May 16, 1974

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Electronics®

Ludwig Lectures.

Getting a fix on fast settling.

In numerous linear-circuit applications where the nature of the signal is pulse-like or step-like it is essential to reach a new level quickly and accurately after a large signal transition. However, we find that we cannot predict this performance from the classical specifications of frequency response and slew rate. Therefore, a direct specification — settling time — was established which defines the maximum total time required from the occurrence of an abrupt input transition until change is *satisfactorily complete*.

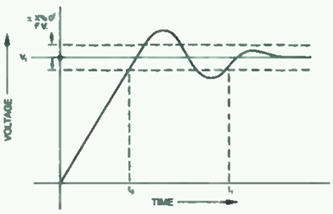
A slight misunderstanding...

The major areas of concern are in defining the input conditions, and what it means for the output change to be satisfactorily complete.

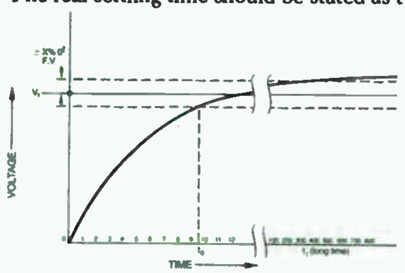
The real settling spec ought to cover these by defining a settling time to within X% (for example .01%) of final value for a large signal change (usually 10V) on the input. But both must be stated.

Close, but no cigar.

Some vendors base "Settling Time" specs on a small step change at the input and you still don't know what will happen in the large signal case. But the issues of "satisfactorily complete" on the output is full of cute pitfalls — let me show you.



Notice in the curve that the output first occurs with ±X% a full-scale-error-to-final-value at t_0 but doesn't stay within this error band. It thereafter bangs around due to the underdamped nature of the system. The real settling time should be stated as t_1.



Now look at graph B. The response is critically damped and settling seems to occur at t_0. But watch out. If we look far down scale we note that the apparent final level V_1 wasn't the final level at all. Question, how long do you wait to define what V_1 (final level) really is? You have to figure that out.

This long settling "tail" often occurs with time constants long compared to any computable electrical time constants in the system and is usually the result of less than ideal thermal management or slight pole/zero mismatch. If you're trusting your vendor's settling time measurements, make sure that you (and your vendor) understand his definition and their use of it, otherwise you're in trouble.

Who needs it?

Anyone handling signals having discontinuities needs fast settling. For example, following a multiplexer, on a PAM Bus, at the output of a DAC, in building a precision square wave, at the input to an oscilloscope, etc.

How good can you have it?

At Philbrick we give you *guaranteed* settling time because we figure your system has to always meet its spec — not just typically and that's more than just important. We offer a host of op amps, discrete modules, hybrid IC's and monolithic IC's with state of the art settling including our T099 units, 1322 (300 ns to .1%), 1324 (1 μsec. to .01%). guaranteed. The star of the show is our new DIP unit with FET inputs, the 1430, which offers 100 ns to .1% and 200 ns max to .01%. And you don't give up dc performance to get it. The 200 ns to .01% is just what you need for a fast 12 bit system and open loop gain of 200K plus, input currents of 10 pA, and offset voltage of 1mV give you the dc accuracy to go with it. The 50 mA output capability will let you drive almost anything, but you don't pay for it with high quiescent current and its attendant power consumption.

Don't settle for less.

You could have the fastest settling op amp in the world and get lousy system settling unless you're very careful. Some of the common pitfalls that catch people are things like too much load capacity, too much summing point capacity, too high a circuit impedance for the stray and input capacities, use of inductive wire-wound resistors, and not figuring on the effect of current source output capacities in current-to-voltage converter applications. You've got to handle your power supplies very carefully too, by bypassing up close to the unit with the right kind of capacitor.

In any event, to make sure you get the right story on settling time and use the information properly, telephone, (617) 329-1600. Or write us, Dedham, Mass. 02026. In Europe, Tel. 73.99.88, Telex: 25881. Or write, 1170 Brussels, Belgium.

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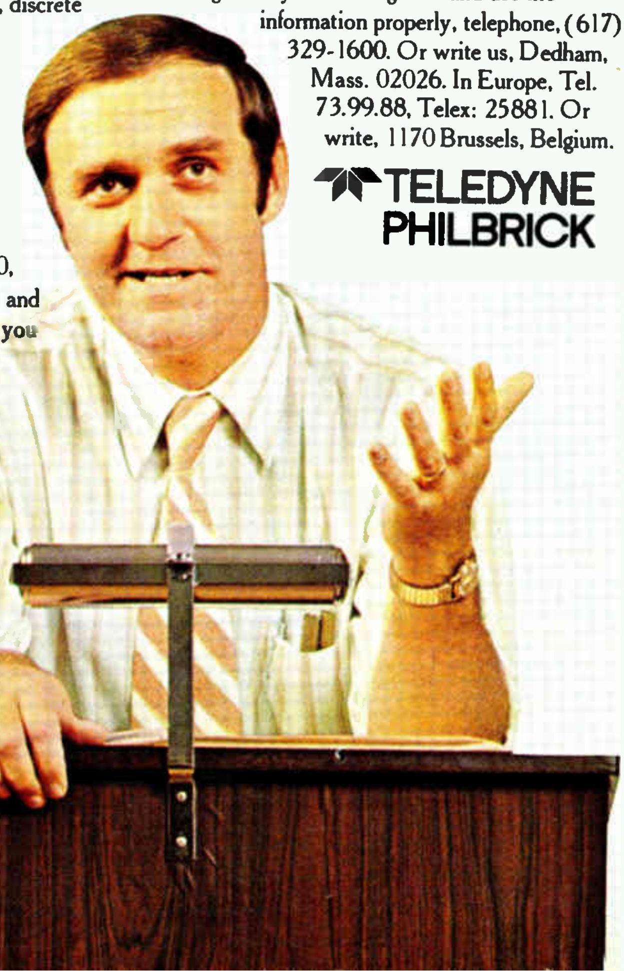
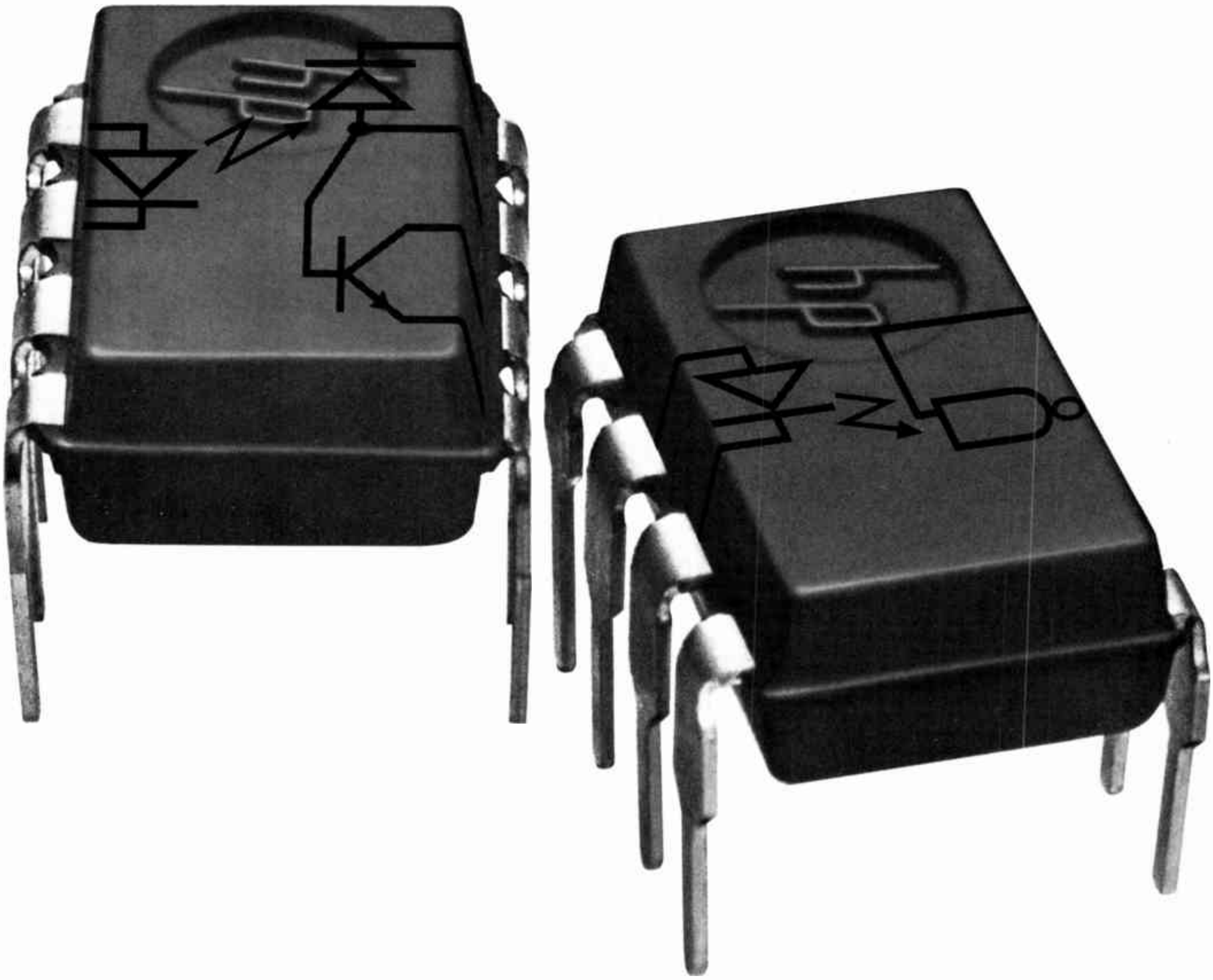


Dave Ludwig
Director of Engineering

Circle 900 on reader service card

SURPRISE!



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Electronics

The International Magazine of Electronics Technology

Vol. 47, No. 10 • May 16, 1974

Highlights

Cover: Film-carrier method packages ICs fast, 89
Lead frames carried on plastic film are gang-bonded to IC chips almost entirely automatically in the latest technique for reducing the costly labor content of packaged integrated circuits. The process achieves 10 times the assembly rates of the wire-bonding approach.

Japan's boom is ending, 65
Soaring inflation, soaring wages, tight money, and possibly a 25% drop in profits—problems all too familiar in the West—are now being encountered by Japanese electronics companies.

Whether to automate with a calculator, 100
Measurement and control systems can now be automated either with a minicomputer or, at much lower cost and with much less sophistication, by a programable calculator. Sometimes the choice is difficult, so Part 1 of this two-part article compares how well (or poorly) each satisfies various system requirements.

How to automate with a calculator, 104
Part 2 discusses the problem of interfacing a programable calculator with an instrumentation system, describes some applications, and lists some off-the-shelf equipment that makes it simple to customize a system.

EEs differ on promotion, agree on evaluations, 111
Whether they supervise others or are themselves supervised, readers who filled in *Electronics'* March 7 questionnaires agree that performance evaluations today are generally fair and thorough. But though promotions seem to work out well from a supervisor's and presumably a company's viewpoint, individuals often feel they have too little control over whether they become managers or rise as engineers.

And in the next issue . . .
Special report: passive components thrive in the IC era . . . minicomputers in action, part 8: how minis are automating newspaper typesetting.

Electronics

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Publisher's letter

What ever happened to. . .? That's one of the most asked of questions—especially in electronics, where the pace of technology and marketing is so frenetic. So, we have started a new column, called Update, designed to bring you up to date on last year's newsmakers. On page 18 you will find a rundown on how some of the ideas that were hot a year ago have fared. And in subsequent issues, we'll be updating other developments, looking at the successes as well as the failures.

We think that the new column adds a different and valuable perspective to our news pages. And, if you wonder what ever happened to something in particular, let us know. If we find an interesting story there, we'll run it in Update.

And speaking of updating, our Packaging and Production Editor, Steve Grossman, has put together a what's-the-status report on film-carrier IC packaging techniques (see page 89). We have beer following this cost-cutting route for bonding chips to lead frames since General Electric revealed the details of its technique—called MiniMod and later acquired by Texas Instruments—more than three years ago. In fact, we first reported on the film-carrier concept in 1967.

But the technique and its variants were slow to catch on. And, still, manufacturers using the approach are reluctant, understandably, to give details that might help their competitors. Yet after assembling the bits and pieces of available data and, with the help of our field bureaus, digging out the behind-the-scenes details, we have found that the film-carrier idea is one whose time has come.

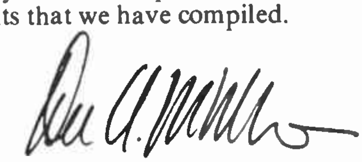
For those who have wondered how the Japanese electronics giants are weathering current world-wide economic pressures, we have the answer. As Mike Mealey, Tokyo bureau chief for McGraw-Hill World News, speels out in the Probing the News story starting on page 65, the boom times have ended.

Consumer spending is down. Industrial companies are cutting back on capital investment. The cost of energy has skyrocketed. Prices, fed by inflation, are soaring. Labor demanded a one-third jump in wages.

What's more, with the domestic market riddled with problems, the push will be strong in export markets, where resistance is building to Japanese wares and where rising pricetags will limit sales. Put together, all these factors add up to a 25% erosion of profits for the Japanese electronics industry.

How do engineers feel about the way career evaluations are handled? Generally, they believe evaluations are performed fairly, although their own freedom to make career choices is much too limited. Yet, a hefty majority of engineering supervisors—the raters—feel that promotion systems work well.

That's one of many divergences of opinion that we uncovered through the questionnaire that we included in the March 7 issue. We know you will find the article starting on page 111 instructive as you compare your company's program and your own experience with the results that we have compiled.



May 16, 1974 Volume 47, Number 10
94 249 copies of this issue printed

Published every other Thursday by McGraw-Hill Inc Founder James H McGraw 1860-1948 Publication office 1221 Avenue of the Americas, N Y , N Y 10020, second class postage paid at New York N Y and additional mailing offices

Executive, editorial, circulation and advertising addresses Electronics, McGraw-Hill Building 1221 Avenue of the Americas, New York, N Y 10020 Telephone (212) 997-1221 Teletype TWX N Y 710-581-5234 Cable address M C G R A W H I L L N Y

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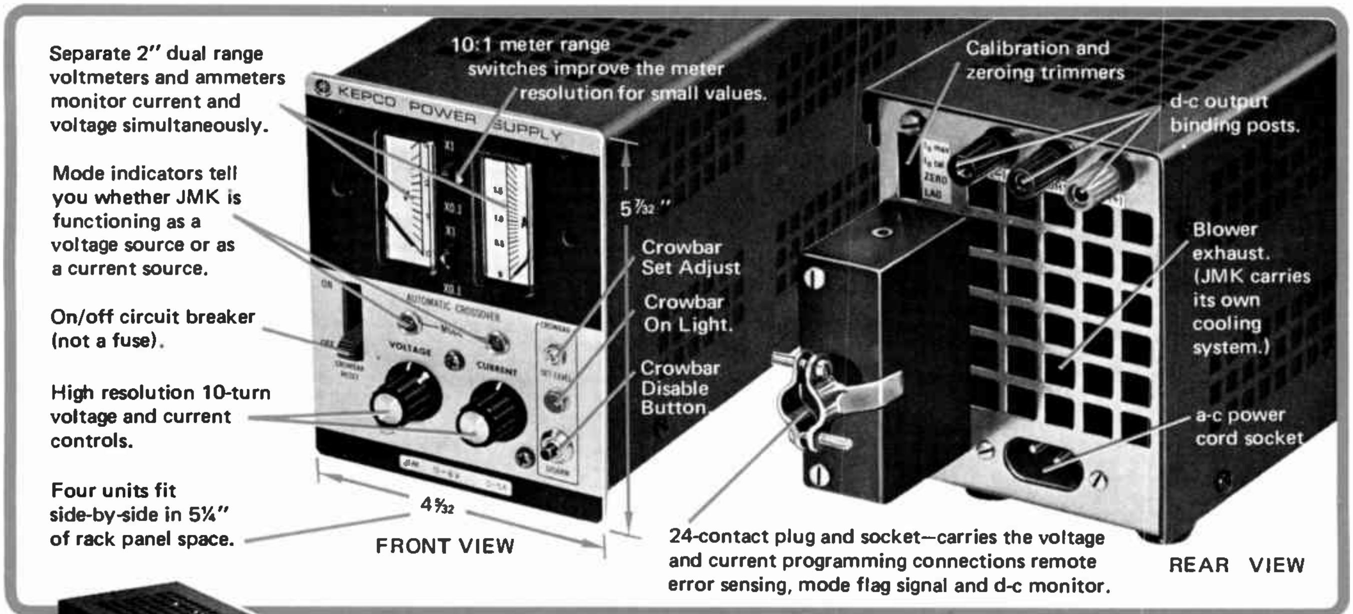

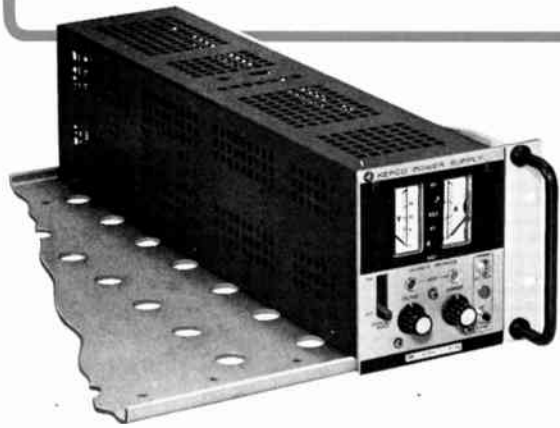

Kepco designed JMK to answer the special needs of the system designer for practical rack-mount systems power supplies.

The shape of JMK, for example, minimizes precious panel space—four of them will fit in a 5¼" high drawer (Model RA—24) which has provision for slide mounting. The connections to JMK are all at the rear so they don't clutter your panel—moreover, they're all *plug-in* That means you don't need to fool with a screwdriver and wire-list to mount or remove a JMK. Just plug it into its prewired cable connector.

Kepco's JMK doesn't have hot radiator fins protruding in all directions —nor does it require elaborate derating for the elevated temperature of jammed systems racks. JMK has its own built-in blower system exhausting air (heated only about +15°) directly to its rear. You'll get *full output* from your JMK from −20°C to +71°C, no derating, no baking the equipment above.

JMK is fully programmable, you can control it with resistance, analog signals, or digital instruction with up to 12-bit resolution.* JMK, as an automatic crossover power supply, can be controlled in either mode with a degree of precision and stability that is close to standards-lab performance (5 ppm source effect, 50 ppm load effect, 50 ppm temperature effect coefficient. . .).

Kepco designed JMK for the systems man who needs a full-performance, programmable power supply to run his test program (on instructions from the computer) or a stable current source to energize sensitive circuits, or perhaps an ultra-stable voltage supply to which repeatable measurements can be referred.

Kepco's catalog contains the full specifications for the 14 JMK models ranging from 0—6 volts at 5 and 10 amperes to 0—100 volts at 0.5 and 1 ampere. Write to Dept. EK-14 for your free copy.

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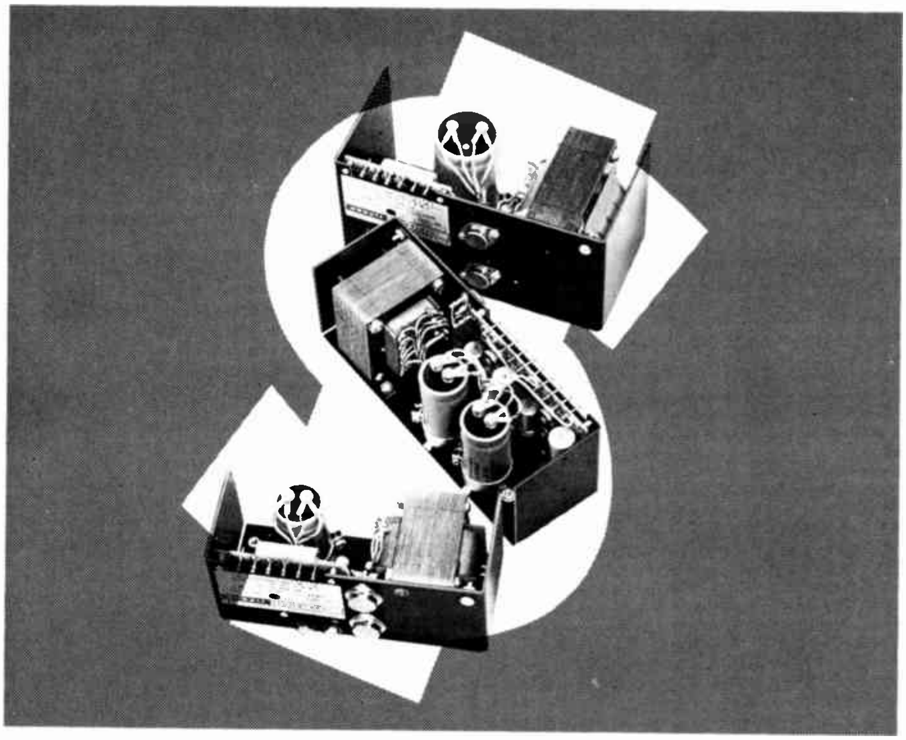

Readers comment

Arguing plastic packages

To the Editor: Although most of us are aware of ECOM and RADC activities, including RAC, we're fully aware of the differences of opinion between the two ["Military argues over plastic semis," *Electronics*, Feb. 21, p. 38]. I fail to see how the industry is served by airing simplified subjective opinion.

Historically, plastic's main weaknesses have been its nonhermeticity and difficulty in matching coefficients of expansion, leading to moisure, saline, and bonding problems. So RADC (Barber/Brauer) does have a problem. On the other hand, ECOM's (Reich/Hakim) results in Panama (in small quantities) would appear to point toward epoxy-B's dramatic improvement (an order of magnitude over silicone and phenolic materials).

I would tend to agree with Bernie Reich in that failure modes for plastic are known and that screens may weed out the actual or latent failures. I don't agree with what appears as an editorial comment that suppliers have shown little interest in supplying screened parts during this period of shortage. We buy tens of millions annually.

I sympathize with RADC's concern and the probable logistics implications regarding moisture and salt-spray environments, but the dogmatic stand belies some of the benign π_E (environmental) conditions of volume 11 (TR-67-108) and MIL-NDBK-217B.

R. C. Foster
Xerox Corp.
Rochester, N. Y.

■ *We believe the article to be objective. On screening, Reich points out that, although suppliers are willing to burn in the parts, they are reluctant to make environmental tests.*

Correcting a counter gate

To the Editor: There was a slight error in one of the diagrams of my Designer's casebook, "External gate doubles counter speed," [*Electronics*, Feb. 7, p. 102]. The extra gate in figure (b) should be an OR gate, instead of a NOR. The description in the text was correct.

Jeffrey Mattox
Boxborough, Mass.

Now you have an alternate source for 2GHz & 3GHz microwave transistors

TRW's new 2GHz & 3GHz microwave amplifier parts are available right now, off-the-shelf, from any authorized TRW distributor. So, soon as you qualify these parts, you are no longer at the mercy of a single-source manufacturer!

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These are practically drop-in parts. You can use them right now, in your present amplifiers—and, of course, in future designs. That means instant improvement in the reliability of your amplifiers. Part for part:

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5W	MSC2005	TRW2005	MSC3005	TRW3005
10W	MSC2010	TRW2010	—	—

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40 years ago

From the pages of Electronics, May, 1934

Needed—better antennas

For years an antenna has been any old piece of wire strung up any old place with any old kind of insulation. And for years the increase of man-made static has accelerated.

The year 1934 will be a year of tremendous public interest in short waves; late in the year may see the first high-fidelity receivers. Both short-wave sets and high-fidelity, wide-range sets suffer more than broadcast reception from natural and man-made static. Short-wave signals are weak and may come across thousands of miles of space, high-fidelity receivers will pass to the loud speaker tones (and noises) now lost in the narrow-band receivers universally employed.

Already the antenna problem has become acute. Set manufacturers are encouraging listeners to use two antennas: a high, long wire, well insulated and brought to the receiver through a shielded transmission line; and another high, shorter antenna, brought to the short-wave set through a transposed lead-in.

A campaign on the part of all the radio industry to encourage listeners to put up high, clear, well insulated antennas will hasten the day of noise-free short-wave reception.

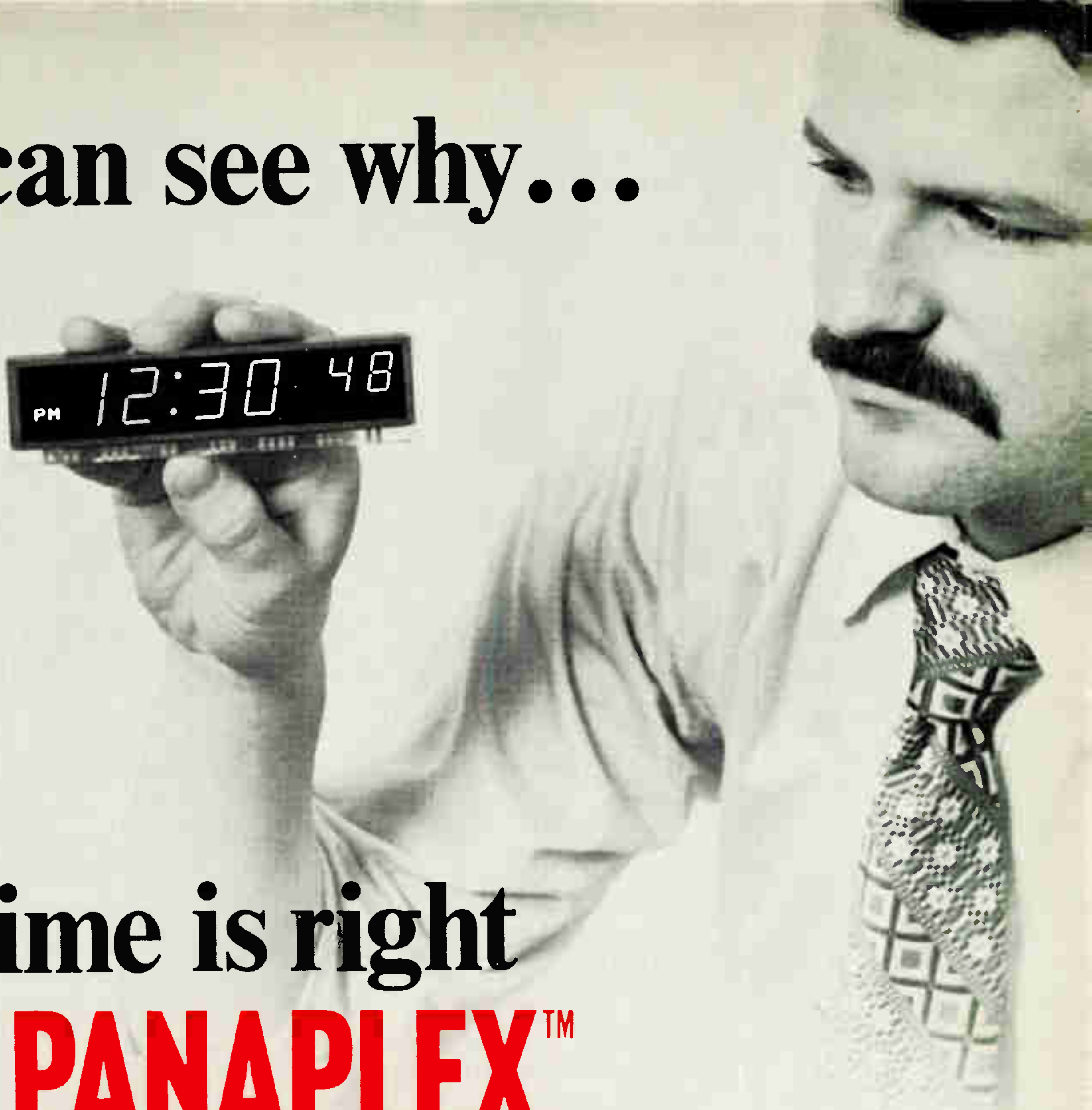
Chicago's electronic 'frisker'

Prisoners taken into the Chicago Detective Bureau can now be "frisked" for concealed weapons by means of a magnetic exploring device, with tube amplifiers operating an alarm. The main wall-plate detects the presence of any iron or steel, even a saw-blade on a prisoner, and the small exploring coil permits localizing the metal body or weapon.

World Broadcasting, Berlin

[H. Mogel, German Post Office] Five more directed antenna systems for sending German programs to South America, Africa and the Far East have been added to the three antennas used for covering North and Central America. All the continents except Australia now receive a two hour broadcast.

you can see why...



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These four- and six-digit clock panels are compatible with MOS clock chips, and have the high reliability and quality that has made the PANAPLEX family of displays the choice of calculator manufacturers.

PANAPLEX clock panels can display either 12- or 24-hour time systems and have integral AM/PM indicators and colons.

Available in two standard sizes (0.5 and 0.7 inch), these thin panels (0.2 inch excluding tubulation) offer design flexibility that's hard to beat

The soft, neon-orange color is easy to read at a glance: — no magnifier needed, no eyestrain, no LED-red fatigue factor.

For additional information on the PANAPLEX clock panels, write Burroughs Corporation, Electronic Components Division, P. O. Box 1226, Plainfield, New Jersey 07061, or call (201) 757-3400 or (714) 835-7335.

You can see the difference

Burroughs

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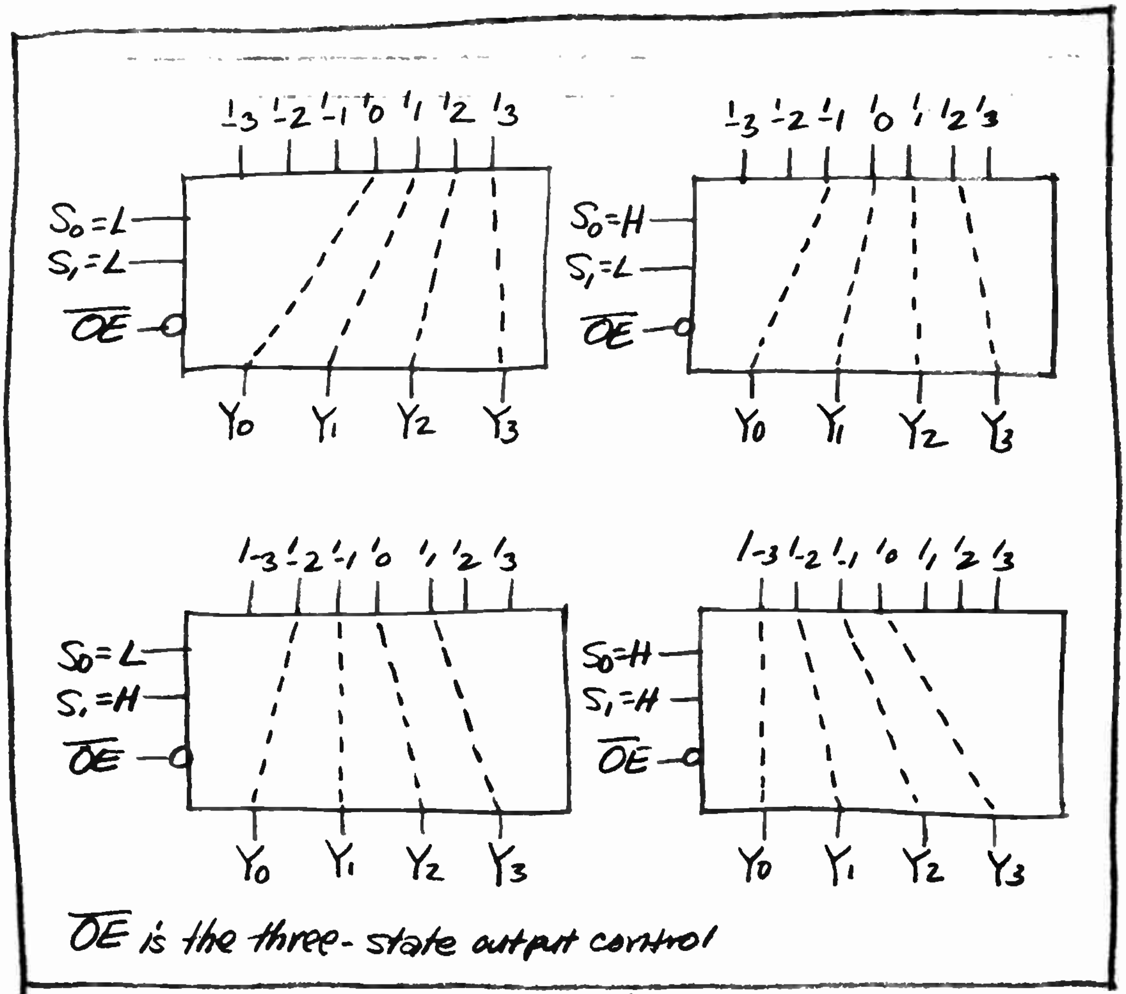
The Am25S10.

(The S is for Simple. See also: Schottky, Speed, System Space Saving, Signal Processing, Shifting and Scaling.)



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You can shift an N-bit word N places either up or down, logically, arithmetically or end around. The Am25S10 is a 4-bit shifter with three-state outputs for bus organized systems.

It has a data propagation delay of 6.5 nanoseconds.

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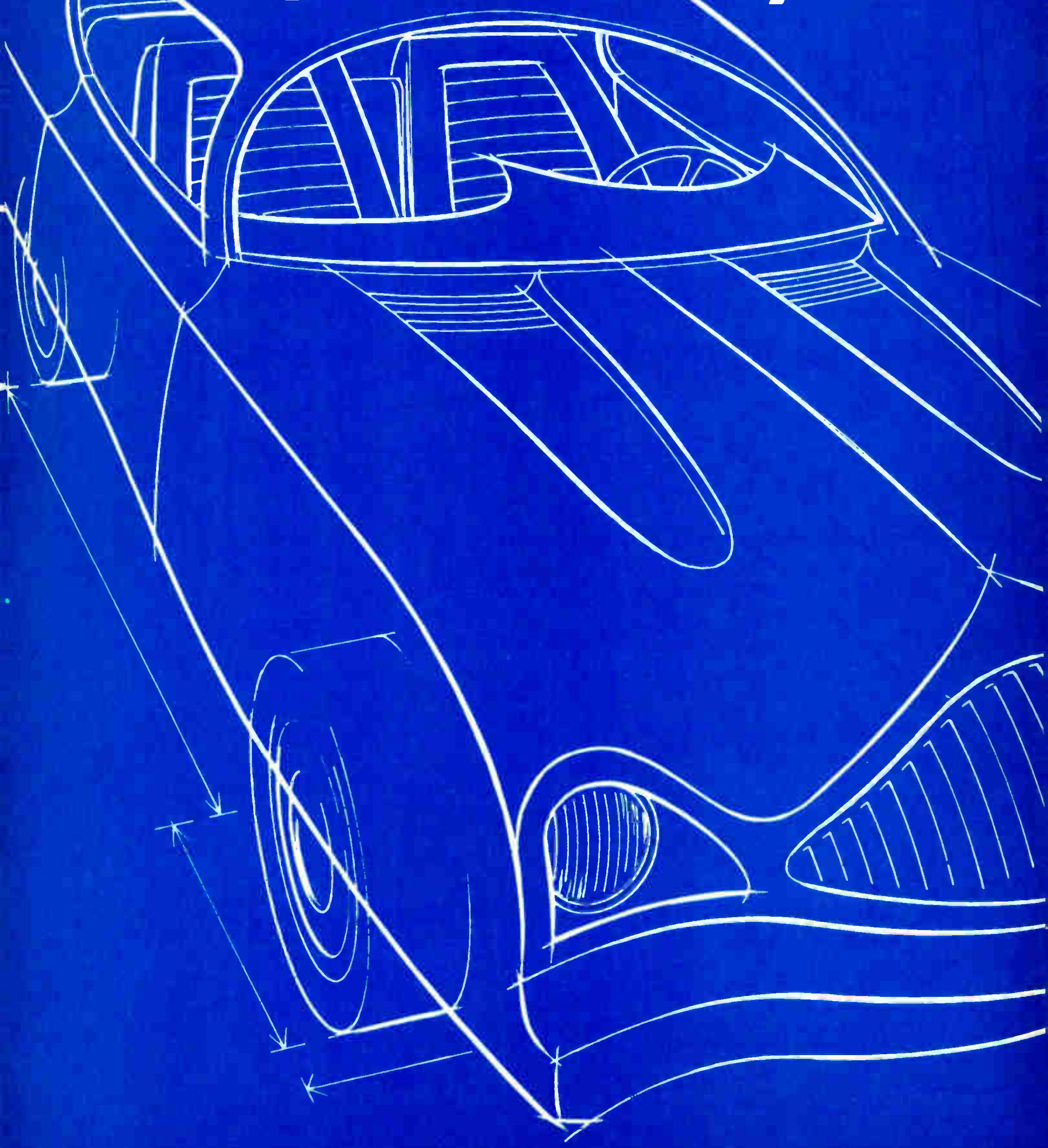
By 1980 electronic circuitry will control, correct and protect virtually all automotive systems.



