories, standards and protocols for data communications, computer-aided-design software and an in-depth interview with a leading industry authority. It's an issue you'll want to keep for months to come.

PLUS
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PLUS
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MINIATURIZED POWER SUPPLIES

For Logic and Op Amps

With Screw Terminals

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PCB Mounting

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<td>1</td>
<td>130</td>
<td>D15-50</td>
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</table>

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

Case Sizes and Weight:
EB-10: 3.5" x 2.5" x 1.375" (1 lb)
EB-13: 3.5" x 2.5" x 1.625" (1 lb 5 oz)
EB-20: 3.5" x 2.5" x 2.375" (2 lb 1 oz)
EL-10: 3.5" x 2.5" x 1" (15 oz)
EL-13: 3.5" x 2.5" x 1.25" (1 lb 3 oz)
EL-20: 3.5" x 2.5" x 2" (2 lb)
ES-10: 2.3" x 1.8" x 1" (7 oz)

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Input Voltage: 105-125 Vac, 47 to 420 Hz, single phase.
Output Voltage Setting: Single output models are factory preset to within ±2% of nominal output voltage, and may be more precisely trimmed to the nominal voltage rating with an external trim resistor. Dual models are set to within ±1% of their nominal ratings, and are not trimmable.
Polarity: Either positive or negative terminal of a single output module may be grounded. Dual output modules have a positive/common/negative output terminal configuration.
Ambient Operating Temperature: -20 to +71°C (Model 5E150 and 5EB150, 0 to +71°C) No derating required.
Temperature Coefficient: 5-volt models, .03%/°C; dual output models, .015%/°C.
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Trace FET bias curves on any oscilloscope, and save extensive computation time. A simple curve tracer can be made with relatively few parts.

You can build a simple curve tracer with a quad op amp and a handful of parts. The circuit displays drain current-vs-gate voltage for both p and n-channel JFETs on any oscilloscope at a constant drain voltage (Fig. 1).

The circuit may be limited to merely displaying $I_D$ vs $V_{GS}$, but this curve is the one most needed by designers—it provides insight into parameter variations of bias circuits, and can be used to observe temperature effects on the FET.

The oscilloscope’s vertical input shows the drain current and the horizontal shows gate voltage. If no horizontal input is available, the horizontal sweep can be used. In that case, a sweep rate of 0.5 ms/cm corresponds to 0.5 V/ms, which allows the curve tracer to be used with any scope.

The problem with calculations

By their very nature, JFETs are voltage-controlled devices. Unfortunately, gate-to-source variations of several volts can exist among different versions of a given type at the same operating conditions. Consequently, JFETs don’t easily lend themselves to analytic solutions of bias networks. Multiple suppliers and inadequate or nonexistent data-sheet curves further compound the problem by requiring the use of a curve tracer.

The circuit consists of an op-amp, current-to-voltage amplifier with a positive or negative-gate sweep voltage (Fig. 2). The amplifier takes up one-fourth of the quad op amp and uses switchable feedback resistors to scale drain current: 1 kΩ for 1 mA/V, 200 Ω for 5 mA/V and 100 Ω for 10 mA/V. An npn-pnp emitter follower buffers the amplifier to handle high FET currents (to 100 mA). A unity-gain inverting amplifier provides proper drain-current polarity.

The gate-sweep generator consists of a resettable linear ramp generator and a window comparator. The ramp generator is an op amp with a capacitor in its feedback loop (Fig. 3).

John Maxwell, Senior Engineer, National Semiconductor, 2900 Semiconductor Dr., Santa Clara, CA 95051.

1. Output of the curve tracer is a typical FET transfer curve, like this one for an n-channel unit.

Sweep rate is set by a constant current supplied to the capacitor through a resistor tied to either the plus or minus voltage supply.

Going from p to n channel

The positive (p-channel) ramp mode makes use of the positive reference on the plus input of the comparator, with the ramp connected to the minus input. The comparator output stays high (+15 V), and pinches the FET off until the input exceeds the reference (+10 V). At that point, the output snaps to the negative supply to turn the FET switch on and discharge the capacitor. When the comparator output is in a low state, the reference voltage at the plus input is set near ground by the 51-kΩ input resistor, diode D, and 68-kΩ feedback resistor. When the capacitor is discharged, the comparator resets, and restarts the ramp (Fig. 4a).

A negative sweep is more difficult to generate with the comparator. The reference (−10 V) is now on the minus input, with the ramp connected to the plus input. As with the positive sweep, the comparator output stays high until the negative sweep exceeds the reference. Now, the reference cannot be set to ground for the reset sweep but must be set to a negative voltage so that when the ramp is at zero, the comparator resets (Fig. 4b). The function of Q, is to short R,
2. **Basis of the tracer** is a current-to-voltage converter designed around an op amp (A₁), one-fourth of a quad. Amplifier A₂ forms a unity-gain inverter, while A₃ and A₄ form the sweep generator. Sweep rate is 0.5 V/ms.

3. The linear ramp generator: the J176 resets the ramp, and the RC combination determines the sweep rate.

4. **Switching operation from p-channel to n** charges the sweep from a positive (a) to a negative-going ramp (b). In both instances, the sweep time is 10 ms.

which changes the reference voltage from -10 to -6 V.

In both positive and negative cases, the sweep takes 10 ms. The resistive attenuator on the FET gate terminal divides the voltage in half to yield a sweep rate of 0.5 V/ms with a maximum gate voltage of ±5 V. This rate should be adequate for most FET amplifiers. If additional gate voltage is required, the attenuator can be switched out.

---

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**SELECTION OF TIMING COMPONENTS**

<table>
<thead>
<tr>
<th>Timing components</th>
<th>Oscillator period</th>
<th>Time period</th>
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<tr>
<td>C₁, R₂, R₃, C₄ (Internal Rᵥ, Cᵥ)</td>
<td>2736R, Cᵥ (300 kΩ Rᵥ)</td>
<td>7500R, Cᵥ</td>
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<tr>
<td>0.01 μF</td>
<td>39 kΩ</td>
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<tr>
<td>0.1 μF</td>
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<td>1 μF</td>
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</tr>
<tr>
<td>1000 μF</td>
<td>2-2 μF</td>
<td>220 sec</td>
</tr>
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</table>

Recommended values of Rᵥ for linearity and temperature performance should be between 50 kΩ and 1 MΩ. Similarly, Cᵥ should be above 0.01 μF.

---

**LOGIC DIAGRAM**

---

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CIRCLE NUMBER 59

---

**ELECTRONIC DESIGN** 7, March 29, 1977

---
Need a PIN-diode attenuator? An improved circuit provides a constant characteristic impedance, logarithmic control and temperature compensation.

If you configure a PIN-diode attenuator properly, you can achieve a constant characteristic impedance, temperature compensation and a logarithmic control of attenuation. Here’s a simple arrangement that provides all these properties and operates to 120 MHz with better than a 1.1-to-1 VSWR. The maximum attenuation is over 30 dB and the minimum attenuation, or insertion loss, is 0.3 dB.

At high frequencies, PIN diodes function as current-controlled resistors whose resistance can be varied over a range of about 2 Ω to 10 kΩ. This behavior allows them to be used as rf switches and electronically variable attenuators.

At low frequencies, PIN diodes act like conventional diodes. The transition frequency between the two modes is governed by the diode’s minority-carrier lifetime and may be as low as 1 MHz for the latest diodes. Above the transition-frequency, distortion introduced by the diode rapidly declines.

In fact, PIN-diode attenuators produce much less intermodulation distortion than variable-gain transistor stages. And with proper combinations of shunt and series diodes that are suitably biased, the PIN attenuator can provide a constant-impedance characteristic.

However, it’s difficult to maintain a correct relationship among the dc currents that are used for biasing the different diodes at all attenuation settings. Conventional drive circuits employ combinations of current and voltage sources, but they are at best only a compromise solution. The circuits don’t keep the impedance constant over the whole attenuation range. Before attacking the problem of biasing the diodes, let’s look at the criteria for constant impedance in L and T pads.

Keeping the attenuator impedance constant

A single-section attenuator pad can have three variable elements, such as in a T or π section, or two variable elements, R₁ and R₂, as in the L or bridged-T sections of Fig. 1. When correctly configured, the L-pad sections present a constant impedance, only when “looked at” from the input side. The bridged-T configuration, however, is matched in both directions.

If the voltage ratio, \( V_{\text{out}} / V_{\text{in}} \), is r, then for the L pads,

\[
R₁ = \frac{Z_n (1 - r)}{r}
\]

and

\[
R₂ = \frac{r Z_n}{(1 - r)}
\]

Roger S. Viles, Principal Electrical Engineer, Xerox Research (UK) Ltd., 99 Bridge Rd., East, Welwyn Garden City, Hertfordshire, AL7 1LQ, UK.

1. L-pad attenuators can provide a constant characteristic impedance, \( Z_n \), as the attenuation is varied—but only at the input terminals. A bridged-T configuration can keep \( Z_n \) constant at both input and output terminals.

2. A pair of PIN diodes in an L-pad configuration can be used to attenuate rf signals controlled by dc current. Both \( I_1 \) and \( I_2 \) must be varied appropriately to control attenuation and keep \( Z_n \) constant.
to keep the input constantly equal to $Z_0$ as $r$ is varied. For the bridged-T pad, 
$$R_e = Z_0 \frac{1 - r}{1 - r}$$
and 
$$R_i = \frac{Z_0}{1 - r}.$$  
Therefore, the two-variable-element attenuators have a characteristic impedance given by 
$$Z_{2n} = \sqrt{R_e R_i}.$$  
(1)  
And maintenance of a constant impedance independent of the attenuation setting requires that the product, $R_e R_i$, be held constant.

**Implementing a PIN L-pad**

A constant-input impedance, $Z_0$, can be attained for variable attenuator action if two PIN diodes, $D_1$ and $D_2$, are arranged as in Fig. 2, and the dc currents through them, $I_1$ and $I_2$, respectively, are properly controlled. The inductors and capacitors in Fig. 2 merely serve to separate the $rf$ signals and dc-current paths; variable resistor $R_e$ provides a path for dc current and allows variations in $I_1$ and $I_2$.

The high-frequency resistance of a PIN diode is given by the equation, 
$$R = \frac{A}{I},$$
where
$$I = \text{forward current},$$
$$x = 0.88 \text{ (a constant)},$$
$$A = \text{diode constant}.$$

To satisfy the constant-impedance criterion of Eq. 1, the product of the resistance, $R_e$, $R_i$, of $D_1$ and $D_2$ must be kept constant. So if $A, A_x/I, I_x^z$ is to be constant, then $I_1 I_2$ must be held constant.

Most methods for keeping the product of two currents constant involve expensive circuit elements such as analog multipliers or logarithmic amplifiers. However, a simpler method can be used for a two-PIN-diode attenuator pad. Since the diode's forward current is an exponential function of forward voltage, keeping the sum of the two forward voltages constant will hold the product of the two currents constant.

For each PIN diode, the forward current can be expressed as 
$$I = I_s e^{q(V_i + V_s)/kT},$$
when forward-biased by a voltage, $V$. The other terms in this equation are defined as 
$q = \text{charge on an electron},$
$k = \text{Boltzmann's constant},$
$T = \text{temperature in }^\circ \text{K},$
$I_s = \text{reverse saturation current}.$

As a result, 
$$I_1, I_2 = I_{10}, I_{20} e^{q(V_i + V_s)/kT},$$
However, this result is true at only one temperature, because 
$$I = B f(T),$$
where $B$ is a constant for any one diode. Therefore, 
$$I_1, I_2 = B, B_2 f(T) e^{q(V_i + V_s)/kT}.$$  
**Compensating for temperature changes**

The temperature sensitivity of the PIN diodes can be compensated with two reference diodes, $D_1$ and $D_2$, as in Fig. 3. If in each reference diode the current is 
$$I' = B' f(T) e^{qV'/kT},$$
for the two diodes in series, the current product is 
$$(I')^2 = B_1 B_2 f'(T) e^{q(V_i + V_s)/kT}.$$  
By maintaining 
$$V_i + V_s = V_i + V_s',$$
then 
$$I_1 I_2 = B, B_2.$$  
Consequently, $I_1 I_2$ can be constant as required if $I'$ is held constant, and if all four diodes, when mounted in the circuit, are kept at the same temperature by close thermal coupling.

In Fig. 3, the voltage follower, IC, keeps the input constant by using the constant-current diode, $IC_2$. The op amp, $IC$, keeps the voltage drive to both sets of diodes equal, and $IC_2$ acts as a current-sink control for the PIN diodes and as a temperature compensator.
sum voltage across the PIN diodes equal to the sum voltage across the reference diodes, in accordance with Eq. 4. And voltage follower IC₂ acts as a current-source and sink to change the PIN-diode current and control the attenuation.

As derived previously, temperature compensation of the constant-impedance part of the circuit is inherent in the four-diode design. However, the temperature compensation of the attenuation-control function is achieved by referencing the attenuation-control input to the midpoint of the reference diodes.

Since the attenuation-control voltage varies the PIN-diode currents exponentially (Eq. 3), a fairly linear relationship exists between control voltage and attenuation on a logarithmic, or dB, scale. This relationship is highly advantageous for many applications.

**Building a practical attenuator**

The functional circuit of Fig. 4 follows the configuration of Fig. 3 and provides the necessary blocking capacitors, inductors and low-pass filters to separate the dc and rf paths. The circuit is designed as a 75-Ω L-pad attenuator with HP5082-3081 low-distortion PIN diodes. For these diodes the I₁I₂ needed to attain 75-Ω impedance is (540 µA)² and the corresponding sum of forward voltages is 1.2 V. The 68-Ω resistor in the path of D₂ differs from the theoretical value of 75 Ω because of the residual series resistance of the PIN diode.

Of course, good high-frequency design and layout techniques are essential to take advantage of the circuit’s ability to achieve a constant impedance over a wide frequency and temperature range. The use of chokes and blocking capacitors with low parasitic reactances is especially important.

---

4. A working PIN-diode attenuator must provide separation of the dc control-current and rf-signal paths.
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The tough SBL-1 covers the broad frequency range of 1-500 MHz with 6 dB conversion loss and isolation greater than 40 dB. Only well-matched, hot-carrier diodes and ruggedly constructed transmission-line transformers are used. Internally, every component is bonded to the header for excellent protection against shock, vibration and acceleration. Here are some of the steps taken to ensure quality: Every SBL-1 is RF tested two times, every solder connection is 100 per cent inspected under a high power microscope, all transformer leads are double-wrapped, and all components are rated for more than +85 °C operation. Of course, our one-year guarantee applies to these units.

For demanding industrial and commercial applications, where low cost and high performance are critical, model SBL-1 will fill your need.

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Simple CMOS keyboard encoder circuit programs voltage source in 1-V steps

You can now easily get the convenience of keyboard control of a voltage source by using a CMOS IC key encoder. The encoder scans, de-bounces, encodes and latches the position of any key in an array.

In the circuit shown in the figure, the keys program output voltage in 1-V steps from zero to 15 V, when a 74C922 IC encoder is used. A 1-V vernier, \( R_v \), adjusts voltages between steps, increasing them above the keyed value, so the full range is zero to 16 V. The arrangement can easily expand to 20 V maximum by using a 74C923, a 20-key assembly and another resistor-ladder section. At least 100 mA can be supplied without the aid of an external heat sink.

The encoder binary outputs are summed in an R-2R ladder and then added to a properly weighted vernier voltage to become the reference input voltage for the circuit's output op amp, \( A_o \).

The \( V_{cc} \) supply of the encoder, derived from op amp \( A_v \), is adjusted accurately to 8.00 V for a 16-key encoder and 10.00 V for a 20-key unit.

Gerald Buurman, National Semiconductor, 2900 Semiconductor Dr., Santa Clara, CA 95051.

CIRCLE No. 311
The NEW POCKET SIZE DVOM for all occasions. $140

Triplett’s New 3000 DVOM goes everywhere . . .

At the bench . . . away from the bench . . .

This super-compact five function, 22 range DVOM has all the features you’d expect from Triplett. Like 3½ digit hi-intensity LED display, rechargeable snap-in Ni Cad Battery Pac™ with an AC charger. And, you get all the “automatics” that make life a lot simpler: Auto-zeroing, auto-polarity and auto low-battery warning. The red and gray probe includes a switch with momentary “ON” and lock “ON” and “OFF” positions for convenient operation.

1 HAND-SIZE, 3½ DIGIT—Easy operation with 22 ranges and Hi/Low Power Ohms. Auto-zeroing and Auto-polarity.

2 OVERLOAD PROTECTION—Protected up to 600 volts on all ranges with special 2A/600V fuse arrangement.

3 BATTERY PAC™—Easily removed, snap-in Battery-Pac™ provides convenient field exchange for fully charged Pac. Battery Pac™ rechargeable in tester or externally.

Price does include Ni Cad batteries and AC Charger.

Ask your Triplett distributor to demonstrate the rugged little Model 3000 DVOM and show you our complete line of handy accessories, too.
Phase-sequence detector built with a dual D-type flip-flop

One CMOS dual D-type flip-flop and several easily obtainable discrete components are all that is needed to build a circuit to detect the correct phase sequence in a three-phase ac source (Fig. 1). The circuit energizes a relay when the phase rotation is correct. Though the values shown are for a 115-V, 400-Hz three-phase source, the circuit can work on other power frequencies and with little modification on other voltages. The relay de-energizes when the sequence is wrong, or if one of the phases drops below 50% of the nominal voltage value.

The sine wave of each input phase is squared by the zener diodes Z1, Z2, and Z3, and square waves A and B (Figs. 1 and 2) are applied to the flip-flop clock inputs, C1 and C2, respectively. Square wave C is differentiated by the C1R1 combination.

Positive-going pulses that develop across R1 are fed through diode D, to both reset inputs of the two flip-flops. As a result, when the input sequence is correct, a train of rectangular pulses appears at the Q3 output of the second flip-flop (Fig. 2). Finally, after some low-pass filtering by R1 and C1, these Q3 pulses drive the output Darlington, T1, and T2, into conduction and energize a relay.

If the phases are in a wrong sequence, or if \( \phi_n \) or \( \phi_m \) is missing or less than 50% of the nominal voltage, the output Q2 remains LOW. In addition, the relay won’t pull in if \( \phi_n \) drops below the 50% threshold since the circuit’s power voltages, \( V_{cc} \), and \( V_{dd} \) are both obtained from \( \phi_n \).

The neon lamps, NE1, NE2, and NE3, give a visual indication when the three phases are present, and together with the 10-V zener diodes provide the required 50% threshold.

If a visual indication is not desired, the neon lamps can be replaced by suitable Diacs or four-layer diodes.

Amos Blumin, Technician Engineer, Ministry of Defense, State of Israel, P.O.B. 2250, Haifa, Israel.

CIRCLE No. 312

1. The phase-sequence detector circuit derives its supply voltage, \( V_{cc} \), and \( V_{dd} \), from \( \phi_n \). This factor, together with the neon lamps and zener diodes in the phase inputs, establishes a 50% threshold that detects low voltage or absence of one or more phases. Relay K1 energizes for correct phase volts.

2. Any one of the following correct phase sequences ABC, BCA or CAB will produce a train of rectangular pulses at the output Q2, in Fig. 1. For incorrect sequences BAC, ACB or CBA the output, Q2, stays LOW.
VARO’s “Hot Line” Schottkys can take your heat

- 150°C max. Tj
- 20–40V, PIV
- 1–40A, Io

Varo Semiconductor, Inc. is the only manufacturer offering a complete line of Schottky Barrier Rectifiers with 40V PIV rating and 150°C maximum junction operating temperature (Tj). These Schottkys can simplify your design problems by allowing a greater safety factor in component selection. You are no longer limited to 30V PIV and 125°C max. (Tj).

You also have the option of dual center-tapped devices in a convenient TO-3 package. They are priced lower than two comparable stud-mount units, simplify installation and reduce assembly costs.

So, when you are considering Schottky, specify Varo. You will be convinced that the “Hotline” is the way to go.

Other Features Include:
- Low Forward Voltage Drop (0.62V max @ 40A and Tj = 25°C)
- Low Reverse Leakage (150mA max @ 40V and Tj = 100°C)
- Very Fast Recovery (<10nsec.)
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- Epoxy axial lead, DO-4, DO-5 and TO-3 packages.
- Competitive Pricing

For more information and data sheets call Mike Hawkins, 214-272-4551. (Components available from stock from Varo distributors.)