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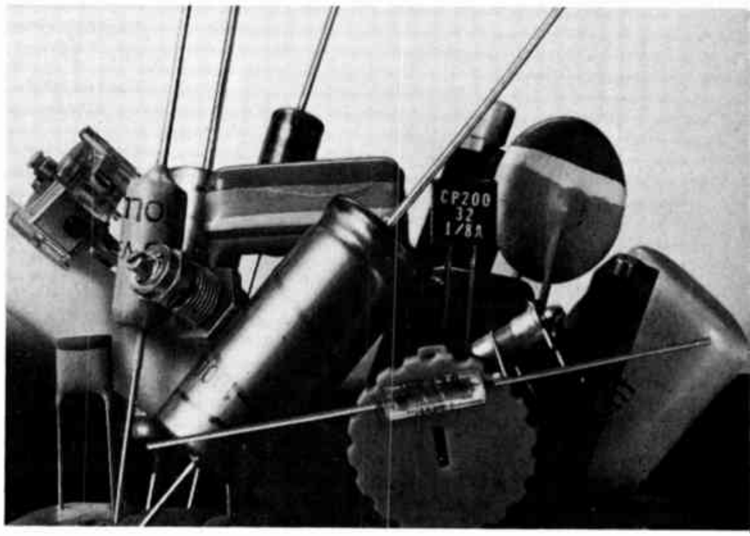

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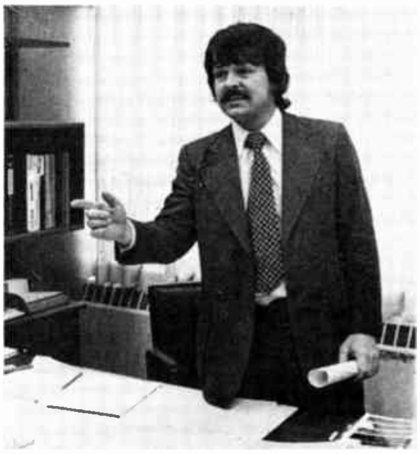
Circle 13 on reader service card

People

But Randlett is confident. "We feel we can dominate in technology," Randlett says. "By the end of the year we will have introduced a line of converters combining dielectric isolation techniques and thin-film technology, which we feel will have the best cost-performance ratio." Philbrick claims better speed and lower error rate using its new technique, and faster settling time in quad current switches. It also claims that its prices will be lower than the competition's.

Having developed a highly qualified staff over the last few years, Philbrick brought in Randlett to regroup for a production push.



Group effort. Randlett believes productivity will be enhanced by his team approach.

In 1967, after working at IBM for two years as a staff engineer, Randlett and two physicians founded Vertek, which made pulmonary-analysis equipment, and later sold it to Hewlett-Packard. Randlett then got into the analog-to-digital-converter business with the founding of Adac, which eventually was merged with Dynamic Measurement Corp.

At Philbrick, he has organized his staff into teams of three to five people, with each team following its work throughout all phases of production. The group leader must be able to communicate with all areas of the company.

The value of the team concept is accountability. "The groups can see results in terms of the number of products and the money they can generate," says Randlett.

Our Hustler 45 is a big name dropper

When it comes to testing dynamic RAMS and LSI random logic.

Our new Hustler 45 — a 10 MHz parallel functional tester has been purchased by some of the world's largest IC users. Here are a few reasons.

Extremely High Throughput

The Hustler 45 is in a class by itself when it comes to functionally testing MOS & Bipolar memories, shift registers and logic arrays at rates to 10 MHz.

In fact, Hustler can test access time or propagation delay on all pins simultaneously. With 1 ns resolution!

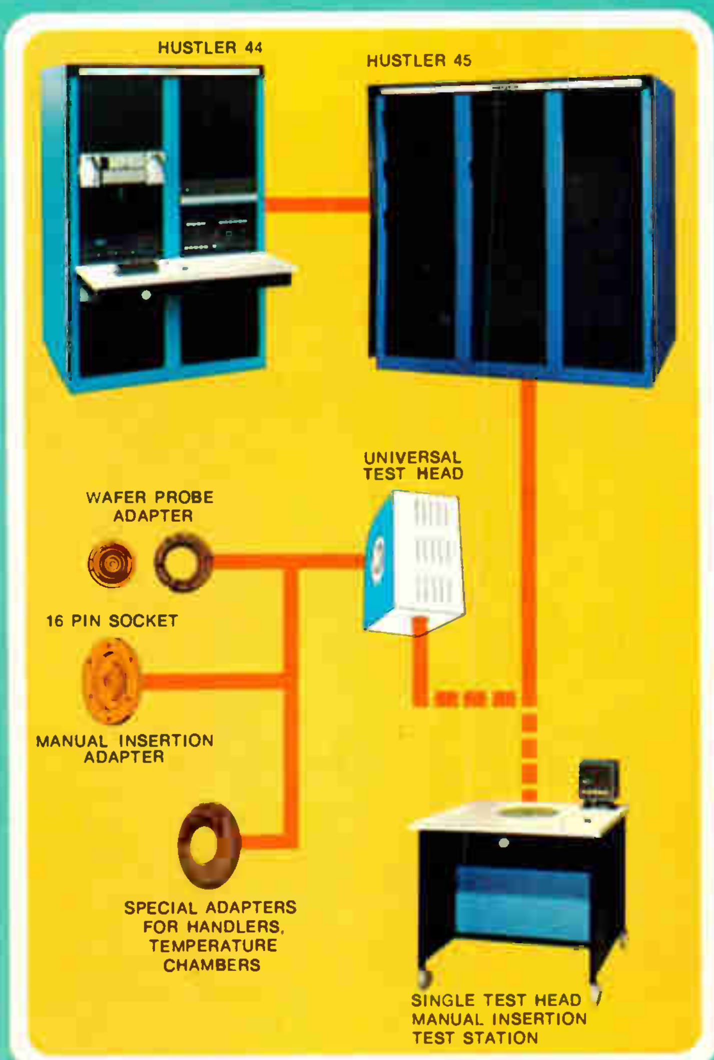
How does Hustler 45 accomplish this? With a separate high slew rate electronic card (PEC) for each pin. With drivers and comparitors located just inches from the device under test. With a RAM behind each pin. With 4 fully programmable clock phase periods. And an independent error strobe. With a computer programmed pattern generator. (optional)

Each pin can act as an input, output or be disconnected. All inputs are exercised in parallel. All outputs are measured in parallel. Throughput is dramatically increased. IC's are tested as they actually operate in the real world.

Functional Flexibility

Hustler 45 is flexible too. With 100 pin capability. And behind each pin a fast access RAM configurable to 4096 bits. Which means you can perform high speed functional & dynamic tests on large arrays — even complete memory boards.

Interfacing is just as versatile. Choose from a low cost, manual insertion, single station test head. Or a universal test head for operation with wafer probers, automatic handlers, temperature chambers or manual insertion fixtures — single station or multiplexed two station.



Parametric Tests, Too

You can specify Hustler 45 as a stand-alone system for 10 MHz functional and dynamic testing with sequential parametric testing. Or couple it with our field-proven Hustler 44 to also perform parallel parametric tests on devices with up to 256 pins — with time sharing of up to 8 remote stations and data logging of test results.

Simple English Language Programming

Hustler 45 software is simple. Your techs and engineers can generate programs after a few hours of training. Using simple English language programming designed for the test operator — not a computer expert.

In a Nutshell

Our Hustler 45 offers unmatched speed, versatility and programming ease at a surprisingly low price. So talk to a Datatron field engineer before you decide on any high speed tester. And send for our informative brochure.

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Circle 17 on reader service card

Update

A year ago, the FAA and Congress were about to collide head on over aircraft collision-avoidance systems. Specifically, the issue was Sen. Frank E. Moss' (D., Utah) bill requiring the FAA to select a national CAS standard by June 30, 1974 [May 10, 1973, p. 49]. And that's about where things still stand. Hearings on the bill are scheduled for May 21, and the warring parties are still adamant: the FAA wants a ground-based system, the Air Transport Association wants an airborne system, the general aviation lobby doesn't want its members to pay for any system, and the military says its planes already cost too much.

With much ballyhoo and optimism, Multipoint Distribution Service was launched about a year ago as the future third type of television network [May 10, 1973, p. 65]. The system combines the features of over-the-air, cable, and closed-circuit TV with point-to-point microwave transmission. Now, says Mark Foster, president of Microband National Systems Inc., his omnidirectional closed-circuit system is in full-scale operation in four cities—Chicago, Washington, New York, and Houston. Three others—Philadelphia, Baltimore, and Miami—are just coming on the air. Foster says the bulk of the time is being used for pay TV; corporate communications are coming onstream.

RCA Corp. called itself the first manufacturer of color television sets to add built-in cable capability when it announced some top-of-the-line XL-100 sets incorporating the feature [May 24, 1973, p. 42]. But after finding that most consumers apparently don't mind having a separate converter/selector sitting atop their sets, RCA never got its sets to market. A spokesman explains that the trend in the industry is to shrink the number of chassis and models being offered, so RCA decided to keep its cable sets off retailers' shelves.

Computerized nationwide design networks have been started from time to time down through the years, and last year's entry was one that could handle printed-circuit boards [May 10, 1973, p. 32]. The company, ADREC Inc. of Sherman Oaks, Calif., says the network is still in existence, but several other things have changed since then. There's a new product line of interactive graphics, plus backplane wiring for wire-wrap machines. And, says president A.T. Materna, ADREC has signed with a large manufacturer to provide IC designs.

The DOD's "design-to-cost" philosophy of cost-cutting was relatively new last year when defense contractors met with Pentagon officials to complain strongly about the concept [May 10, 1973, p. 36]. But since then, the vendors' ire appears to have dissipated for, in the words of one old Washington hand, "Industry just accommodated itself."

Shouldn't police departments be eager to buy a laser communicator that can be kept lined up even between two moving vehicles? American Laser Systems of Santa Barbara, Calif., thought the answer would be "yes" when it put together its system [May 24, 1973, p. 34]. But that hasn't been the case because, as the company found out, police departments just don't have very much money to spend on sophisticated secure communications systems. However, the Sixth Fleet is testing one in the Mediterranean. **—Howard Wolff**

Intended to bring *Electronics* readers up to date on news stories of the past months.

Meetings

Microwave Power Symposium, International Microwave Power Institute, Marquette University, Milwaukee, Wis., May 28-31.

Submillimeter Waves and Their Applications International Conference, IEEE, Sheraton Biltmore, Georgia Tech., Atlanta, June 5-6.

Consumer Electronics Show, EIA, McCormick Place, Chicago, Ill., June 9-12.

Chicago Spring Conference on Broadcast and Television Receivers, IEEE, Marriott Motor Hotel, Chicago, June 10-11.

Power Electronics Specialists Conference, IEEE, Bell Laboratories, Murray Hill, N. J., June 10-12.

Quantum Electronics International Conference, IEEE, Hyatt Regency, San Francisco, June 10-13.

Symposium on Human Resources and Medical Programs of the Department of Defense, EIA, Pick-Congress Hotel, Chicago, June 11-12.

Automotive Electronics Conference and Exposition, Electronics Representatives Association, Cobo Hall, Detroit, June 11-13.

International Microwave Symposium, IEEE, Atlanta, Ga., June 12-14.

Utilities Telecommunications Council Annual Meeting, UTC, Chalfonte-Haddon Hall Hotel, Atlantic City, N. J., June 16-20.

Design Automation Workshop, IEEE, Holiday Inn, Denver, June 17-19.

International Conference on Communications, IEEE, Leamington Hotel, Minneapolis, June 16-19.

1974 Government Microcircuit Applications Conference, DOD, NASA, AEC, U. of Colo, Boulder, (clearance required), June 25-27.

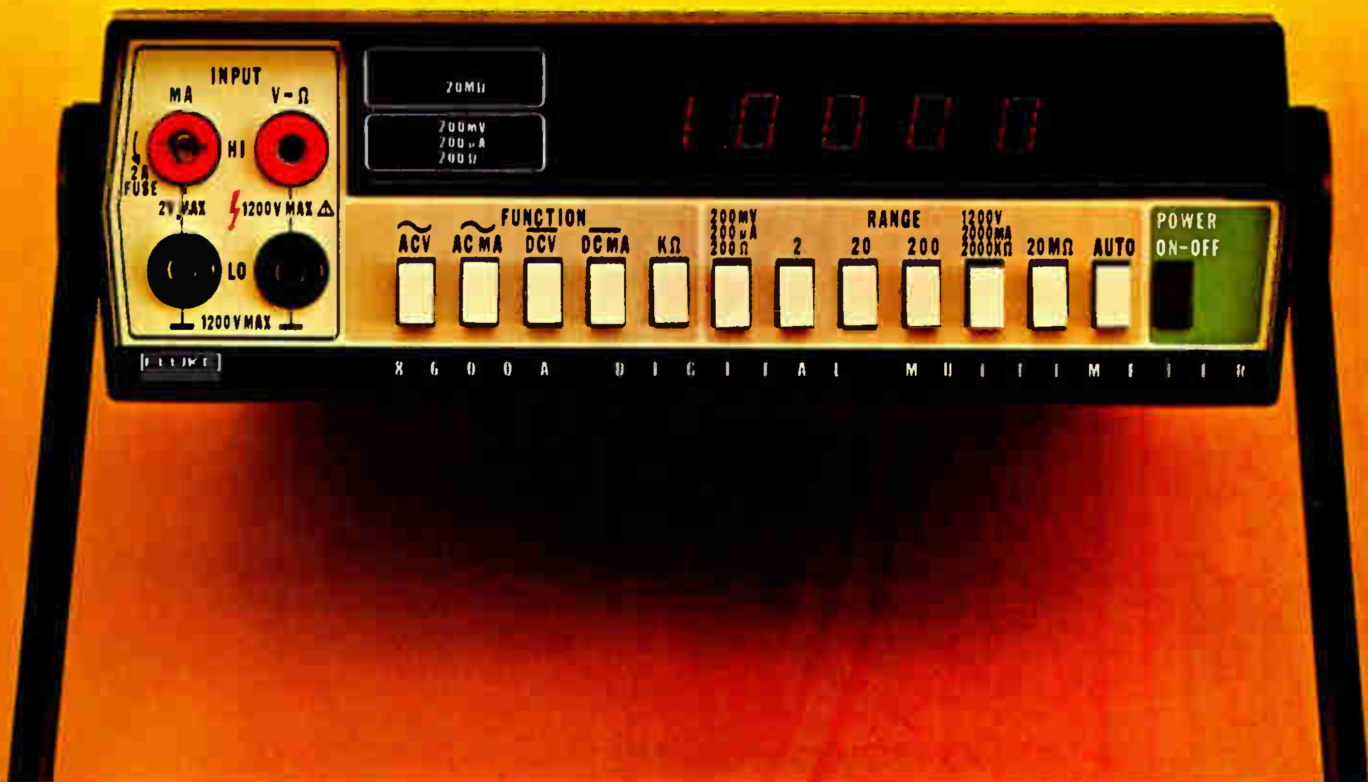
Precision Electromagnetic Measurements Conference, Royal Society, IEE, London, July 1-5.

From the voltmeter house...

The most important announcement you'll see this year about digital voltmeters

Introducing the new Fluke...

8600A 20,000-count DMM



8800A 200,000-count DMM

New automatic digital multimeters use advanced Fluke LSI technology. They're accurate and complete— just as they come from the box. Everything you need is built-in. They're small, tough and reliable. Maximize multimeter measure power for little more than half the price you're used to paying.

The 26-range Fluke 8600A, $599

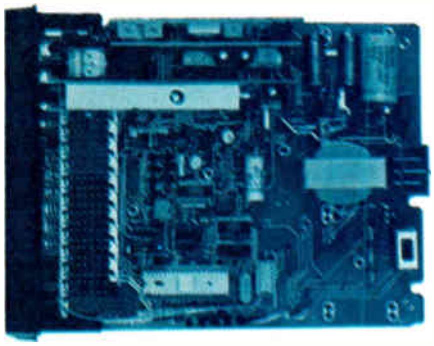
Here's what you get: a 4½ digit autoranging multimeter with five ranges of dc volts, five ranges of ac volts, five ranges of dc current, five ranges of ac current, and six ranges of resistance. Own a digital multimeter with a basic dc accuracy of 0.02% and autozero on all functions. Get up to 1000 megohms input resistance for minimum loading.

All dc ranges from 200 mV through 1200 volts are continuously protected to ± 1200V dc or 1700 volts peak ac. AC bandwidth to 100 kHz offers 10 μV resolution. From 200 ohms full scale through 20 megohms full scale, the 8600A takes a continuous 250V rms or dc. A front panel fuse protects all ac and dc current ranges from 200 μA full scale to 2 A full scale.

Optionally, a rechargeable battery pack with charger is built right in . . . no bulky snap-on's or external chargers. For true portability, the Fluke 8600A offers 8 hours off-line operation for slightly more money.

Weight, 5 pounds (2.3 kg). Two 8600A's fit neatly in a standard EIA rack. Rack mounting kits are optional. Optional low-ccst printer output is fully isolated and TTL/DTL compatible for use in datalogging applications.

Accessories, we've got 'em galore. There's a best buy high voltage probe that measures one kV to 40 kV. There are two RF probes, a 20 kHz to 250 MHz probe and a l GHz probe. To measure high currents there's a clamp-on probe that reads 2 to 600 amperes. Other accessories include deluxe test leads, rack kits, dust covers and two different carrying cases.



Notice the clean functional layout and careful workmanship of the Fluke 8800A.

The .005% Fluke 8800A, $1099

Here's what you get: a 5½ digit autoranging multimeter with full guarding on five ranges of dc volts, four ranges of ac volts, and six ranges of 4-wire ohms. With a basic accuracy of 0.005% and common mode rejection better than 120 dB, it's the top voltmeter for the money.

The 8800A gives you full guarding, 1000 megohm input resistance on the 200 mV, 2V and 20V ranges, excellent ac accuracies over the entire frequency range of 30 Hz to 100 kHz and autoranging on all functions. Completely isolated four-terminal ohms measurement on the 200-ohm full scale through 20-megohm full scale ranges with less than 4 volts open circuit voltage.

For datalogging, add low-cost isolated printer output. Weight is 10 pounds (4.5 kg). Width of 9 inches (23 cm) allows the Fluke 8800A to fit conveniently into a standard EIA rack.

Both instruments feature LED readout with easy-to-read numbers. Both instruments use a proprietary Fluke digital LSI chip for low parts count, high performance and extraordinary reliability. And, remember, Fluke has more LSI experience in instrumentation than anybody else.

These instruments are rated for a minimum 10,000 hour MTBF as a result of exhaustive Fluke environmental testing. They are rugged and will take a lot of abuse and still work well within specs.

Fluke backs you up after the sale

When you buy a new Fluke instrument, you may be gone from the salesman's short term prospect list, but you're not forgotten. We have technical and service centers throughout the United States, Canada, Europe and Japan. The one nearest you will give you super service on both in and out of warranty repair. We also invite you to become a member of our **user's group**, for service notes and seminars on getting the most out of your Fluke instrument.

Maximize measure power now

Fluke invites you to try one or both of these new multimeters on your bench right away. Call your nearest Fluke sales engineer for details or simply dial our hotline.

In the continental U.S., dial our toll-free number 800-426-0361 for the name and address of your nearest local source. Abroad and in Canada, call or write the office nearest you listed below. John Fluke Mfg. Co., Inc., P.O. Box 7428, Seattle, Washington 98133. Phone (206) 774-2211. TWX: 910-449-2850. In Europe, address Fluke Nederland (B.V.), P.O. Box 5053, Tilburg, The Netherlands. Phone 013-67-3973. Telex: 844-52237. In the U.K., address Fluke International Corp., Garnett Close, Watford, WD2 4TT. Phone, Watford, 33066. Telex: 934583. In Canada, address ACA, Ltd., 6427 Northam Drive, Mississauga, Ontario. Phone 416-678-1500. TWX: 610-492-2119.

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Common Market easing entry for U.S. wafers

It looks like U.S. companies are winning easier access to the Common Market's semiconductor wafer customers. The European Economic Community's commission has proposed a regulation shifting wafers to a new tariff position and **cutting duty on imports to the nine member countries from 17% to 9%.** The proposal is due to come up for approval by the council of ministers in early June.

If the regulation is adopted, it will mean **a success for U.S. trade negotiators, who protested against the duty** through the machinery of the General Agreement on Tariffs and Trade. Wafers were, in fact, grouped together with microstructures in the higher duty position in early 1972.

McGraw drops meter reader

The energy crisis has claimed another victim. McGraw-Edison Co. has withdrawn its automatic meter-reading system, Armeter, and is about to close that division of the company. T. Schuyler Banghart, general manager of the Armeter division, says the Elgin, Ill., company is making the move because of the **energy shortage and difficulties with AT&T's tariff structure.** McGraw-Edison makes components for utilities.

"Automatic meter reading was a high priority among utilities four or five years ago when we began working on the system, but now the energy crisis has put a financial bite on the utilities and it's low priority," he says. Banghart adds that McGraw-Edison, which invested several million dollars in the project, **will try to sell or license the technology** used in the Armeter transponder, which was developed jointly with American Microsystems Inc.

Price cuts loom for scientific calculator makers

Watch for Texas Instruments to set off a round of price cuts by scientific calculator manufacturers, despite the fact that the calculator giant is still limiting slashes of its SR-50 unit to direct mail. Industry sources are **predicting a $20 price cut to $149.50,** even though delivery times are still quoted at eight weeks.

While a Hewlett-Packard spokesman admits that last month's price reductions on its HP-35 and HP-45 were due in part to competition from the SR-50, he indicates that the firm **will not respond to further price cuts by TI** at this time. H-P, which hopes to have the U.S. blanketed through retail outlets by year-end, also attributes its new prices of $225 and $325 to a cosmetic redesign that paid off in manufacturing efficiencies.

TI, which has been exceptionally aggressive in pricing, used last week's National Computer Conference to lower the price on its hexadecimal calculator, aimed at computer programers and designers, from $295 to $249.50.

Space-funding forecasts paint grim picture . . .

A grim picture of future Federal space program funding is contained in new data presented to Congress by NASA and the Department of Defense. Where contractors previously looked to the Pentagon to offset declines in spending for civilian space programs, the Director of Defense Research and Engineering has indicated to the Senate Aeronautical and Space Sciences Committee that **military space expenditures will remain essentially flat at about $2 billion annually** for fiscal years

1975-1979. Outlays of $1.9 billion in fiscal 1975 are forecast to rise to $2.2 billion in fiscal '79, an increase believed insufficient to offset inflation.

NASA, meanwhile, is circulating figures that show the Nixon Administration has apparently dropped its commitment to a constant budget level of $3.4 billion annually. Money made available to NASA over the fiscal years 1973-1975 will be more than $1 billion short of the goal, with more than $900 million of that divided about equally between fiscal '74 and '75.

. . . as engineering job drop is seen in aerospace

The decline in jobs for engineers, scientists, and technicians in the aerospace industry will continue through December, recording **a drop of nearly 4% in 18 months,** according to a forecast by the Aerospace Industries Association of America. Following an overall upturn in U. S. aerospace jobs during the last quarter of 1973, which pushed total industry employment to 962,000 by December, the number of workers is expected to slip back to 948,000 by June and then decline further to 940,000 by December.

Employment of engineers and scientists did not benefit from the 1973 upturn, however, most of which resulted from an unexpected Middle East demand for military and transport aircraft following the October war, says AIAA. This generated jobs for production workers and, to a lesser extent, for technicians. Jobs for engineers and scientists dropped from 167,000 in June 1973 to 164,000 in December. They are expected to decline further to 162,000 by June of this year and then down to 160,000 in December.

McGurk urges computer users to form group

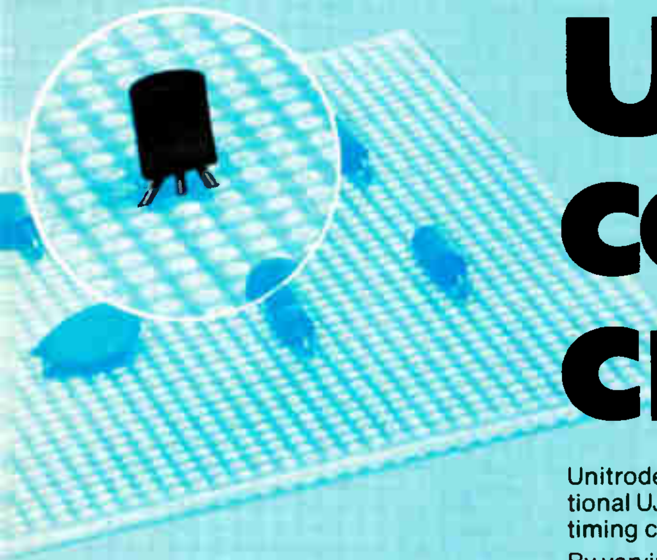
The formation of a nationwide computer users' association has been proposed by Dan McGurk, president of the Computer Industry Association. McGurk wants such a group to represent the user in three primary areas: **standards, data security, and telecommunications interconnection.** The CIA president says he has committed $50,000 of CIA money toward formation and organization of such a group and he called for matching amounts from at least two other associations, companies, or individuals.

But George Glaser, president of the American Federation of Information Processing Societies, says **it's unlikely that AFIPS would be a contributor.** Glaser questioned the need for a users' association on the grounds that users are so diverse.

Supermarket POS making inroads

Electronic checkout systems, either stand-alone or minicomputer-controlled, **have started serious penetration of supermarkets.** According to a report just released by the Supermarket Institute, some 21 companies are now manufacturing electronic cash registers, store-wide systems, or new combined item-code printing equipment and electronic scales. It's estimated that only about 500 supermarkets are now using this equipment, but by fall, when check stands equipped to scan the Uniform Product Code labels are ready, installation totals will soar, says SMI.

Better than any IC or UJT for low cost timing circuits.



Unitrode PUTs provide design freedom unobtainable with conventional UJTs—at a fraction of the cost of comparable ICs or mechanical timing circuits.

By varying the external resistor values you can program turn-on voltage, turn-on current and turn-off current to meet your needs . . . in timing circuits, oscillators, sensing circuits or any application where a variable voltage level threshold is required.

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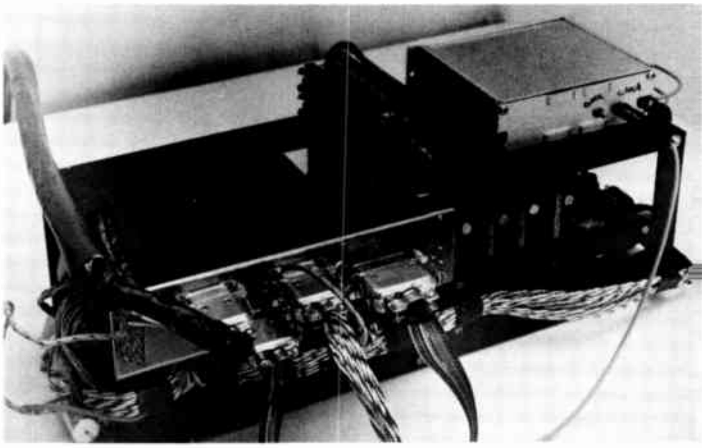
Bubble memory of 500,000 bits could compete with disks

Developed at Bell Labs, the bubble store fits in the palm of the hand, a fraction of rotating memory size

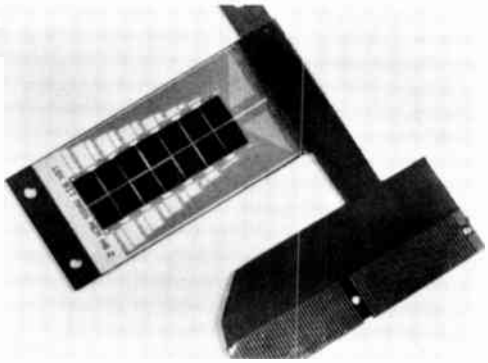
Alert to potential applications in telephone-company electronic switching centers, Bell Laboratories has developed "the first working, fully populated magnetic-bubble memory." Moreover, the Bell prototype's capacity of a half-million bits could be readily scaled up to a million-bit design. If it is decided to develop the memory for production, such a unit could replace fixed-head rotating disk and drum memories in as little as two years, states Peter I. Bonyhard, supervisor of the subsystems group in Bell's magnetics department in Murray Hill, N.J.

The prototype stores 460,544 bits on two ceramic substrates measuring 2½ by 1⅛ inches. Each substrate holds 14 garnet chips, and each chip contains 16,448 bits. The substrates fit between a pair of high-permeability plates, which help form the magnetic field that biases the bubbles. Altogether, the half-million-bit store measures 3¾ inches long, 1⅜ inches wide and 13/16 inches high and fits easily into the palm of the hand. It weighs about 1½ pounds.

Because two substrates containing the additional storage elements could be slid in between the biasing plates, a megabit memory would be no larger, points out Paul C. Michaelis, the engineering physicist within the subsystem group who coordinated the design of the memory system. In addition, control and detection electronics in a fully engineered system could fit on a single side of a 5-by-8-in. printed-circuit board with multi-level wiring, he estimates, while the driver electronics providing the rotating field and master clock for the T, bar, and chevron propagating structure might occupy about 4 in.[3] All told, the memory might occupy less than a third of a cubic foot, a fraction of the volume occupied by rotating memories. Total power would be just a few watts.



Bubble power. Bubble memory chips containing 16,448 bits are placed on 2½-by-1⅛-in. ceramic substrate in prototype developed at Bell Labs.



System operating times for the bit/slice organized memory are in the same ball park as for fixed-head disk units. Average access time to data is 2.7 milliseconds, and a full read/write cycle takes 5.1 microseconds, according to Michaelis. Data rate for a 14-bit parallel word is 700 kilobits per second. Error rates—or the probability of obtaining a false output—have been checked out at 1.6×10^{-12} per read cycle, says Michaelis, quite acceptable for an operational system.

Each 250-by-185-mil memory chip is organized into 64 minor storage loops of 257 bits each. A single major loop acts as the communications link between data stored in the minor loops and the outside world. With the bit/slice organization, each of the 14 chips on a substrate contains one bit of a word. Output is 14 parallel bits in groups or pages of 64 words.

Michaelis remarks that the operating characteristics of the chips turned out to be quite "forgiving." Nominally, the chips operate with a bias field of 90 oersted ±4.5 oersted. This range is broad enough for yields to be relatively high, he adds.

For example, the first 30 1½-in. wafers processed in the laboratory had a yield of device 15%, says A.J. Perneski, supervisor of the device and subsystem fabrication group. And he hopes to do even better in the future, using what he calls "straightforward" processing.

Typical semiconductor processing

techniques are employed, he points out, beginning with a non-magnetic substrate of gadolinium gallium garnet on which a 6-micrometer-thick film of magnetic samarium yttrium-iron-gallium garnet is grown epitaxially. This is followed by an aluminum-copper metalization layer, a silicon dioxide spacer layer, then a permalloy layer in which the propagating structure is patterned, and a final silicon-dioxide passivation layer. Altogether there are only four relatively simple layers, three photomasks, and an ion-implantation step on the magnetic garnet layer that prevents the formation of unwanted "hard" bubbles, according to Perneski.

Two of the prototype memories have been built and are being evaluated by Bell engineers concerned with switching systems. As Michaelis observes, "We're at the point now where bubble memories have proved a viable technology. They should have a design life of 20 years. Moreover, there are no mechanical failures or periodic maintenance to worry about."

However, Bell has not yet made the decision regarding production of the bubble memories, nor will it say when such a decision can be expected. □

Bubbles break into applications at NASA

While Bell Labs engineers consider ground-based applications of bubble memories (previous story), their colleagues at Rockwell International Corp. are looking for bubbles to burst into space applications. Researchers at the firm's Electronic Research division have developed a 61,440-bit bubble memory that could be an important building block on the way to units with memories of up to 100 million bits.

The 61-kilobit memory consists of six 10,240-bit serial shift register chips mounted in three multilayer ceramic packages. Using the experience gained in developing the 10,240-bit chips, Rockwell is working on larger 100-kilobit devices for spacecraft recorders, and it is this work that may lead to multi-million-bit bubble memories. Rockwell received a $328,000 NASA contract for three chips incorporating 4-micrometer bubbles that have a data density of 2.5 million bits per square inch.

If Rockwell successfully develops a multimillion-bit memory using this approach, bubbles would supplant the present magnetic-tape transports now used in satellites. A big advantage over the mechanical memories would be higher reliability since no moving parts are required.

Thomas T. Chen, who is presenting a paper on the 10,240-bit serial shift registers at this week's International Magnetics Conference in Toronto, says the firm is now assembling and checking out the system. The 61-kilo-bit memory measures 3 by 5 by 1 inches, and its six chips in their three multilayer ceramic packages are mounted in a closed, temperature-compensated, magnetic bias structure.

The module is operated at 25 kilohertz, and can accept asynchronous input data up to this frequency. A two-level thick-film chevron detector developed by Rockwell is used to sense the bubbles. Signal

Small bubbles in amorphous films look promising

Although the 4- or 5-micrometer diameters of the magnetic bubbles in the memories developed by Rockwell and Bell Labs may seem small, they are much larger than need be. So say physicists in the Applied Research department at IBM's Research Laboratories in Yorktown Heights, N.Y.

The company is concentrating on "small bubbles," with diameters of at most 1 μm, which could yield denser, faster memories with lower power dissipation. Moreover, the researchers are using IBM's electron-beam lithography techniques to fabricate the small bubbles in thin amorphous films, rather than in carefully structured garnet material. The advantage here is cost—sputtering amorphous film a few micrometers thick on a substrate made of a material such as glass is relatively simple. It avoids both the elaborate crystal pulling, cutting and polishing procedures involved in preparing the single-crystal garnet substrate and the following epitaxial step.

Recently, in fact, IBM succeeded in building the first sizable small-bubble arrays, packing approximately 8,000 bits onto a 40-by-40-mil chip. (Last year, the company reported a 100-bit small-bubble shift register.) The bubbles are contained in a film of gadolinium-cobalt-molybdenum alloy sputtered on a glass substrate. Atop the alloy, permalloy T-bar, Y-bar, and chevron propagating structures are electroplated with linewidths as small as 1 μm. The amorphous film has nominal 2-μm-diameter bubble domains and is approximately 2 μm thick.

IBM built several of the arrays in order to study the effects on bubble propagation of varying magnetization levels. It found that the drive field required for device operation was linearly dependent on the saturation magnetization of the bubble material over a range of 350 to 1,200 gauss.

Characteristics of the bubbles in the amorphous film are claimed to be at least as good as those in garnet. For instance, the drive field to propagate the bubbles around the permalloy structure could be in the range of the fields required with the larger bubbles. The 8,000-bit test array itself is organized in the major/minor loop manner also used in Bell's device. IBM next intends to make a fully functioning device.

A technical paper describing the work done on determining the drive fields needed for operating the small-bubble devices is being given this week at the International Magnetics Conference in Toronto. Authors include M.H. Kryder and K.Y. Ahn of the IBM Research Lab.

level is about 150 microvolts per milliampere and the signal-to-noise ratio is better than 6 to 1.

Rockwell's 10,240-bit chip is basic to the larger systems. R.L. Stermer of NASA Langley Research Center says that it will be used as a building block for a bubble memory up to 100 million bits. At Intermag, Stermer, Chen, and other Rockwell scientists are presenting projected data on a 51-million-bit memory using the 100-kilobit devices.

The 5.12×10^7-bit bubble recorder uses design goals typical of the operation requirements for a small scientific satellite tape recorder. Four memory cards will hold eight coil assemblies, each containing sixteen 100,000-bit serial registers. A total of 1.28×10^7 bits per track is contained on a single 6-by-7-in. card. A bubble memory element of the order of 100,000 bits capacity was necessary to maintain an acceptable parts count. Estimated capability of the recorder includes an operational power dissipation of 4 to 6 watts and zero standby power dissipation.

NASA wants to develop the new data recorder so that it can be easily adapted to a variety of spacecraft that could be launched in "the late seventies or early eighties," but officials note that it is not tied to any specific satellite program at this time. □

New crystal for thinner watches

What has kept the small electronic watch from becoming any smaller has been the conventional quartz crystal, which vibrates in the X-Y direction. Statek Corp's latest tuning-fork-shaped crystal, the tiniest so far developed, could halve watch thickness, especially as it also has a 20°C "turning point."

"Turning point" is the temperature at which such a crystal's frequency changes least with temperature. From the watchmakers' viewpoint, the trouble with earlier Statek tuning-fork crystals was partly their low turning points—at most 10°C, well below the average temperature to which a watch is subjected. But 20°C is much nearer skin temperature and should be satisfactory for a watch, says the Orange, Calif., company's marketing manager, Michael S. Nusbaum.

The crystals, which can be batch-processed using photolithography like ICs, come in leadless ceramic flatpacks 400 mils long, 150 wide, and 65 high. The package's clear glass top allows the crystal to be laster-tuned after assembly. Small bonding pads make the leadless device ideal for automated assembly.

By June Statek expects to be producing 50,000 crystals a month. A unit price of $2.50 is being quoted for quantities of 100,000.

CCD memory designs evaluated

While manufacturers are working out the last bugs in the production of 4,096-bit MOS memory ICs [*Electronics*, March 21, p. 70] and the first production units are beginning to appear [*Electronics*, May 2, p. 87], an even more efficient semiconductor memory technology is emerging. Researchers are studying charge-coupled devices (CCDs) with an eye toward putting as many as 65,000 bits on a single chip. Last week, at the National Computer Conference in Chicago, James E. Carnes of RCA Laboratories, Princeton, N.J., discussed various memory organizations.

A major advantage of CCD technology is the small bit cell—perhaps half a square mil per bit, compared to 5 to 10 square mils per bit in the 4,096-bit metal-oxide-semiconductor arrays. If half the chip area is devoted to overhead circuits such as regenerators and input-output stages, and half to storage, then 32,000 to 65,000 cells can easily fit on a chip 300 mils square. That chip size is huge by today's MOS standards, but because the manufacturing process for CCDs is inherently simpler than for MOS, yield can be high, even of such large sizes. Other CCD arrays, for use as imagers in television cameras, have been built successfully on chips as large as 500 by 750 mils [*Electronics*, March 21, p. 29].

But when it comes to memories, two major tradeoffs have to be considered, according to Carnes. The first is between total storage capacity and power dissipation. The CCD memory is a dynamic shift register that must cycle continuously, even when its stored data is not in immediate use. The power it dissipates in this standby mode is minimized if the clock frequency is low. However, whenever charge is transferred from one bit-storage cell to the next, a fraction is left behind; and this charge build-up gradually reduces the distinction between stored 1s and 0s. Because of this degradation, a long chain of CCDs must be interrupted at intervals with special regenerating stages that restore the original charge states.

The stored information, however, degrades as a function of time, as well as of the number of stages traversed. Therefore, the lower the standby clock frequency, the closer together the regeneration stages must be placed. These regeneration-stages are much larger than the individual CCD storage cells, so that large numbers of closely spaced regenerators sharply reduce the chip's total capacity.

The second major tradeoff is between storage capacity and access time, says Carnes. In a CCD memory, no bit can be read except from an input-output circuit incorporated into the shifting loop. The loop can have several input-output stages interspersed along its length, to provide several opportunities to read a particular word as it progresses through the register, and thus to reduce the access time. But these input-output stages, like the regenerators, are larger than the bit-storage stages and reduce the total capacity of the chip. □

Siemens gets on the 4k RAM wagon

Enter another supplier in the market for multi-kilobit random-access memories. This summer, West Germany's Siemens AG will offer samples of a dynamic MOS 4,096-bit read/write memory based on n-channel silicon-gate technology.

Erich Gelder, the company's marketing manager for integrated circuits, says this makes Siemens Europe's first semiconductor producer to come out with a 4k RAM. It also puts the Munich firm in the league of the half dozen or so American companies that either already supply such devices or are planning to do so shortly [*Electronics*, March 21, p. 70]. The samples will be priced at about $80 each. Volume deliveries will start next year.

That Siemens is hitting the market with a 4-k RAM at a relatively early stage is no accident. According to Gelder, work on the device began two years ago and has been considered a high-priority project ever since. Research and development money, amounting to "several million marks," was readily made available by company management because the device was intended for Siemens computers. The memory will now be sold to outside customers as well.

Device specs. Designated the S142, the new device uses n-channel silicon-gate fabrication methods for speed and area-saving. Information is stored in a three-transistor element with an area of roughly 1,200 square micrometers (about 1.8 mil^2). The device packs a total of 15,160 transistors into 4.4 by 4.1 millimeters. In addition to the memory elements, the chip contains the address and timing circuitry, the read amplifiers, and other peripherals. Every 2 milliseconds, 64 refresh cycles refresh the binary signals in the 4,096 elements.

The S142's electrical and mechanical specifications resemble those of Intel's 2107. The S142 uses a 12-volt timing pulse from which all others are derived. Inputs and output are TTL-compatible. Typical time values for the device are an access time of 350 nanoseconds and a read-refresh cycle of 600 ms.

The supply voltages are 12 V, +5 V, and -5 V. Power consumption under operating conditions is 400 mW, under standby conditions only 10 mW. The device, which has a temperature range from 0 to 70°C comes in a 22-pin dual in-line package. □

Solid state

Josephson junctions inch computerward

The first Josephson junctions to perform useful computer functions have been fabricated in experimental circuits at IBM's Research Laboratories in Yorktown Heights, N.Y. The result is a heretofore unheard-of combination of switching speeds measured in trillionths of seconds and power dissipation levels down in the microwatt range.

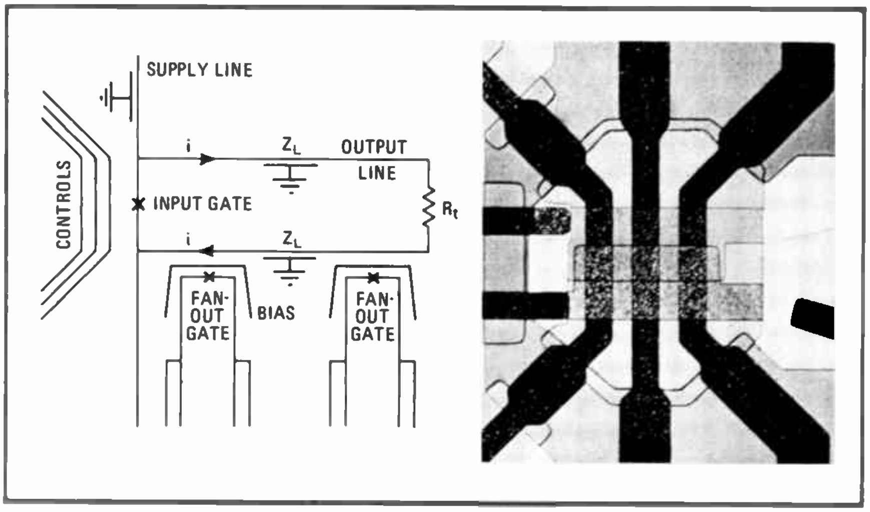
The circuits consist of:

- A three-input, two-output gate with a 165-picosecond rise time.
- A 1-bit full adder with a minimum add time of 500 ps for a worst-case data path.
- A memory cell that switches between states in 600 ps.

According to Juri Matisoo, manager of devices and circuits within the exploratory memory group at IBM, "The results are interesting because even from devices having relatively coarse dimensions we've obtained performance in memory, logic, and adder circuits that is appreciably better than what's being achieved with conventional semiconductor technology."

The Josephson junctions [*Electronics*, March 1, 1971, p. 38] in the IBM devices consist of two superconducting films separated by a thin oxide insulating layer. Such devices can switch extremely rapidly-in picoseconds-between two stable states with very little power dissipation.

Josephson junctions in the IBM devices use 5-mil-wide lines of a vacuum-deposited lead alloy placed one atop the other and separated by a 20- to 30-angstrom-thick oxide layer. This is placed atop a niobium ground plane which, in turn, has been rf-sputtered onto 1-inch-diameter oxidized silicon wafers. Semiconductor photoprocessing techniques were used to form the



Cold logic. Superconducting logic circuit based on Josephson junction has three input control lines (left of schematic) and two output gates. Input control line portion is in photo.

patterns. At the junctions, the lead lines overlap a 4-by 5-mil area while the input gate measures 235 by 55 micrometers. Critical superconducting temperature for lead is 7.2 K; operation is at liquid helium's temperature of 4.2 K. The three-input gate, for instance, consists of three superconductive control lines passing over a Josephson junction gate, plus a resistor-terminated output line that serves as a control for two fanout gates. The magnetic field across the input gate is created by the current in each of the input control lines and is therefore a function of how the currents are superimposed. AND, OR, and invert gates are formed by adjusting the directions of the supply and control currents.

Before the circuit was built, IBM points out, its operation was simulated on a computer using a model consisting of three Josephson junctions and 28 transmission-line sections corresponding to the physical layout. In a high-speed test, the gate was operated with bursts of pulses with 700-ps rise times, tightly spaced so as to simulate a repetition rate of about 1 gigahertz. The circuit is being described in detail this week in a paper by IBM's W.H. Henkels at the International Magnetics Conference in Toronto.

The next phase in the IBM work includes such things as determining the best way to interconnect the logic circuits on the power-supply line and studying the problem of reflections encountered on the lossless interconnections, according to Matisoo. □

Solid state

Josephson-device design optimized

A new configuration of Josephson-junction devices may make them ideal parametric amplifiers for operation in the range of 100 gigahertz to 300 GHz. Although some experimental Impatts, LSA diodes, and tubes can operate as signal sources beyond 100 GHz, such devices rapidly lose efficiency as amplifiers as they approach the millimeter-wave range.

Josephson-junction devices, each of which consists of a thin insulator sandwiched between contacts made of superconductors, have been used as parametric amplifiers before. However, the new geometry, developed by researchers at the Aerospace Corp., El Segundo, Calif., operates in a multi-idler mode, greatly relaxing operational requirements. In this mode, the pump frequency is not critical and can assume values slightly below the signal frequency. In other parametric amplifiers, which operate in a degenerative mode, the pump frequency must be twice the signal frequency.

The self-oscillating negative-resistance design of the Aerospace Corp. device is relatively simple. The oscillation frequency depends on the voltage across the device. At 9 GHz, this is 20 millivolts; at 90 GHz, only 0.2 mv. The same junction then acts as pump and variable reactance.

Niobium exhibits Josephson effects (tunnelling of paired electrons at zero voltage via superconductive currents) up to 700 GHz. Aerospace Corp. has already built a 9-GHz amplifier and a 100-GHz mixer. The goal of the project is to construct an amplifier that operates at 100 GHz.

Tradeoffs. The Josephson junction has not been widely used, partly because it requires cooling with liquid helium to 4° kelvin. Also, the device requires critical adjustment, and it must be made of expensive superconductive material, such as niobium. Hence, operation at lower frequencies, where other satisfactory amplifiers are available, isn't very attractive. At millimeter-wavelengths, however, the choices are rather limited.

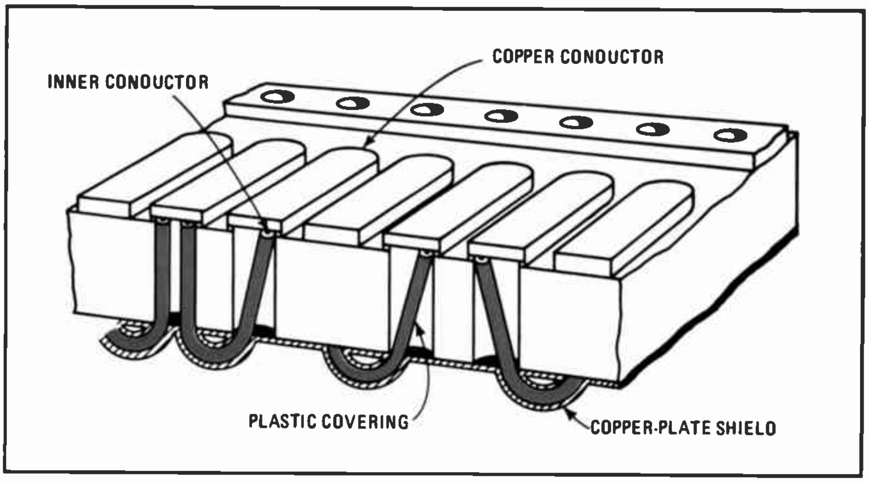
In its present configuration, the Aerospace Corp. design gives 12 decibels gain and a narrow bandwidth (a characteristic of the multi-idler model) of 100 megahertz. Although the multi-idler mode is noisier than the degenerative mode, it is still quite low compared to other forms of microwave amplification. For example, the noise temperature of an amplifier is typically below 100°K (under 1.5 dB). The device is expected to be most useful at high frequencies. "At 300 GHz, there isn't any competition," says Helmut Kanter, staff scientist at Aerospace.

The next steps planned by Kanter are to quantify the noise and overload characteristics and to move to higher frequencies. □

Packaging & production

Coax connections cure crosstalk

By marrying coaxial cable with the printed-circuit board, it is possible to transmit digital signals at subnanosecond rates with virtually no



Anatomy. Tiny coaxial cables with a plated shield virtually eliminate crosstalk.

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crosstalk. This makes possible interconnection of as many as 700 coaxial cables on a pc board measuring only 2 by 3 inches. Called Picowire by its developers at AMP Inc., Harrisburg, Pa., the technique was spurred by development of emitter-coupled logic, which generates rise and decay times of about a nanosecond.

Until now, digital designers have been using multilayer boards or mechanically wrapped back panels to transmit fast-switching signals from point to point. As rise times reached the low-nanosecond range, various forms of controlled-impedance techniques—stripline, microstrip and twisted pair—were added in printed-circuit boards to preserve pulse fidelity.

But these techniques have one common flaw: lack of shielding. This causes crosstalk between adjacent leads and all the headaches that go with spurious signal-generation in logic circuits.

But Picowire uses coax which, because of its shield, is free of crosstalk. The 40-gage wire has a 10-mil Teflon covering. Shielding is added by a copper-plating process that surrounds each coated wire with a copper jacket, forming a true coaxial geometry. The tiny wires are connected point to point in a chain-stitch fashion, by means of a tape-controlled wiring machine which can connect over 500 wires per hour.

Edward Dowling, manager for the advanced packaging product department of the General Product group, points out that Picowire eases the problem of aligning the leading edges of pulses in digital systems, which is vital to synchronous operation.

"With Picowire, a designer can select the lengths of coax he needs to provide the proper propagation delays," he says. Dowling says Picowire interconnections provide nominal impedances ranging from 30 to 75 ohms and can be connected between points spaced as close as 50 mils. AMP is preparing to make the boards in-house or to license others to make them. Dowling says Picowire is cheaper than a four-layer board with controlled-impedance interconnections, and it prices out about the same as a mechanically wrapped board—Wire-wrap or Termipoint. □

Commercial electronics

Modified X-ray units are back at airports

More than 190 X-ray machines designed to examine passenger hand baggage at 52 U.S. airports are now operating under a new Federal radiation-safety standard, thanks to consumer activist Ralph Nader and a Federal judge.

Moreover, the Federal Aviation Administration says it plans to have a notice of proposed rulemaking before the end of June to permit public comment on their safety prior to final adoption of the baggage-inspection technique.

The issuing of the standard near the end of April and the FAA's planned rulemaking notice were part of a Government agreement with the Nader group, which had obtained a court order temporarily banning the use of X-ray machines.

Standard. The performance standard for carry-on baggage at airports was proposed last October, and put into effect April 25. For other X-ray equipment—excepting medical and dental diagnostic systems, which already have their own standards—the Food and Drug Administration's Bureau of Radiological Health said the new standard would take effect for remaining X-ray equipment on April 10, 1975.

The safety standard provides that X-ray emissions can be no greater than 0.5 milliroentgen in 1 hour at 5 centimeters (about 2 inches) from the equipment.

It also requires that:

- A barrier or other means be used to make it impossible for any part of an operator's body to enter the primary X-ray beam.
- Each cabinet door have at least two safety interlocks to disconnect the system as the door is opened.
- A locked control that will not function with the key removed be installed.
- A control be available inside walk-in cabinets to prevent X-ray generation by an outside operator
- Audible and visible warning signals be inside the cabinet with cautionary labels outside.

The FAA said 26 systems made by Astro-Physics Corp., Harbor City, Calif., are now back in service after being modified to meet the interlock requirements. They, along with 29 others made by Bendix Corp., Ann Arbor, Mich., were temporarily taken out of service after failing to meet the standard. The Bendix units are still undergoing modification.

In its rulemaking notice, the FAA will solicit comments on the adequacy of the new standard, operator training requirements, establishment of limits on operator working times, environmental considerations raised by the X-ray devices, and public exposure. □

Organizations

Components firms have their own show

Tired of talking to the tire-kickers, literature-gatherers, and students that frequent larger computer, instrument, and telephone shows, three vice presidents from three components companies have banded together under EIA's aegis to start their own: a show strictly limited to manufacturers of passive, active, electromagnetic, or electromechanical electronic components.

Thirty firms—a roster that reads like a components industry "Who's Who"—set up booths in Washington, D.C., at the new Design Engineers' Electronic Components Show (Deecs). Attendance figures are not complete, but attendees of this week's concurrent Electronic Component Conference guaranteed a nucleus of equipment and systems design engineers.

"Many shows have taken the component manufacturer and made a second-class citizen out of him,"

An offshore plant will reduce your electronics manufacturing costs.

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The competitive challenge of imports hasn't hit any market harder than electronics. An offshore plant with low labor rates seemed to offer a convincing way to regain the profitability edge. Until the plant was built and local realities set in. Restrictive labor regulations, stretched logistics, and unfamiliar conditions all tended to eat up those paper profits. It didn't really take a palace revolution to put you in the red.

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For the new generation of automotive electronics, the Universal In-Line Assembly System can put together circuit boards for digital clocks, anti-skid controls, fuel injection and other devices faster and more economically than any other system. It can assemble approximately 1,260,000 boards per 10-month seven-hour single-shift production year. A production advance that enables electronics and auto makers to meet this high volume demand—profitably—at home.

Then there's the flexible new "Quadrasert" that handles circuit boards automatically, computer-controlled wire termination systems, and the "Multisert" system that inserts up to ten components at once. Plus emerging production technology developments from Universal to help make your present domestic production at least as cost-effective as past offshore production. Even in 1985, when U.S. manufacturers will need over one billion circuit boards.

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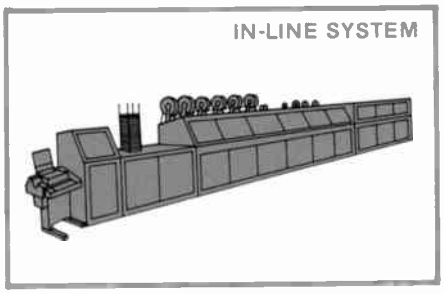

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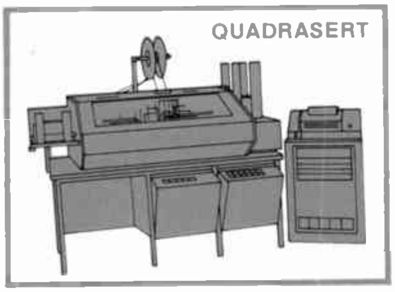

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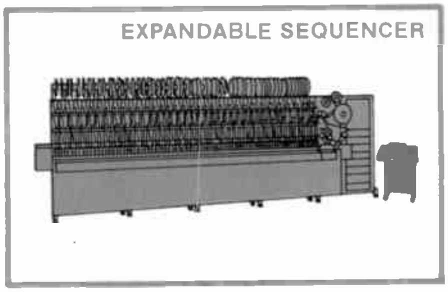

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says Clyde J. Schultz, marketing vice president at Switchcraft Inc., Chicago. "They just haven't made an effort to satisfy the needs of the components people," adds J. Earl Templeton, vice president at Illinois Tool Works, and president of ITW's electronic group. "The fact is they're working for too many masters: systems, instruments, materials, semiconductors."

Components companies are not a large part of any show any more, although most shows admit them, and even welcome them. "But these shows are oriented toward equipment and systems, and companies don't send components engineers,"

News briefs

IBM discovers new storage effect
An information storage effect that handles phase and amplitude data over a bandwidth of 10^8 to 10^{10} hertz or higher has been discovered at IBM. Storage takes the form of a stable pattern of electrons trapped in a photosensitive piezoelectric crystal. The pattern is produced by interference between two input signals, one electrical and the other acoustic. Information is read by applying a signal at the same frequency as that of the original input, which causes the sample to radiate an echo. Information is erased by shining a light on the sample.

FCC gives RCA expenditure approval
RCA Global Communications Inc. and RCA Alaska Communications Inc. have received Federal Communications Commission approval to spend an additional $1 million on three satellites for domestic service. The FCC temporarily and partially waived its ruling against granting the RCA companies domestic satellite construction permits pending a decision on whether RCA should be required to establish a separate domsat subsidiary in order to make domsat operations more visible to the commission.

Motorola withdraws IC process
Officials at Motorola Semiconductor claim they have solved a problem that affected its linear IC production lines last summer. The problem, phosphorous contamination resulting from glass passivation, was spotted by customer Zenith Radio, causing Motorola to quietly recall deliveries produced over at least a 10-week period. Motorola had increased the amount of glass passivation on certain of the plastic-cased ICs in order to improve reliability, but early failures occured due to moisture leakage. Motorola has returned to its original process.

GA introduces SOS minicomputer
General Automation, having produced the industry's first silicon-on-sapphire microcomputer [*Electronics* Dec. 6, 1973, p. 39] is keeping the lead with a full 16-bit SOS minicomputer, which it introduced at the National Computer Conference. The single-board processor has the full-size capability and 1.8-microsecond cycle speed of the company's SPC-16 minicomputer, excellent performance for that size of computer. With 1,000 words of memory, the LSI-16 model is priced at under $1,000 in 200 lots.

Transponder requirement is halted
General-aviation interests, long opposed to the cost of installing automatic altitude reporting transponders, again appear to have halted the implementation of the Federal Aviation Administration's requirement that transponders be used in high-density terminal areas. The FAA has proposed a six-months postponement of the effective dates on which aircraft must carry the 4,096-code radar beacon transponders and altitude encoders, claiming that supply problems make it impractical or impossible for aircraft operators to obtain the equipment in time.

Postal Service orders electric vans
AM General Corp. has won a U.S. Postal Service competition for 350 electric-powered light delivery vans with a $1.95 million bid. The award, the largest yet for electric vehicles in the U. S. [*Electronics*, March 7, p. 70], was made through the General Services Administration as part of a program that calls for 1,000 trucks in fiscal 1976 and an additional 5,000 vehicles in fiscal 1977 each costing $5,595. Bidding against the Wayne, Mich. unit of American Motors Corp. were Otis Elevator Corp., Stockton, Calif., and Electromotion Corp., Bedford, Mass.

DMM fits in shirt pocket
A shirt-pocket-size digital multimeter from Data Technology, Santa Ana, Calif., built with the capability of larger bench models, offers a capacitance range along with the usual DMM functions. The model 21 measures capacitance as high as 2 microfarads with an accuracy to within 0.15% of reading plus 0.05% of the range setting. Price, with test leads, is set at $269.

Dana Labs to use elastomer connectors
Dana Laboratories is substituting elastomer connectors for the mechanical connectors it has used so far for the liquid-crystal display in the Danameter [*Electronics*, Jan. 24, p. 32]. The new connectors, made by Teknit, will act as a Band-aid in the digital VOM to prevent the abrasion encountered with the old connectors. Dana will also retrofit meters with an elastomer shim between the metal connector and the display contacts.

Duplicator makes 2 copies/second
A new Xerox duplicating system, called the model 9200, makes two copies a second on most standard paper, collates up to 50 originals into as many as 999 sets, prints on both sides of a sheet, and includes three reduction modes to reduce originals to 8½-by-11-inch size. Containing MOS LSI control logic on plug-in boards, plus four high-intensity stroboscopic lamps and a selenium-coated belt of flexible nickel, the 9200 will be available first to customers in the Chicago area in late 1974.

Audio power standards are set
After more than a decade of consideration, the Federal Trade Commission has ordered manufacturers of home-entertainment audio amplifiers to aid consumers by standardizing their power output claims. Effective Nov. 4, 1974, manufacturers will be required to disclose, for example, an amplifier's rated minimum sine-wave continuous average power output in watts per channel.

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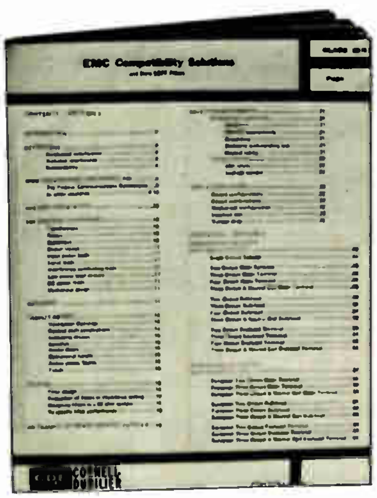

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Templeton says. "They're watching their bucks, and the days of platooning engineers into these shows have gone by."

The man. "The guy we're looking for is the components engineer, and every company of any size has them. But many of them never show up at the current shows," Schultz says.

"We're getting a smaller audience, but our audience is more concentrated in the people that have a professional business interest in components," says Bruce E. Vinkemulder, sales vice president at Grayhill Inc., La Grange, Ill. Adds Schultz: "It's engineers talking to engineers. They're talking new requirements, of course, but more important, they're talking substitutions because of shortages."

The show is taking a different tack from the large shows: booths are staffed with design engineers from the component firms, and "not with sales engineers, and not with reps," Vinkemulder points out. "It's designed as a conference vehicle where the guy with the problem can talk directly to the guy with the answer," he says. "They can sit down and make the design decision—and make all the tradeoffs—in a half-hour."

There's still a lot of custom design in the components industry, and with that in mind, Deecs is pushing the engineering conference setup. It's eschewed the show biz of oversize backdrop booths for more utilitarian tabletops and displays. Exhibitors are limited to two booths.

But the EIA has been lax about promoting Deecs to the membership. Several major components firms in the Midwest learned about the show less than a week before it opened; "There's a definite need for a National Components Show," says one, "and we would have exhibited had we been contacted." □

Deecs exhibitors

Included in the exhibitors at Deecs were these mainstays of the components business: Airco Speer Electronics, Allen-Bradley Co., AMP Inc., AVX Ceramics Corp., Belden Corp., Burndy Corp., Centralab Electronics, Grayhill Inc., Indiana General Corp., Illinois Tool Works Inc., P. R. Mallory & Co.

Also present were Ohmite Mfg. Co., Stackpole Carbon Co., Statek Corp., Switchcraft Inc., TRW Cinch Connectors, TRW/IRC Fixed Resistors, Union Carbide Corp., Varadyne Inc., and Vitramon Inc.

Microwaves

Constrained lens fits multi-beam satellite

One of the key problems in the next generation of synchronous altitude satellites concerns how to pick up signals and transmit them to a number of widely separated receiving stations. Philco Ford's Western Development Laboratories division in Palo Alto, Calif., is attempting to solve the problem by using a wide-band microwave constrained lens and feed array that uses printed-circuit technology for simultaneous multiple co-frequency band pencil beams from a single aperture.

At an altitude of 22,500 miles, the frequency re-use multiple-beam concept requires sidelobes below 34 decibels for at least 37 beam positions over a 15° conical field of view. But to avoid co-channel interference, radiation from all adjacent channels must be below a predetermined level relative to the radiation of the beam at a given spot on the earth. Typically, this ratio is required to be 27 to 30 dB.

Consequently, as the number of simultaneous co-frequency beams per satellite increases, the sidelobe level per beam must decrease to meet a given isolation requirement. If only two beams are required, each covering its own 3-dB beamwidth spot, the 30-dB maximum sidelobes per beam is enough to meet the isolation specifications. But for six beams, the required sidelobe level per beam is 34 dB.

In a year and a half of research, Philco Ford engineers found three ways they could go to produce the low sidelobe multiple re-use pencil beams necessary: multiple-feed horn antennas with one large reflector, or phased microwave arrays, or a combination approach.

Multiple feed-horn antennas with one large reflector would result in the lightest possible satellite. But this approach has a serious drawback: as a feed horn is moved off axis to keep a well-shaped beam, the transmission deteriorates, the side lobes rise and interference increases.

With phased microwave arrays, there is complete control of the aperture: every point in the array can be made to have whatever phase and amplitude are necessary. But for simultaneous multiple transmission, a separate set of waveguides is needed for each beam.

Philco engineers settled on a combined approach. The combination they found most suitable is one of two types of constrained microwave lenses. These typically are space-fed arrays, and their receiving surface consists of a set of pick-up horns connected to rf transmission lines that run up through the lens to another set of horns.

With one kind of lens, which has a waveguide configuration, the minimum cross-section size of each wave pipe in the lens is limited by a certain cutoff frequency. The other kind, the TEM (transverse electromagnetic) lens, has waveguides similar in structure to coaxial cable, but its cutoff frequency is not dependent on geometry. These will transmit assigned frequencies so long as certain electrical characteristics are not changed.

Philco Ford's WDL scientists are now building a 5-foot-diameter prototype using the printed-circuit approach that will operate in C band at 4 to 6 gigahertz. The lens itself is about 1 foot thick at the edge and 6 inches thick at the center. It contains 400 printed-circuit TEM waveguide elements 6 inches to 1 foot long.

Philco Ford developed techniques so that each triplet of pickup horn, delay-line guide, and re-radiating

element can be printed as a mass-production item. The guides are a flattened-out version of TEM coaxial cable called microstripline—two flat pieces of metal with a third, a conductor, sandwiched in between.

The cards are made of fiber glass with very thin copper foil bonded to their surfaces. The copper foil is photo-etched with the patterns that become the pickup, guide, and reradiating elements.

These printed-circuit guides will feed an array of 2-inch diameter feed horns about 5 feet away. In the final version, 100 of these horns will be in a cluster 2 feet in diameter. □

Materials

Air-firable metals may cut hybrid costs

Thick-film users who have glumly watched noble-metal prices soar out of sight can take heart from a new series of base-metal, air-firable, thick-film materials that can save about 50% in metalization costs. Developed by Engelhard Industries, East Newark, N.J., the new materials promise to have a vital impact on hybrid manufacture, where thick-film metalization provides the interconnection between components.

Air-firing does away with a reducing atmosphere, such as hydrogen, which has been necessary to prevent oxidation of the metalization during firing—the high-temperature process which transforms the film into a durable conductor intimately bonded to its ceramic substrate.

Both nickel and aluminum are in the series, and they are attractive alternatives to popular, though costly, palladium-silver. The aluminum offers conductivity comparable to palladium-silver and is an economical substitute for large-area conductor requirements. Though lower in conductivity, nickel lends itself well to metalizing in visual displays.

Engelhard is also offering gold and silver films in its new metalization series. "We describe these materials as molecular bonding," says Paul Sayers, applications engineer at Engelhard, "because, unlike the fritted films, they form true chemical bonds with the ceramic substrates."

Fritted films, so called because they are filled with tiny glass particles, have some drawbacks, he adds. They develop a glass interface between the film and the substrate, vulnerable to cracking during the temperature cycling in the thick-film process. Also, if a fritted film becomes a wire-bond pad, there will be glass present at the surface. Thus, since less metal is presented for wire bonding, bondability suffers. □

New ceramic cuts capacitor costs

The rapid price rise of precious-metal inks used to contact the individual ceramic layers in multilayer capacitors may be reversed by a form of barium-titanate ceramic with a high dielectric constant. The material was developed by Siemens AG, Munich, Germany, and independently by Erie Technological Products, Erie, Pa.

Inks, which are used to form contacts on the edges of a capacitor, account for more than half the materials costs of capacitors. The new ceramic has a dielectric constant of 50,000, compared to the 5,000 to 8,000 of conventional high-dielectric-constant materials. This means fewer ceramic layers are needed to realize a given capacitance. This, in turn, results in an 80% reduction in capacitor size, a decrease of about 80% in the amount of precious-metal inks needed, and about 25% reduction in cost. Alternatively, for the same cost, higher capacitance can be achieved, rivalling some tantalum devices.

The material was developed at Siemens in 1972, but the pressure of producing a standard product has made the marketing of these capacitors sluggish and delivery slow. But Erie is considering a large-scale marketing effort in late 1974. □

MECL 10,000 or...Schottky TTL?

A few tips to help you become a winner!

10K or Schottky TTL . . . which logic form offers the best performance per dollar? And, just how competitive will that design be? We now have available an objective study that evaluates many of the points which you should consider when selecting a logic family for use in high speed systems or subsystems. Here are a few items from that comparison.

Propagation delay

MECL 10,000 circuits are faster than comparable Schottky parts.

PART	SPEC.	MECL (NS)	TTL-S	RATIO
Gate	Typ. Max.	2.0 2.9	3.0 5.0	1.5 1.7
Flip-Flop	Typ. Max.	3.0 4.5	5.0 7.0	1.7 1.6
MSI	Typ. Max.	4.0 6.0	8.0 12.0	2.0 2.0
LSI ALU	Typ. Max.	8.0 11.0	14.0 22.0	1.75 2.0

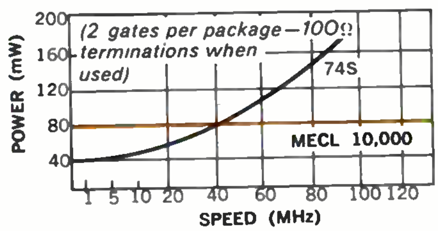
Toggle Rates

MECL 10,000 flip-flops are faster than Schottky TTL equivalents.

CIRCUIT	SPEC.	MECL (MHz)		TTL-S
Dual "D" Flip-Flop	Min. Typ.	125 160	200 225	— 90
Dual J-K Flip-Flop	Min. Typ.	125 140		80 125
4-Bit Shift Register	Min. Typ.	150 200		75 110

Circuit power vs frequency

MECL 10,000 power dissipation is constant with frequency.



Additional design considerations

High speed, high performance systems require techniques geared to handle high-frequency signals. MECL 10,000 is designed for high speed environments and provides advantages that are not available from any form of TTL. Advantages such as: lower logic swings to reduce crosstalk between lines . . . complementary outputs eliminating additional inverter devices . . . wired-OR connections to cut back propagation delays . . . open-emitter outputs for system flexibility . . . and the capability of driving transmission lines without the necessity for auxiliary line drivers.

Competition — today and next year

In addition to engineering merits, you must consider the competitive life of your design. The product life cycle must incorporate cost-performance advantages over present competitive equipment and be flexible to take advantage of future technologies offering greater performance.

MECL 10,000 is an open-ended technology. You may apply MECL III as needed and take advantage of latest state-of-the-art circuits such as 1 GHz flip-flops and sub-nanosecond gates.

The choice is yours!

For your copy of the comparison study, write to Motorola Semiconductor Products Inc., P.O. Box 20912, Phoenix, Arizona 85036 and ask for MECL Design File #4. Better yet, call your local Motorola distributor for immediate evaluation devices. You'll find out first-hand why MECL 10,000 is specified for new designs . . . and upgrading of present systems.

MOTOROLA MECL

. . . new logic capabilities for the 70's!

Circle 45 on reader service card

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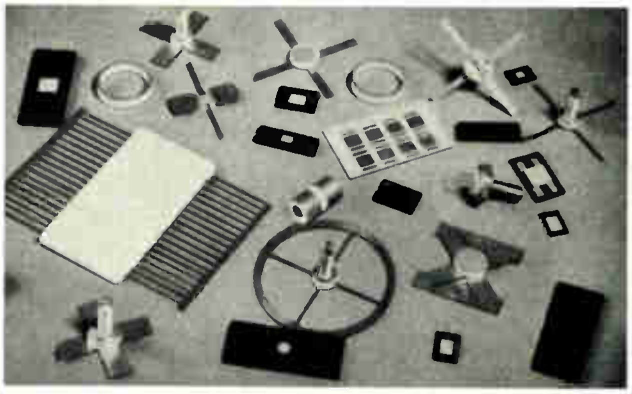

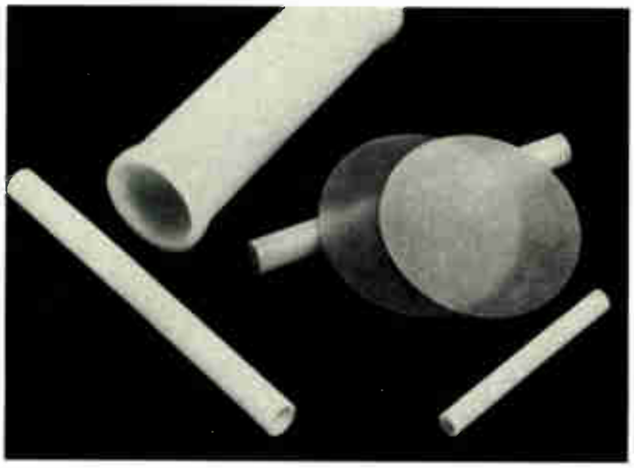

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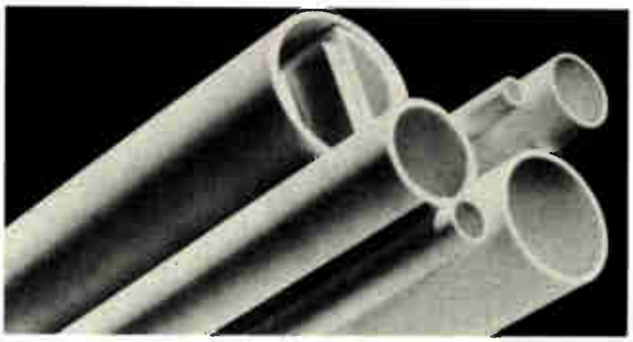
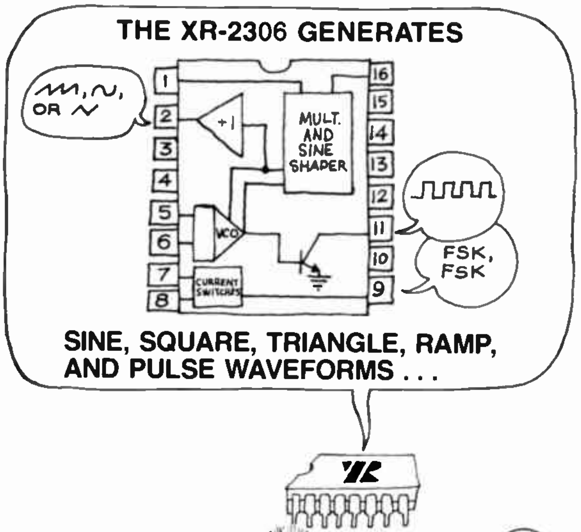
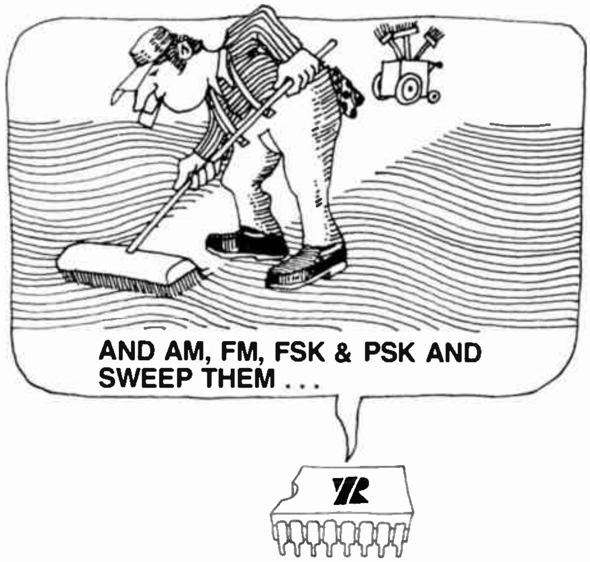
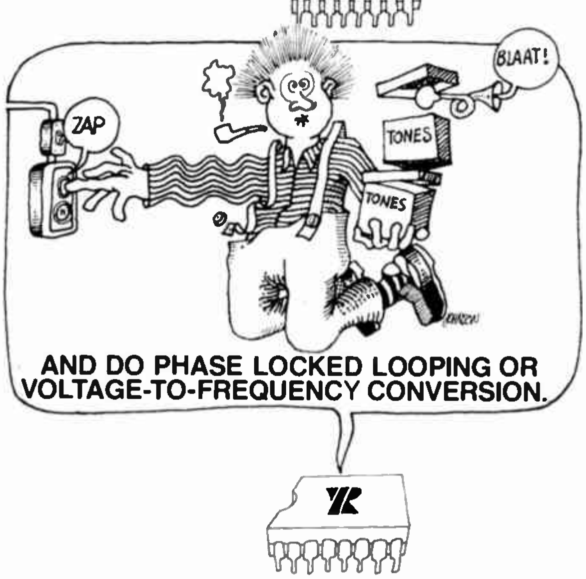
*Crystar® brand

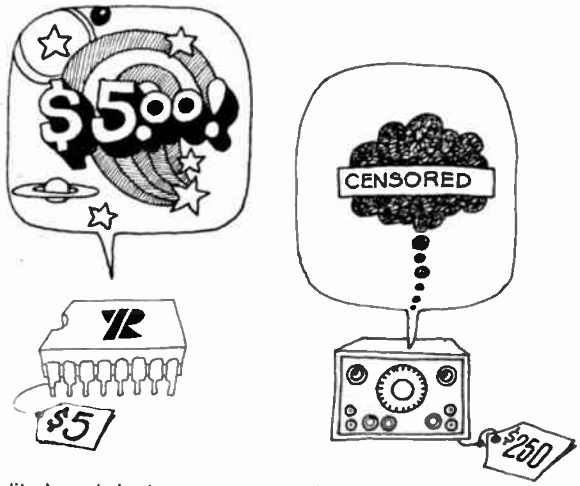


THE $5.00 FUNCTION GENERATOR









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The XR-2306 does it all with a minimum of extra parts because the VCO, analog multiplier and sine shaper of a quality bench instrument are on the monolithic chip.