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Pincushion distortion on CRT displays can be solved by the Syntronic problem solvers when electronic circuit correction is out of reach.

A Syntronic yoke with carefully calibrated and accurately positioned magnets will “push” in the corners and “pull” out the sides for near-perfect geometry. Any remaining distortion or defocusing is corrected with Syntronic’s stator core design combined with special coil turns distribution.*

To see the difference 28 years experience makes, let Syntronic solve your geometry problem.

*Be sure to get “Geometric Distortions” AP Note, Syntronic Booth 340 at the SID Show.

SYNTRONIC INSTRUMENTS, INC.
100 Industrial Road
Addison, IL 60101
Phone (312) 543-6444
Build a warbling alarm generator with two op-amp oscillators

A penetrating alarm that's difficult to ignore and capable of cutting through high background noise is generated by the circuit in the figure. It consists mainly of two op-amp oscillators. One oscillator, A₁, operates around 1/2 Hz and another, A₂, operates at a variable frequency, sweeping from 200 to around 5000 Hz. Oscillator A₁ generates a triangular signal at its inverting input terminal. The signal is amplified by the Darlington, Q₁, which drives a LED. The LED current changes from 0 to about 30 mA and back. The resistance of the light-sensitive resistor, LDR, which is illuminated by the LED, varies accordingly and changes the frequencies of oscillator A₂.

With the components shown on the diagram, the sound from the speaker rises gradually from about 200 to 5000 Hz in 1.02 s and then decreases in 1.32 s. The frequency range can be shifted by changing C₂ and the time of rise and fall by changing C₁.

Gunnar Gotschalken, Lavrans vei 15, Oslo 6, Norway.

CIRCLE NO. 313
Small Wonder

*It's PICOTEMP® thermal cutoff
New from Micro Devices
(Actual Size)

PICOTEMP® thermal cutoffs
Fit tight spaces—and limited budgets. Same
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- current capacity—to 5 amps. at 120 VAC. Will hold this rating up to and including 240 VAC.
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  +0°C to 3.3°C
- temperature ratings
  63°C to 105°C (146°F to 300°F)
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CIRCLE NUMBER 68
Compact YIG film delay line is nondispersive

A compact, low-loss microwave delay line with a 150-MHz bandwidth in the 7-to-11-GHz operating range has been developed by the General Electric Co., Wembley, England. Magnetostatic-wave propagation within an epitaxial yttrium-iron-garnet (YIG) film is used to provide such delays.

Earlier delay lines of this kind suffered from a major drawback—they were inherently dispersive because the group delay was a monotonic function of frequency. The delay line provides nondispersive delays of 75 to 125 ns over any 150-MHz bandwidth from L to the X-band. An applied magnetic field controls the operating frequency. Delay is achieved with forward-traveling magnetostatic volume waves that propagate within a dielectric layered structure. The magnitude of the delay, like the nondispersive bandwidth, remains virtually constant.

An 18.4-μm YIG film is grown by the liquid-phase-epitaxy technique on a <111>-oriented gadolinium-gallium-garnet substrate. Preliminary measurements have revealed no saturation effects for forward-traveling magnetostatic volume waves at frequencies down to 0.6 GHz. Below this frequency, excessive insertion loss occurs because the YIG film is no longer magnetically saturated.

Gallium-arsenide LED has high bandwidth

A gallium-arsenide LED produced by researchers at the University of Munich, West Germany, has an unusually high 3-dB modulation bandwidth that is greater than 1 GHz. Usually, the bandwidth of such a device—which is used in optical-transmission systems—is limited by a long electron lifetime as well as the diode’s space-charge capacitance.

For high-speed LEDs, a short electron lifetime can be obtained by high active-layer doping. But as the doping level is increased, LED efficiency is reduced and its spectrum broadened. A homostructure with an active-layer width shorter than the electron diffusion length can be used to reduce the electron lifetime further. The time delay due to the diode’s space-charge capacitance can be shortened as well by using a small area for the p-n junction and a low doping level for the electron-emitting n layer.

All these techniques have gone into making the German-produced LEDs. The devices consist of a 2-μm wide layer of n-GaAlAs doped with Sn (n = 5 \times 10^{16} \text{ cm}^{-3}) and an active layer of p-GaAs doped with Ge (p = 1.5 \times 10^{18} \text{ cm}^{-3}). Active-layer width is 1.2 μm. The p-layer doping level corresponds to a bulk electron lifetime of 1 μs and an electron diffusion length of 2.3 μm. Because the width of the active layer is only 1.2 μm, the effective electron lifetime is reduced to less than 200 ps. Isolation of the p-n junction outside the light-emitting area is achieved by proton bombardment to obtain a small active area 50 μm in diameter.

The figure shows the normalized light output against modulation frequency; the broken lines indicate a 3-dB modulation bandwidth of 1.1 GHz (1100 MHz).

For a dc bias of 100 mA, the LED emission is W/steradian/cm² with an emission wavelength of 895 nm and a spectral line width of 36 nm.

Laser used for remote air pollution sensing

In a two-year research project, sponsored in part by the National Swedish Environment Protection Board in Stockholm, laser beams are being used for the remote sensing of air pollution.

Beams are directed at smoke emitted from chimneys. Reflections from smoke particles are returned to a receiver and converted into computer data.

Tests have been made at Sweden’s West Coast Scanraff refinery and AB Ferrolegeringar in Trollhatten.

Remote sensing of pollution has so far been carried out from a distance of between 300 m and 2 km.
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One failure in 3,810,000 unit hours proves our success.

At MF Electronics, people were constantly telling us how good our oscillators were, usually over the phone.

In fact, an engineer from Stromberg-Carlson, one of our major customers, told us some pretty impressive facts. Also over the phone.

Could you, we wondered aloud, put that in writing? We're not asking for an endorsement. Just tell us your experience with our product.

He did. And what he wrote back to report to us was this:

Our oscillators were used on a clock card assembly in the common control to provide primary timing signals for switching network and feature operation. Since the system was designed with a non-redundant single common control, reliability of the clock card and oscillator was essential.

Breathlessly, we read on.

Out of approximately 3,810,000 part-hours of crystal oscillator operations, he wrote, ONLY ONE failure was identified!

Just as we were about to burst with pride, we remembered the one failure. Because we guarantee our oscillators, naturally we replaced it.

But what we won't replace is our determination that none of our oscillators will ever fail.

And from this we will not waver.

Below, we have listed various types of the oscillators we make. Browse through it. If you are interested in a quality oscillator, MF Electronics makes it.

CPS specializes in medium-to-high resolution and fast settling time devices for data acquisition, instrumentation, process control and many other signal converter applications where product reliability is a must.

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Call or write CPS, the "Can-Do" company, for the economical answer to your signal converter requirements.

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Opening new frontiers with electro optics

RCA Helium-Cadmium lasers offer long life: we ran one for more than 12,000 hours.

If you need 20 mW typical output in the blue region (441.6 nm), you get that and a lot more in RCA's Helium-Cadmium Laser System LD2186A.

You also get excellent long-term stability: ±1% typ. Low noise: 0.7% rms typ. (10 Hz to 10 MHz).

Convection cooling: no fans or water. And—very important—long life.

As the graph shows, typical life is greater than 6,000 hours—but we operated one continuously for more than 12,000 hours. A helium reservoir plus an innovative recirculating cadmium system are what make the LD2186A a reliable, long-life system for facsimile, COM, phototypesetting, pollution monitoring, video recording and non-impact printing. LD2186A is available from stock. For UV applications, we also offer a version with 325 nm output.

Solid state laser breakthrough: CW output at room temperature!

You get at least 5 mW of continuous lasing in a solid state package. RCA's new AlGaAs CW injection lasers have a rise time of less than 1 ns—allowing modulation rates beyond 100 MHz. This plus small source size (13 x 2 μm typical) and 820 nm wavelength make the C30130 and C30127 well suited to optical communications, facsimile, fiber-optic transmission, document reading, flying spot scanning.

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. Sunbury-on-Thames, Middlesex TW16 7HW England; Ste.-Anne-de-Beauvoir, Quebec, Canada; Belo Horizonte, Brazil; Hong Kong.

Circle 141

Circle 142
Fast fall-time power transistors handle large secondary breakdown energy

Unitrode Corp., 580 Pleasant St., Watertown, MA 02172. (617) 926-0404, $5.62: UMT 1009 (100 up); spring, 1977.

A significant advance in the state of the art of switching power transistors has just been announced by Unitrode. Under uniform test conditions, its UMT1008/9 (8 A, 400/500 V_{ce}) npn transistors, which are built into an innovative, triple-diffused mesa configuration, can provide about half the fall time (\(t_f\)) and more than three times the reverse-biased, secondary-breakdown energy capability (\(E_{sb}\)) of such competing units as the popular 2N6514, 2N6544 and 2N6579.

Since fall time, in particular, greatly depends not only on circuit configuration but also voltage, current and load levels, uniform test conditions are mandatory for valid comparisons. Representative units were checked in the circuit and under voltage/current conditions specified by both Unitrode and the competition. Most often, according to Unitrode engineers, UMT1008/9 units had a superior \(t_f\).

Preliminary specifications for the UMT1008/9 guarantee a maximum \(t_f\) of 0.4 \(\mu\)s and \(E_{sb}\) of 1.5 mJ at 25 C. In the comparison tests, however, units typically checked out with a \(t_f\) as fast as 0.17 \(\mu\)s and an \(E_{sb}\) as high as 5 mJ. And at 100 C, the Unitrode transistors came out even better than the other units tested.

Unitrode claims that its new proprietary transistor design eliminates the performance compromises imposed by conventional designs: Low \(t_f\), designs usually result in poor \(E_{sb}\). In addition, when a conventional power transistor is turned off, the transistor's conduction region shifts from the periphery of the emitter structure toward the center. This shift has two adverse effects:

1. As conduction shifts away from the emitter edge, the base resistance between the shifting conduction site and the base terminal increases. Consequently, when the base is driven from a practical impedance source with a finite resistance, the increasing base resistance reduces the turn-off base drive by 1/2 to 1/4 the initial value and greatly increases fall time.

2. As the conduction area shrinks and moves toward the center of the emitter, the power density increases and severely limits the conventional device's \(E_{sb}\).

Unitrode's design innovation holds the conduction region at the emitter periphery during the entire turn-off period. As a result, the turn-off base drive remains substantially constant during device turn-off, \(t_f\) improves considerably and the \(E_{sb}\) limitation caused by current crowding vanishes.

As a result, the cost of the base-drive circuitry can be reduced by trading the improved \(t_f\) off against reduced turn-off base drive. For example, fall times adequate for efficient operation of a 20-kHz, off-line switching regulator can be achieved without using a high negative-voltage turn-off signal. Simply putting a resistor and a ferrite bead between base and emitter can provide a suitable turn-off time.

An efficient switching transistor must possess a low \(t_f\), because a major portion of the transistor's power dissipation occurs during this time: The collector current, although falling, is still substantial, while the collector voltage is at least 90% of the circuit's \(V_{ce}\). Therefore, manufacturers invest considerable effort in designing power transistors with low fall times. In addition, the circuit designer is advised to strongly reverse-bias the transistor when turning it off, which also reduces fall time.

Since many loads are inductive, the \(E_{sb}\) rating is important: It defines the amount of energy that the transistor can safely absorb, unclamped, in a reverse-biased avalanche mode. Although circuit designers should avoid working the transistor in the avalanche mode, by using clamping or snubbing devices, a high permissible \(E_{sb}\) indicates a high safety factor.

Unitrode
Motorola
RCA
TRW

Five-digit LED display offers many options

National Semiconductor, 2900 Semiconductor Dr., Santa Clara, CA 95051. (408) 737-5000. $8.40 (100 up); stock.

The 5900 series of GaAsP LED reflective displays, 0.5-in. high, offers both common-anode (NSB-5922) and common-cathode (NSB-5921) multiplexed versions for five digits, and an option of direct-drive overflow/polarity indication with four digits in a common-anode multiplexed format (NSB-5917). Electrical connection is by PC-board terminals on the edges of the displays.  

CIRCLE NO. 308
DISCRETE SEMICONDUCTORS

Power transistor rated 100 W at 500 V
International Rectifier, 233 Kansas St., El Segundo, CA 90245. (213) 322-3331. $7.93 (100-999); stock.
A new power transistor, the npn 2N5157, rated for maximum power dissipation of 100 W and designed for operation at 500 V (collector-to-emitter) and 3.5 A is available with collector-to-base voltage ratings as high as 700 V. The units are especially well suited for applications in inverters and chopper regulators, automotive ignition circuits and high-voltage power supplies. Packaging is in industry standard JEDEC TO-3 metal cases. Maximum junction operating temperature is 150°C, and the maximum thermal resistance (junction-to-case) is 0.75°C/W.

CIRCLE NO. 309

Opto-isolators operate directly on ac inputs

Clairtex Electronics, 560 S. Third Ave., Mount Vernon, NY 10550. (914) 664-6602. $1.10 (1000 up); stock.

Four new opto-isolators permit operation directly with an ac input. The units use two infrared emitting diodes connected in inverse parallel in the input circuit. Two of the units (CLI-25/26) use phototransistors in the output circuit, and the other two units (CLI-27/28) use photo-Darlington outputs. All of the units provide a minimum isolation of 2500 V peak.

CIRCLE NO. 310

LEDs directly replace incandescent lamps

Data Display Products, 5428 W. 104th St., Los Angeles, CA 90045. (213) 631-1232. $1.21: 5 & 6 V (1000 up); stock to 5 weeks.

Direct replacement of incandescent bulbs with LEDs in the same package and at the same brightness, but with 10 times the lifetime and only half the current required is now possible. Designed the MF200 series, these lamps available in three colors (red, amber and green) require a drive current of 20 mA and put out typically 50 mcd (red), 35 mcd (amber) and 24 mcd (green) with a clear tinted encapsulation. They are also available with diffusive encapsulation. Although pulsing operation drastically reduces the life of incandescent, LEDs can operate either pulsed or continuously for at least 10 yr at 20 mA. LEDs can also display short pulses for which an incandescent can’t respond quickly enough. All of the LED lamps are available with built-in resistors for various voltages ranging from 3.6 to 28 V dc. Units are also available for ac operation.

CIRCLE NO. 320

Darlingtons offered in complementary series

Solitron Devices Inc., 1177 Blue Heron Blvd., Riviera Beach, FL 33404. (305) 848-4311. $12: 2N5286/3, $15: 2N6284/7 (1-99); 2 to 4 wks.

All planar, the 20-A complementary Darlington power-transistor series is packaged in standard TO-3 cases. The npn units are identified as 2N6283-84 and pnp as 2N6286-87. Typical specifications for these devices include $V_{CE}$ (sat) at 10 A of 2 V, an $h_{FE}$ of 750 to 18,000 at $I_{C}$ = 10 A and a maximum power dissipation of 160 W. The 2N6283 and 2N6286 units feature a $R_{V_{CE}}$ of 80 Ω; the 2N6284 and 2N6287, a $R_{V_{CE}}$ of 100 Ω.

CIRCLE NO. 321

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Electronic Design 7, March 29, 1977
New counters from Mostek.

Our 28 pin up/down series feature price and performance.

Mostek's new MK 50398N and MK 50399N P-Channel MOS counters offer important cost/performance advantages to a broad range of up/down counting applications: six decades, single power supply, plus the economy of a plastic package.

More Features that Count.

Versatile, up/down counting with the ability to pre-set the individual decade stages to any BCD number, increases your systems operating capability.

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►CMOS Compatibility. Interfaces with CMOS logic operating in the 10 to 15 volt range.

►BCD or 7-Segment Outputs. The MK 50398N presents 7-segment output data from the counter contents, while BCD outputs are provided by the MK 50399N.

More Mostek counters to choose from:

The MK 50398 counter series joins Mostek's complete family of counter circuits ranging from four decade to multifeatured six decade devices. Contact your Mostek representative or franchised distributor for full specifications.

Mostek's complete counter family.

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</tr>
</thead>
<tbody>
<tr>
<td>MK.50398/7N</td>
<td>6-decade Up/Down Counter w/compare &amp; 3-digit Register</td>
<td>1MHz</td>
<td>40</td>
<td>7 Segment and BCD</td>
</tr>
<tr>
<td>MK.50398/5N</td>
<td>6-decade Up/Down Counter</td>
<td>1MHz</td>
<td>28</td>
<td>7 Segment or BCD</td>
</tr>
<tr>
<td>MK.50037N</td>
<td>4 digit Counter / Latch Decoder</td>
<td>250KHz</td>
<td>24</td>
<td>7 Segment and BCD</td>
</tr>
<tr>
<td>MK.50038N</td>
<td>4 digit Counter / Latch Decoder</td>
<td>250KHz</td>
<td>24</td>
<td>7 Segment only</td>
</tr>
<tr>
<td>MK.50079N</td>
<td>4 digit Counter / Latch Decoder</td>
<td>250KHz</td>
<td>24</td>
<td>BCD only</td>
</tr>
<tr>
<td>MK.50392N</td>
<td>Counter Timer Base</td>
<td>20KHz</td>
<td>16</td>
<td>Single TTL, companding</td>
</tr>
</tbody>
</table>

MOSTEK
1215 West Crosby Road • Carrollton, Texas 75006 • (214) 242-0444 • MOSTEK GmbH • West Germany • Telephone: (0711) 70106 • MOSTEK ASIA • Hong Kong • Telex: 85148MKA HX
24-channel, 8-bit a/d comes in just two 32-pin DIPs

Micro Networks, 324 Clark St., Worcester, MA 01606. (617) 852-5400. P&A: See text.

Now, you can pack 24 channels of analog data acquisition and 8-bit analog-to-digital conversion into less than five square inches of board space. Using hybrid-circuit technology, Micro Networks has developed a complete 8-bit, 24-channel data-acquisition system that is packaged in two 32-pin dual-in-line packages.

The fundamental building block of the system is the MN7100, by itself an 8-bit, 8-channel system. Another system component, the MN7110, provides the multiplexing and logic for 16 more channels. With additional MN7110s and a few standard TTL ICs, you can expand the system to over 256 analog-input channels.

Unlike most other data-acquisition systems, these thin-film hybrid circuits are available in versions that can be operated over the full −55 to +125°C military temperature range.

Both the MN7100 and the MN7110 are packed in hermetically sealed, 32-pin DIPs and fabricated with thin-film chip-and-wire hybrid construction. In addition, the MN7100 is laser-trimmed during manufacture, which eliminates the need for user-supplied offset and gain-adjusting trimmers.

Also, while data-acquisition systems employing these DIPs are small, they have all the features of their larger counterparts. Input channels may be randomly addressed or controlled from the internal sequential-address counter, and both channel-address inputs and outputs are provided. All digital inputs and outputs are TTL-compatible, and either internal or external clocks can be used. Other specifications are 90,000-channel/s throughput, guaranteed ±1/2-LSB linearity over temperature, and low power consumption. The analog-input range is ±10 V with a typical input impedance of 10 MΩ.

These circuits are particularly intended for microprocessor-based systems. However, these units do not offer their own three-state outputs. So when operating with a bus-oriented µP like the 8080, you must provide additional three-state buffers to isolate the data-acquisi-
Magnetic cams slice to tenth of a degree

Astrosystems, 6 Nevada Dr., Lake Success, NY 11040. Don Wade (516) 328-1600. $1000-$3000 (1-9).

With Solid-State Limit Switches you get position programming and control without the use of cams, followers or mechanical switches. The switches consist of a magnetic position-sensing device and an electronics package, which provides control signals at selectable rotary positions. Coded-key or thumbwheel-switch programming lets you change settings. These units feature accuracies to 0.1" and operate bidirectionally with virtually no backlash or hysteresis. Control signals can be supplied as relay contacts, logic levels or open-collector outputs. A display and BCD output indicates shaft position for initial-setup and monitoring purposes. For dual-limit units a control signal tells you when the transducer reading is between two programmed values. For set-point units a control signal is provided when the transducer output is greater than the programmed value. In addition to the control signals a front-panel light for each limit or set point indicates the output status. Transducers are supplied in NEMA-12 and waterproof packages. Zero-reset, offset and no-motion options are available.

CIRCLE NO. 322

CIRCLE NUMBER 77

Nail the Noise Axe the Alias Save the Signal

For multichannel data acquisition, or signal processing, our System 816 provides optimized filtering in up to 16 channels, under remote digital and/or local on-card or front-panel control. How optimized? No significant insertion loss; flat passband; fast rolloff; wide dynamic range; low noise; accurate cutoff programming.