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Washington newsletter

Air Force promises more industry funds for RPVs . . .

Anxious to keep defense electronics contractors turned on to the potential of remotely piloted vehicles (RPVs), **the Air Force would like to counter industry grumbling that most of the growth in RPV budgets is being spent at Air Force laboratories.** But when USAF Secretary John L. McLucas said major increases in future RPV funding will contain **more money for drone instrumentation,** he only partly won over company officials at an RPV symposium at Dayton, O., in early May.

McLucas called fiscal 1974 RPV dollars the "low ebb," explaining that, as the programs switched from trial status to normal management, they began competing for funds against other established programs, like the F-15 fighter. Research and development money for RPVs, he said, will almost double from fiscal 1974 to 1975, to be followed by approximately a 50% increase each year for several years. But he conceded that **the money spent with industry "represents a very small fraction of the Air Force RDT&E budget."** The service will spend $13 million on RPVs in fiscal 1974, $25 million in fiscal 1975.

. . . and sees more avionics required to prevent crashes

The Air Force secretary's call for more and better RPV instrumentation seemed to his industry audience to be addressed as much to the service's project managers as to contractors. On RPV avionics, McLucas declared **"Drones do not offer an escape from the demanding requirement of high reliability. I get the feeling that some people mistakenly think that all RPVs, being unmanned, are meant to be expended,"** adding that "it isn't progress to develop a system which performs well in the air but crashes on landing because of inadequate instrumentation."

The future of RPVs as Comsat aircraft, he said, "is not quite so clear" as it is in reconnaissance and electronic warfare, since more experience is needed on effectiveness, vulnerability, and cost.

OTA plans to study mass transit, solar energy first

The Congress' fledgling Office of Technology Assessment disclosed plans for its initial projects in early May and is calling on likely contractors to submit their qualifications. Organizations found qualified to research a given problem will receive copies of "assessment solicitations." The projects include assessments of: **the state of the art of automatic train control technology for rapid rail transit systems,** the systems' potential for development, and the testing procedures they will need; **community transit planning technology,** including a look at planning criteria, and **solar heating and cooling technology.**

The programs "frankly provide **some great opportunities for industry to get Government money** to do what is really no more than good market research," observes one OTA official. Firms interested in transit should write the Office of Technology Assessment, c/o Administrative Officer, Transpo-1, U.S. Congress, Washington, D.C. 20510.

National satellite net for criminal justice is proposed . . .

A nationwide criminal justice telecommunications system, using satellites and **run by a Federally chartered but private not-for-profit corporation,** will be proposed in a bill being drafted by the Department of Justice for presentation to Congress later this year. An outgrowth of the Law Enforcement Assistance Administration's Project Search, it will call for creation of **"a Comsat of criminal justice,"** says LEAA chief

Donald E. Santarelli. Project Search began in 1969 as a multistate effort to develop a prototype computerized criminal justice information system that later successfully demonstrated coast-to-coast fingerprint transmission by satellite.

LEAA officials say **the Comsat approach is designed to anticipate congressional criticism of expanding Federal law enforcement authority and expenditures.** Santarelli sees the concept as **leaving the administration and control of criminal justice "to state and local governments, where it belongs."** Costs of the network would also be borne by the participating state, local, and Federal law enforcement agencies.

. . . but challenges to separate satellite develop quickly

Questions about the need for a separate and independent satellite for law enforcement, as called for in the National Criminal Justice Telecommunications system, developed quickly in Washington following LEAA's proposal. And LEAA's Santarelli is already **hinting that the agency might settle for "at least a piece" of a bird.**

Virtually all domestic satellite operators already formed would be willing to provide channels for the system, say company representatives. Some of them are as yet uncertain about the need for a separate, non-profit corporation. **There are also questions within the telecommunications community about the system's getting a satellite orbital slot and spectrum space from the FCC.** From the legal side, the LEAA proposal also raises the "police-state-like issues" of invasion of privacy and citizens' rights, in the view of one Senate Judiciary Committee staffer.

All-channel-radio bill hit in Senate by EIA . . .

Radio manufacturers are lobbying hard against the passage of S.585, the all-channel radio bill that would require receivers sold in the U.S. consumer market to have an fm as well as an a-m capability. The latest argument against the bill by the Electronic Industries Association was delivered in a letter by Jack Wayman, staff vice president of EIA's consumer electronics group, to Sen. John O. Pastore, chairman of the Senate Commerce Committee that is now considering the bill.

In an apparent appeal to the Rhode Island Democrat's widely known preference for network broadcasting over cable television interests, Wayman **opposed the argument that the all-channel TV bill, mandating uhf on TV receivers, is a precedent for fm radio,** adding that "if the all-channel radio becomes law, we can well see cable-system operators urging that their financial difficulties be alleviated by Federal legislation requiring cable connection for every television receiver." Moreover, it is **"by no means farfetched" to suggest that stereophonic and quadraphonic broadcasters could later ask Congress for similar privileges.**

. . . as advantages of ICs for a-m/fm are seen as limited

The argument in favor of S.585, to the effect that costs of **a-m/fm radio receivers "will markedly decrease as new technological developments, such as microchips** used in electronic calculators, are employed in the manufacture of radios" was also disputed by the EIA consumer group. **ICs will not reduce radio prices, argued Wayman, because "only 10–25% of an a-m/fm radio receiver's circuitry can be integrated,"** whereas calculators, which have 10 to 15 times as many transistors as a radio, are amenable to having 90% of their circuitry put on chips.

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System uses airborne sensors to display aircraft position

A new moving-map navigation system from West Germany's Teldix GmbH continuously indicates an aircraft's position using inputs from on-board navigational aids. In contrast to other systems, it does not depend on ground radio stations for its operation. This is a decided advantage when flying over enemy territory.

Built for the German version of the German-French-developed Transall C160 military transport, the Teldix automatic map-display system AKT5 uses speed and drift information from the plane's doppler-radar equipment and course data from a gyro platform or a magnetic compass. Using a small built-in hybrid computer, the system calculates aircraft position and displays it by way of illuminated cross-hairs moving under the map.

Production ahead. The AKT5 is the result of a three-year-development effort that was triggered by research at Stuttgart University's Institute for Aerial Navigation. Now that flight tests have been successfully completed, the AKT5 is slated to go into all of West Germany's 100-odd Transalls, once Bonn's defense ministry gives the go-ahead.

The system's accuracy, a Teldix spokesman says, is "excellent for this type of equipment." When input signals are errorless, the firm guarantees an indicating accuracy within 0.5% over the distance flown. But the flight tests have shown the error to be much better than that—0.1%, Teldix says.

Contained in the AKT5 is a rolled-up map that comes in 110 different sections, each 40 by 40 centimeters in area and carrying a specific number for identification. By push-button operation, the navigator can bring the section of interest into view on the display. He can select any of six different map-scale factors between 1:500,000 and 1:20 million. The latter scale factor, for example, is for a section showing a geographical area of 6,000 by 6,000 kilometers.

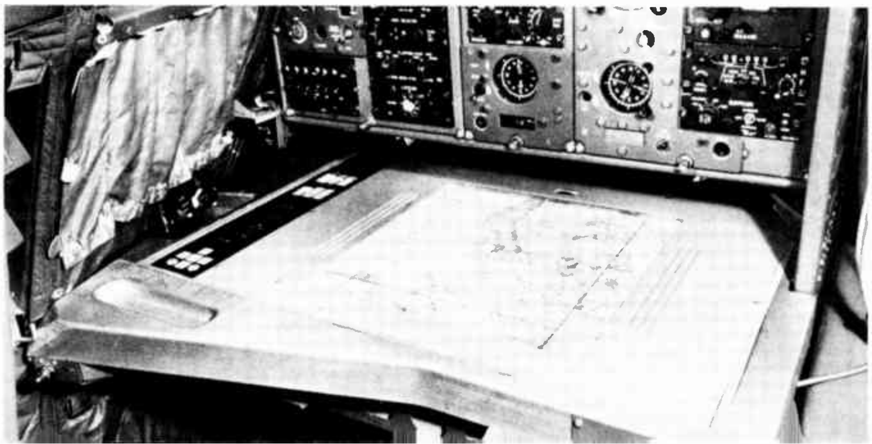
Simplicity. System operation is exceedingly simple. Before takeoff, the navigator merely sets the light mark under the map to the point of departure, and, from then on, the computer handles most of the rest. Besides calculating the aircraft's position during flight, the computer determines and displays the number of the map section in which the plane happens to be.

And when the aircraft crosses the boundaries of that section, the computer figures out and indicates the number of the section into which the plane is headed. The navigator pushes map-control buttons until right section is in view.

During its calculation, the computer takes into account gyro drift, map scale, and other factors that the navigator feeds into it via controls on the system's operating panel. The computer uses both digital and analog techniques, depending on data-input devices. Analog methods are employed, for example, in determining the coordinates needed to move the light marker.

In addition to indicating the aircraft's position, the AKT5 system can also calculate the aircraft destination. To do this, the navigator first sets the light mark so that it coincides with the destination point. Then, by push-button operations, he feeds the end-point-coordinate values into the computer. The computer continuously calculates the difference between the coordinates of the aircraft position and those of the destination, figures out both the distance and the direction to that point, and displays the results on cockpit instruments. □

Plotting. Computer-controlled navigation display for the German version of the Franco-German Transall military transport runs on airborne data generators alone.



Great Britain/France

Systems replace data slip rings

The obvious way to get performance information out of a rotating machine is simply to fit the main shaft with a set of data slip rings, the way it has been done for years. But for all their simplicity, slip rings have their drawbacks. For one thing, sliding contacts generate noise even when they are made of expensive metals. For another, they wear out.

Now researchers on both sides of the English Channel have come up with better ways. At Britain's University of Manchester, Barry Jones has worked out a scheme based on infrared transmission and a four-channel time-division multiplexer. At France's Laboratoire Central des Industries Electriques, Angel Carballeira does away with slip rings by means of ultrasonic transmission and frequency-division multiplexing. Both systems had an airing at the late-April Eurocon '74 meeting in Amsterdam.

Infrared. The Manchester method takes advantage of the fact that perhaps the cheapest way to pick a single channel of data off a rotating shaft is to mount an infrared emitter on the axis and line up a receiving photodiode opposite it. But the limit with this approach is two channels—an emitter/receiver pair at each end of the shaft.

To up the data-transmission capacity, Jones puts a rotating transmitter on the shaft. Its circuitry time-division-multiplexes samples from four channels, then pulse-width-modulates them for transmission to a single fixed receiver. The receiver has to be followed by a demultiplexer/demodulator synchronized with the transmitter, of course. But even so, Jones says that a four-channel system costs no more than four sets of slip-rings, and when more channels are needed the savings should be considerable.

Jones says the crucial component that makes possible the transmitter's small size and thereby minimizes centrifugal forces is an MOS integrated-circuit four-channel multiplexer, made by Siliconix. This device has four MOS switches feeding into a single output, and each switch is turned on and off by bipolar circuitry on the same chip. That dispenses with numerous discrete items. Another factor is that circuitry for pulse-width modulation is simple, and filters are all that are needed in the receiver for handling the decoding.

The present system, says Jones, is a halfway house to systems with eight or more channels, which will be much better than slip rings. Eight channels can be obtained quite simply by using an eight-channel MOS multiplexer that's now available. Alternatively, Jones suggests that he can fix more than one diode to the end of a shaft and get them all to be effectively stationary in relation to passing data pulses.

Ultrasonic. The system developed at LCIE by Carballeira can handle 50 or so channels in frequency division. As its name indicates, LCIE is an industry-supported facility, and this system was developed at the behest of the state-owned public utility Electricité de France. The lab first tried the idea of transmitting data by ultrasonic waves to get temperature readings from inside large oil-filled transformers.

Like the transformer application, that for rotating machinery is mainly intended for temperature readings. The transducers, actually, are quartz crystals mounted in pairs. Usually, one is cut for 15-megahertz operation, the other for 14.5 MHz. There's an associated oscillator for each crystal, and the oscillator outputs are mixed to get a nominal 500-kilohertz difference signal, which is amplified to drive a lead-zirconate ultrasonic transmitter.

Because of the different cuts for the crystals, they track differently in temperatures, giving a frequency shift of about 30 hertz per °C for the mixer output. What's more, the shift is linear over a range from 20°C to about 130°C. The sensitivity is better than 5×10^{-3}°C.

At the receiving end, a lead-zirconate transducer picks up the ultrasonic signal, which is processed by a kind of superheterodyne receiver. Channel selectivity in the receiving circuitry is some 5 kHz, which means at least 50 sets of sensors can be monitored. Because only frequency counts here, signal level is not important. As long as it is higher than the noise at distances of several meters between transmitter and receiver, then signal level is adequate.

LCIE packages its sensors as thick-film hybrid circuits. The modules can withstand accelerations up to 6,500 g. Drift of individual crystals because of acceleration is automatically controlled by the way the crystals are mounted. □

Around the world

Swedish plan stresses strong computer industry

Sweden now has its mini-answer to the French Plan Calcul. And if it's accepted by the government and parliament, it might be called Plan Pengar—the Money Plan. The proposal, as presented by a royal commission established in 1971 to look at the future of Sweden's computer industry, calls for close to $100 million to be invested in research and development, special projects, and marketing over the coming five years. In addition, the commission recommended that the state invest about $75 million in the same period for computer and data-processing education—starting with junior high school courses.

The commission, which included members of parliament, industry, the government, and trade unions, said bluntly that significantly increased support to research and development, and strengthened educational measures, are essential economic measures that must be taken if Sweden is to have competent computer users and for the Swedish computer industry to be internationally competitive.

Ultrasonic instrument probes ocean temperatures

To help in mapping temperature profiles in the ocean, Matsushita Electric Co. has developed a bathythermosender that measures the spacing between ultrasonic pulses to measure water temperatures at various depths. The new instrument, which was developed by Matsushita's Wireless Research Laboratory, looks almost primitive. The instrumentation is built into an iron pipe 38 millimeters in diameter and 170 mm long.

A small thermistor protrudes slightly from the weight that plugs the front end of the pipe. Inside the pipe are temperature-sensing and oscillator circuits, powered by five N-size miniature dry cells. A piezoelectric ultrasonic transducer is mounted piggyback on the rear plug. The transducer launches radial vibrations at 50 kilohertz that travel to the rear. Since there is no forward radiation, no confusing signals are reflected from the bottom, and the pulses are easy to receive. Individual pulses are 2 milliseconds wide, and their spacing is varied from 50 ms to 100 ms for temperatures from 0°C to 30°C. Thus, pulse spaces are increased by 2 ms per °C. Pulses from the pinger can be received for a distance of 1 kilometer, which with a moving boat is equivalent to a depth limit of about 500 meters.

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International newsletter

French electronics companies eye election impact

French finance minister Valery Giscard d'Estaing has the edge over Socialist-Communist rival François Mitterand in the May 19 race for the French presidency. But the polls show that 200,000 votes could swing it either way. **At stake for the electronics industry is the independence of Thomson-Brandt,** the country's largest builder of components and electronics equipment. Mitterand has pledged to nationalize the Thomson group if he wins. A Giscard victory would mean little change for Thomson or any other French company, as Giscard has been shaping the country's economic policy since 1969. However, **Giscard has said he would take a fresh look at the national computer maker, Compagnie Internationale pour l'Informatique,** and possibly recommend a new structure and new types of collaboration. This could mean an opening for a U.S. partner in Unidata, the CII-Siemens-Philips computer alliance.

High-resolution sonar contract goes to Marconi

The British government is providing Marconi Space and Defence Systems Ltd. with $2 million to develop **two highly accurate scanning sonars capable of detailed mapping and depth measurement of the sea bed and close monitoring of undersea operations.** The systems will use the within-pulse, sector-scanning technique, in which a complete scan takes place within a single pulse and allows very high resolution. Engineering of both units will be similar, but one will have a range of 500 yards and resolution of 0.3°, while the other will have a range of 650 yards and resolution of 0.5°. One or both units will be installed in a Royal Navy hydrographic ship, and if they're successful there'll probably be a production run.

One main reason for building such expensive sonars is that **very large modern tankers often risk striking their hulls on the mass of sunken ironmongery** that two wars have left in some parts of the English Channel and the southern North Sea. Ordinary sonars can't map these wrecks with sufficient accuracy. Another important reason is that some of the **oil rigs soon to be towed into the North Sea in large numbers will have drafts of 300 feet and more,** and towing routes will have to be chosen carefully.

Computer market in France to show healthy growth

French producers of data-processing equipment now think that the total value of installed computers will double during the next four years. Market figures released this month by the country's capital-electronics and office-machine trade associations peg the end-1973 total at $4.3 billion. **The figure will hit $8.8 billion by the end of 1977, they estimate.**

Fastest-growing segment of the computer market will be office types. Some 84,500 of them, worth some $1.95 billion, should be in service by the end of 1977. That works out to an average annual gain better than 30%. For regular computers, growth is tagged at 17.5% yearly through 1976, followed by a slight slide to 15% in 1977. With that growth, the value of regular computers would reach $6.85 billion.

Sensational growth is also predicted for data-transmission equipment in France. From some 12,200 terminals worth $155 million at the beginning of 1974, there is a spurt expected to 55,400 terminals worth $900 million at the beginning of 1978.

International newsletter

Court puts cable TV under government wing

The European Court of Justice has ruled broadly in favor of Common Market states extending their broadcasting monopolies to cover cable TV. The decree came in response to a complaint by the operator of an unauthorized CATV network in Biella, Italy, who had refused to pay rental on TV receivers in his network.

The case reflected the thorny problem of CATV in Europe, where state monopolies are gingerly experimenting with private participation in CATV projects. The court pointed to the difference between interfering with the free movement of goods on the one hand and monopolizing services on the other. Most Treaty of Rome rules on monopoly refer only to trade in goods.

But the controversy continues. For one thing, the local court in Biella has still to rule, and at this stage the European Court's decree is largely advisory. **For another, there is a loophole through which the Italian plaintiff might squeeze.** The court noted that the state monopoly cannot discriminate against nationals of member states on grounds of nationality. And that poses the question of some state broadcasting organizations permitting foreign stations to be transmitted in their territories by CATV networks, but restricting development of competitive national programs.

Single IC generates tones for organ's top octave

Intermetall GmbH, the German member of the ITT Semiconductor Group, will soon go to market with **an integrated circuit that can produce all 13 tones of the highest octave in an electronic organ,** a job that formerly took three Intermetall organ ICs. The largest deviation of the 13 tones from the tempered-tone scale is but ±0.011% percent. Designated the SAH 200, the IC is an MOS device needing only one supply voltage, −22 volts, and one clock pulse generator in its periphery. The circuit comes in a 16-pin dual in-line plastic package.

British in trials of conference TV link to Stockholm

The British Post Office is experimenting with extending its conference television service to the Continent. **A studio has been set up in Stockholm, and between now and the end of the year businessmen in Stockholm and five major British cities will be able to confer by closed-circuit TV.** If it proves popular and technically viable it will be continued. During the experimental period, the charge is about $240 an hour. Up to five people can be televised simultaneously at each end. The video signals go by microwave link through France, Belgium, Germany, and Denmark to Sweden, and the sound goes by 8-kilohertz-bandwidth cable across the North Sea. **The Dutch are interested in being included in the experiment and are building a studio for operation later this year.**

Laser market in West Germany to spurt ahead

West Germany is Europe's largest user of laser equipment, with consumption expected to rise from an estimated $200 million in 1973 by about 50% during each of the following two years. According to a recent industry analysis, **American suppliers, with an 80% share, are the leading contenders on the West German laser market.** Accounting for half of West German laser consumption are government research institutes. They are followed by industrial users, who take a 25% share. While purchases from institutes will remain steady, the demand from industrial organizations should increase by 100% annually during the next few years.

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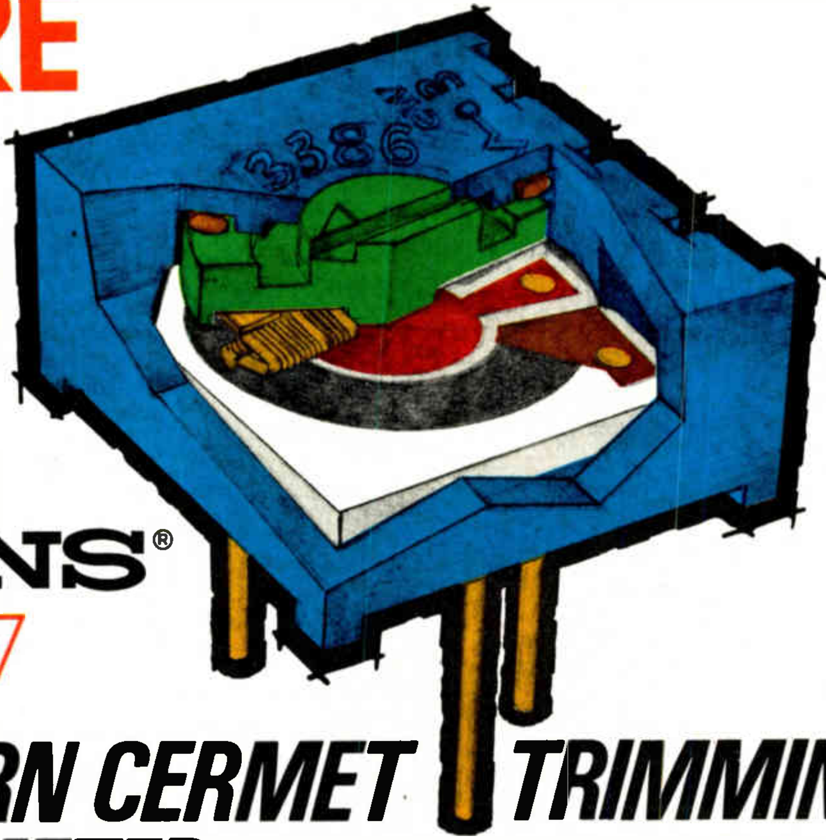

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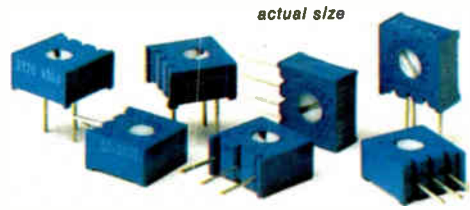

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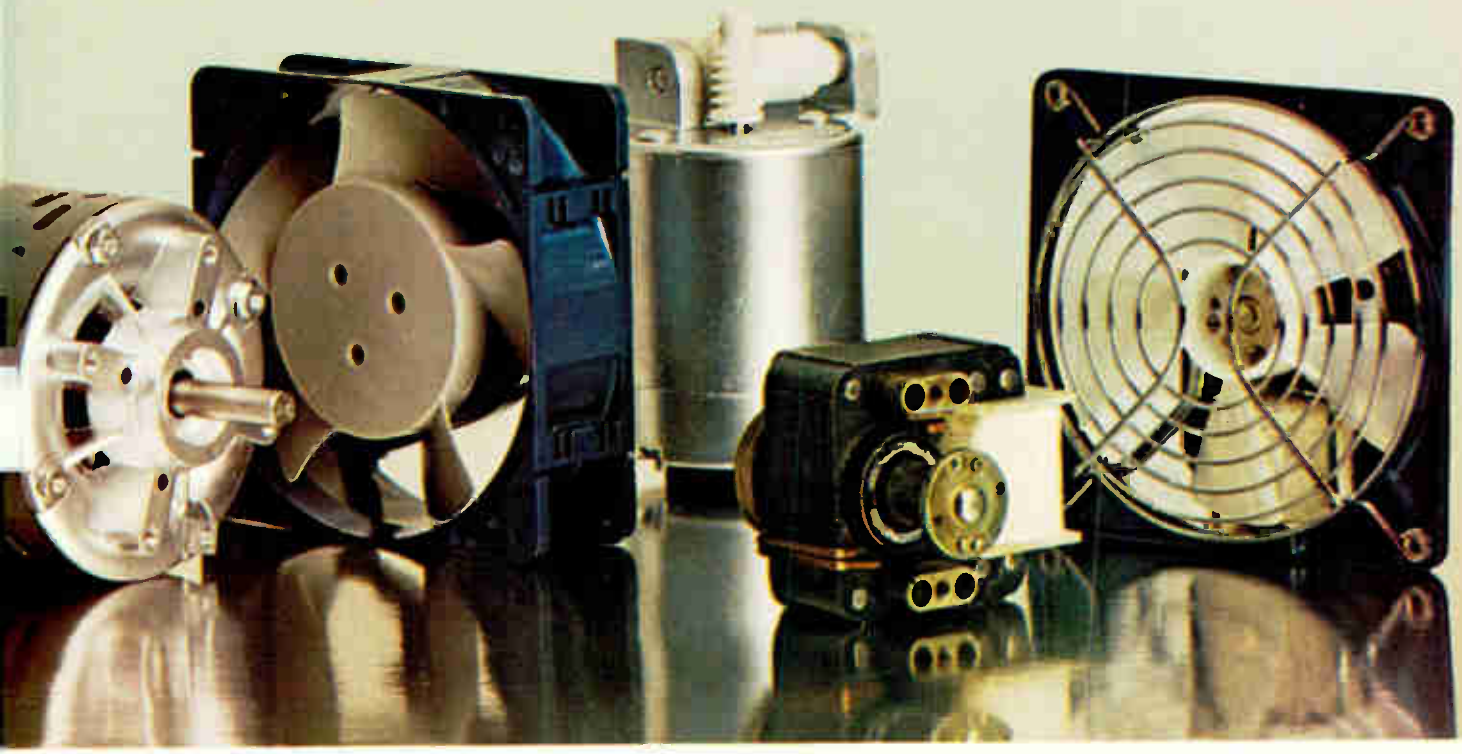

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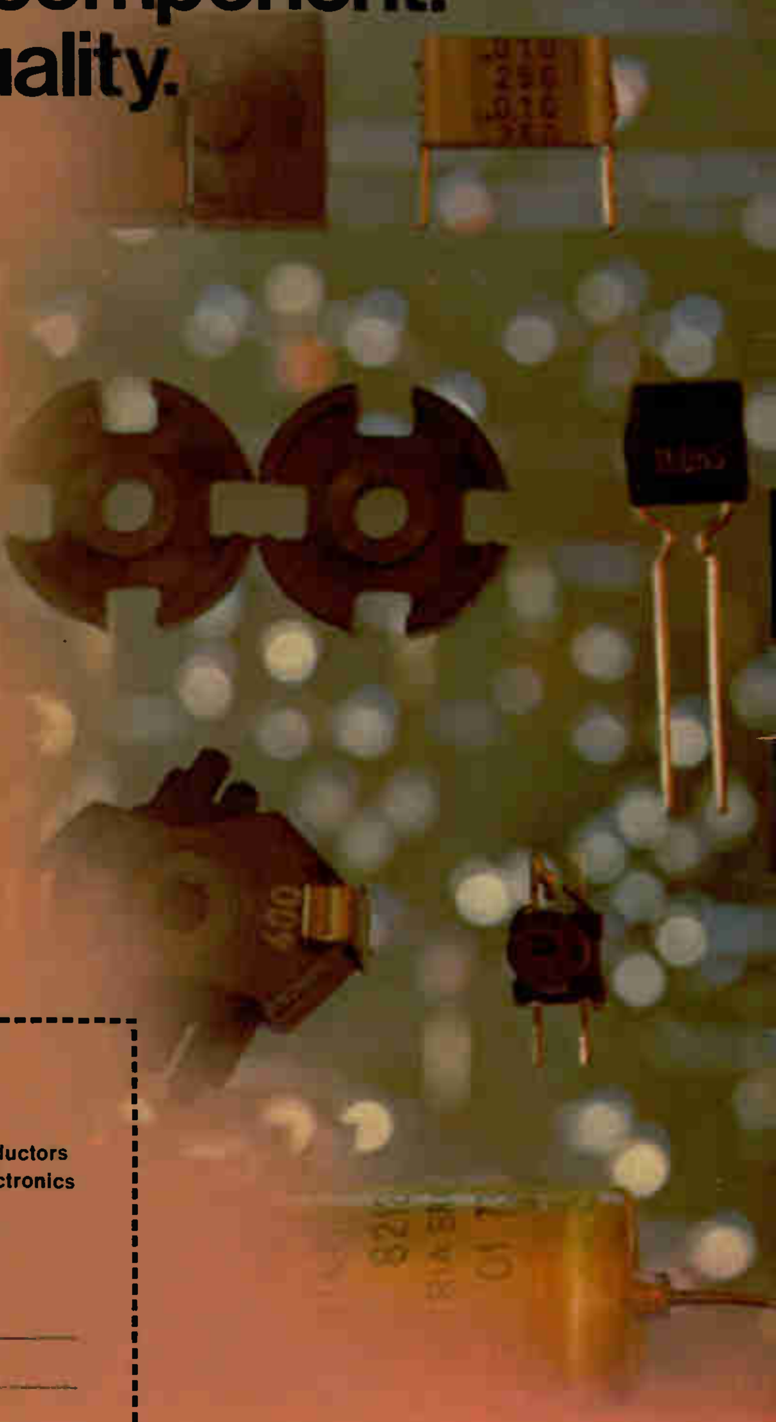

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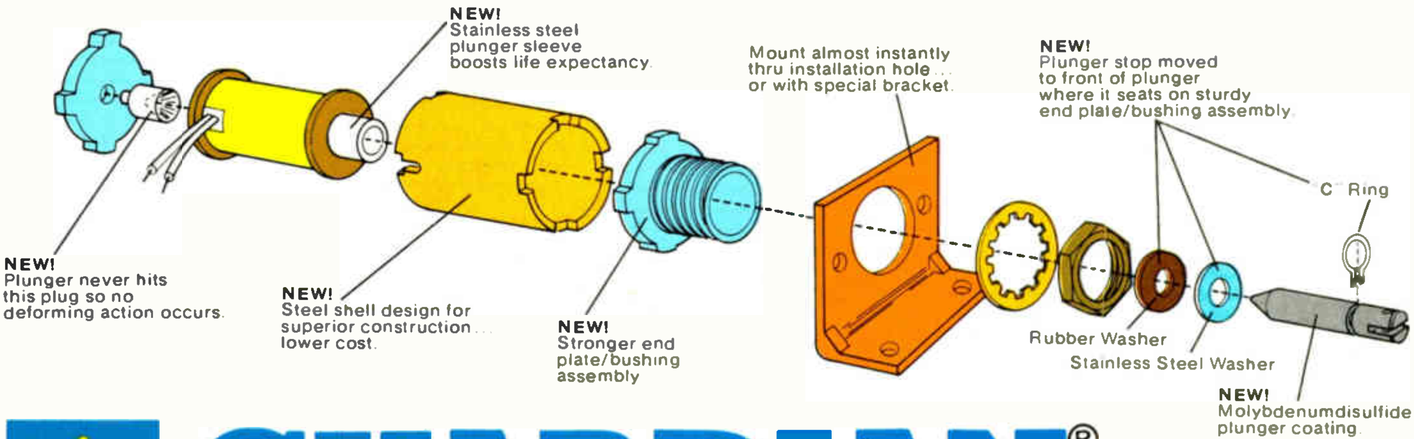

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'Good old days' fade in Japan

Electronics industries, troubled by inflation, soaring wages, and investment cutbacks, see 25% profit decline in 1974

by Mike Mealey, McGraw-Hill World News

Declining consumer spending, cutbacks in capital investments by industry, skyrocketing inflation, and whopping wage increases will combine in 1974 to cut the profits of the Japanese electronics industries by 25%. The decline bears out the fears of Japanese economists, who suspected that last year's boom would be short-lived [*Electronics,* Nov. 22, 1973, p. 90].

On a unit basis, most consumer-electronics goods won't grow at all, and production of color-television sets, traditionally one of the biggest profit makers among the electronics industries (30% to 35% until last year), will probably decline about 10%, to 7.8 million units from 8.7 million. Also, predicts the Electronic Industries Association of Japan, radio production will dip to 17.4 million from 20.4 million, car radios to 7 million from 7.6 million, while hi-fi amplifier production will chalk up an increase: to 3.5 million units from 2.8 million.

The outlook for industrial electronics is not much brighter. Computer sales will rise 15% to 20% in value, thanks to inroads being made by minicomputers. In terms of units, peripheral-equipment sales will gain an estimated 20%, and desktop-calculator sales will be up 15% to 20%. However, because of the tremendous competition in the big calculator market, the actual value of sales will be up only 5% to 10%. Semiconductors will see an essentially flat year because the increased output of the biggest users, computer makers, will be eaten up by fall-offs among other big customers, especially in the consumer field.

Communications equipment will gain 5% at most in sales, however, while heavy-duty appliances and motor-goods sales will decline about 7%. Sales of numerical-control machine tools are expected to suffer a 20% drop, but officials of Fujitsu Fanuc, which controls well over 90% of the market, say that it will match 1973 production.

Pressure. The biggest problems for electronics are sagging consumer demand and the government's tight-money policy, aimed at discouraging capital investment by industry. Private institutions are estimating that private consumption this fiscal year will fall 2% below the 1973 gain, growing only 5% in real terms over the level of a year ago. Private investment is expected to decline about 2% in real terms below the outlays of 1973.

Moreover, while there is no longer a shortage of materials, the electronics companies are paying as much as 40% more for petrochemical products, such as plastics, and an average of about 20% more for other needed materials. And pay increases that have been agreed upon by major producers are running 30% to 35%.

On the average, this has resulted in price increases averaging 15% to 20% and, in some instances, as high as 40%. Yoshihiro Kayama, a specialist in the electronics industries at Nomura Research Institute, says that, for some products, 12% price hikes instituted last fall no longer are enough to sustain a good return for the manufacturer. But he adds that, because of government pressure, makers are reluctant to increase retail prices again. The government, fighting a wholesale price rise of 35% during the past year, is adamant in demands that industry live with smaller profit margins.

Kayama says that price markups instituted during the past six months will mean that total sales gains by electronics could possibly approach 10%—or only half of the growth recorded in 1973. He looks for that performance to dent profits by 25%, and most of the major producers agree with that outlook. Says Masao Adachi of the Electronic Devices group at Hitachi, predictions of such profit declines "are probably pretty close to the mark."

Because of big wage increases, the ratio of labor costs to total sales will probably climb from the present 15% to nearly 20%; moreover, the industry is going to be hard-pressed to carry out extensive modernization because of tight money.

Cutbacks. The result is that most of the major makers are curtailing the number of models offered in individual appliance lines in an effort to ease the pinch of declining unit sales. But Japan Victor Corp., part of the Matsushita group, has taken a unique approach to the problem. It has cut back color-television production by 20%, then converted those assembly lines to production of audio equipment, one of the few consumer-electronics products expected to attract customers in greater numbers this year. Production of tape recorders will probably grow 7% this year, stereo sets by 10% to 15%, and stereo components by a healthy 25%.