You can program each channel, individually, for cutoff frequencies you can order between 0.1Hz and 150kHz. Butterworth or Bessel characteristics, you get low-pass, high-pass, band-pass, band-reject functions. If 48dB/octave rolloff still isn't fast enough to prevent aliasing, you can cascade two channels for 96dB/octave.

Everything's modular. Buy only as many channels as you need. Expand later, as required. Program via DTL/TTL, contact closures, or front-panel switches. Read the setting of any channel at any time, via front-panel display.

System 816 is the logical choice when analog signals are to be sampled and digitized ... to prevent aliasing errors by band limiting before sampling and/or A/D conversion. It is equally useful as a multichannel analog recovery filter, following D/A conversion. In fact, wherever multichannel analog signals are to be band limited, programmably, the 816 is the flexible, economical way to go. (Domestic prices: main frame, $1600; individual channel plug-ins start at $750.)

HOW & WHY optimized filters enhance S/N ratios, yet avoid aliasing errors, is explained in greater detail in this new 24-page Rockland Handbook. Get it -- free, by requesting data on System 816.

Use the inquiry number or write:
Rockland Systems Corporation
230 W. Nyack Road
W. Nyack, N.Y. 10994
TEL: (914) 623-6666
TWX: 710-575-2631

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ROCKLAND

SYNTHESIS · PROCESSING · ANALYSIS

Our Second Decade of Leadership
**MODULOS & SUBASSEMBLIES**

**Quadrature oscillator gives more for less**

*Burk-Brown, International Airport Industrial Park, P.O. Box 11400, Tucson, AZ 85734. G. Athey (602) 294-1413. $9.85; stock to 4 wk.*

When you need sine and cosine outputs, the 4423 quadrature oscillator offers three unique characteristics: First, you can resistively program frequency from 0.002 Hz to 20 kHz; second, it comes in a DIP; and third, you get an uncommitted op amp. In addition, the hybrid device features performance comparable with $50 modular quadrature oscillators: frequency stability is better than ±100 ppm/°C and quadrature accuracy is better than ±0.01%/°C; sine-output distortion is less than 0.2% over 0.002 Hz to 5 kHz and less than 0.5% from 5 to 20 kHz. The unit can be used as a self-contained 20-kHz oscillator, without external components or adjustment. For the range of 2 to 20 kHz, you need but add resistors to program frequency. From 0.002 Hz to 2 kHz, you program the frequency with two resistors and two capacitors.

**CIRCLE NO. 323**

**Optoelectronic unit eases on-off control**

*Beede Electrical Instrument, Penacook, NH 03301. (603) 753-6362. From $40; stock.*

An optoelectronic switching device, called the Meter Switch, combines analog indication with on-off control in a compact unit no larger than an ordinary panel meter. This hang-bang-type controller features optical isolation that eliminates the need for conditioning the input signal and protects against noise and ground-loop problems. Isolation gives you flexibility in selecting input-signal transducers. The device's output can control SCRs, Triacs and is also CMOS and TTL compatible.

**CIRCLE NO. 324**

**Add alphanumericics to your μP terminal**

*Matrox Electronic Systems, P.O. Box 56, Ahuntsic Stn., Montreal, Quebec, H3L 3NG Canada. (514) 481-6338. $169 (100 qty); 2 to 4 wks.*

Like other video RAMs, the MTX-1632 SL interfaces a μP to a TV monitor, producing a 16-line by 32-character alphanumeric display. The device accepts external sync pulses so it can be slaved. Therefore, you can use the unit for video mixing. Each character position corresponds to a memory location. Thus the μP is free to manipulate data for display. The unit doesn't require external refresh and features 550-ns access time, TTL compatibility, character blanking and single-supply operation.

**CIRCLE NO. 325**

**5-or-6-digit counters take wide input range**

*Master Electronic Controls, P.O. Box 25662, Los Angeles, CA 90025. (213) 393-3177. $3 (100 qty); stock.*

Two series of 5-and-6-digit counters, the C05 and C06, include units that accept eight input levels. These devices operate from 6 to 110 V dc and from 24 to 230 V ac, with allowable variation from the nominal voltage of ±10%. The devices count at a speed of 600 counts per minute and require on and off times of 50 ms. The counters can be operated over a wide range of temperature and humidity conditions with a life expectancy of 1-million operations. They can be panel or surface mounted, have black numerals on a white background, and weigh 5 oz.

**CIRCLE NO. 326**
8 Bit A to D/D to A Converter - the first priced at only $4.50*

The Ferranti Model ZN425E—an 8 bit dual mode analog to digital/digital to analog converter features:

- Single chip monolithic construction
- Typical settling time 1.0 µs for 1 L.S.B. step
- 8 bit binary counter, R-2R ladder network and switches
- On-chip precision voltage reference
- Self-contained, precision ramp generator
- TTL and CMOS compatible

better by design
FERRANTI semiconductors

*1000 piece price

FOR COMPLETE SPECIFICATIONS, CONTACT: FERRANTI ELECTRIC, INC. / SEMICONDUCTOR PRODUCTS EAST BETHPAGE ROAD, PLAINVIEW, NEW YORK 11803 PHONE: (516) 293-8383 / TWX: 510-224-6483

CIRCLE NUMBER 79

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Landing Lights to LEDs

The TEKTRONIX J16 Portable Digital Photometer/Radiometer makes a wide variety of light measurements, in the lab or in the field. Landing lights, lasers, fiber optics, crts, and LEDs are just a few.

Eight precalibrated probes help give the J16 versatility. Each probe snaps quickly and easily into place. Or it may be operated remotely with an extender cable.

The J16 is tough as well as versatile. An aluminum extrusion case, silicon photodiodes, and the extensive use of ICs make it rugged enough for field measurements. And it's small (2.4 x 4.6 x 8 in.), light (3.3 lb.) and battery operated, so it's easy to take along.

For a demonstration, contact your nearest Tektronix Field Office. For applications assistance, call Peter Keller, (503) 644-0161 ext. 7769. For a free brochure describing the J16 Photometer, circle the number below, or write Tektronix, Inc., P.O. Box 500, Beaverton, Oregon 97077. In Europe, write Tektronix Limited, St. Peter Port, P.O. Box 36, Guernsey, Channel Islands.

CIRCLE NUMBER 80

Electronic Design 7, March 29, 1977
THE SOURCE FOR POWER SUPPLIES!

New 1977 issue Technipower design/data catalog no. 771

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Technipower presents the widest range of mil-qualified, industrial and commercial power supplies ever compiled – all backed by a comprehensive 5-year warranty.

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Benrus Technical S.A., #6 Rue de la Corsaz, C.H.-1820, Montreux, Switzerland

CIRCLE NUMBER 81

POWER SOURCES

Small switcher supplies lots of watts

Trio Labs, Inc., 80 Dupont St., Plainview, NY 11803. (516) 681-0400. From $350; stock.

Single outputs of 125 W come from the dense Model 600's 3.28 × 7.55 × 6.78 in. You get up to 87% efficiency with a ridethrough of 30 ms and a low-line of –30%. This compact unit also contains over-load and overvoltage protection. The standard switcher can be upgraded to meet environmental MIL specs. Standard outputs are 5, 12 and 15 V dc.

Efficient dc converters take wide input range

Semiconductor Circuits, 306 River St., Haverhill, MA 01830. (617) 373-9104. $30.95 to $99.95; stock to 4 wks.

Input-voltage ranges of up to 200% of nominal makes these dc/dc converters a good choice when operating from poorly regulated input power sources such as batteries, motor-generators, and fuel cells. Efficiencies of up to 85% conserve input power. SW units are plug-ins for PC boards, while CW units are chassis mountable. Thirty models are available with nominal inputs ranging from 12 to 24 V and outputs from 5 to 24 V. Models that deliver output currents up to 3 A boast line-and-load regulation of 0.3%, output-ripple and noise of 7-mV rms and need no derating over –25 to +71 C. Models with higher output currents feature line-and-load regulation of 0.5%, output ripple and noise of 13-mV rms and need no derating over 25 to +60 C. Storage temperature for all models is –25 to +85 C.
30 Ah crammed into lithium cell

Power Conversion, 70 MacQuesten Pkwy S., Mount Vernon, NY 10550. S. Chodosh (914) 699-7333. From $10; stock to 2 wks.

Lithium batteries boast the highest energy per weight and volume. The 550-5A provides 30 Ah at a 1-A drain for an energy density of 135 Wh/lb. The 10-oz cell measures 1.64 × 5.5 in. Additional features include shelf life of over 5 yr, operation down to −65 F, nominal output of 2.8 V (double that of ordinary batteries) and high rate-discharge performance. The cells are available with a positive button terminal or positive and negative solder tabs.

CIRCLE NO. 329

µP molded supplies don't feel the heat

Dynamic Measurements Corp., 6 Lowell Ave., Winchester, MA 01809. (800) 225-1151. $180 to $155 (unit qty); stock to 4 wks.

Solid molding in hard epoxy permits full-power operation (30 W) with no derating up to +40°C ambient for MPS single, dual and triple dc supplies. With models tailored to specific µPs you get line-plus-load regulation within 0.03% for 5-V outputs, and within 0.1% for 9, 10, 12 and 15-V outputs. Positive and negative outputs track within 100 ppm/°C, and max. output-voltage error is +1%. 5-V outputs are current limited and all others fold back to 20 mA. The modules measure 5.1 × 4.25 × 3 in.

CIRCLE NO. 330

Before you buy another filter, consider our moveable passband.

Our tunable bandpass filters provide two big benefits for anyone working in RF and microwave up to 4 GHz.

First, just one of our tunables replaces a whole drawer full of fixed bandpass filters. Less costly, more convenient, faster test set-ups.

Secondly, our tunables are calibrated directly—you get the center frequency you see on the dial—no interpolation or charts needed.

With over 50 standard versions in stock, we can supply a unit for frequencies as low as 48 MHz all the way up to 4 GHz. Each one covers a full octave, and comes with 3% or 5% 3 dB bandwidths. We even stock special purpose units for the military band (210-420 MHz) and many telemetry bands (210-2310 MHz). And if one of those standards doesn't meet your needs, we'll be glad to quote on special designs for any lab or OEM situation.

Our new Filter Catalog gives complete data on all Telonic Tunable Filters as well as other types we produce—tubulars, cavity, interdigital, comb-line—all the way to 12 GHz. If you wish a copy, write on your letterhead. If you need immediate information, call us TOLL FREE (except CA) at 800-854-2436.