JVC's approach is one that's not generally open to other major producers, however, because of their vertical production and management structures. As Hitachi's Adachi explains, each product division is left to its own devices to produce profits, and, moreover, because of the sheer volume of production, single factories are seldom devoted to production for more than one division.

Because of the limited numbers of options available to allay the effects of lagging sales to both consumers and industry, tremendous pressure is being put upon export departments to get sales moving overseas. Here again, though, electronics officials face big stumbling blocks. Because of rising price tags on Japanese goods, significant export gains are going to be difficult—if not impossible—to achieve. While trade with developing nations continues to boom, both in terms of consumer and industrial-electronics goods, unit volume still is not appreciable; the key to export growth lies in the hands of U.S. and European buyers.

Bearish. Masao Adachi of Hitachi agrees profits will decline by 25% in 1974.

Nomura's Kayama predicts that exports to the U.S. will remain even, at best, in terms of unit sales, while products shipped to Europe will experience a slight increase. Performance will be hindered by the fact that price tags for some Japanese products will be higher than the selling prices of domestic products they compete with. □

The Japanese seek cheaper labor

It's ironic that labor costs in Japan, which were once so low that they attracted foreign investment, are now so high that they are forcing Japanese electronics firms to build plants offshore. To Americans, the 30% to 35% wage increase granted this year borders on the incredible. But considering the 35% inflation, and the fact that raises are granted almost *pro forma* with contract negotiations conducted on the company-union level, it's not that surprising. All this, coupled with protectionist clamor abroad for barriers against Japanese goods and the desire to get closer to sources of materials, has induced leading manufacturers to build or plan facilities in America, Asia, and Europe.

After starting plants in the UK and San Diego, Sony shortly will announce plans to build a color-television plant in France. Hitachi also will announce that it is going into a developing nation—probably somewhere in Southeast Asia—to produce semiconductors.

Toko will soon be producing variable condensers in Malta, and similar ventures are being eyed by component makers for the U.S. Nomura Research Institute's Yoshihiro Kayama says that the U.S. will see a "lot more investment" in the next few years.

Contrary to attitudes toward Japanese export goods, "countries are welcoming Japanese investment," he says, and Japanese are finding that production costs even in the U.S. will not be much greater than in Japan in the not-too-distant future, television sets aside. Sony, it is estimated, will spend $16.5 million overseas this year, while Matsushita will spend more than $20 million during the next two years. This is in addition to a sum in the neighborhood of $100 million it will spend to acquire Motorola's Consumer Products division, providing that sale gets U.S. Government approval.

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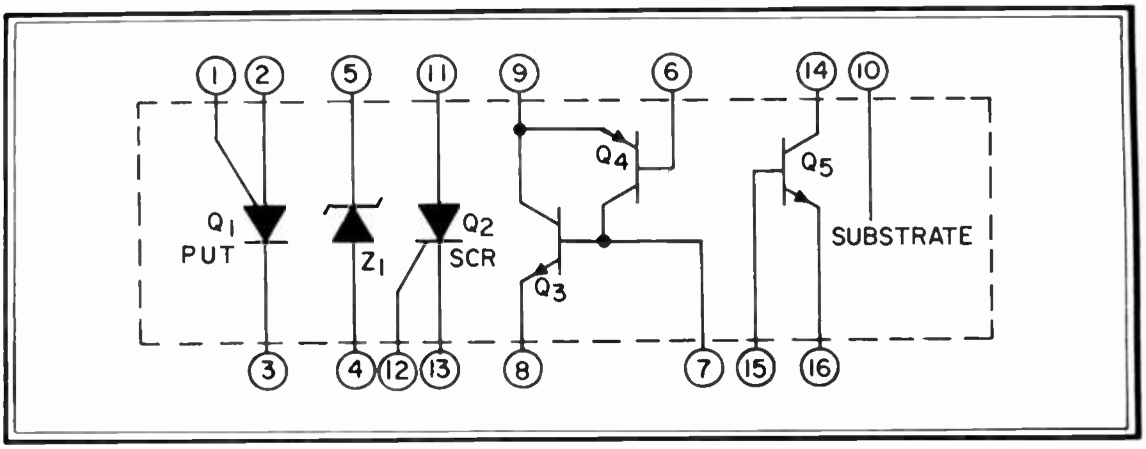

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Companies

Chrysler Huntsville's auto odyssey

From Saturns to Imperials, Chrysler's electronics operations made successful transition from space to car business

by Gerald M. Walker, Associate Editor

What's a nice space-electronics firm like Chrysler Corp.'s Huntsville, Ala., Electronics division doing in a place like Detroit and automotive electronics? The answer is that it's now doing about 10 projects for current-model cars. These range from radios and digital clocks to electronic ignition, seat-belt interlocks, and emission-control devices.

In addition, the facility has taken a lead in introducing some of these products into American cars. And having survived the transition from high-cost, low-volume NASA business to high-volume, low-cost auto products, the Huntsville division is preparing to introduce other electronic controls into automobiles—including new microprocessors.

Established in 1956, the division's original job was to provide engineering services in support of the Redstone and Jupiter missile programs, as well as for several space-vehicle projects of that period, including Jupiter C, Juno 11, and Mercury-Redstone. A high-water mark in its NASA period came in the early 1960s when Chrysler won the Saturn 1 and 1B contracts and Huntsville assumed all static-test and ground-support-engineering functions for both stages.

But before NASA's work wound down in 1969, the facility had already begun seeking a new role. Today, the engineering department insists that the division has won over Detroit, not despite its sophisticated space orientation, but because of the design, test, and systems know-how learned while shooting for the moon.

The changes have been quite noticeable. For one, far fewer engineers are on hand, now that Government projects constitute a minor percentage of the work. For another, engineers accustomed to working with the state of the art had to ease back into more common components that perform less complex tasks. And the design challenges changed from products requiring high reliability for a short period of time at any cost to products that must last five years under the hood of a car, are neglected by their owner, are often serviced by untrained mechanics, yet still must be cost-competitive.

Asset. Nevertheless, John L. Webster, manager of electronic-product development, points out that space-age organization proved to be a major plus in meeting the

Space helped. John L. Webster says know-how gained in NASA work has paid off.

Testers. Allen G. Seitz, above, handles reliability and analysis jobs. W. Frank Henley, right, is in charge of design and manufacture of test equipment.

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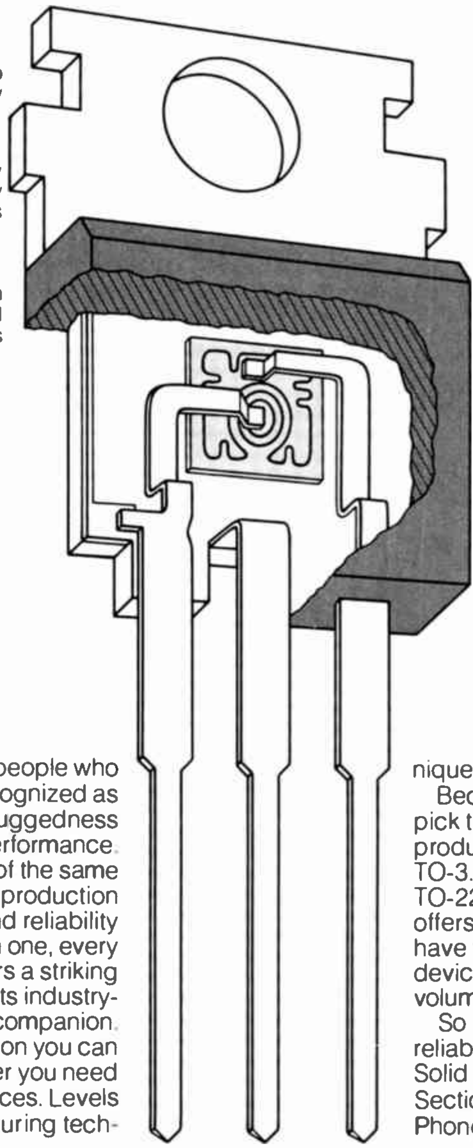

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new challenges, once the auto production arm of Chrysler got used to the idea. Unlike other diversification efforts by aerospace-electronics companies—projects that often led to the design of solutions in search of problems—Huntsville patiently waited for the auto producers to set the goals.

Vendors, too, had to make adjustments. Electronic-components firms that might have sold perhaps a dozen $200 transistors to Huntsville during the NASA period are now likely to be supplying more than a million 10-cent devices. This change probably caused the most trauma in the quality-control sections for both Chrysler and its suppliers. But testing disciplines used for space vehicles came to the rescue for cars.

These test operations are really two-sided. One side, headed by W. Frank Henley, handles design and manufacture of test equipment. The other side, headed by Allen G. Seitz, does reliability and analysis tasks. Both men are alumni of Government quality control and testing. The reliability and analysis section is an 11-man group devoted to tracking the causes for electronic failures in the field, at the auto-assembly plant, and on the Huntsville production floor.

Records. Using computer-stored records, this group is primarily responsible for finding failure mechanisms in components and analyzing how changes in specs, tighter controls by vendors, or improved handling will reduce breakdowns. "We probably keep more records on semiconductor devices in the auto environment than any semiconductor company," Seitz remarks.

The test section is involved with equipment development, not only for use at the Huntsville plant, but on the assembly line and by the car dealer or garage. For example, pollution-control requirements have led to the development of a portable emission analyzer weighing 18 pounds that is being marketed to dealers, service stations, and garages. These may also be sold to state and municipal auto-inspection stations. Using an infrared beam that simultaneously determinates the precise amount of hydrocarbons and carbon monoxide coming out of an engine's exhaust, the unit will be used to "tune" antipollution devices now going into cars. While all of Huntsville's auto-electronics products presently go to Chrysler and American Motors Corp. assembly plants, this analyzer will be sold directly to users.

As for further diversification beyond automotive products, Webster believes that there's little need to look elsewhere. Waving to a plant addition of 120,000 square feet about to be opened, he remarks, "There's so much auto business that we're up to our ears for as far as we can see. The Government, by requirements that push electronic answers, and the auto companies, by interest in improving performance for gas savings, are making the future of electronics." □

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Companies

Sprague savors its comeback

Recession was just one of the problems that caused maker of components and semiconductors to lose a million dollars a month at one point

by Gail Farrell, Boston bureau

Most electronics companies suffered through the recession of the early 1970s and then snapped back when the economy improved last year. But for Sprague Electric Co., the comeback has been far more satisfying, because its troubles ran deeper than the recession and more than a favorable economic climate was needed to get it back in the black.

And back in the black it is. In 1973, Sprague realized profits of $11.6 million on sales of more than $197.6 million, and 1974 promises to be even better. So far, the company has chalked up a record first quarter: $54.2 million in sales, $5.4 million in profits.

Four years ago, however, the storm clouds were big and menacing. A 10-week strike at the main North Adams, Mass., plant, while not affecting other operations, scared off customers. Sprague watched its share of the total market in components, including semiconductors and relays, slide from 2% to 0.7%. Already burdened with high overhead from its capital-intensive business and heavy losses, the company had to cut prices to get back into the market at the end of the strike. Meanwhile, customers had signed contracts with other suppliers, and Sprague found itself with low prices and less business.

Furthermore, the semiconductor division, a drain on the company since it was started in 1965, was weakened by the TTL price war of the late 1960s. When recession followed on the heels of the strike, Sprague found itself struggling to keep its head above water—for a while, losses were as high as $1 million a month. In 1971 sales slumped to $117.86 million, down from $127.5 million in 1970, and losses mounted to $8.02 million.

In 1970 Neil W. Welsh, who had taken over from founder Robert C. Sprague as chairman of the board and chief executive officer, together with president and chief operations officer Bruce R. Carlson, undertook a program to turn Sprague around. That program included careful cash management to keep losses down. But to get operations costs under control Carlson says the company "had to take drastic and not necessarily pleasant steps. I'm not a believer in the meat-ax approach as a desirable tool of management, but in emergency times drastic measures are sometimes called for."

Job totals dropped, promising programs were cut back, R&D was slashed, and capital equipment expenditure was kept to about $5 million a year, the level of depreciation on old equipment. And neither Welsh nor Carlson had qualms about getting rid of product lines or divisions, even in traditional product areas, if they were unprofitable or did not fit into long-term plans.

TTL, an area where Robert Pepper, technical assistant to Welsh, confesses, "we didn't bring a whole lot of innovation or manufacturing capacity," was de-emphasized, and more attention was paid to linear in-

Drivers. Bruce R. Carlson, left, Sprague's president, and Neil W. Welsh, chairman, have led the company's comeback to the point where its first quarter of 1974 saw sales soar to a record $54.2 million, with $5.4 million of that on the books as profit.

tegrated circuits for the consumer market. Though the wire-wound-resistor operation in Nashua, N.H., was profitable, Welsh says it was a case of "either beef up or get out," so Sprague chose to sell the facility and concentrate its money elsewhere. Subsidiaries were also shown the door: Vectrol was sold in 1972, Dynacor and Pirgo in 1973.

Doing more. One result of Sprague's effort to tighten up operations was a marked increased in productivity. Although capital-equipment expenditures were kept low for several years—they are not quite back to about $11 million—Carlson says, "A lot of things came to fruition in 1973 that had been in the works for two to three years." The result was a rise in output per employee from $11,300 per year in 1971 to $14,800 in 1973, well above the industry average of $12,000 to $13,000.

Also during this period, decision-making was decentralized into three operations groups, for capacitors, for other passives, and for semiconductors. This move, Carlson says, "strengthened our ability to reach quickly to the market, and as a result, when volume came along in 1973, we were able to carry much of the increase through to profits." Still, the cutbacks in capital spending did limit the company's ability to react. For example, Sprague could have used the etched-foil plant for aluminum electrolytics a year before it opened in Clinton, Tenn., in November 1973, had there not still been problems of cash flow.

At the same time as it was cutting back on expenditures and unloading unprofitable operations, Sprague took a major gamble that has paid off handsomely on the balance sheets. The company invested $3.4 million in Mostek Corp. over a period of one and a half years and now owns 42% of the stock in the Carrollton, Texas, MOS maker, an investment worth $50 million. "Mostek took a good deal of nerve, with our losses increasing," Carlson admits now, "but the opportunity that appeared to be there was sufficiently attractive that we could not back away from it." With this initial experience Sprague went on to invest in other companies with products ranging from liquid-crystal displays to loudspeakers, as well as retaining a large minority interest in the thin-film division it sold to Hybrid Systems Corp. "We don't necessarily believe the others we've invested in will be Mosteks," concedes Carlson, "but we hope two or three will be significant investments with significant equity appreciation."

This year Carlson expects a good increase in sales volume, though not as dramatic as 1973. He will also work on another basic strategy to "maximize our participation overseas—potential market growth is greater outside the U.S." Overseas sales now account for 20% to 25% of the total, and this may increase to 40% over the next few years. He is particularly interested in the "transnational sourcing concept" of selling a product anywhere in the world from any source in the world, working to avoid tariff barriers as much as possible for the most profitable results.

Carlson now feels Sprague's turnaround is completed "in the sense that we have done what it was necessary to do in order to get through a period of higher demand and increasing costs. But there is no question that in some product lines we have farther to go than in others." Welsh notes that "we have a lot to do in paper, film, and oil-filled caps." By the mid-1960s it was believed that these would be replaced by semiconductors, but instead demand kept increasing. So Sprague started pouring more money and effort into them and reports that area "made the most dramatic improvement over 1972 outside of ICs."

Moving fast. The semiconductor division, which didn't show a profit until the last quarter of 1972, is now the fastest growing division, and Carlson terms it "a significant factor in our turnaround." Welsh sees "a tremendous market in the IC area" for all types of electronic control in cars, and he feels that ceramics should take off with fuel injection.

But despite the record first quarter, there still may be some clouds on the horizon. Nearly 20% of Sprague's sales is to the automotive industry, which of course was hit hard by the energy crisis. This may be partly offset by increased demand for options like stereo radios in smaller cars and by the increasing penetration of electronics in areas such as fuel injection. Welsh also believes the dip in auto sales will not last, and he expects to see sales pick up within a year. But he also forsees materials shortages "for the next four or five years across the line, although if we get enough high-purity aluminum the foil situation will ease. But some of the materials we once used may not be available again as suppliers find more profitable things." □

Consumer electronics

Is 1974 the year of the digital watch?

C-MOS and display suppliers, eyeing sales of 1.5 million units, think so, but watch companies are less enthusiastic

by Marilyn Offenheiser, Assistant Editor

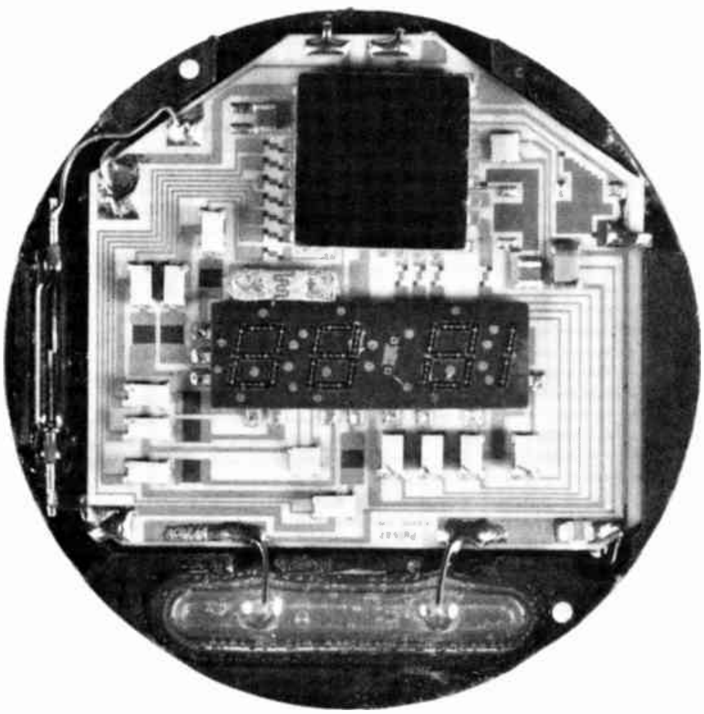
Digital electronic watches are getting close to the $100 retail price threshold, now that sales in 1974 are expected to reach as much as a million and a half units—not much to watch makers but a good market for the makers of C-MOS circuitry and displays. Timex says it will have a model on the market this summer at that price, and Speidel, known as a maker of watchbands, says it too is entering the low-price watch market. And Rockwell's Microelectronics Group will soon join other suppliers of components making whole watches—Hughes, AMI, Intel, and Solitron.

Even though one semiconductor supplier calls 1974 "the inceptual year for digital watches," watchmakers like Benrus, Bulova, Gruen, and Hamilton are less sanguine. They base their conservatism on that familiar drawback—the display, with light-emitting diodes using too much power and liquid crystals promising a life of only two years or so. Still, with each watch's electronics costing $35 to $80, depending on display, and 45 million watches of all kinds sold in the U.S. alone last year—worldwide, the figure was 180 million—it's easy to see why there is excitement among component and display suppliers. They include American Microsystems Inc., Hughes, Intersil, Intel (maker of the Microma watch), Inselek, Ilixco, Integrated Display Systems, Optel, and RCA.

John Bergey, president of the Hamilton Watch division of HWM Industries, predicts liquid crystals and LEDs will split almost evenly in 1974, and that digital watches this year will have a mean price of $210. Hamilton, which made the first digital watch, Pulsar, sold 50,000 digital watches last year.

Yet the Swiss and the Japanese are confident that mechanical watches will be their bread and butter for a long time to come. And even though Switzerland's Ebauches and Japan's Seiko, Citizens, and Sharp are set to introduce digital timepieces, they agree with watch-industry statistics that cite only a 22% market share for digital timepieces in 1980. In contrast, RCA's Sanford Roth, planning administrator for timekeeping products,

The time is here. Hamilton's Pulsar, below, uses light-emitting-diode display. At right are quartz-crystal C-MOS movement, top, and liquid-crystal display from Cox Electronics Systems. Shortcomings of the two displays—LEDs draw too much power, while liquid crystals have relatively short life—are said to be holding back quicker development of market.



More than meets the eye

In CMOS MC14500 series price cut

Price reductions are rare in these days of spiraling inflation, so cuts as high as 56% across practically the complete MC14500 CMOS series should be welcome. We suspect they are. But there is greater significance to these reductions than meets the eye at first glance.

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Here are just a few typical examples using 1,000 to 4,999 quantity prices.

BCD Up/Down Counter,	MC14510CP	Now $3.75,	Down from $4.77
Programmable Timer,	MC14536CP	Now $5.75,	Down from $9.94
Dual Binary to 1 of 4 Decoder/Demultiplexer, (*inverting)	MC14555CP / MC14556CP*	Now $1.50,	Down from $2.60
4-Bit ALU,	MC14581CL	Now $7.15,	Down from $9.75

We've lost track of the number of times we've heard, "Your McMOS MC14500 Series is an outstanding logic family, but I just can't afford it." Now, with yields taking off, and quantities like a million devices hitting the warehouse shelves in May, we can price them where you can afford them. With that many units available, you shouldn't encounter delivery problems. Motorola sales offices and franchised distributors will be pleased to provide further details when they accept your order.

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predicts 25% as a market share in five years.

Bergey, who says Hamilton is working on a solution that will call up the LED display momentarily without a pushbutton, also says the display that will break the digital watch market open hasn't been invented yet. Meanwhile, he sees LEDs being used in the more expensive watches, liquid crystals in cheaper models.

Other attempts at improving the displays are also being made. Intersil is trying to modify the one-chip LED module used in its Chronus 1 stopwatch, some liquid-crystal makers are backlighting the displays, and Benrus, says Nicholas Mercurio, senior vice president of operations, is going to introduce a new liquid crystal this fall that will "be very clear without using another light source."

Despite the failings of the displays, a plus for the future of digital watches is that the C-MOS circuitry continues to become simpler. Intel's Tony Livingston, product manager of C-MOS watch circuits, says his company has succeeded in reducing the circuit's components from 50 to 25 and expects to get down to 10.

On the whole, display makers have achieved simplicity by switching to field-effect liquid crystals from the dynamic scattering types. Not only do the new ones provide a clearer readout, but they use less power, and have no need for voltage-conversion components. AMI's Glenn Dumas adds that using a hybrid approach also reduces the components on the substrate. This, combined with AMI's decision to go with liquid crystals and thus get along with only one chip (LEDs require two) and by refining design to eliminate components, tends to reduce complexity still further.

Optel's marketing manager, Peter Stearns, says his company is working on new packaging techniques to reduce complexity, while Integrated Display Systems president Tom Saldi says his company is using new materials. "We've gotten watch thickness down to 0.300 inch," says Saldi, "and we have a prototype watch 0.100 in. thick in test now." □

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SP607B	÷2	600	12
SP613B	÷4	700	60
SP614B	÷4	800	60
SP615B	÷4	900	60
SP616B	÷4	1,000	60
SP620B	÷5	400	55
SP621B	÷5	300	55
SP622B	÷5	200	55
SP630B	÷10	600	70
SP631B	÷10	500	70
SP632B	÷10	400	70
SP634B	÷10 w/BCD outputs	700	80
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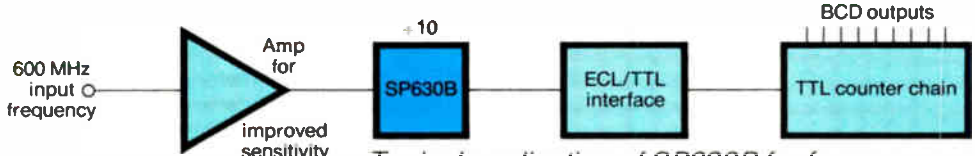
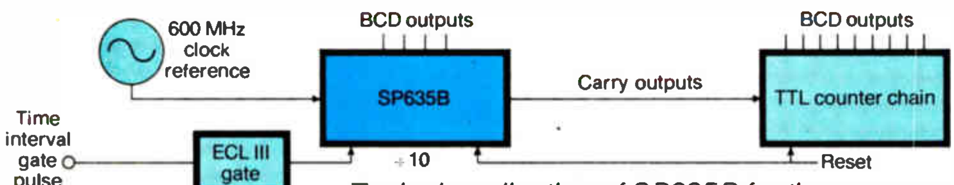


Typical application of SP630B for frequency measurement



Typical application of SP635B for time measurement

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Industrial electronics

Computers permit Volvo to drop assembly line

Teams of workers assemble cars, system by system, on computer-controlled wagons in Swedish plant

by Robert Skole, McGraw-Hill World News

When Volvo opens its American auto assembly plant in Chesapeake, Va., in the fall of 1976, it will be using a revolutionary assembly method made possible by electronics. Instead of the one-man-one-task assembly line first used by Henry Ford for the Model T, the Swedish company will use a computer-controlled technique that allots each system in a car to a team of workers.

This team approach already is in and working at Volvo's plant located in Kalmar, Sweden. But without computer control, the workers would still have to follow the old tighten-a-bolt work pattern.

At Kalmar, as will happen at Chesapeake, each car being assembled moves around on its own transport wagon. The wagons may be controlled by a central computer, or they may be taken off the line and moved manually. But where the Kalmar plant turns out 30,000 cars a year in one shift, the American plant will produce 100,000 cars annually working two shifts per day.

The way the system works in Sweden, there are 25 teams of about 15 workers each. Each team is responsible for an entire system in the car—interior, electrical controls, wheels, and so on. The team decides for itself how it will work: one person might install an entire system, several people might work together, or each might be responsible for one special detail.

As each body moves into the plant, it is assigned an individual wagon. This is rubber-wheeled and powered by four 12-volt batteries, which are good for one full shift between chargings, at a top speed of 1.8 kilometers per hour. The wagons have three functions: to transport the cars, to carry information, and to serve as a work platform. Volvo will not say how much it paid for the wagons and control system.

When a car body is assigned to a wagon, the wagon number, body number, and details of the car to be

Easy does it. Volvo worker moves battery-operated robot wagon from one position in assembly plant to another. Computer-controlled system will be used in new American plant

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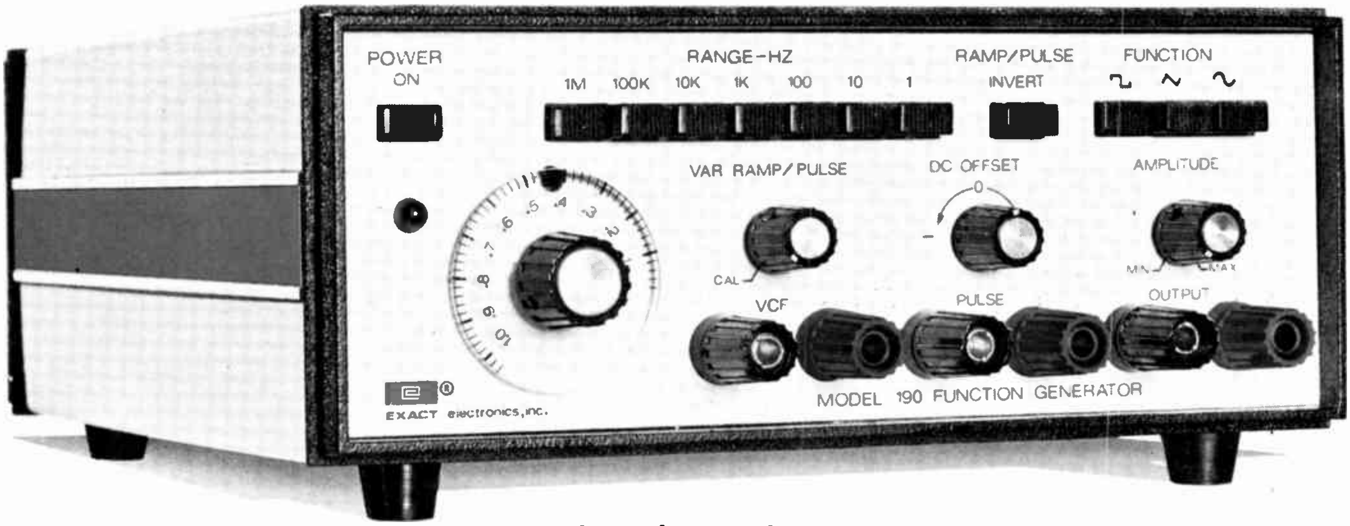

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assembled are recorded in one of the four PDP 11/40 computers in the plant.

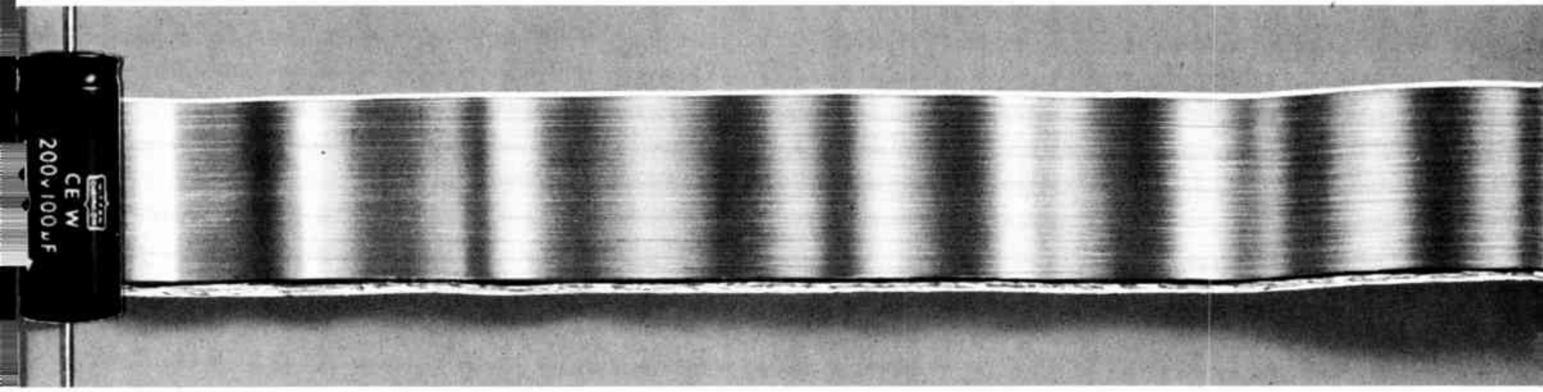
The wagons, which Volvo calls robot carriers, move from team to team through the plant, guided by an inductive cable buried in the concrete floor. Each wagon carries its own receiver, transmitter, and logic control system, which contains C-MOS circuits. The control system was conceived by Volvo and developed and built by Digitron Co. of Switzerland.

The robot carriers move along the inductive wire automatically. But a worker can stop a carrier, and even pull it off the line, through a manual control device containing nine pushbuttons and a potentiometer. Light-emitting diodes signal whether the carrier is positioned properly over the inductive cable, whether it is operating manually or automatically, and whether there is a failure.

Signals. Three computers are used for quality control, production control, and process control, and a fourth serves as back-up for process control. The control system for directing wagons around the plant employs what can be described as a barrier system. When a carrier reaches an inductive loop where a decision to turn or stop has to be made, the carrier transmits a signal to the computer, and only then does the computer reply with the correct control signal.

Each assembly team station has its own computer terminal, consisting of a CRT screen and keyboard. Here are displayed information about production rates for the day, number of cars in that area of the plant, and also any information—such as notice of errors—needed by that specific team.

Teams can enter data to, say, notify the computer that a car has been taken off the line for some reason, and then that it has been returned. Each team station has room available for stacking cars, enabling it to set its own production pace within general limits. Throughout the plant, there is a total of 32 CRT displays, 18 printers (for logging information), and intercom and telephones at each team station. □



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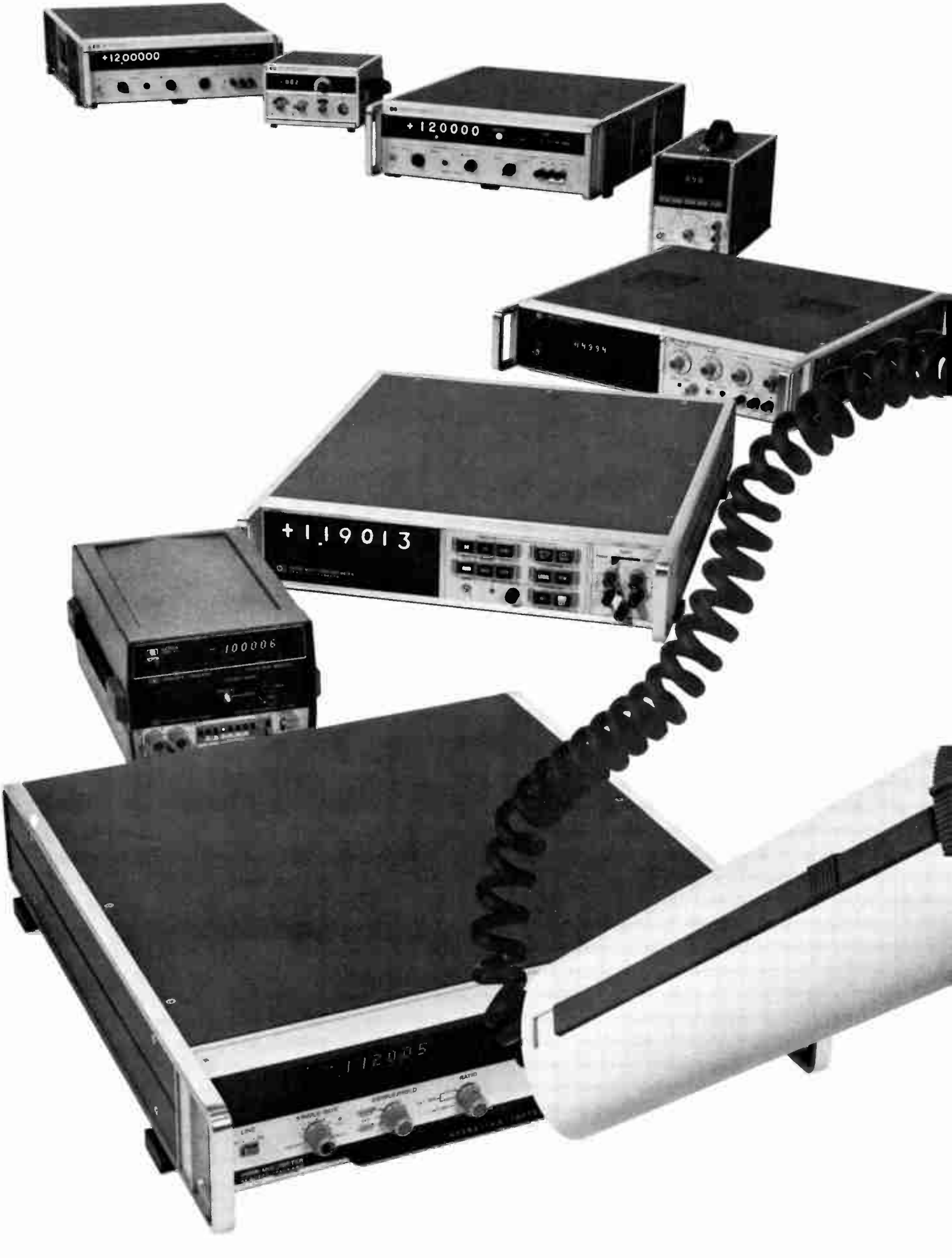
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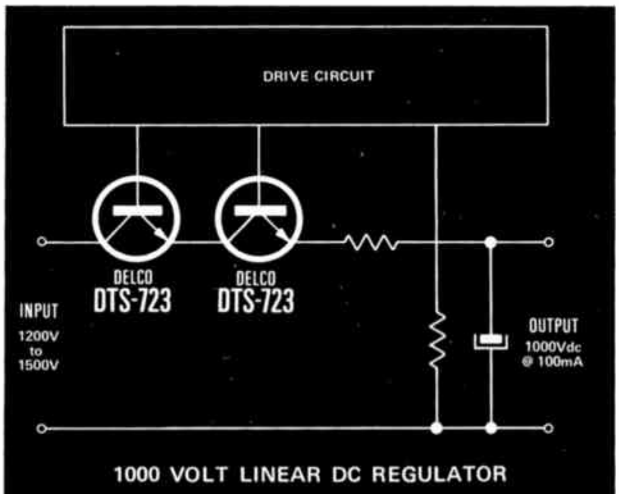
DTS-801	2.0 A	800V	—	700V	—	100W	20/— @ 200mA, 5V
DTS-812	5.0 A	900V	1200V	700V	—	100W	2.2/— @ 3.5A, 5V
DTS-814	5.0 A	900V	1400V	700V	—	100W	2.2/— @ 3.5A, 5V



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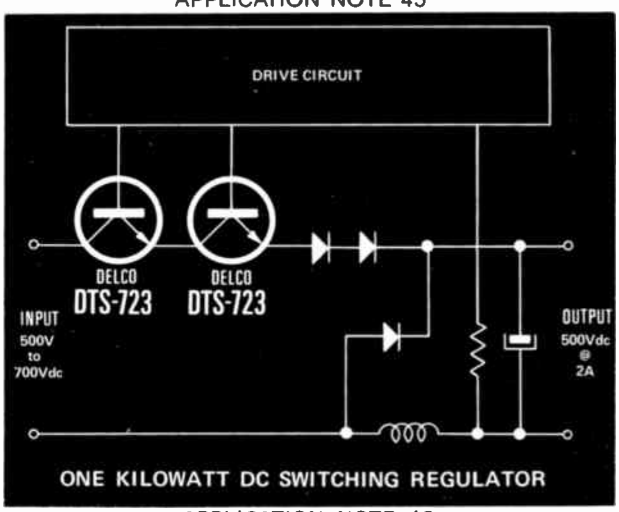