Telonic Altair, 2825 Laguna Canyon Road, Box 277, Laguna Beach, CA 92652, 714/494-9401 TWX 910-596-1320 Cable: TELENG Toll Free: (800) 854-2436

CIRCLE NUMBER 83

Electronic Design 7, March 29, 1977
DATA PROCESSING

Superplotter draws dashed lines in four colors, doubles as printer with five type fonts


Now you can have a µP-based X/Y plotter that automatically, under program control, selects any four different-colored pens. The Model 9872 provides crisp plots at higher speeds and with greater resolution than now available, and accommodates paper up to 11 x 17 in. The plotter is designed to be used with HP's 9825 and 9831 desktop computers. Four-color plotting in solid lines and seven dashed-line fonts, five built-in character fonts, user-defined characters and symbol-mode plotting can be combined to produce clear, easy-to-read plots.

38 different µP instructions provide such features as point digitizing, labeling and character sizing, directly through the plotter's IEEE-488 interface. The 9872's resolution is 0.008 mm, and writing speed is program-controlled from 10 mm/s to 360 mm/s in each axis. The four pens are stored in a "stable" and are picked up by the plotter arm. The pens are automatically capped after return to the stable. Five different character fonts are stored in the plotter: ANSI ASCII, 9825A ASCII, and three European sets. Character size, slant and direction are variable under program control. Window plotting can be done automatically by merely defining the limits of the desired window. User-defined characters, such as a complex logotype, can be stored in the desktop computer controlling the 9872, and written with a single command. To aid in precise positioning of the plotter arm, the Model 9872 contains a digitizing sight that can be put in the pen carriage automatically, or manually.

CIRCLE NO. 305

Batteries last 2000 h in pocket calculator


For the outdoorsman, the Model LCD 2000 pocket calculator features a liquid-crystal display that's easy to read in the sun. For the energy conscious it offers 2000 hours of operation from each set of three silver oxide batteries. In addition to the four basic functions, the super-thin Model LCD 2000 offers chain and mixed calculations, square root, automatic constant, π-key and memory. A budget model (LCD 8RM at $25) gets less battery life, but features a π-key.

CIRCLE NO. 331

Sonic pen automatically inputs coordinates


To convert coordinate location into binary computer inputs, the Graf/Pen NT211 sonic digitizer employs two solid-state "ears" and a stylus that emits ultrasonic pulses. You position the stylus anywhere on a surface up to 36 x 48 in. The NT211 then automatically converts the sensor distances into X-Y coordinates, correcting for sound velocity variations with temperature. Up to 140 points/s can be converted, with a resolution of 100 points/in.

CIRCLE NO. 332

Electronic Design 7, March 29, 1977
MDB SYSTEMS presents... The LSI-11 Connection

GP Logic Modules • Peripheral Controllers • Communications Interfaces • Special Purpose Modules • Accessory Hardware

Here are some MDB Systems connections to LSI-11 microprocessors:

□ General Purpose Interfaces:
  Parallel for programmed I/O and DMA.
  Do-it-yourself dual and quad wire wrap for any DIP design.
□ Device Controllers for most major manufacturer's
  Printers
  Card equipment
  Paper tape equipment
  Plotters
□ Communications/Terminal Modules
  Asynchronous Serial Line
  Synchronous Serial Line
□ MDB Backplane/Card Guide Assembly (8 Quad slots)
  Rack mount chassis 5¼” front panel.
□ Special Purpose Modules and Accessories
  System monitoring unit provides front panel switch addressing, power on/off sequencing, line frequency clock.
□ Bus extenders/terminators.
  E-PROM and PROM modules.
  Bus connectors for backplane assemblies.

MDB Systems products always equal and usually exceed the host manufacturer's specifications and performance for a similar interface. MDB interfaces are software and diagnostic transparent to the host computer. MDB products are competitively priced; delivery is usually within 14 days ARO or sooner.

MDB also supplies interface modules for DEC PDP*-11 Data General NOVA* and Interdata minicomputers.

CIRCLE NO. 121 FOR LSI-11; 122 FOR PDP-11; 123 FOR NOVA; 124 FOR INTERDATA

If you compare...

Digital Display
  • 10-turn precision potentiometer
  • Adjustment accuracy: 0.3%!
  • Replaces additional voltmeter

Watt/Liter Power Ratio
  • Cooling sections incorporated in housing yield optimum volume/power ratio

Superior Control Characteristics
  • Due to automatic control system decentralization with the aid of discrete Zener references and operational amplifier - no integrated stabilization circuits - improved noise voltage and drift values.

Output:
  0— 7,5 V/3 A (5 A)*
  0—17 V/1,5 A (2,5 A)
  17—40 V/1,25 A (2,1 A)
  * Power-Boost Output Current

For further details please contact:
OLTRONIX LABOR AG, Rüschlistrasse 21, CH-2502 BIEL, Switzerland,
Phone: 032/238103, Telex 34637

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CIRCLE NUMBER 86
Step-by-step coverage of defense radar system design . . .

INTRODUCTION TO DEFENSE RADAR SYSTEMS ENGINEERING

James N. Constant

This all-inclusive handbook covers virtually every facet of radar technology that must be mastered in order to design a complete defense radar system. In fact, it concludes with a step-by-step procedure for specifying and designing a complete radar system for a given application. Separate chapters cover target characteristics; radar detection; radar receivers; radar system error model; flight of a ballistic missile; ballistic reentry trajectories; trajectory prediction; radar data processing; reflector antennas; and array antennas. Order your 15-day examination copy today! #9194, 344 pages, cloth, illustrated, $22.95

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DATA PROCESSING

Expandable RAM board is thrifty & quick


The Model Z-16 is a 16-k × 8-bit static RAM board that features extremely fast access times, very low power consumption and low cost. Its EMM Semi 4200 memory chips are organized as 4 k × 1 bit and have a max access time of 200 ns. This gives the Z-16 a worst case access time of 250 ns. The board conforms to the S-100 bus standard (used in Altair 8800, Imsai 8080, etc.). Three nonregulated supply voltages are used, drawing typically 105 mA from the +8 V, 200 mA from the +16 V, and 20 mA from the −16 V supply. The Z-16 is organized in four blocks of 4 kbytes each, which can be individually switch-protected. The board will be compatible with TDL’s Memory Management Board which will handle 256-kbytes in one system. Modules are available either as kits or as assembled and tested units.

CIRCLE NO. 333

Brushless torque meter checks floppy discs

Vibrac Corp., 11 Alpha Rd., Chelmsford, MA 01824. Bruce C. Chrane (617) 258-6581.

The Model 200 floppy-disc tester is designed to provide a fast and accurate means to measure both the starting and the running torque of diskette cartridges within their protective envelope, using a Vibrac optical brushless torque transducer. The Model 200 displays running torque on a 4-1/2-digit panel meter, in either Newton-cm or oz-in.

CIRCLE NO. 334

Programmer has version for many popular PROMs


Versions of the Model 107K programmer are now available for many PROMs, including Intel, National, Signetics, Harris, Fairchild, and Intersil units. The 107K features hex keyboard entry, autocode between selectable min and max address, verify while reading or writing, and stop-on-error. Technitrol offers a general computer interface as an option. The version for 1702A PROMs is normally in stock.

CIRCLE NO. 335

Interface kit marries punch/reader to LSI-11

EECO, 1441 E. Chestnut Ave., Santa Ana, CA 92701. Dennis McLaughlin (714) 835-6000. $250.

Interfacing between DEC LSI-11 computers and EECO punch/reader units is easy if you use the Model E-9000-LSI-RP kit. It contains a circuit card, interconnecting 10-ft cables, test tape and instruction manual. Existing PDP-11 software can be used to program the interface for specific applications. The circuit board plugs into the computer backplane bus. Jumpers permit you to select the peripheral device address and interrupt vector.

CIRCLE NO. 336

4 and 8-channel MUX integrates with Nova

MDB Systems Inc., 1995 N. Batavia St., Orange, CA 92665. (714) 998-6900. $1250 to $2250; 1 to 2 wks.

The Model 8063 multiplexer for Data General’s Nova interfaces four to eight asynchronous data sets or terminals that have RS-232C output. The system can be expanded to 64 channels sharing the same device address. The 8063 is not only completely compatible with DG 4060 software, but offers additional software-controlled features including data overrun and line-break detection.

CIRCLE NO. 337

ELECTRONIC DESIGN 7, March 29, 1977
MOS/LSI comes to Dual-Tone detection.

The Collins MOS/LSI digital Touch-Tone* detector is now in production. High quantity production.

It's the Collins CRC-8030.

For a low cost, high performance solution to dual-tone multi-frequency (DTMF) detection, you can't beat it. You get the economics of MOS/LSI — plus central office quality.

Here are the CRC-8030's features: Digital range filter detects all 16 Touch-Tone signal combinations. Detection in 22 to 39 MS. On-chip-oscillator operating at 3.579545-MHz color burst crystal frequency. Binary or 2-of-8 coded outputs. Operation with single or dual power supply. Many parameters can be mask programmed for custom applications.

A product of Collins high technology MOS/LSI experience, the CRC-8030 performs the key critical functions of a DTMF receiver. When used in conjunction with a front-end band-split filter/limiter, it implements a complete DTMF receiver.

Also, if you need DTMF-to-dial pulse conversion, use the CRC-8030 in conjunction with our CRC-8000 (a MOS/LSI Binary-to-Dial Pulse Dialer).

For more information on our telephony or custom MOS/LSI products and services, call your local Collins MOS/LSI Product Sales Representative. Or use the coupon below.

*Touch-Tone is a registered trademark of AT&T

I want Collins to come to me.

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Newport Beach, California 92663
(714) 833-4638

I want information on □ CRC-8030 □ CRC-8000 □ Custom MOS/LSI □ Send it by mail □ Call me

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Company ________________________
Address _________________________ City ___________________________
State __________________ Zip Code __________ Telephone ____________________

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...where science gets down to business

See us in the Collins Exhibit at Electro '77, April 19-21.

CIRCLE NUMBER 88
Wire-brush connector contacts mate easily, provide low contact ohms


The Bendix bristle-brush-bunch (B³) contact, a new advance in contact design, combines the features of very low mating and disengaging forces and highly redundant current paths with a minimum of constrictive contact points and resultant nonuniform current densities.