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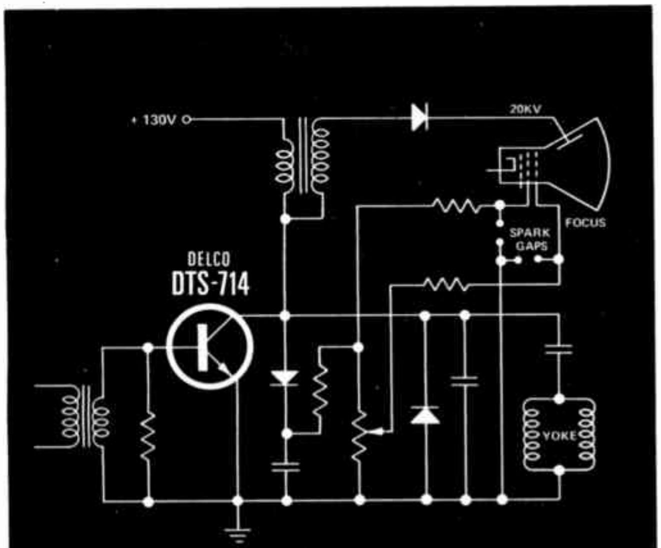

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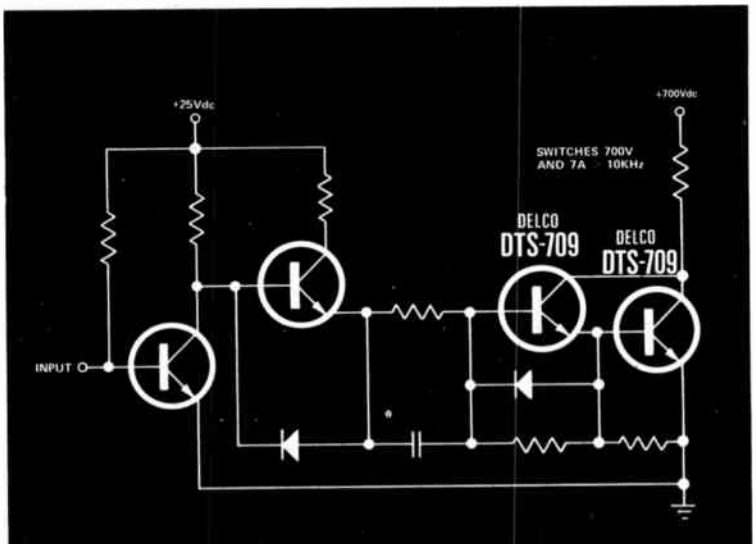

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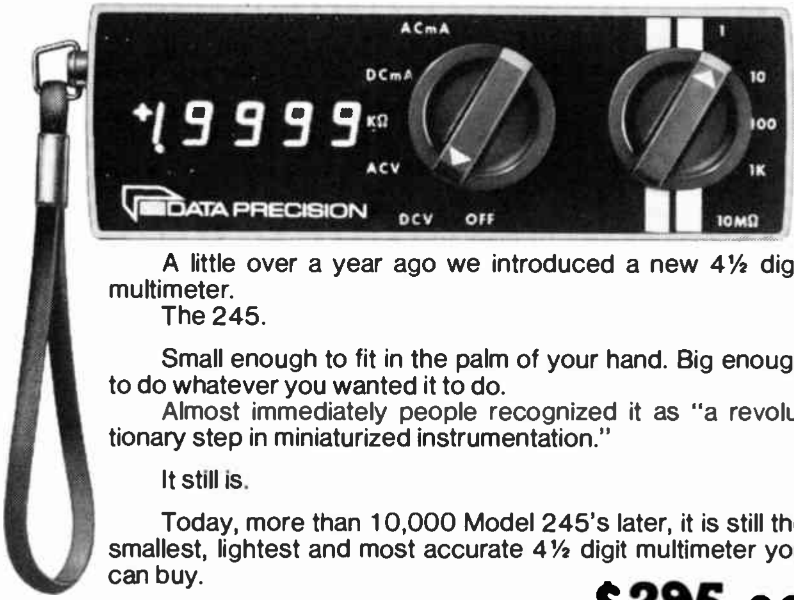

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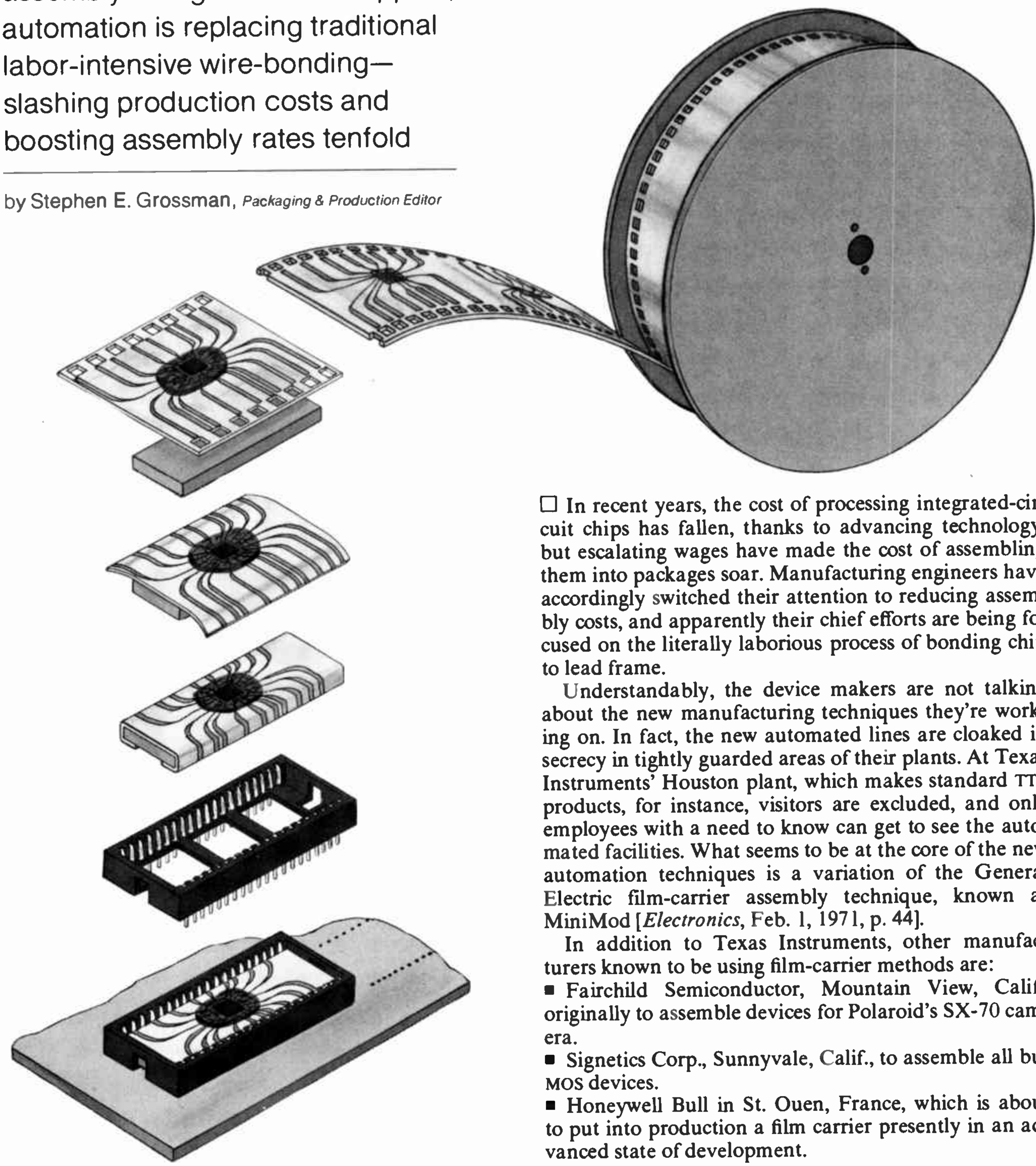
Film-carrier technique automates the packaging of IC chips

With wages rising and offshore assembly losing some of its appeal, automation is replacing traditional labor-intensive wire-bonding—slashing production costs and boosting assembly rates tenfold

by Stephen E. Grossman, *Packaging & Production Editor*



□ In recent years, the cost of processing integrated-circuit chips has fallen, thanks to advancing technology, but escalating wages have made the cost of assembling them into packages soar. Manufacturing engineers have accordingly switched their attention to reducing assembly costs, and apparently their chief efforts are being focused on the literally laborious process of bonding chip to lead frame.

Understandably, the device makers are not talking about the new manufacturing techniques they're working on. In fact, the new automated lines are cloaked in secrecy in tightly guarded areas of their plants. At Texas Instruments' Houston plant, which makes standard TTL products, for instance, visitors are excluded, and only employees with a need to know can get to see the automated facilities. What seems to be at the core of the new automation techniques is a variation of the General Electric film-carrier assembly technique, known as MiniMod [*Electronics*, Feb. 1, 1971, p. 44].

In addition to Texas Instruments, other manufacturers known to be using film-carrier methods are:

- Fairchild Semiconductor, Mountain View, Calif., originally to assemble devices for Polaroid's SX-70 camera.
- Signetics Corp., Sunnyvale, Calif., to assemble all but MOS devices.
- Honeywell Bull in St. Ouen, France, which is about to put into production a film carrier presently in an advanced state of development.

MiniMod and its variants use a plastic carrier, resembling movie film, that has lead frames mounted along its surface. A gang-bonding technique, faster and potentially more reliable than wire-bonding, attaches each film-mounted lead frame to an IC chip in a single, swift stroke. The bonded chips are reeled onto a take-up spool, ready to be attached to a flexible or rigid board or encapsulated in a ceramic or plastic IC package.

Such film-carrier techniques are the great hope of hard-pressed IC-manufacturing engineers, not just because they promise to reduce the labor content of each IC, but because they can increase production volume tenfold and ease lead time in plants that long since may have become capacity-limited. (In recent years, offshore assembly had lightened the delivery burden a little, but it had become evident that there would never be enough hands in the Orient or anywhere else to deliver the product in the quantities forecast for the coming years.) And there is a dividend because the gang bond, an integral part of the film-carrier technique, may eliminate the perennial headache in small-chip, high-volume IC assembly—the wire bond.

Wire-bonding woes

Wire-bonding is the most commonly used method of making connections from the silicon IC chip to the outside world. Although it has the advantage of not imposing tight dimensional tolerances, wire bonding is usually a manual, one-bond-at-a-time process and is therefore slow and costly.

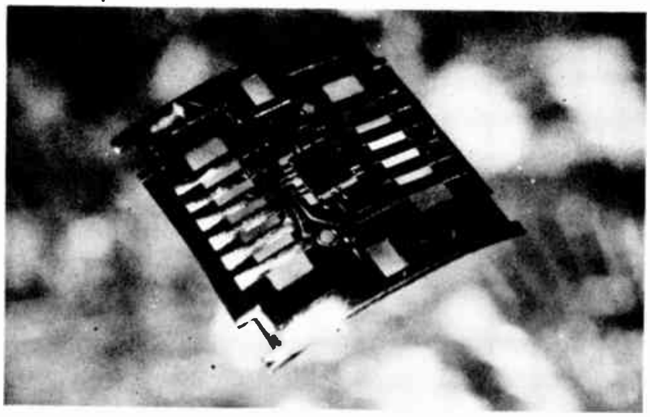
Typically, an operator peers through a microscope to position the bonding tool by hand and to bond a wire to a pad on the chip and then to a finger of the lead frame, again by hand. She repeats the sequence at each chip pad. Thus, if she is assembling 14-lead devices, she must make 28 bonds per device—one at each end of 14 wires. At one bond per second, she finishes about one IC per minute, or about 60 per hour. Assume her labor costs her employer $10 an hour, then the labor content of the device, for wire-bonding alone, is about 16 cents. This is a heavy labor burden for a device that must sell for less than a dollar. Also, 16 cents is more than the cost of the chip (maybe no more than a penny) or the package (worth about a nickel).

There are automatic wire-bonders on the market, but they can't, as yet, deliver products in the volumes that manufacturing engineers seek—upwards of a 1,000 devices per hour.

Worse still, the wire bond is responsible for many IC field failures. The failure often occurs at the heel where the bonder tool has work-hardened the wire, forming small microcracks. So if the bond experiences any stress, whether from thermal excursions, physical shock, or perhaps lift-off due to the expansion of the plastic encapsulating material, failure is very likely. A wire bond seldom survives a pull of more than 15 grams.

A number of techniques have challenged the wire bond. The controlled-collapse flip chip has IBM's backing, and beam-lead devices are on stream at Western Electric. But these alternatives are costly and do not adapt easily to the large catalog of chip geometries in major IC houses.

Thus, a welcome is assured any technique that adequately bonds small-chip ICs in volume at a reasonable cost. And automated film-carrier assembly appears to be receiving that welcome.



1. Chip shot. When an IC is mounted on a film carrier, no die-attach is necessary, and wire bonding is replaced by gang bonding, which boosts assembly rates tenfold. Film-carrier assembly may become standard throughout the IC industry within five years.

In the film-carrier approach, a film, usually polyimide, carries a copper lead frame. Figure 1 shows a chip mounted to such a film carrier. Note that 15 inner leads support the chip over the window in the film but only 11 function as circuit connectors. These leads are gang-bonded (i.e. bonded simultaneously, as a gang) to the pads on the chip by an inner-lead bonder. The two narrow rectangular regions enable the outer leads to be formed by a blanking or punching operation, which removes the extremities of the film so that the outer leads can extend in a cantilever fashion. They are later gang-bonded to a package—a dual in-line, perhaps, or a flexible or rigid circuit board.

The sprocket holes along the sides of the film serve two functions: they enable the drive mechanism in the inner-lead bonder to advance the film after a chip has been bonded, and they also serve to register the lead frame precisely over the chip, ensuring that each lead is centrally located over its own pad on the die.

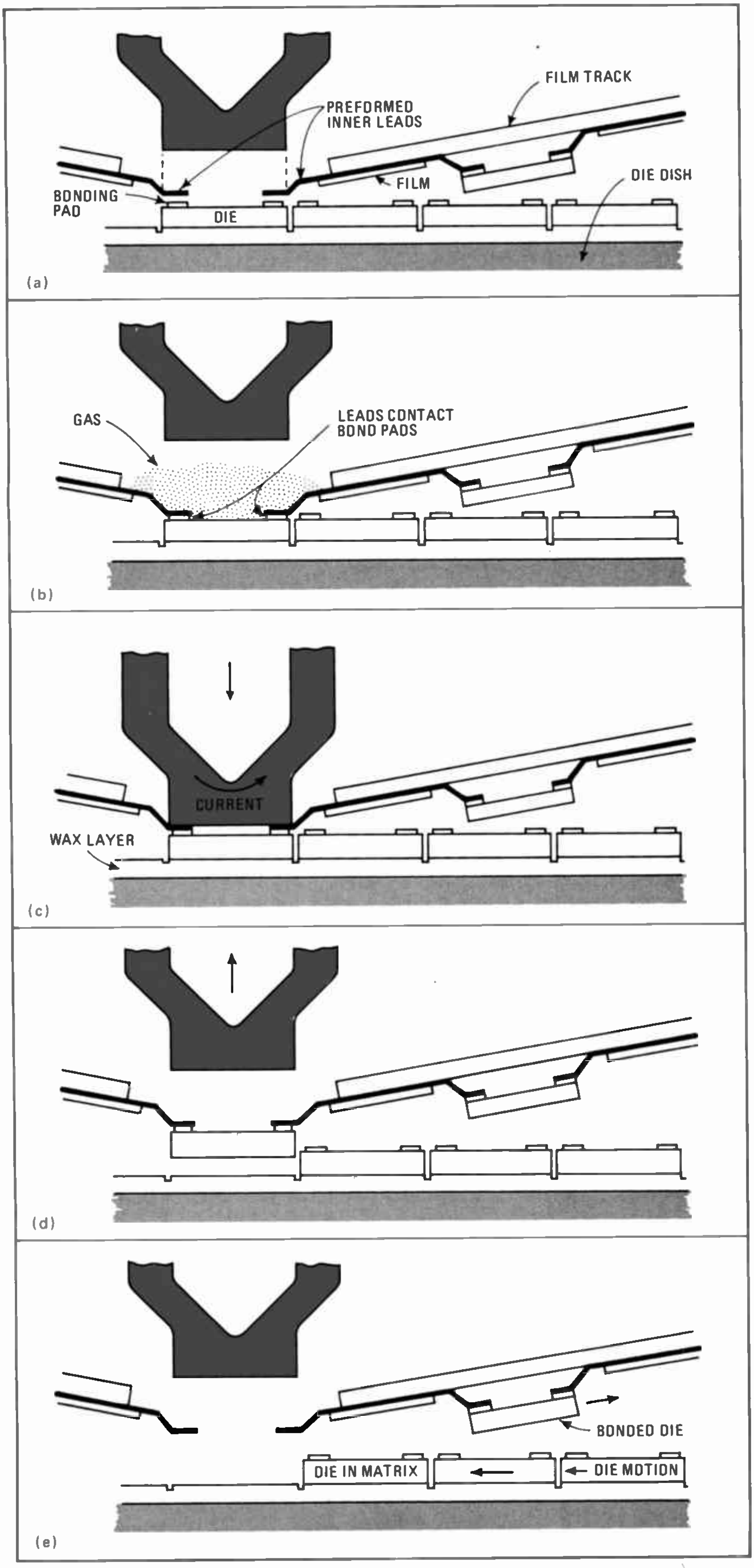
These two functions mesh with the needs of gang-bonding, which requires a transport system to handle the film and a means of registering lead frames over chips, as well as a tool to apply heat and pressure.

Gang-bonding

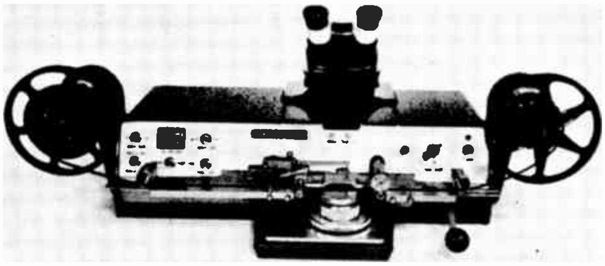
Figure 2 illustrates a typical bonding sequence. In Fig. 2(a), the film, with lead frame attached, is positioned directly above the row of chips. The gang-bonder descends (b and c), attaching all leads to the bonding pads in a single stroke. In (d), the carrier assembly rises, lifting the bonded chip free of the table. Finally, the film-transport system moves the film to the right, bringing a new lead frame into bonding position, and the row of chips shifts left, bringing the next chip into bonding position and completing the bonding cycle (e).

Several companies have inner-lead bonders for film carriers in development, but West Bond's model 8800 film bonder (Fig. 3) is on the market right now. With reel motors, X-Y table for manual registration, and lead former, it carries a price tag of $11,665.

Designed for solder reflow, the 8800 employs a step-



2. Bonding a film carrier. For alignment (a), preformed inner leads are lowered to position just above the bonding pads on the die, which is secured to the plate by wax. Die is viewed optically and aligned, manually or automatically. As bonding step begins (b), film is positioned to bring inner leads into contact with die bumps. An inert gas flushes away the ambient environment. In bonding (c), tool descends, pressing inner leads against die pads. Pulsed electric current heats the bonding tool, forming bond between the leads and the bonding pads. Heat also melts the wax, which releases the die. After bonding (d), the film track is raised, lifting the bonded die clear of the wax. Finally, film is indexed (e) to the right, bringing a new set of inner leads into bonding position. X-Y table is indexed to the left, bringing the next die into bonding position.



3. In the flesh. West Bond's machine bonds chips to lead frames carried by film. Stepper motor advances the film in 5-mil increments at speeds of 1.5 inches per second. Each chips is aligned manually by positioning the circular anvil directly below the microscope.

per motor to advance the film and an induction motor to provide the necessary film tension. An anvil work holder, shown directly below the microscope, supports the chips. The bonding-tool travel is motorized and requires about 375 milliseconds to move into the bonding position. It can bond approximately 1,000 chips per hour.

This bonding rate is more than 10 times faster than wire-bonding rates. It is directly due to the replacement of the many steps of wire-bonding with the single gang-bonding step, in which all leads are bonded to all chip pads at once.

Moreover, the actual bonds are stronger. Bond strengths of 60 grams per lead are readily attainable—about four times better than with wire. Also, the copper leads, typically 3 mils wide by 1.4 mils thick, provide a better thermal path than a 1-mil wire.

Then there is the matter of gold. Conventional gold-plated lead frames today sell for about 3 cents each in high volume, but about half the cost is the gold in the die-attach area. Since the film-carrier technique requires no die-attach, the film-carrier lead frame in the 16-mm format could eventually fall below 2 cents apiece.

On the debit side, the plastic carrier plays essentially no role once the bonding is done, yet unprocessed polyimide film comes expensive at about ⅛ cent per device. There are also stability problems, since even small changes in the film's dimensions, on the order of a mil or so, go a long way toward hampering efforts to achieve high-volume automation.

Changes all around

A switch to gang-bonding breaks new ground, because the materials and the geometry have changed. The leads are copper foil, not the round gold and aluminum wire familiar from wire bonding. So the process engineer, who spent years bringing respectability to the wire bond, must begin again, selecting and then perfecting a technique that can deliver a reliable, inexpensive bond. Fortunately, he has a wide choice of both bonding methods and bonding metals.

Thermocompression bonding, as the name suggests, employs heat and pressure to create adhesion between mating parts. A combination of plastic deformation and diffusion brings the molecules of the mating materials into intimate contact, thereby creating adhesion. Though temperature is raised to achieve a bond, it is not elevated to the point where the mating metals actually melt.

Eutectic bonding depends on an alloy being formed between two mating materials. The composition of the alloy is described as eutectic when the molten material, as it cools, goes from liquid to solid instantly, without passing through a semisolid, mushy stage.

Soldering is unique in that it makes use of a third metal, which may be an alloy, to bond both the mating parts. Its success depends on the ability of the solder to wet and form sound bonds with both mating parts. A drawback of soldering is that the joining surfaces must be fluxed, and since fluxes are usually corrosive, all traces of them must be removed after the bond is formed.

Selecting metals suitable for joining the silicon chip to the lead frame requires a process engineer to chose from a wide range of metallurgical alternatives, many of which are closely guarded company secrets. Nonetheless, there are certain metallurgical systems whose usefulness is common knowledge.

Building bumps

The metallurgical systems used for gang-bonding usually require a bump, perhaps 1 mil high, on each pad of the chip. The bump provides a bond interface with the lead frame on the film carrier. Not all the bumps will be exactly the same height, yet they must be bonded simultaneously. But if they are ductile, the higher ones will be compressed as the bonding tool forces the leads against the chip, assuring that both high and low bumps bond to the lead frame.

The bump is built on a first-level metalization, usually aluminum. It consists of one, or perhaps two, barrier metals, plus a capping material, which is selected for the best bonding properties possible with the bonding method selected—eutectic, solder, or thermocompression. The barrier metals prevent the aluminum and capping metal from diffusing into each other. The layers are built up on the silicon chip by means of one or more varieties of thin-film deposition techniques. (See "A guide to film-carrier metallurgy," p. 93).

However, compatibility problems are not confined to the device. The film carrier has its problems, as well. Marrying a flexible material to a thin metal foil has posed some monumental technical problems. A major requirement is that the copper remain securely bonded to the film. This isn't so easy because the film carrier encounters a number of harsh environments. First, a chemical etchant removes unwanted copper to form the lead frames, a second etchant may remove the windows, and then, if thermocompression bonding techniques are employed, the carrier must survive thermal cycling to temperature extremes as high as 350°C. Finally, the carrier is again subjected to an elevated temperature when a device is encapsulated.

Dimensioning the film and the circuit pattern has been another major obstacle. Tolerance buildups of more than a mil are unacceptable. As Fig. 4 shows, if the leads shift off the pad centers by just 2 mils, the actual bonding area common to the pad and its mating

A guide to film-carrier metallurgy

Capping materials

GOLD

A forgiving material for capping because it doesn't work-harden and lends itself well to thermocompression bonding at temperatures of about 300°C. Time-pressure-temperature values can be varied considerably and still yield good bonds. Thermocompression bonds to titanium-silver, silver, indium, aluminum, silicon and lead are possible. Can be reflow-soldered with popular soldering alloys. Losing popularity in high-volume, low-cost production because of soaring gold prices.

TIN

Solders poorly to gold but can be thermocompression-bonded to it. However, forms a weak intermetallic, which is weakened by low-temperature cycling.

LEAD

Solders well; good thermocompression bond intermediate. Commonly alloyed with tin to form a eutectic solder.

GOLD-TIN-LEAD

Can be evaporated in place, but tends to be weak. Requires remelting to form a pad.

COPPER

Is soft, solderable and cold-weldable. Also lends itself to thermocompression-bonding. Because it oxidizes, requires a protective layer such as nickel or silver. Should not be deposited directly on silicon because it diffuses into a chip and changes device properties. Also diffuses into copper, forming an intermetallic.

SILVER-TITANIUM

Provides a good thermal match to silicon. If evaporated, is usually graded silver-rich at the surface to enhance solderability or bondability.

ALUMINUM

Is poor thermal match to silicon. The metal is ductile, however, so that it cold-flows when stressed. What's more, it is difficult to solder, but is frequently ultrasonically bonded. Aluminum can form a brittle intermetallic known as "purple plague" when mated to gold. However, if temperature is held low and there is sufficient aluminum, this need not be a worrisome problem. Forms a weak bond to silver.

SILVER-TITANIUM

Developed for solar cells, has an excellent thermal match to silicon and good bondability. Can be graded on evaporation for a titanium contact and barrier and a silver thermocompression pad. However, the silver is vulnerable to oxidation.

Barrier metals

TANTALUM, TUNGSTEN, MOLYBDENUM, TITANIUM

Called refractory metals because of their high melting temperatures. Diffuse very slowly into neighboring materials and are therefore good as barrier metals—provided that work functions are carefully matched to ensure that ohmic rather than Schottky junctions are formed.

CHROMIUM NICKEL, IRON, COBALT, MANGANESE

Called transition metals because outer valence shells are filled and are similar chemically. Are easier to process than the refractory metals.

First-level metalization

ALUMINUM

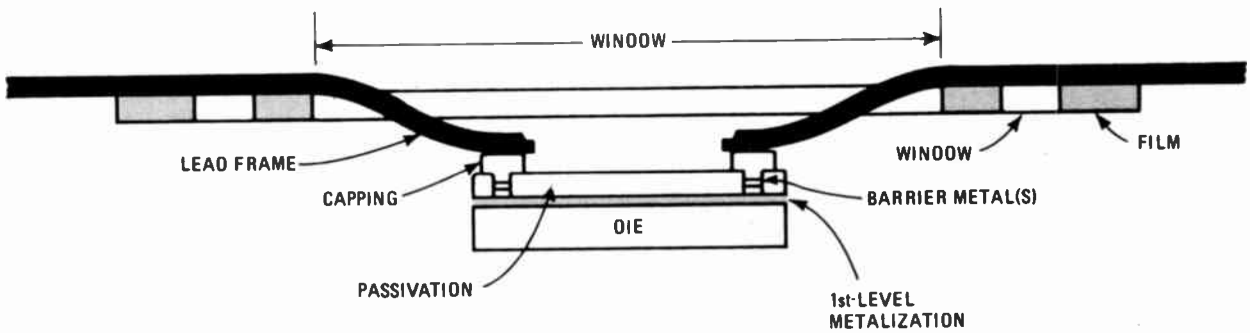
Is an important first-level metalization. Goes down where it is wanted and goes well over silicon-dioxide passivation steps. Can be processed to form an ohmic rather than a Schottky barrier form.

GOLD OR DOPED GOLD

Similar to aluminum, but doesn't form an oxide. Is easier to bond but more costly than aluminum. Requires a barrier to prevent its diffusion into silicon.

Solders

If low-temperature, are useful and do not damage chip even though their melting temperatures are usually above the processing temperatures that the chip will experience after being soldered to the lead frame. Are sometimes hard to apply. If thin, may cause diffusion problems. Most solders bond well to copper. Usually require flux, followed by a flux, removal step. Gold diffuses into solders so that soldering of gold, especially thin-film gold, can be a problem, since a poor bond—or even no bond—may be the result.



lead is greatly reduced, weakening the bond considerably. Also, the lead on the left almost bridges both pads and may cause a short circuit. Accurate registration helps speed production, too, because it shortens the time required by an operator to accurately superposition each lead frame over the chip. It also improves yield.

The year 1971, when MiniMod was introduced, was unkind to the film-carrier innovation because it meant abandoning manual wire-bonding at a time when major IC manufacturers were deeply committed to the process. In about 1964, they had begun to invest huge sums in establishing assembly operations overseas—in Hong Kong, Taiwan, and Malaysia—where inexpensive labor was plentiful and they could hope to raise volume and lower costs. Moreover, in the recession of the early 1970s, manufacturing engineers were hard pressed for the R&D funds to examine this new technology.

Nonetheless, some companies pressed on. Texas Instruments acquired the MiniMod process from General

Electric. A company called International Micro Industries was formed in Cherry Hill, N.J., with the express purpose of mastering film-carrier assembly. And by early 1974, two manufacturers had disclosed some results of their developments at professional meetings—Honeywell Bull and Fairchild.

Honeywell Bull, in St. Ouen, France, is employing film-carrier in a technique that it terms tape-automated bonding (TAB).[1] Its carrier is described as polyimide, bearing a tin-plated copper lead frame. A gold-tin eutectic bond is formed at 280°C, the bonding tip being raised 50°C above that point during the bonding step. The heat from the tip melts a wax, freeing the chip from a glass plate. Honeywell Bull's Gérard Dehaine estimates that film-carrier assembly has cut costs some 20% to 30%. Shear strength of the bonds ranges from 60 to 100 grams—more than four times greater than that obtainable in wire-bonding. Dehaine adds that his company is in an advanced pilot production and will use the technique soon in upcoming hardware.

Fairchild put film carrier to use in assembling modules for Polaroid's SX-70 camera.[2] Its engineers used a 16-mm film to carry chips that were then fastened to a 70-mm flexible circuit to form the camera's flash-firing assembly. They also used the technique to fabricate the exposure-control module. Frank Perrino, manager of the project, says that assembly rates of around 1,000 ICs per hour were achieved. A solder-reflow technique was used to attach the outer leads of the circuits to the modules. A heat-sinking arrangement kept the heat from reaching the inner leads and lifting them off the chip. Perrino estimates that adding the pad regions required for film-carrier gang-bonding added no more than a penny to the cost of the chip.

A film-carrier market?

Several suppliers are eager to capture a portion of the film-carrier market of a billion units or more that may be just over the horizon. Though IC manufacturers are assembling the circuits in-house, they are also encouraging vendors to develop the capability to etch frames to their specifications. Pricing is a challenge. The IC houses hope for film-mounted lead frames in a 16-mm format at a penny apiece—about half the price of traditional stamped lead frames.

Some large companies, confident that film-carrier is a coming technology, are backing up their convictions with intensive development and marketing efforts. Jack Norrie, marketing manager for AMP Inc.'s Electronics Product group in Winston-Salem, N.C., points out that offshore assembly may be losing some of its luster. Says Norrie: "Labor rates are rising in the Orient, so that domestic assembly teamed with film-carrier is becoming an attractive alternative. Manufacturers expect film-carrier to be cost-competitive, even with offshore." Norrie adds that watches, cameras, and calculators have helped steer development money to the manufacturing-engineering groups, and film-carrier will play an important role in assembly.

Minnesota Mining & Manufacturing Co. is another major company actively engaged in film-carrier technology. William Foster of 3M's Electronic Products division in St. Paul, Minn., expects that within five years the bulk of ICs will be assembled by film-carrier techniques. Foster is convinced of manufacturers' dissatisfaction with offshore assembly: "Some would like to bring assembly back onshore, even if film-carrier offered no savings. . . . I would not be surprised to see several semiconductor manufacturers beginning to consume tape in substantial quantities by the end of this year."

Stewart M. Harris, market manager for duPont's Electronic Materials division, thinks that the ease of making changes in lead-frame patterns is crucial to the growing interest in film-carrier. Says Harris: "The current hard-tooled stamped lead frames confined chip designers to one chip size and pad geometry. However, the modern trend to chemically etched film carriers, which we market, enables change without prohibitive expense."

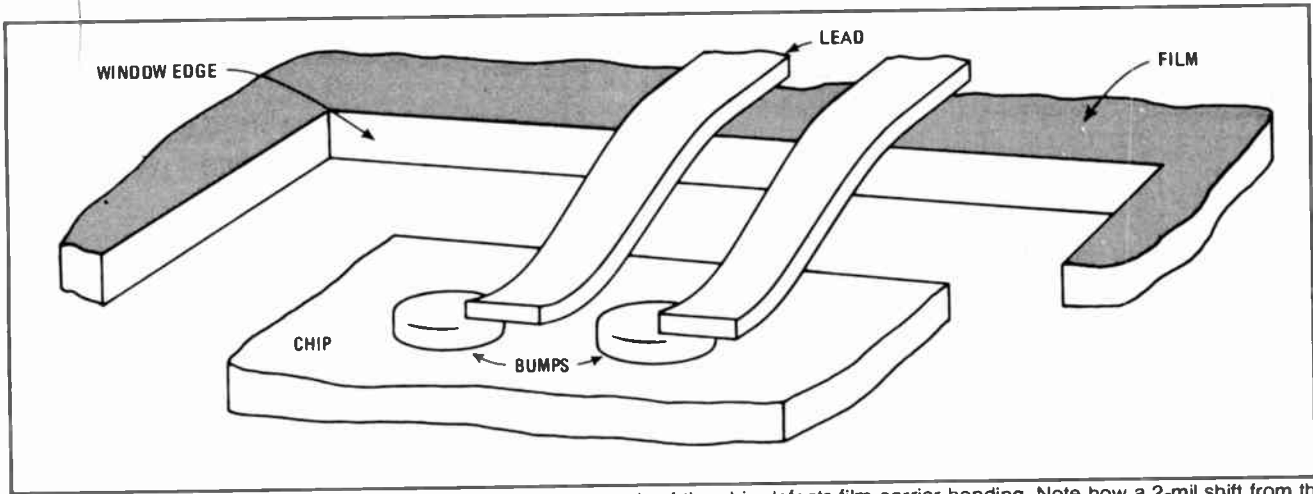
Some companies, such as Sheldahl (formerly Schjeldahl) of Northfield, Minn., a major supplier of flexible circuits, question the return on the capital investment required. Steve Gurley, marketing manager for Sheldahl's Electrical Product division, forecasts that even if the entire small-chip IC industry were to switch to film-carrier assembly, the total film-carrier market may not exceed $30 million in the foreseeable future. And if that pie must be divided among too many suppliers, payback on investment may be a long way off. There is no question that the IC manufacturers would like to buy the film carrier on the outside. But if they enforce a price of 1 cent per lead frame, they could destroy the marketing incentive, says Gurley.

The most pressing technological challenge confronting film-carrier suppliers is to meet the demand for tight-tolerance dimensioning—the requirement that the dimensioning from sprocket hole to lead be held to a mil or less. Also, IC manufacturers expect adhesion of copper to film to withstand 270°C for 5 seconds—a stiff requirement.

There are at least two ways to form a circuit. The subtractive technique predominates. It begins with the bonding of a 1-ounce copper foil (1.4 mil thick) to the film with an adhesive, then photoresist techniques form the image of the desired lead frame in a step-and-repeat fashion along the film-mounted copper laminate. Finally, the unwanted copper is etched away in essentially the same manner that copper is removed from a rigid printed-circuit-board laminate.

But there is another way which A.J. Siegmund, product manager at MacDermid Inc., Waterbury, Conn., thinks may be more economical. Instead of using an adhesive to attach a copper foil, copper is deposited in an additive fashion. That is, the photoresist is applied first, covering those regions where copper is not wanted. Then a combination of electroless deposition and electroplating builds up the lead frame to the required thickness. A second resist and etch step would form the windows in the film. Siegmund believes that the additive technique is less likely to build in those destructive stresses that develop in some adhesive systems. He estimates that the additive approach will cost less than 5 cents per square inch.

One company that has been working steadily on film-carrier techniques is International Micro Industries,



4. Fatal mismatch. Failure to register leads accurately on the pads of the chip defeats film-carrier bonding. Note how a 2-mil shift from the true position produces an inadequate bond area and causes the left lead almost to short-circuit the two bonding pads.

Cherry Hill, N.J.. Thomas Angelucci, president of the firm, says it began three years ago to develop both bonding equipment and film, since at that time they couldn't purchase a satisfactory film carrier. To make the film carrier for their system, which they call ECTA the company begins with 24-inch wide polyimide film and slits it to width—mostly 16-millimeter, which adapts well to TTL chips.

Users may complain about its $25-per-pound price tag, but there is, at present, no other material that delivers the performance of polyimide. Known as H-film and Kapton (the latter is a duPont trademark), this thermosetting-type plastic boasts two qualities that put it out in front of rival materials—high-temperature survival, and dimensional stability. Being a thermosetting material, it doesn't melt, and it won't char until raised to over 800°C.