Multiple-wire brush contacts (usually about seven wires/brush) on each half of a contact pair intermingle with sufficient normal force between the wires to provide good wiping action and low-resistance contact points. Each wire end in a contact bunch is cut at a precise burr-free angle to enable smooth intermingling and eliminate the butting of wires when contacts mate. As the engagement depth increases, cantilever action provides contact pressure between engaging wires.

Wire strands (6 to 8 mil dia.) are gold plated (50 × 10⁻⁶ in.) and crimped into contact holders in male and female configurations. Average initial contact resistance is about 6 mΩ and in tests increased to only 11.7 mΩ after 20,000 cycles of mating—a very high amount of matings for the usual connector. Engaging force is under 0.8 oz/contact; thus, a 200-contact connector can fully mate with less than 10 lb of force and disengage with even less, perhaps 6 lb.

Bendix plans to introduce many types of connectors using the B³ contacts. Available now are a mother/daughter board line, types MB and DB, containing two-row patterns to 60 contacts/row. Two, three and four-row patterns to 100 contacts/row and other types will soon follow.

CIRCLE NO. 307

Spray on rf shielding, up to 100 dB


Eccoshield ES is a highly conductive silver-based surface coating, formulated for rf-shielding applications. Adhesion to metal, plastics, ceramics, wood and concrete is excellent, and the spray produces a surface resistivity substantially less than 1 Ω/sq. Successive coats decrease surface resistivity further. A 6-oz aerosol can normally covers about 30 ft². By applying Eccoshield ES to joints and seams of metal housings, it is possible to obtain greater than 100-dB insertion loss from 15 kHz to 10 GHz.

CIRCLE NO. 340

Zero-expansion ceramic is also machinable

Aremco Products, Inc., Box 429, Ossining, NY 10562. Herbert Schwartz (914) 762-0685. See text; stock.

Can you use a ceramic that survives the temperature drop from a 2000-F furnace into ice water? The Aremcolox 502-1300 boasts a zero thermal expansion coefficient over its useful temperature range of 2200 F, and is machinable to boot. Brazing fixtures, hot-gas nozzles and the like can be made with conventional carbide-tipped tools, and need no firing. Off-the-shelf rods range from 1/2 to 4 in. dia. Plates are 1/2 thick, and up to 5-3/4-in. square. A typical 12-in. rod, 1 in. dia. costs $17.15.

CIRCLE NO. 341
new count/time data system

NEW Count/Time Data System (C/TDS) counts switch closings, totalsize ON/OFF time on up to 248 channels. With it and your own switches you have everything you need for a sophisticated production or statistical activity monitoring system—with on-board printout, plus tape records, calculator or computer feeds. Even provides time-of-event data on selected channels!

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FOR INFORMATION ONLY CIRCLE 132
Packaging & Materials

Flat cable assemblies come in rainbow colors

AP Products Inc., Box 110, 72 Cors- win Dr., Painesville, OH 44077. (800) 321-9668.

AP has come up with a faster, easier and less expensive way of interconnecting PC boards through flat ribbon cable with the company’s family of Great Jumper PC connectors. The fully tested flat-ribbon cable/connector assemblies are available in a wide variety of configurations, including several line widths, a choice of conductors, and a selection of opposite-end terminations. The Rainbow cable is color-coded line-by-line on the front, and color-striped in groups of ten on the reverse, and is intended for use with single-ended Great Jumpers. Double-ended and Daisy-chained configurations include flat ribbon connector terminals, standard double-row (0.100-inch) socket connectors and card-edge connectors.

Thick-film multilayer ink uses no gold

Du Pont Co., Wilmington, DE 19898. (302) 774-2358. Stock.

A cost-effective alternative to precious-metal thick-film structures is now available in the form of type-9923 copper composition conductors for deposit on alumina or type-9949 substrates. After nitrogen firing, the composition has a 1.5-mΩ/square max resistivity, and can be readily soldered. Adhesion on alumina is 4 to 5 lb (90° wirepull test), and remains over 3 lb after 150-C firing. On the low-K type 9949, adhesion is also high, and thus provides a complete material system for multilayer interconnects. Composition 9923 gives a resolution of 7-mil lines and spaces. The compositions fire at 900 C in commercial nitrogen furnaces for 45 to 50 minutes, and no preliminary burnoff of organic is required.

IC mounting pads form and spreads leads, too

Bivar Inc., 1617 E. Edinger Ave.,
Santa Ana, CA 92705. Edward Muldoon (714) 547-5832. See text; stock.

A new selection of 45 different IC mounting pads and spreaders for both circular and DIP devices has been added to the Bivar product line. The nylon pads and spreaders improve component mounting, and spread leads to desired configurations, acting as both tools and fixtures. The new selection includes mounts to spread circular IC leads to DIP patterns, and circular lead spreaders to 0.300, 0.350, 0.400 dia and 0.100-in. grids. Typical price in lots of 10,000 is $19 per thousand.
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Your microprocessor-based system should have an alphanumeric readout device. In addition to the ability of your product to present alphanumeric information, such displays are extremely useful for debugging and for data recall during programming.

Burroughs' SELF-SCAN panels readily interface to the I/O devices of the popular microprocessors, including the MC 6800, Intel's 8080 and 4040 series, National's IMP, and many others. An "off-the-shelf," inexpensive, dc-dc converter uses your system's low voltage (+5 or +12V) to supply the display. Your software programming effort to control the display represents a small portion of the overall program development.

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SELF-SCAN panel displays are available from our distributors: Hamilton/Avnet, Cramer Electronics, Arnold Barnes Associates. For overseas inquiries, write Burroughs ECD International, 11-15 Betterton Street, Drury Lane, London.

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MC6800 chip photo courtesy of Motorola Corporation.
INTEGRATED CIRCUITS

Dual amp replaces 1458 with improved specs

Precision Monolithics, 1500 Space Park Dr., Santa Clara, CA 95050. Donn Soderquist (408) 248-9222. From $3.70 (100-up); stock.

A dual matched high performance operational amplifier, the OP-14, provides improved specifications over the industry standard 1458 amplifier. Input-offset voltage and common-mode rejection ratios of the two op amps in the OP-14 are matched to within 1 mV (max) and 94 dB (min). Key maximum specifications for the individual amplifiers include input-offset voltage of 0.75 mV, input offset current of 2 nA, and input bias current of 50 nA. All units come in TO-99 packages and are pin-for-pin improved replacements for 1458/1558 types.

CIRCLE NO. 344

JFET-input op amps come in five models

Texas Instruments, P.O. Box 5012, Dallas, TX 75222. Dale Pippenger (214) 238-2011. From $0.52 (100-up); stock.

A line of five BiFET operational amplifiers, the TL080 series, includes single, dual and quad circuit types. The op amps incorporate matched, high-voltage JFET and bipolar transistors in a monolithic integrated circuit. The single op amp circuits, TL080 and TL081, have offset-voltage null capability and the 081 is also frequency compensated. The dual circuits, TL082 and TL083, both include internal frequency compensation. The TL083 also has offset-voltage null capability. All four devices complement the previously announced TL084 quad op amp. The TL080, 81 and 82 are offered in 8-pin plastic DIPs and TO-99 metal-can packages. The TL083 and TL084 are available in 14-pin plastic DIPs. All units operate over a 0-to-70-C range.

CIRCLE NO. 345

Bipolar 4-k RAMs access in only 100 ns

Fairchild Camera and Instrument Corp., 464 Ellis St., Mountain View, CA 94042. (415) 962-3816. From $24 (100-up); stock.

Available in two versions, the 93481 and 93481A dynamic bipolar RAMs provide 4096 bits of storage and use only a single 5-V supply. The faster version of the new device, the 93481A, has a maximum access time of 100 ns and a 240-ns cycle time. The standard 93481 has a maximum access time of 120 ns and a 280-ns cycle time, both over the range of 0 to 70 C and with a 5-V ±5% supply. Organized as 4096 x 1 bits, all the RAMs consume 350 mW active, 70 mW standby, and 500 mW in page mode. Access and cycle times in the page mode are 75 ns for the 93481 and 65 ns for the 93481A. Provided on the RAM are an independent data latch pin and two chip select pins, as well as seven addresses, ground and power, separate data-in and data-out, write enable, and a single timing control input. The 93481 and 93481A are available in 16-pin ceramic DIPs.

CIRCLE NO. 346

Bipolar PROMs access in only 40 ns

Signetics, 811 E. Arques Ave., Sunnyvale, CA 94086. Ralph Kaplan (408) 739-7700. From $15.50 (100-up); stock.

A 4-k bipolar PROM with an access time of only 40 ns, typical, is organized as 1024 4-bit words. The PROM comes in an 18-pin ceramic DIP and with either open collector outputs (82S136) or three-state outputs (82S137). Both commercial and military temperature range parts are available.

CIRCLE NO. 347
Six-decade counters have BCD preset inputs

Mostek, 1215 W. Crosby Road, Car-
rollton, TX 75006. Don Ward
(214) 242-0444. $6 (100-up); stock.

Designated MK 50398N/399N, a
series of PMOS counter circuits
housed in 28-pin DIPs features
six-decade synchronous up/down
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counting stages may be loaded
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input data and have an asynchro-
nous clear function. Multiplex
scanning of the decode outputs
is controlled by the scan oscillator in-
put, which is self-oscillating or can
be driven by an external signal.
Input count frequency is dc to 1
MHz. The MK 50398N presents
seven-segment output data from
the counter contents while the MK
50399N presents BCD output data.

Matched transistor pair

National Semiconductor, 2900
Semiconductor Dr., Santa Clara,
CA 95051. Jerry Robertson (408)
737-5000. For the LM194, $14
(100-up); stock.

Matched to within 50 μV of
each other, the npn transistors in
the monolithic LM194 have a noise
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LM394 operates over 0 to 70 °C.

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CIRCLE NUMBER 101

INSTRUMENTATION

5-MHz scope enters low-cost market

Tektronix, P.O. Box 500, Beaver- ton, OR 97077. (503) 644-0161. $375.

The S61 single-trace, 5-MHz Tel- equipment oscilloscope costs only $375. The S61 is completely solid state (except for the CRT) and fully backed by a one-year warranty. The 6.5-kg (14.3 lb) features a full 8 × 10-cm display. Triggering features include variable level, polarity controls and automatic mode, which free runs in the absence of a trigger signal.