It carries a continuous temperature rating of 250°C and can withstand short-term thermal excursions to 400°C. So it withstands both soldering and thermocompression bonding temperatures. As for dimensional stability, it expands and contracts no more than 1 mil per inch when heated to 200°C.

Polyimide does have one fault; it absorbs more water than some competing films. However, this poses no serious threat to its use as a carrier because the film can be readily passed through a drying oven prior to processing and encapsulating.

Pick a polyester?

At $1.25 per pound, users would certainly prefer to switch to a polyester film such as polyethylene terephthalate, better known by its duPont trademark, Mylar. Despite the fact that it melts at 250°C, polyester may be the film of the future. For lead-attach, bonding temperatures (280°C) are seldom applied for more than 1 second. Thus, the heat traveling down the lead cannot raise the polyester to its melting point.

Films are commonly marketed in thicknesses ranging from 0.5 to 5 mils. Though 5-mil film is common, manufacturers would like to go to thinner, narrower film to save money. As an example, switching from 35-millimeter-by-5-mil to 16-mm-by-2-mil film offers an 84% savings in polyimide. And since the larger film may represent one eighth of the cost of the circuit, this is a sizable saving. However, the thinner film tends to stretch and also proves difficult to punch. Moreover, Cutter Palmer, a technical consultant with duPont's film department, believes that at the current stage of film-carrier development, the cost of the film is negligible.

What's ahead

The current state of the art, which employs manual registration of each chip, has brought bonding rates to about their present 1,000 an hour. However, manufacturing engineers have their sights set on raising throughput above 2,000 units per hour, which makes fully automated registration a necessity. "If you can achieve 2,400 devices per hour, you are really flying along," says Frank Perrino, a product manager at Fairchild. "This doesn't allow much time for any step in the process. You must advance, register, and bond, then allow the bonds to cool before moving on to the next device—and all in 1½ seconds."

To break through that 1,000-unit-per-hour rate barrier, manufacturing engineers are endeavoring to reduce, and perhaps eliminate entirely, operator participation in the chip-alignment phase. One answer may be a sensor to register alignment optically by a servo system.

As for the film, if the price of the carrier does approach the hoped-for penny lead frame, then engineers will intensify their efforts to replace polyimide with an alternative. There may even be attempts to do away with the film completely. After all, its role is essentially sacrificial. Once the chip is bonded in place, it has no further use. So why not eliminate the film and find an alternative, non-consumable carrier?

Manufacturing engineers have built a fine track record automating complex assemblies at macroscopic levels. There is no reason why the microscopic dimensions of IC assembly should form an insurmountable barrier. In time, engineers will hurdle the obstacles and bring full automation to integrated-circuit assembly. □

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Controlled current source is versatile and precise

by Jerald Graeme
Burr-Brown Research Corp., Tucson, Ariz.

A precision voltage-controlled current source can be made by placing a pair of complementary field-effect transistors in the feedback loop of an operational amplifier. The resulting circuit will have a differential input, as well as a bipolar output current that can be used to drive either grounded or floating loads. From signals of up to ±10 volts, the circuit develops a ±10-milliampere output, accurate to within ±0.01%.

Signal voltages are usually derived from control voltages, but sometimes it is better to derive signal currents from the control voltages for either testing or driving certain loads. For example, a voltage-controlled current source can provide a simple programmable bias current for transistor testing.[1] Or it can be used for resistance measurement, since contact resistance will not affect the test signal supplied by a current source. A current output is also needed for process-control instrumentation or for driving a meter or a dc torque motor.

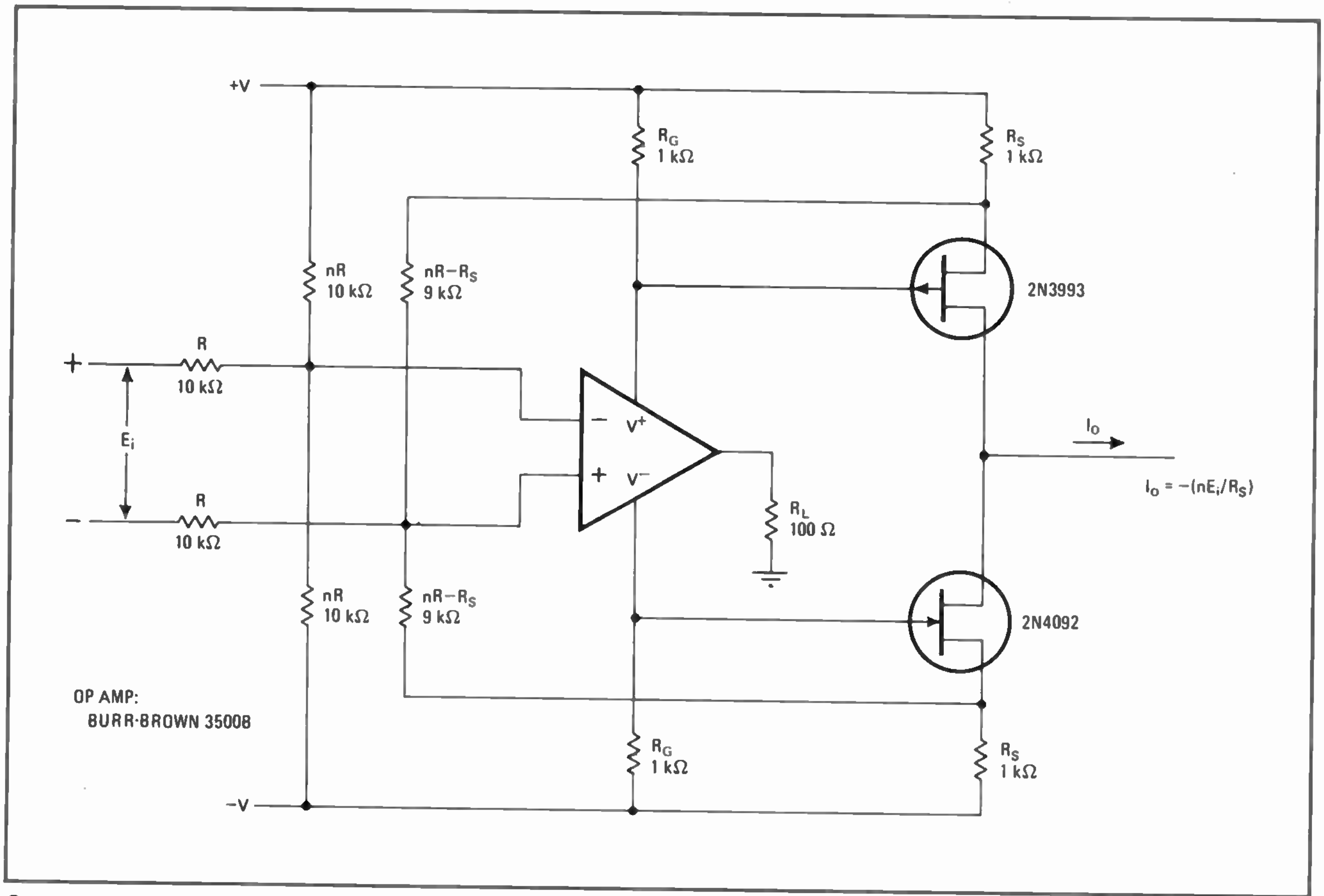
These varying applications may involve unipolar or bipolar output currents, single-ended or differential inputs, grounded or floating loads or sources, and varying degrees of accuracy. The circuit shown in the diagram can satisfy all of these requirements, and it is simpler than many previous not-as-versatile current sources.[1,2]

The circuit here consists of opposing FET current sources that are controlled by high-gain feedback around an op amp. The difference in FET currents produces the output current, and this difference current is controlled by summing the feedback, at the amplifier input, from the current-sensing source resistors (R_S). At feedback equilibrium, the sum of the two feedback signals is directly related to the differential input signal. The circuit's output current is given by:

$$I_o = -nE_i/R_S$$

where n represents the desired resistance-ratio factor.

Differential inputs and high power-supply rejection are provided by an attenuator network at the inverting amplifier input; it matches the feedback network con-



Current drive. Voltage-controlled current source can accept a single-ended or differential input, supply a unipolar or bipolar output, and handle a grounded or floating load or source. The difference current developed by the complementary FETs is sensed by resistors R_S and fed back to the amplifier input, where it is summed with the input signal voltage. Both FET gates are driven from the op-amp supply terminals.

nected to the other amplifier input. This is analogous to the matched input and feedback networks connected to an op amp to form the common difference amplifier.[2]

To simplify biasing and improve large-signal bandwidth, the gates of both FETs are driven from the op-amp supply terminals, rather than from the op-amp output terminal. Quiescent biasing for the FETs is obtained from the quiescent current drains of the op amp, and no level-shifting bias must be set up from the amplifer to the FETs.

Large-signal bandwidth is also improved by the reduced output swing required from the amplifier. Only a 1-volt swing is needed across amplifier load resistor R_L to obtain the rated output current, which is drawn through the supply terminals for maximum drive to the FETs.

Additionally, the lower amplifier output swing is not as greatly bandwidth-limited by the amplifier slewing-rate limit, as it is in other designs. Optimum bandwidth is achieved by making resistor R_L small enough to limit output swing without excessively lowering amplifier gain. Large-signal bandwidth is then limited by the amplifier's maximum common-mode swing rate.

The circuit's output current is controlled by the input voltage to within the accuracies of the resistors selected and within the gain-bandwidth and power-supply-rejection limitations of the op amp used. Most accuracy limitations caused by the FETs are overcome by the feedback, except for the small contributions from gate-drain leakage currents.

Output current is limited to the I_{DSS} level of the FETs but can be boosted by using the transconductance multiplying technique sometimes employed for common FET controlled current sources.[1] Output impedance is multiplied, through the feedback, from that of the FETs to the practical limit imposed by stray and parasitic effects—it is around 10^{12} ohms shunted by 10 picofarads.

By virtue of the circuit's differential inputs, common-mode signals are eliminated by a common-mode rejection that is adjustable to over 90 decibels. The primary common-mode-rejection limitations are the accuracies of the resistor ratios and the resistor matches, except for the noncritical match between the FET gate resistors (R_G).

The common-mode rejection can be adjusted by trimming the input resistors. Prior to this adjustment, any desired nulling of dc offset voltage should be performed by trimming the resistors denoted as nR. □

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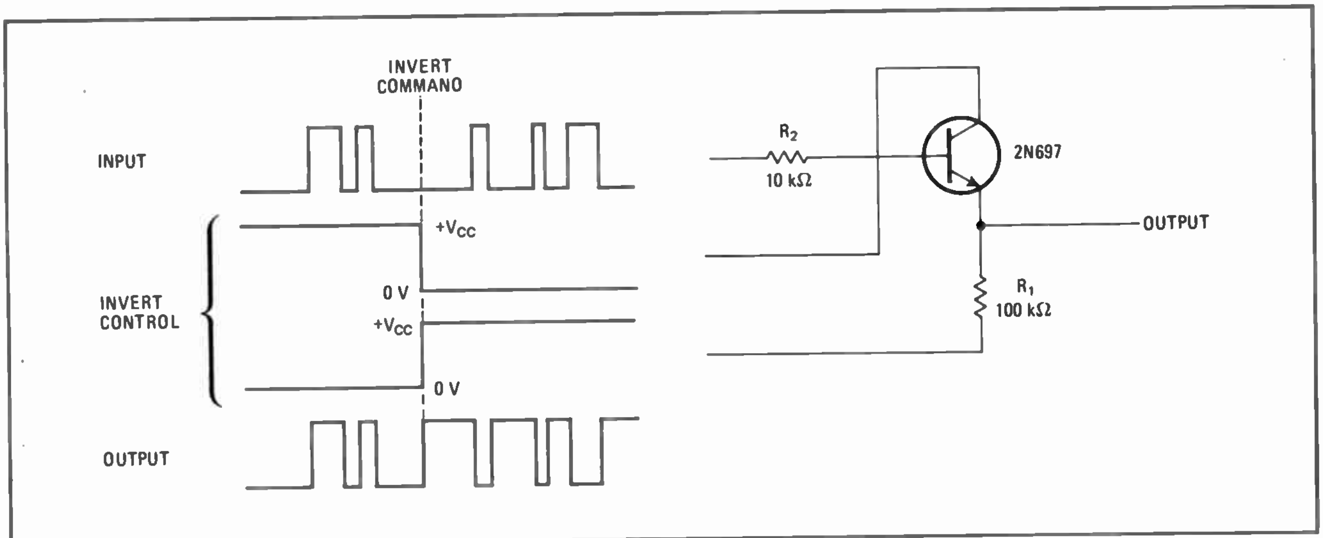
Single bipolar transistor inverts pulses on command

By Dale Hileman
Sphygmetrics Inc., Woodland Hills, Calif.

An ordinary bipolar transistor can be made to function as a command inverter—that is, it will pass a pulse signal without modifying the pulse, but it can invert the signal upon command. The command is a simple reversal of the polarity of the supply voltage.

To do this usually requires several gates, involving perhaps dozens of parts and interconnections. The command inverter shown here, however, requires only three parts: a single bipolar transistor and two ordinary resistors.

The key to this circuit's operation is that the role of a transistor's emitter and collector can be interchanged if the supply polarity is reversed. When the polarity of the invert control signal is normal, the transistor operates as an emitter-follower, so that the polarity of the output



Command Inverter. With normal supply polarity, this bipolar transistor operates as an emitter-follower, passing the input pulse train to the output without modifying it. But when the supply polarity is reversed, the transistor's emitter acts as its collector, and the transistor's collector acts as its emitter. Now the polarity of the input pulse train will be inverted at the transistor's output.

pulse train is the same as the polarity of the input pulse train.

The invert command reverses the polarity of the supply voltage, making the transistor's collector act as an emitter and its emitter act as a collector. Now the circuit becomes an inverting amplifier, with resistor R_1 serving as the collector load resistor. Under this condition, resistor R_2 simply limits the transistor base current to a safe value.

Any general-purpose npn or pnp bipolar transistor may be used in the circuit, and the precision of neither resistor R_1 nor resistor R_2 is critical. This command inverter will work with virtually any value of supply voltage and any input pulse level that the transistor will tolerate. □

Norton quad amplifier can be a low-cost function generator

by P. Vlcek
Orbit Controls Ltd.,
Cheltenham, Gloucester, England

A versatile function generator that minimizes hardware as well as cost can be built with one of the newly introduced Norton quad amplifiers [*Electronics,* Dec. 6, 1973, pp. 116-120]. The price of the complete generator is less than $3, and the entire unit can fit on a circuit board as small as a 1½-inch square.

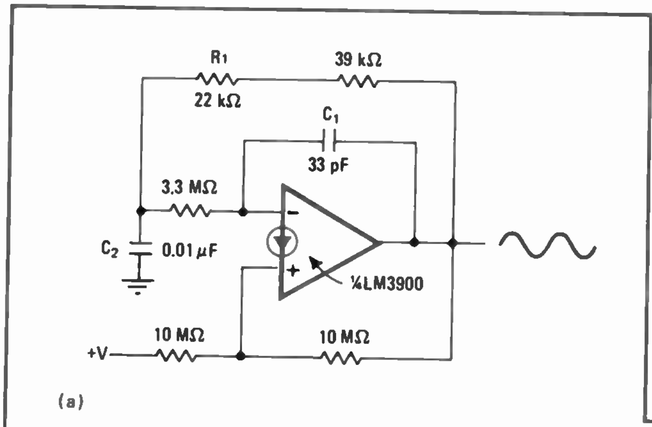
Only a single Norton amplifier is needed to obtain a sine-wave generator (a). When resistor R_1 and capacitor C_1 are omitted from this circuit, the resulting configuration is the standard one for a Norton-amplifier square-wave generator, with the timing current passing through capacitor C_2.

The addition of integrating capacitor C_1 to this square-wave generator produces a resonably accurate sine wave at the output. Resistor R_1, which helps to match the circuit's time constants, can be used to adjust the output sine wave for minimum distortion.

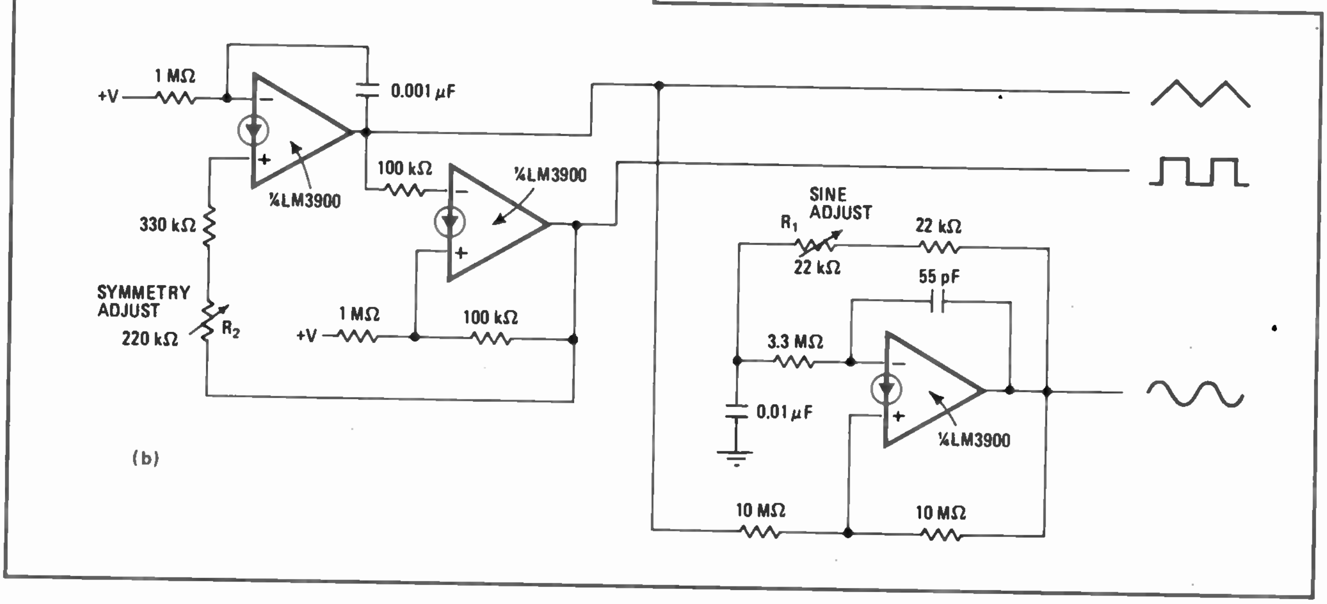
A similar circuit can be used to add a sine-wave output to the conventional hookup for a square-wave/triangular-wave generator built with two Norton amplifiers. As shown in (b), the triangular output acts as the input for the sine-shaper amplifier.

For the component values given here, the circuit's operating frequency is around 700 hertz. Resistor R_1 is the adjustment for minimum sine-wave distortion, and resistor R_2 is the adjustment for the symmetry of the square and triangular waves.

The fourth amplifier in the Norton quad package can be connected as an output buffer for all three output waveforms. □



Economical approach. Norton quad amplifier, which is one of the newer ICs, reduces the circuitry and the cost of waveform generation. If a single amplifier is used, as in (a), a sine wave can be generated, with provision (through resistor R_1) for minimizing distortion. With three amplifiers, as in (b), triangular, square, and sine waveforms can be obtained, and the fourth amplifier can act as a buffer.



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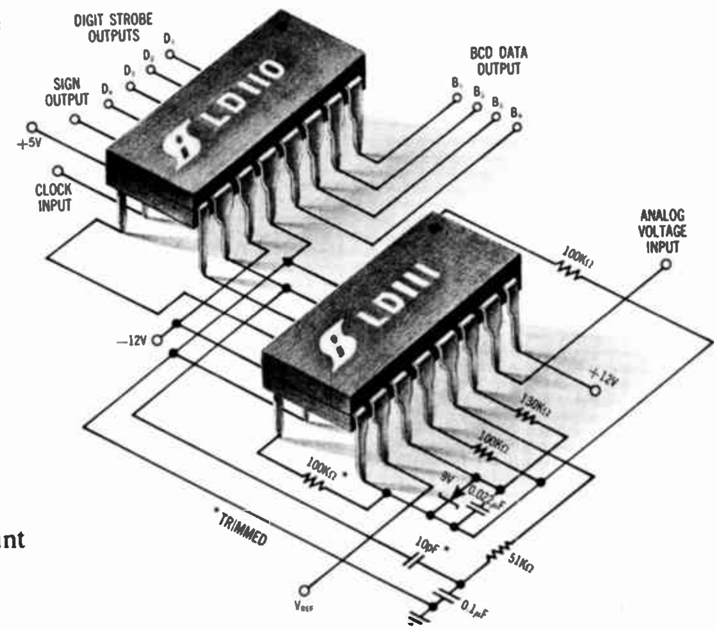

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Part 1: When to use a programable calculator or a minicomputer to automate a system

When it's unclear whether a given instrumentation system can be automated with a calculator, a rational decision requires seven factors to be considered—from language needs to size of memory

by P. David Fisher and Stephen M. Welch,
Michigan State University, East Lansing, Mich.

☐ A programable calculator can serve as the brain of an automated instrumentation system if that system does not need the speed and memory capability of a minicomputer or if it cannot run to the cost of the mini itself, plus the cost of its peripherals, plus the cost of its software development. But for any given instrumentation system, the choice between calculator and minicomputer can be difficult.

At least seven factors must be taken into account

- Program entry methods.
- Languages.
- Instruction sets.
- Execution speeds.
- Memory characteristics.
- Costs.
- Input/output features.

All these factors must be balanced against system requirements, user characteristics, and plans for future expansion.

Entering the program

In minicomputers, merely preparing programs for execution can easily be the most manpower-consuming phase of system implementation. A contributory factor is the need to use software to translate the program into machine language before it can be executed—a process that can take up more than half the debugging cycle.

With calculator-based systems, by contrast, programs are entered and edited through the keyboard and are interpreted directly by the hardware at execution time. The assembly, or compilation, phase is completely eliminated, and debugging time is about halved. This capability may be mimicked on minicomputers with interactive software packages, but at the expense of dedicating a large chunk of main memory to the task.

Programable calculators have three language levels. The first may be called keystroke language and resembles assembly-level computer language (Fig. 1a). It is found both in older calculators and in the lower-priced members of many newer product lines. These machines have a basic set of instructions, each of which is represented by a unique code, is stored in memory, and executed sequentially in the order programed.

Programing at the equivalent level on a minicomputer, though it maximizes the flexibility of the machine, is very difficult and time-consuming and requires the attention of a specialist. To a lesser extent, this is also the case with keystroke-language calculators. The user has to break his problem down into an organized string of operations, and he must pay attention to addressing. On the other hand, he need not worry about fixed- versus floating-point formats, index registers, assemblers, loaders, and so on.

The next language level on a calculator is called formula language. No comparable minicomputer-language type exists, except for a few routines written by end-users. Basically, programs are entered in the form of algebraic statements to be evaluated (Fig. 1b). As before, the statements are keyed in directly, without needing to be translated by software. In addition, however, the hardware has the capability of interpreting statements in the order dictated by the well-known mathematical hierarchy.

At the formula-language level, the calculator user is

Wedding calculators and instruments

This two-part article shows how the versatile programable calculator can be used to automate an instrumentation system economically. Part 2 appears on pg. 104.

freed from many of the minicomputer user's problems in moving quantities into and out of working registers and in allocating temporary storage. The calculator user needs less programing experience, too, since he can also organize the program at the statement level as opposed to the single-instruction level.

The top language level is occupied by those machines capable of handling a full-fledged scientific programing language. The most common one is Basic (Fig. 1c), which has the great advantage of being implemented on many computers. Thus, programs developed for these calculators will remain useful, should system needs expand to the minicomputer level. On the other hand, the expanded power of Basic and other such languages (which include arrays and often the options of string variables and matrix operations) again requires the attention of programing specialists.

Different instructions

One major difference in orientation between calculators and minicomputers lies in their instruction sets. In minicomputers, the emphasis is on processing the binary patterns that make up computer words. These patterns may therefore be shifted and logically altered, tested, and transferred from one part of the machine's environment to another. Numeric processing, particularly addition and subtraction, is handled by binary integer arithmetic. Full integer multiplication and division are rarer, and floating-point hardware (or microprograming) is almost always an expensive option.

In calculators, on the other hand, the emphasis is on numerical processing, and logic arithmetic is available only to a very limited extent as an option on the most expensive machines. Some byte processing is possible, however, if the byte is treated as a numerical value. On the other hand, floating-point capability is standard. In addition, a wide variety of mathematical and input/output functions, which require subroutines on minicomputers, is present as firmware and may be activated by a single keystroke. This feature can greatly reduce memory requirements and simplify programing.

When no single key exists for a task that must be executed frequently, the calculator user may resort to subprograms. The depth to which subroutine calls may be nested, however, is more restricted in calculators than in minicomputers. The execution of a "call-subroutine" instruction requires the storage of a return address in both minicomputers and calculators, and the number of return addresses that may be stored simultaneously determines the allowable depth of nesting. In calculators, which use special registers to store return addresses, much less space is available than in minicomputers, where central memory is used. While the actual limit of nesting varies widely from machine to machine, common programing practice suggests that four levels are the bare minimum for comfortable programing, and 10 to 15 levels are more than adequate.

A convenient alternative to subprograms is provided by the calculator's "user-definable" keys. A special routine is stored in memory and is activated by a single stroke of such a key. If the user changes the programing, he in effect redefines the key and so tailors the keyboard to his specific needs. For instance, depressing one

(a) KEYSTROKE LANGUAGE

ADDRESS	INSTRUCTION
00	CLEAR
01	STOP
02	z → a
03	STOP
04	z^2
05	z → b
06	STOP
07	z → c
08	4
09	c•
0A	a•
0B	b–
0C	CHANGE SIGN
0D	PRINT
0E	10
0F	z ↔ m
10	INCREMENT
11	IF z= m
12	STOP
13	z ↔ m
14	GO TO 01
15	END

(b) FORMULA LANGUAGE

0.	0 → m
1.	Enter A, B, C
2.	B ↑ 2–4 AC → x: Print x
3.	IF m+1= 10 STOP, ELSE
4.	m+1 → m: GO TO 1

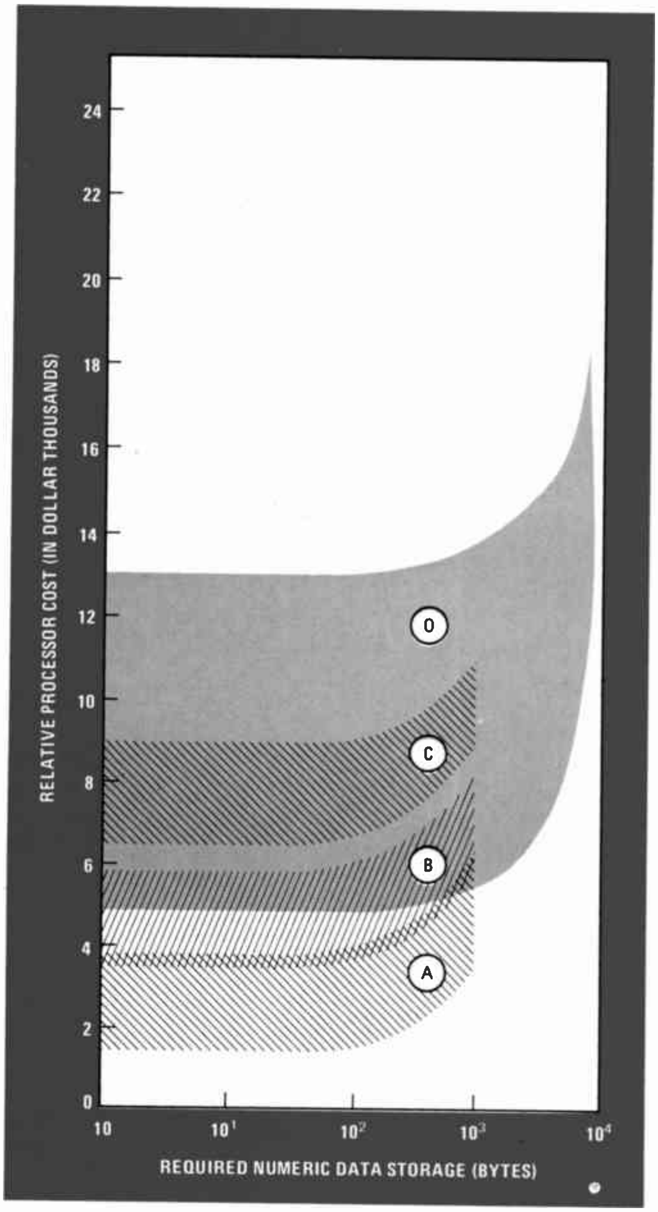
(c) 'BASIC' LANGUAGE

```
100   FOR J=1, 10
110   READ A, B, C
120   PRINT B ↑ 2–4 * A * C
130   NEXT J
140   End
```

1. Languages. All three of these calculator programs compute the value of the expression B^2-4AC for 10 different sets of arguments. Keystroke language (a) is similar to computer assembly language, while Basic (c) is the same as the well-known interactive language that is widely used with computers. Intermediate in complexity, formula language (b) usually has no direct minicomputer counterpart.

OPERATION	CALCULATOR	MINICOMPUTER
ADD/SUB	15 ms	0.3–0.5 ms
MULT/DIV	20 ms	0.3–0.6 ms
x^2	25 ms	0.3–0.7 ms
SQUARE ROOT	30–50 ms	2–4 ms
e^x	20 ms	3.5–7.5 ms
LOG	20 ms	4.6–9.7 ms
SINE	40–140 ms	4.5–9.1 ms
ARCTANGENT	70–140 ms	4–8 ms

2. Speed comparison. Execution times for a few commonplace instructions show speed difference between calculators and minicomputers. All of these figures assume floating-point operands.



3. Memory costs. Although calculator and computer memory costs are byte for byte about the same, the inefficiency with which calculators use memory to store data makes them much more costly if a great deal of storage is needed. Areas A, B, and C represent costs of calculators that use keystroke, formula, and Basic languages, respectively. Area D is for minicomputers.

key might automatically calibrate an instrument, and depressing another might cause a measurement to be taken. To save memory, some manufacturers sell read-only memories (ROMs) for special routines. In fact, at least one manufacturer even sells basic firmware in the form of separately marketed, preprogramed ROMs, which the user selects to fit his unique requirements and plugs into special slots in the mainframe. The ROMs provide various mathematical and statistical functions, as well as special input/output routines for mass-storage devices and other peripherals.

Relative speeds

Calculators are much slower than minicomputers. Although calculator speeds vary over a considerable range, generally they have execution times in the range of a few milliseconds to hundreds of milliseconds per instruction. Minicomputers, except for a few special instances, have instruction-cycle times of less than 5 microseconds. Of course, a simple arithmetic operation, such as addition, requires many instruction cycles in a minicomputer, but only a single keystroke instruction in a calculator. So the actual difference in execution time for the complete operation is not as large as might be expected. Nevertheless, computers have speed advantages for complex numerical calculations. This fact, which eliminates calculators from consideration for high-data-rate applications like communication processors, does not preclude their use in many measurement and control tasks, in which data is often limited in both amount and speed.

Memory characteristics

Calculator memories usually have one of two basic structures. The basic element in each is the keystroke, represented by a binary code, though the codes are generally not available to the user for bit manipulation as in minicomputers.

The first memory structure distinguishes between register memory, where data is stored, and step memory, where programs are stored. Various size combinations are available, ranging up to several thousand program steps and several hundred registers. The advantage to the user is the freedom to select the right memory size for his needs, but the complication of interfacing two separate memories to the external world is a distinct drawback.

The second type of calculator memory structure uses the same space for both instructions and data and may be conceptualized either as a string of instructions or as a string of registers. Basic machine configurations range from 100 to 200 registers up to options providing 10 times as many registers. Such a structure makes for easier interfacing but uneconomic data storage—it takes between eight and 14 keystrokes to specify a single data number, whereas an instruction can be specified by a single keystroke. This contrasts with minicomputer memories in which an instruction needs one or two words and floating-point data only two or three words.

For calculator users who require extra storage, several mass-storage devices are available. Most common are tape-cassette transports, which may be built into the mainframe or bought as separate units. They extend storage into the tens of thousands of instructions. Often, however, they do not use the tape-storage medium efficiently. One manufacturer advertises the ability to put 48,000 instruction steps on one 300-foot cassette tape—a sad contrast to the 150,000 to 200,000 bytes that may be stored on the same tape when it is used with a typical minicomputer's cassette peripheral.

The second type of mass-storage peripheral that is beginning to be used with high-level programable calculators is the disk drive. Disk drives range in size from 1.2 to 4.9 megabytes, consistent with many minicomputer systems, and typically allow the user to access files by name, all the required directory lookup procedures being handled by hardware. Minicomputers, on the other hand, often require relatively bulky software packages to achieve the same performance.

The bottom line

Comparing the costs of programable calculators and minicomputers is made difficult by differences in the principal cost-determining factors for the two classes of devices. For calculators, base prices are set by language level and memory size. Under $2,000 is the starting price for keystroke-language machines, between $2,000 and $4,000 the least paid for formula-language machines, and $5,000 to $7,000 has to be paid for machines that respond to Basic. Typical minicomputer base prices are in the range of $5,000 to $10,000, and different language levels merely represent different software packages, which usually cost less than $500. (All these figures are based on machines with a minimum-size central processing unit and one peripheral device with hard-copy output.)

Comparison of memories above and beyond minimum configurations requires great care. Byte for byte, the cost of calculator and minicomputer memory is about the same: 25 to 33 cents per byte. In actual applications, however, the tradeoff between register memory and program memory, mentioned earlier, becomes important (Fig. 3). Once the need for numeric data storage increases beyond 1,000 registers: calculator costs skyrocket. Minicomputer costs, on the other hand, stay fairly stable until more than about 40,000 bytes are needed. More than 8,000 bytes of quick-access mainframe memory are seldom available in a calculator, although a few machines with minicomputer-like architecture may provide as much as 32,000 bytes.

Input/output features

Important input/output considerations include character-processing capabilities, character codes, data rates, and transmission modes. To a minicomputer, a character code is just another bit pattern and can therefore be logically altered or tested and be packed together by shift instructions for efficient storage. The code may also be freely transmitted back and forth to external devices. In calculators, the emphasis on numerical processing diminishes their ability to handle nonnumeric data. To process alphabetic data, as opposed to merely outputting preprogramed titles or legends, a Basic-level machine with string variables as an option is generally needed. Short character strings may be processed on lower-level machines with special programing provided by the manufacturer, but this is cumbersome at best.

As far as the data codes themselves are concerned, two conflicting trends are evident. On the one hand, the American Standard Code for Information Interchange (ASCII), intended for data communications, is widely used. Appropriately enough for general communications, it enables a wide variety of messages to be interchanged. But the requirements of instrument systems are generally limited to just the 10 numeric digits plus a few control characters, so that binary-coded-decimal (BCD) codes are also widely used. Consequently, a suitably broad line of interface products must contain both BCD and ASCII capabilities.

For calculators, a rough upper limit on the data rates of interfaces is 1 kilobyte per second. This rate is sufficient to handle user interactions, typical peripherals (printers, tape-cassette transports, and so on), low-speed communications channels, and most instrument interfaces. Still, hardware offering higher rates may be found: one manufacturer claims a 90-kilobyte transmission rate for a disk system with 512-byte blocks.

For high-speed data transmission, a minicomputer is necessary. In minicomputers, data-transfer rates through the working registers top out at 100 to 150 kilobytes per second. Much higher rates may be obtained by using direct memory access (DMA), which transfers data without the intervention of the CPU. With DMA, data rates of 1 to 2 megabytes per second may be achieved.

One serious shortcoming of calculator input/output structures is the lack of a hardware-interrupt capability, although appropriate software can compensate for it in some cases. The lack poses no serious problem for many automatic testing or production-control applications, because of the sequential nature of the tasks—that is, step one must be completed before step two can start, so there is no risk of overlap. However, as calculator control expands and starts to encounter different or more complex situations, calculator manufacturers will have to provide hardware-interrupt capability.

Modes of data transfer may be classified as synchronous or asynchronous, and as parallel or serial. Synchronous communication is to be avoided. Its need not just for common data rates but also for common clocking between the mainframe and the peripheral seriously complicates interfacing, since peripherals seldom, if ever, operate at processor speeds. While a few calculator manufacturers have fallen into this trap, most rely on asynchronous communications. In the asynchronous mode, data is never transmitted unless the readiness of both devices has been established, usually by some form of handshake procedure.

A byte may be presented to an external device in two basic ways. All the bits may be transferred at once on different lines (parallel), or they may be transmitted one at a time on a single line (serial). The former method is commonly used between local system components, while the latter is useful for long-distance communications, where the cost of separate conductors would be prohibitive. Both schemes are available in minicomputers and calculators, but parallel transmission is preferred for automated instrumentation systems. □

Part 2: How to build an automated system around a programable calculator

The present lack of a standard interface between calculators and programable measurement and control devices may soon be remedied; off-the-shelf modules make it easy to customize systems

by P. David Fisher and Stephen M. Welch,
Michigan State University, East Lansing, Mich.

☐ By costing much less than a minicomputer, the programable calculator opens up whole new areas of measurement and control to automation. Less obviously, it can also be used to upgrade automation instrumentation systems that at present employ inflexible hard-wired logic or relatively inflexible paper tape.