CIRCLE NO. 356

Transient recorder captures waveforms

Datalab Inc., 222 Milwaukee, Suite 102, Denver, CO 80206. (303) 321-4601. $1500; 4-6 wks.

Model 901 transient recorder can turn your general scope into a low-cost storage unit, or your X-Y and strip-chart recorder into high-speed graphic devices. The 1024 shift-register MOS memory stores the waveform before and after an event by converting the analog signal into an 8-bit digital value at a 200-kHz rate. In addition to its ±0.5-V analog outputs, the 901 can be controlled from, and has standard RS232/parallel interfaces to, micro and minicomputers allowing use as a front-end for computer-based systems.

CIRCLE NO. 357

Electronic Design 7, March 29, 1977
**COMPONENTS**

**Indicator-light kit contains 24 units**

Industrial Devices, 7 Hudson Ave.,  
Edgewater, NJ 07020. (201) 224-4700. $10 (unit qty); stock.

An indicator-light sampler kit for engineers and designers contains working samples of a large variety of IDI indicator lights for breadboarding or building working prototypes. The kit consists of 24 complete indicator and pilot lights, all different. There are 16 different styles in seven colors for five operating voltages from 6 to 250 V. The units have five different mounting-hole sizes. Included are incandescent, neon and solid-state LED units with both wire-lead and solder-terminal types.

**CIRCLE NO. 358**

**Thumbwheel switch only 8-mm thin**

EECO, 1441 E. Chestnut Ave.,  
Santa Ana, CA 92701. (714) 835-6000. $2 (1000 qty); 6 wks.

EECO 1800 series thumbwheel switches feature extra-slim 8-mm wide switch modules and switch assemblies that can be snapped into panels without tools or screw holes. Across-the-room legibility is available with 0.234-in. high characters. The switches are available in a number of 10-position codes including BCD, BCD with complement, BCD complement only, decimal and repetitions. Options include direct-wire or connector termination, gloss or matte finish, decimal points, custom dial markings, stops and diode provision. Contacts are gold-plated, the housing is self-extinguishing nylon and the circuit board is flame-resistant glass epoxy. Operating temperature range is –20 to 65°C. Initial contact resistance is 0.1 Ω max.

**CIRCLE NO. 359**

**4-digit-LCD displays multiplexed inputs**

UCE Inc., 20 N. Main, Norwalk,  
CT 06854. (203) 838-7509. $13 (1000 qty); stock to 6 wk.

In the Model 3624, the inputs to this four-digit liquid-crystal display are multiplexed. Characters in the unit are a variation of standard digits with heights of 0.5 in. Each digit is electrically isolated with separate backplanes to allow sequential seven-segment-digit driving. Generally, four digits are considered the crossover point in terms of parts count in multiplex vs latch drive. A latched option of the instrument, the 4LDD-7, offers drive and display and accepts either BCD or pulse-counting inputs.

**CIRCLE NO. 360**

**Magnetic contact feels vibrations**

Mountain West Alarm Supply, P.O.  
Box 10780, Phoenix, AZ 85064.  
(602) 263-8821. $2.50; stock.

Although the S9 Magna-Vibe is basically a sensitive magnetic contact for use in closed-circuit burglary-alarm systems, it can be easily converted to also act as a vibration detector by simply adding a supplied sensitivity adjustment screw. Its four sets of contact surfaces scrub and polish themselves during each opening and closing. The one simple moving part has been estimated to have an almost limitless life even if operated thousands of times a day. Heavy-duty contacts are designed for very low resistance, no pitting or oxidation.

**CIRCLE NO. 361**

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**TEXTOOL “mini” series ideal for high density multi-socket mounting**

New TEXTOOL miniature 12 and 16 lead TO-8 test sockets are designed for highest density mounting in multi-socket installations. Both sockets have an extremely small diameter (.660 inch) to allow increased P.C. board density, and they accept devices with .500 inch minimum lead length.

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In addition, solder “hold down pins” are an integral part of TEXTOOL miniature TO-8 test sockets. This feature further increases socket durability by preventing damage to contacts during normal use by securely anchoring the socket to the P.C. board.

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Ask today for your copy of the new 1977 TEXTOOL CONDENSED CATALOG!
TV controllers

Physical and electrical characteristics of video-random-access-memory (VRAM) TV controllers are given in a catalog. Matrox Electronic Systems, Montreal, Quebec H36 3N5.

CIRCLE NO. 362

Digital displays

Digital measurement and display devices for use with microwave antenna measurement systems are described in a 32-page catalog. Scientific Atlanta, Atlanta, GA

CIRCLE NO. 363

Pressure transducers

Applications and specifications for the Model SA-E soil and Model SA-P pore pressure transducers are described in an illustrated two-page data sheet. Sensotec, Columbus, OH

CIRCLE NO. 364

Hardware components

General specifications and finishes of electronic hardware components, drawings, and tabulations indicating sizes, lengths, diameters, etc., are contained in a 60-page booklet. Accurate Screw Machine, Nutley, NJ

CIRCLE NO. 365

Transducers

A 24-page catalog and selection guide for linear and angular displacement transducers covers the theory of the LVDT. Cut-away sections, graphs and performance tables are included. Schaevitz Engineering, Camden, NJ

CIRCLE NO. 366

LED panel lamps

Full electrical and mechanical data, as well as ordering information for the P405 and PR405 snap-in LED panel lamps, are provided in a data sheet. Data Display Products, Los Angeles, CA

CIRCLE NO. 367

Hybrid support capability

Technical background information on the design, manufacture and QA aspects of the company's products for military and aerospace programs are given in a 12-page brochure. Amperex Electronic, Slater’sville, RI

CIRCLE NO. 368

RF/audio connectors

A right-angle RF/audio connector, which offers quick connect/disconnect for coaxial cables and twin leads, is featured in a two-page catalog. Connector Corp., Chicago, IL

CIRCLE NO. 369

Computers

"Computers in Engineering" discusses the use of computers in various fields of technical analysis and design and their value in data-acquisition, reduction and processing. Digital Equipment, Communication Services, Northboro, MA

CIRCLE NO. 370

Wire

"A World of Wire" describes various products available for both precision electrical-conductor and electromechanical applications. Production, QC, customer-engineering assistance and R&D capabilities are shown. International Wire Products, Wyckoff, NJ

CIRCLE NO. 371
Switches
Eighty-four pages cover the company's snap-action, contact, selector, rotary, thumbwheel and lever-wheel switches as well as keyboards and keyboard switches. Also included is a price list. Cherry Electrical Products, Waukegan, IL
CIRCLE NO. 372

Connectors
Technical data on the company's RAPMATE 354 series connectors are featured in a four-page folder. Malco, Montgomeryville, PA
CIRCLE NO. 373

PROM programmers
Features, specifications and ordering information for a portable PROM programmer can be found in a two-page data sheet. PROM Programmers, Mountain View, CA
CIRCLE NO. 374

Rf instruments
A 62-page catalog features instruments for rf power measurement. Bird Electronic, Cleveland (Solon), OH
CIRCLE NO. 375

Connectors, terminal strips
Blade-contact rack-and-panel connectors and barrier terminal strips are featured in a four-page bulletin. Beau Products Div., Laconia, NH
CIRCLE NO. 376

Components
Fully described and illustrated in a catalog's 164 easy-to-read pages are over 4500 practical products. Edmund Scientific, Barrington, NJ
CIRCLE NO. 377

Strip-chart recorders
A 32-page Rustrak strip-chart recorder catalog includes data on a miniature 24-channel event recorder, a miniature three-channel analog recorder and a line of 4-in. servo recorders for OEM and laboratory use. Measurement & Control Systems Div., Gulton Industries, East Greenwich, RI
CIRCLE NO. 378

Cooling systems
A 20-page illustrated catalog covers cooling systems. A product/specification cross-reference is included. Zero Corp., Burbank, CA
CIRCLE NO. 379

Beryllia packages
"Cermatrol Products," an illustrated 24-page handbook, covers beryllia components and includes 38 engineering drawings of tooled microelectronic packages. National Beryllia, Haskell, NJ
CIRCLE NO. 380

Data-acquisition systems
The Digitem System 2000, a new family of data-acquisition systems, is described in an eight-page brochure. FX Systems, Kingston, NY
CIRCLE NO. 381

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Editor
Electronic Design
50 Essex Street
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Electronic Design 7, March 29, 1977

Design Aids

Solar radiation chart

A wall chart shows world-wide annual solar radiation in kJ/cm². Sensor Technology.

CIRCLE NO. 382

Rectifier cross-reference

A cross-reference on full-wave, single-phase bridge-rectifier circuits from 1.8 to 30 A lists over 250 part numbers by manufacturer, along with the corresponding IR replacement. International Rectifier.

CIRCLE NO. 383

Zener diodes

Low, medium and high-powered zeners as well as JEDEC series and transient absorption (TAZ), voltage-reference and chip zeners are shown in a wall chart. Siemens.

CIRCLE NO. 384

Epoxies

Major properties and uses of more than 50 specially formulated epoxies and related compounds are covered in a four-page product selector. Techform Laboratories.

CIRCLE NO. 385

Digitizing equipment

A pocket-sized folder provides a capsule review of digitizing equipment and capabilities and presents definitions for common digitizer terms. Science Accessories Corp.

CIRCLE NO. 386

Standoffs and spacers

Standardized standoffs and spacers are featured in a wall chart. Keystone Electronics.

CIRCLE NO. 387

Programmable memory

A comparison chart shows currently available PROMs and FPLAs. The chart includes a user guide. Data 1/0.

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The COS/MOS devices in this table were of the CD4000 Series, processed to Class A requirements of MIL-M-38510 or MIL-STD 883.

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<td>32</td>
<td>85.5</td>
<td>49.5</td>
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<td>7.200</td>
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<td>Failure rate (%/1000 hours)</td>
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<td>MTTF (hours)</td>
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<td>29,000,000</td>
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Total device hours: 100,000,000 hrs (Data at 60% confidence, usage thru Nov. 1, 1976)

Failure rate: 0.00092%/1000 hrs. MTTF: 108,000,000 hrs.

Write: RCA Solid State. Box 3200, Somerville, NJ 08876; Sunbury-on-Thames, Middlesex TW16 7HW, England; Ste.-Anne-de-Bellevue, Quebec, Canada; Fuji Bldg., Tokyo, Japan.

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