In either situation, the system designer will run into the problem of how to interface the calculator to various programable instruments. His other requirements—for an improvement in calculator efficiency, maybe, or in the over-all system's data communications—are easier to satisfy, thanks to the availability of a large variety of off-the-shelf electronic modules. In fact, the interface problem in calculator-based automated instrumentation systems is so crucial that a discussion of it will precede descriptions of three typical systems and of the modular hardware that can be used to customize them at a reasonable cost.

System costs are still made too high by the lack of a good standard interface between their various measurement, recording, communications, and control elements. The problem is elementary. If two or more programable elements are to exchange information across an interface, the input/output structure of each must be compatible with respect to the cables and connectors, the signal levels, the timing of the signals, the logic convention, the types of control messages, the sequencing and interpretation of these messages, the data format, and so on, that each of them employs. But manufacturers of programable-system components have not yet been able to agree collectively on a set of interface standards.

In fact, many companies have not yet faced these issues within their own product lines. One manufacturer, for instance, offers a package composed of a programmable calculator and a graphic terminal which require an interface modification kit—a $700 accessory—to make their I/O structures compatible.

The issues involved in selecting a set of interface standards are complicated. Nevertheless, just such a set of standards is being drafted by a committee formed by the International Electrotechnical Commission.[1] One of its proposals applies to automated instrumentation systems, or portions of them, that use the byte-serial bit-parallel representation of digital data and in which the data rate across any interface-signal line is no greater than 10^6 bits per second. Systems based on programable calculators fulfill these criteria, and calculator I/O structures may therefore ultimately conform to this standard. Hence, before considering specific applications of calculator-based systems, let us review the proposed interface standard as it applies to calculator-based measurement and control systems.

A bus-oriented system

The standard describes an I/O structure that, for a calculator-based system, is organized around buses, with each component being hard-wired to every other component in the system (Fig. 1). Sixteen signal lines are grouped into a data bus, a flag bus, a transfer bus, and a control bus.

The data bus is a set of eight signal lines (DIO 1 through DIO 8). Four distinct classes of data—encoded address data, basic data, control data, and status data—

Closing the loop

The authors will be available to discuss these articles with readers between noon and 5 p.m. (Eastern Daylight Savings Time) on May 20, 21, and 22. Telephone them at (517) 355-5241.

are transmitted over these lines. Because data is transmitted serially as 8-bit bytes, such an interface structure is referred to as a "byte-serial bit-parallel programable-instrument interface."

The two signal lines of the flag bus are INT (interrupt) and EOS (end of string). They are used to establish which of the four types of message is being transmitted over the data bus in any given time interval. The EOS control line is also used to identify the last byte in a given message.

In principle, any element connected to the transfer bus is capable of being a source of data (talker) or a receiver of data (listener). For unambiguous communications there can be only one talker at any instant of time, but there can be any number of simultaneous listeners. The three transfer-bus signal lines that enable data to be exchanged asynchronously between an addressed talker and all addressed listeners are DAV (data available), RMD (refuse more data), and DNA (data not available). They are basic to the handshake process that transfers the data bytes between various system components (Fig. 2).

Data is exchanged as follows. When all of the listeners are ready to accept a data byte, RMD is set in the high state and DNA in the low state. The talker drives DIO 1 through DIO 8 so as to present the desired data byte to be transmitted. When the data on the lines has settled down, the talker sets DAV low, indicating to the listeners that the data is valid and may be read. Once all listeners have accepted the data, DNA goes high, telling the talker to remove the present data from the lines and set DAV high.

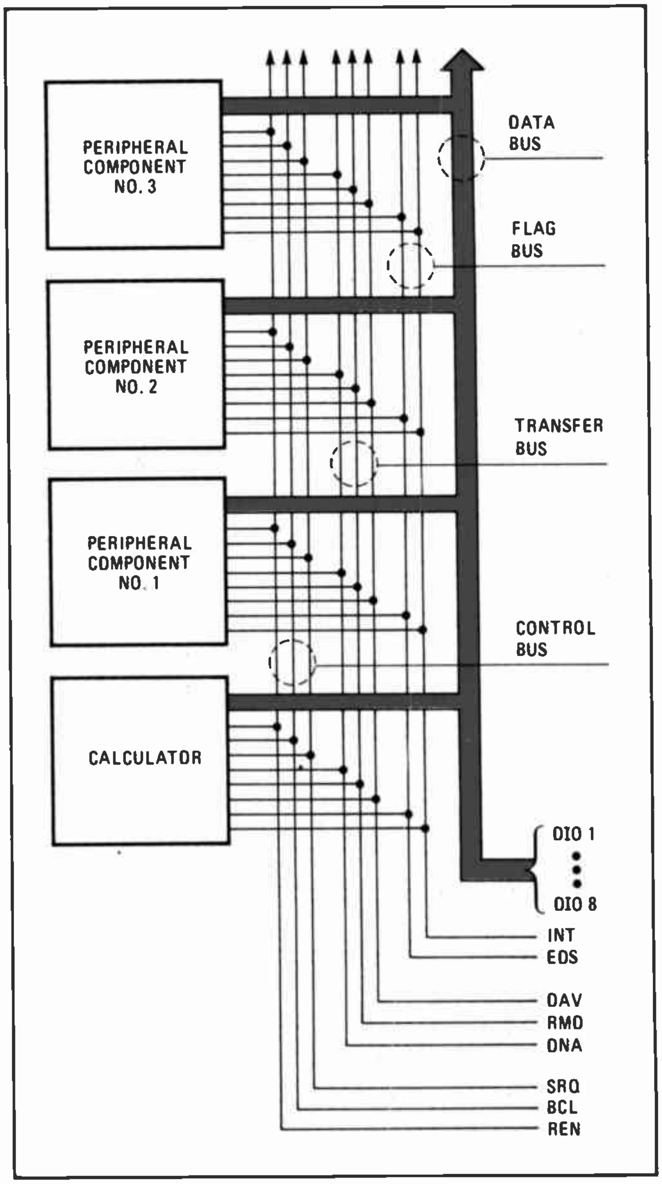
The fourth group of signal lines in the interface is the control bus. The three lines in this group are SRQ (service request), BCL (bus clear), and REN (remote enable). It is worth noting that the SRQ line would enable calculator-based systems, which lack any hard-wired interrupt capability, to operate under a form of software interrupt.

So far as the present draft of the proposed interface standard is concerned, the bus structure has only two physical limitations. At least 15 devices must be capable of being connected to the bus, and the total transmission-path length over the interconnecting cables must be at least 16 meters.

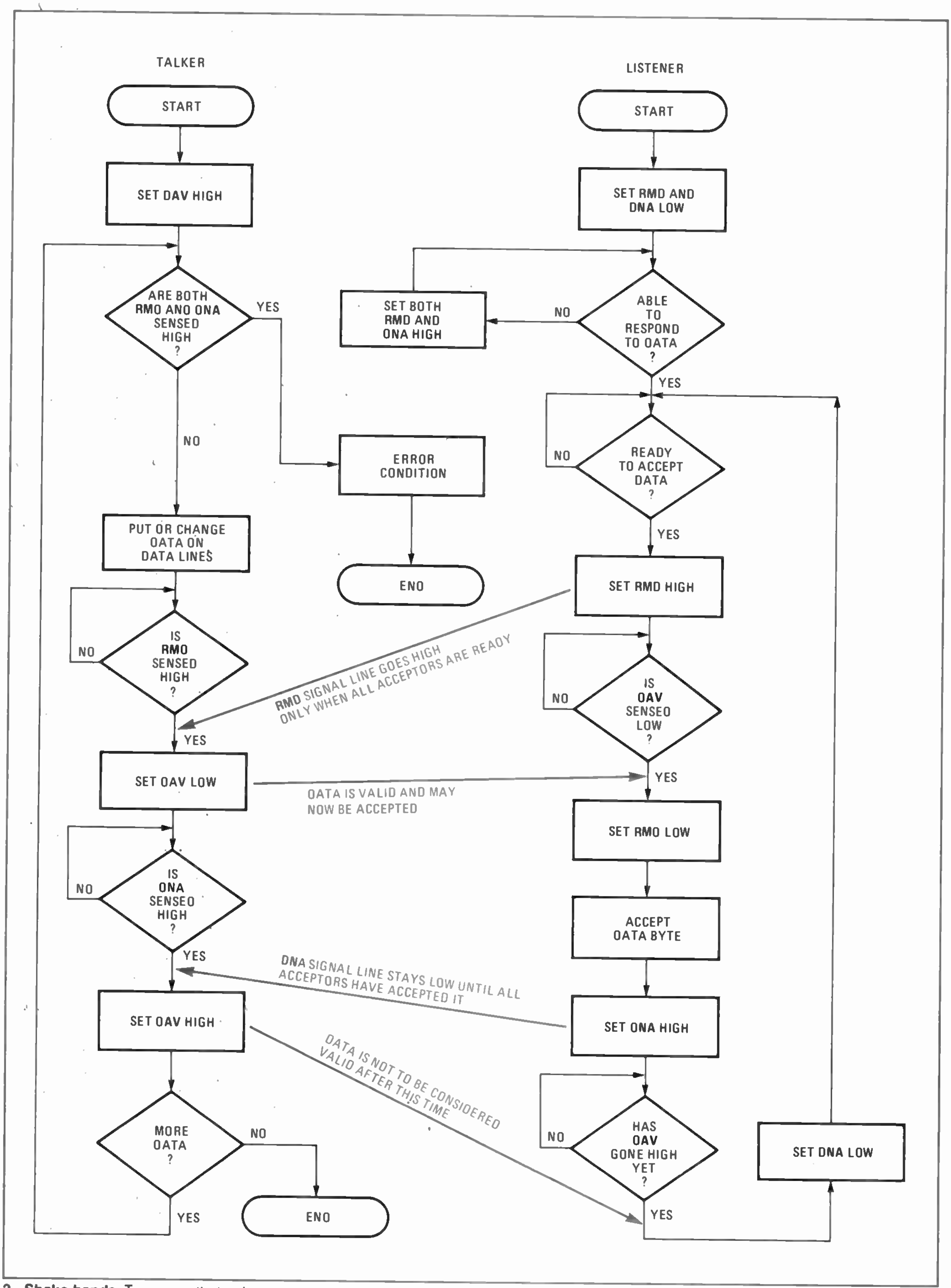
Systems applications

Although the diagram of Fig. 1 indicates the basic nature of the interface bus, it gives no hint of the wide variety of useful systems that can be built around it. In general, the calculator could fill the roles of system controller, on-line data processor, interface for interaction between the system and a human operator, and even supplier of a limited amount of data storage. Other components that can be connected directly to the bus include clocks, mass-storage devices, communications and display equipment, process controllers, and such process-monitoring devices as recorders, alarms, scanners, and analog-to-digital converters—all this in addition to the usual programable electronic measurement and stimulus instruments, like power supplies, signal generators, multimeters, frequency counters, and so on.

These basic components can be interconnected into



1. Bus structure. Proposed interface standard has all system components hard-wired to each other by means of a standard bus structure. Data transfer through the bus is of the byte-serial, bit-parallel variety, and is at rates of 1 megabit per second and below.



2. Shake hands. To ensure that only one system component "speaks" at a time, this handshaking procedure must be performed every time a byte of data is transferred. The DAV line is controlled by the talker, while the RMD and DNA lines are controlled by the listener (or listeners).

very varied automated instrumentation systems. The three examples that follow are: a test system, in which stimuli are applied to the device under test and its responses noted; a feedback system for controlling the temperature and humidity inside an environmental test chamber; and a remote data-acquisition system, which has no direct control over the devices that generate the data it is gathering.

An automated network analyzer

Engineers working with analog signals must routinely determine the transfer function of two-port networks, since it provides them with the information needed to predict the network response to any arbitrary signal. In the laboratory or on the production line, the transfer function is determined experimentally by sweeping the frequency of a test signal and then measuring both the gain (or insertion loss) of the two-port network and the phase shift between the input and output ports.

The Hewlett-Packard Co., Palo Alto, Calif., recently introduced a fully automated, calculator-based, network-analyzer system for making gain-phase measurements in the range of 50 hertz to 13 megahertz.[2] The basic system can be complemented by various peripherals—such as recorders or communications gear—if the user's application so requires. The calculator is the system controller and provides on-line data-processing capabilities, limited data-storage capabilities, and a convenient interface with the operator.

A good illustration of this system's performance capabilities is a filter-analysis problem in which such parameters as insertion loss, stop-band rejections, passband ripple, group delay, and delay distortion must be measured and displayed. A manual data-acquisition and -control system takes about 30 minutes to acquire the necessary raw experimental data, which then has to be analyzed to yield the parameters. In contrast, the calculator-based system acquires the raw data, extracts the parameters, and records or displays the results, all in less than a minute. The speed is limited neither by the processing capabilities of the calculator nor by the I/O data rates, but rather by the time required for the synthesizer, the analyzer, and the two-port device under test to reach steady state at each test frequency. In large-volume applications, a single calculator could simultaneously control and analyze data derived from several network analyzers.

Controlling an environment

Often, scientists studying a certain biological community isolate it in a laboratory chamber and then determine important causal relationships by carefully manipulating conditions within the chamber. An example might be the relationship between soil temperature and mortality rates of a certain insect species. Studies of this nature, along with field observations, aid in the development of efficient and effective pest-management strategies.

But the traditional hard-wired environmental-chamber controllers have three major deficiencies. Most of them do a very poor job of simulating natural conditions. Sunrise and sunset, for example, they imitate crudely by switching a light on or off. Secondly, they do not accurately simulate natural conditions in those cases where they must simultaneously control two or more interacting environmental parameters. Finally, although hard-wired controllers are not particularly expensive, they are very inflexible, and a new controller, or set of controllers, is typically needed for each experiment.

Atmar and Ellington,[3] two entomologists at New Mexico State University, recognized these problems, and in 1971 designed and built a calculator-based environmental-chamber-control system (Fig. 3). Through software, they control simultaneously the temperature and relative humidity of each of two environmental chambers. Their system comprises eight sensors, an analog scanner, an a-d converter, a digital demultiplexer, a set of output relays, a clock, and a calculator. The control system can maintain the temperature in the chamber to within ±0.3°F over the range of 40°F to 125°F and the relative humidity to within ±3% over the range of 30% to 95%.

From their first two years of experience with calculator-based measurement and control systems, Atmar and Ellington have derived three observations that can be generalized to other environmental-test chambers. First, because of the relatively long time constants associated with changing the temperature or humidity of a large chamber, the processing speed of a calculator is more than adequate for any practical situation. Second, a calculator-controlled system is at least as accurate as a hard-wired unit for the control of a single variable, largely because the system can be made to automatically recalibrate itself at regular intervals. (For the control of more than one variable, of course, the calculator-based system is expected to be vastly superior to hard-wired units.) Third, the calculator-based system competes very favorably with hard-wired controllers in cost because of its flexibility.

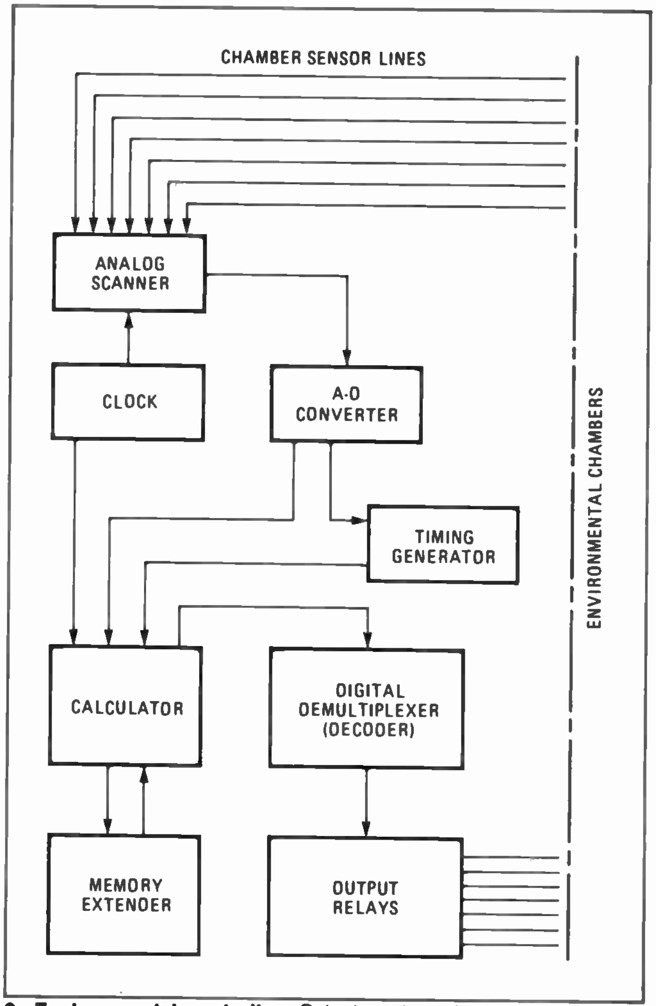
Arguments similar to these might be advanced to show that calculator-based monitoring and control system might be cost-effective in various manufacturing processes. The manufacturer of integrated circuits is an example.

Measurement at a distance

The final application example deals with the problem of data acquisition and data management. This total system comprises a central computing facility and several remote data-acquisition sites. The remote sites might be positioned throughout a production area where assorted quality-control data is being gathered, or they might be used to monitor inventories or perhaps discharges from a plant into either a river or the atmosphere.

Suppose a given application has the following system requirements:

- Data should be acquired automatically and stored in computer-compatible form at each remote site without needing the help of the central site.
- Data should be acquired at regular intervals throughout the day.
- Data should be acquired at any other time during the day when an operator requests it or a critical event occurs (for instance, when the discharge rate of a certain pollutant from a stack exceeds a predetermined thres-



3. Environmental controller. Calculator-based control system for environmental chambers can control more complex situations with greater refinement than hard-wired controllers. It also costs less in the long run because it can be used for many different experiments.

hold or when a temperature exceeds a preset limit).

- Data summaries should be transmitted to the central site at regular intervals and/or on request.
- The remote site should be capable of notifying the central site immediately if a critical event occurs.
- There should be a convenient interface for operator interaction and a simple procedure for the operator to follow in redefining specific data-acquisition tasks.

The calculator-based system of Fig. 4 meets these requirements. The system possesses three basic modes: an idle mode, a data-acquisition mode, and a communications mode.

The data-acquisition mode can be entered as a result of a command from an operator, or a command from the central site, or a signal from the real-time clock, or an alarm. In this mode, data is read and stored temporarily in the calculator along with the time of day. After all data is read, a new file is created and the information transmitted to the mass-storage peripheral. After the data transfer has been completed, the system returns to the idle mode.

The communications mode can be entered as a result of a command from an operator, or a command from the control site, or a signal from an alarm. Upon entering the communications mode, the calculator branches to any one of several different routines. If it enters the mode in order to dump data into the central site, the data is acquired one last time and written, along with the time of day, in mass storage, a trailer record is written at the end of the file, and data records are then transmitted to the central site. After data transfer is complete, the remote site returns to the idle mode.

These three examples demonstrate that calculator-based systems have important applications. The design engineer is limited only by the processing speed of the calculator and the availability of peripherals compatible with the calculator's input/output structure. And this latter problem will be eliminated if calculator and peripheral manufacturers offer a standard I/O structure such as the byte-serial, bit-parallel instrument interface currently under development by the International Electrochemical Commission.

Customization costs come down

The system designer who selects a calculator-based system can elect to interface with existing programable instruments, or he can go further and customize his system by drawing upon off-the-shelf electronic modules. His over-all needs will determine if the simpler approach is also the more prudent. However, customized systems are becoming more attractive each day as growing numbers of low-cost data-acquisition and data-communications function modules become available.

Four representative sets of such modules are: Signetics' 2535 universal asynchronous first-in, first-out buffer register; Analog Devices' STX1003, SRX1005, SCL1006 and SMX1004/SMC1007 serial-data-exchange modules; General Instrument's UAR/T universal asynchronous receiver/transmitter; and Datel's DAS-16 modular data-acquisition system.

The Signetics 2535, an asynchronous buffer memory consisting of 32 8-bit words, basically augments the data-handling capabilities of the calculator itself. Both input and output can be either serial or parallel and have a data rate of dc to 1 MHz in either mode of operation. The unit is fully compatible with the proposed byte-serial, bit-parallel interface standard and in fact uses the same three-wire handshake for inputting and outputting data.

Communications considerations

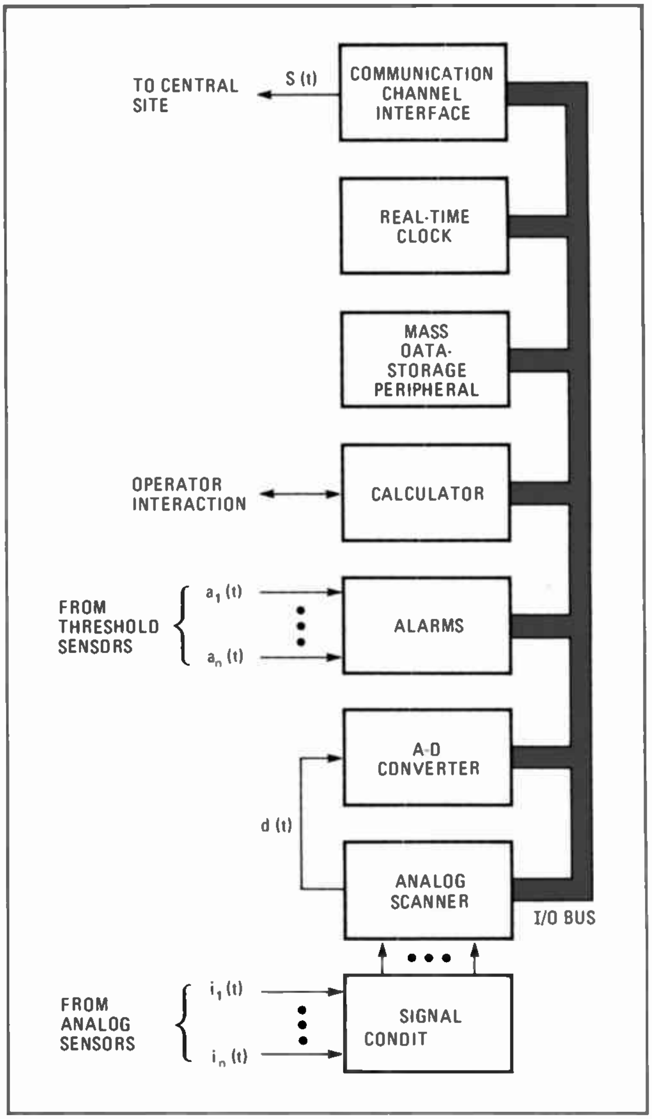
One important application of a calculator in conjunction with Analog Devices' serial-data exchange (Serdex) modules would be with the calculator serving as a digital terminal in a control room and selecting, monitoring, and controlling remote analog processes. Such a system could operate with or without a man in the loop. With the Serdex modules, byte-serial, bit-parallel data may be conveniently transformed into the asynchronous serial ASCII format used in many standard peripherals. Because of their control-character codes, the units seem intended primarily for Teletype or computer-based systems. However, these codes can be modified so that they are fully compatible with calculator-based systems, as well.

General Instruments' universal asynchronous receiver/transmitter will help improve data communications in, say, a hostile factory environment. It can accept binary characters from either a peripheral device or a calculator and will receive/transmit these characters with appended control and error-detecting bits. All characters contain 1 start bit, 5 to 8 data bits, 1 or 2 stop bits and either odd, even, or no parity. Even the transmission rate may be externally selected.

When a programable instrument takes more, or more elaborate, measurements than an application needs, yet several measuring devices are needed, Datel's data-acquisition module may be the answer. It contains in one package an analog scanner (eight or 16 channels), a sample-and-hold amplifier, an a-d converter (8, 10, or 12 bits), and a system controller that includes all the control logic needed to interface the unit with a byte-serial, bit-parallel calculator I/O bus.

As the use of calculators in measurement and control systems expands, a special-purpose calculator may be expected to appear. It will not be a mere desk-top instrument but, through serial data links, will extend its influence over large areas. Different versions will be rack-mountable or ruggedized to adapt them to different environments.

There is also no question that instrumentation-oriented calculators will benefit from computer technology. Features like interrupt processing, previously limited to computers, will appear. Also calculator I/O structure will continue to evolve, to permit simpler and more efficient routing of information within the system, as well as to peripherals. Moreover, as users committed to these systems expand their planning horizons, upward compatibility within calculator product lines will become more important. □



4. Data acquisition. Calculator-based remote data-acquisition system gathers and stores data automatically for transmission, on command, to central site. System is smart enough to alert central site when an emergency develops.

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ANALOG DEVICES

EE performance evaluations win more praise than blame

Whether in supervising or subordinate positions, engineers who responded to *Electronics'* questionnaires agree on criteria for rating performance but differ on promotion systems

by Gerald M. Walker, *Associate Editor*

☐ Freedom to choose the direction of one's career—up the pay scale as an engineer or upward into management—is just too limited. So feel most engineers in supervised positions who replied to a March 7 *Electronics'* questionnaire on performance evaluations, though they also generally believe they are evaluated fairly.

But a good three quarters of responses to the second questionnaire, for supervisors of engineers, maintain that promotion systems work "fairly well." Only 12% of this group consider they work "poorly."

This difference in viewpoints runs through several other responses, notably those concerning competence to judge performance and what to do about below-par performance. But unanimity exists to a surprising degree on the fairness of evaluations, what ought to be evaluated, and even on the merits of upward evaluation of the supervisor by those under him.

To judge by this sampling, formal performance evaluations are virtually universal. Moreover, just over three quarters of both groups say these ratings are done annually. In addition, some form of person-to-person review of the evaluation is generally practiced.

Ninety-five percent of the supervisors actually show the written evaluations to their subordinates. Not quite jibing on this score, but generally in agreement, some 74% of supervised EEs say they see their own evaluations, 59% add they sign or initial the reports, and 42% reply that they add comments of their own to the evaluations.

Significantly, 95% of the supervisors reporting use of formal, written evaluations indicate that the format for measuring engineers is devised, not by the engineering department, but by the personnel department. Thus, EEs are often judged on general work habits.

Satisfaction with the way performance evaluation is working is widespread but far from universal. For instance, over 60% of nonsupervising engineers reply their bosses are doing "a reasonably good job" of evaluating performance. And over two thirds of the supervisors indicate that they evaluate differently, i.e. better, today than the way they were being evaluated as beginners. Most state that they are more objective and stricter than was the case in the past.

Nevertheless, some comments from the nonsupervisory EEs reveal discontent. A senior systems analyst in data/voice communications complains, "The boss remains aloof from the group, unaware of day-to-day operation. He's also unaware of his men's career goals. He had no idea I had a master's in management with a career goal of management. In his evaluation he stated I wanted to stay on the technical ladder."

Commenting on how fair evaluations are, a 34-year-old senior engineer remarks, "Fair? Well, yes. But competent, no. I'm a better man than my boss—my success lies in working quietly around him. So how does he evaluate that?"

Concurring, an EE for a company in digital signal-processing systems says that his boss "doesn't do much of anything except play ping-pong."

Most other complaints about the fairness issue center around technical competence. After all, if supervisors don't understand engineers' individual assignments, some doubt must arise over their ability to rate performance objectively. In addition, a couple of EEs wonder if they are being blocked from doing more and better work by the inability of their bosses to make full use of their knowhow. One engineer, in fact, confides that because of the trifling assignments he gets, he is working to only 20% of his capability and doesn't understand why no one has

Who responded

Engineers in supervised positions who responded to the questionnaire generally had about five to 10 years of experience. Most were 26 to 35 years old, and just 21% were over 40.

As for the supervisors, an equal percentage of responses came from those aged 31 to 35 and 41 to 45—24% each—and 22% were over 46. The majority had up to 15 years of experience.

Most of the supervised worked at companies in computers, components and space and aircraft, in that order. The supervisors came mainly from communications, radar, and space and aircraft firms. However, no single product category claimed more than 15% of the total, so that the response was spread fairly well across all types of manufacturers.

The two coasts dominated the geographical makeup of the sample, with most respondents located in California and New York.

noticed the situation. A few others made similar observations.

For their part, the supervisors comment that they are generally doing a better job than was done in the past. A semiconductor-company manager points out, "I evaluate performance against preestablished and negotiated [with the individual] goals." Another military-products supervisory EE adds, "I am much harder [than his previous bosses] now since I feel that I know most of the qualities needed to perform the work that I manage."

Th engineering section manager for a tape-recorder company states, half jokingly, "Even with my best engineers I always find some weak point to discuss. My supervisors always found me nearly 'perfect.' "

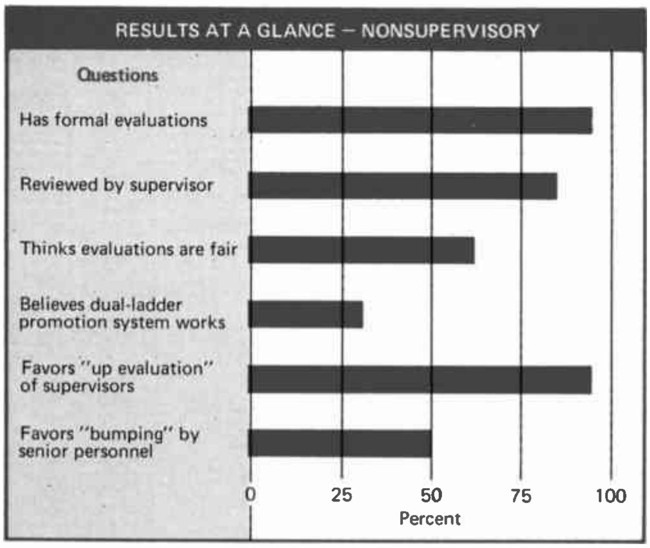
Both sides of the coin

Some of the respondents, who both evaluate and are evaluated, filled out both questionnaires. In this group a slightly different picture of the effectiveness of engineering promotion emerges. On the nonsupervisory portion of the questionnaire, a resounding majority agree there is not enough opportunity for choosing a technical or management career ladder. But, with their supervisors' hats on, half of this same group report that the promotion system is working "poorly." Thus, those EEs who considered the promotion system from both above and below lean more toward the negative view of promotion than the supervising-only group.

Comments on the dual-ladder promotion system from this dual-role group suggest that the management path is their only path to advancement. It appears that some of those in the position of giving and receiving formal evaluations are aware of being on a management track and regret it. As one communications-equipment designer sums it up, "We have the dual-ladder system, but some ladders are more equal than other ladders, that is, the management ladder offers a bit more opportunity than the technical ladder."

Should evaluation be a two-way street?

While an understandably high percentage of nonsupervisors (92%) favor "up evaluation" of their managers' performance, a surprisingly large number of supervisors (64%) agree that subordinates should evaluate their bosses. Asked to weigh the different aspects of a manager's performance, over half of the nonsupervisors check technical and administrative performance as of equal importance. Of the remainder, a high number select administrative capability over technical performance. There's a certain amount of ambivalence on this point—many complain that their superiors should have the technical capacity to understand a subordinate's work yet expect their bosses to concentrate on administration tasks with equal vigor.



"We don't have 'up evaluation,' but we should," a Southeastern respondent writes. "If anonymity can be preserved, it doesn't have to go any higher than the immediate supervisor, need not be seen by upper management."

A veteran of 22 years in engineering echoes the feeling of many others on the management side when he states that he would like to know his shortcomings and good points as a manager from the people he evaluates. However, "I don't ask for it [upward evaluation]," an X-ray instrumentation firm executive moans, "but I get it anyway—they tell me when I'm wrong."

"Too many managers become upward-oriented only. Evaluation by subordinates could vastly improve the quality of supervison as well as total output," a manager for a Midwest company suggests.

Disagreeing, an Eastern engineering department manager scoffs, "Evaluation by subordinates will let a manager look for popularity votes. A popular manager is not necessarily a good manager."

And, reflecting the orientation of an employee in Government contracting, a defense agency supervisory engineer concludes, "Although I think they [subordinates] will fear reprisal, the evaluation will bring problems to light that would not otherwise be discussed."

What's being rated and rewarded

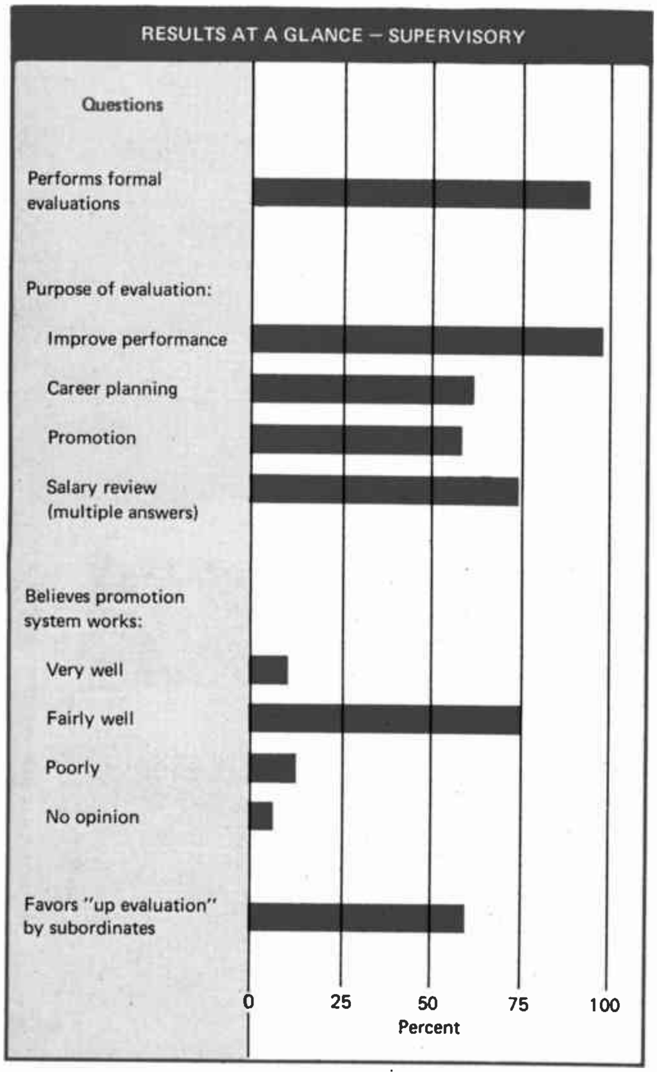
One subject on which supervisors and nonsupervisors agree wholeheartedly is the most important performance characteristics to be rated. Both list technical performance or capability and ability to get a job done properly as the two most important criteria (see "What managers should rate," p. 112). Supervisors add a few others, including self-improvement and motivation, ability to work with others, and adaptability.

Under the heading of getting the job done fall a number of related job qualities, such as quality of work,

What managers should rate

Both supervisors and supervised were asked to list the most important criteria for judging engineering performance. Here, side by side, are the most-mentioned characteristics, in order of importance:

Supervisors	Nonsupervisors
Technical performance, capability	Technical performance
Meeting objectives and schedules	Goal achievement
Self-improvement, motivation	Future potential
Ability to work with others	Self-development
Dedication, dependability	Communication



quantity of work, ability to meet time schedules and cost constraints, as well as willingness to accept responsibility. Several readers also add that contribution to the company's growth as well as to the individual engineer's potential is an important checkpoint. A few young EEs point out that, for now, the most important aspect of their job performance is the ability to learn and only later will it become contribution to the design effort.

The main purpose of employee evaluations, say 93% of the supervisory respondents, is to improve performance. However, almost three quarters also list salary review as an important reason, and two thirds include career planning as another major goal.

Promotion decisions are often considered the most important objective of an evaluation. But they do not get quite as many mentions; only three out of five supervisors stress them.

And what happens to an EE whose performance is under par? The most common course of action, according to supervisors in this sampling, is to explain and discuss deficiencies with the engineer and attempt to find the reasons. More important, they report, is to define an improvement program and plan a course of action. Some feel it's their responsibility to change the job environment, transfer personnel, or at least create an opportunity for improvement.

Low on the list of responses are punitive measures such as those that limit merit increases and set a time limit for improving performance. Judging from the comments of nonsupervisory personnel, however, these steps are more usual than the supervisors care to admit. In fact, a few point out that cuts in pay raises are the most important reflection of their performance.

Still, one young engineer for a computer company proposes that EEs should get pay bonuses in recognition for outstanding performance and be docked in pay for a short time as a result of unsatisfactory performance. Much more common are complaints about not receiving high enough merit raises, no matter what the performance rating system, thanks to the wage freezes imposed on many companies.

Layoffs and bumping

The practice of dealing with layoffs by moving senior engineers to lower-level jobs and bumping out junior employees is not directly related to performance evaluations. But readers were asked their opinions of this way of retaining senior personnel, albeit at lower wages, during employee cutbacks.

The nonsupervisory engineers are almost evenly split on the issue. Half favor "bumping," 44% don't, and 6% have no opinion. Ordinarily a vote in favor of bumping indicates the presence of older EEs among the respondents, but this was not the case here. Over 60% of the nonsupervisory EEs that favor bumping are under 35 and have less than 10 years of working experience.

In addition, comments favoring bumping often come from EEs in their early 20s. One of the strongest statements comes from a 23-year-old West Coast EE who contends, "I agree [with bumping] to a point. After 20 to 30 years at a company, I think that the company has a moral obligation to the person to help him as much as possible."

An aircraft-company engineer, however, points out that there are dangers to the individual in bumping, even if he does retain a job. He states, "In the aerospace industry, demotions in bad times bump managers back to being engineers. A manager cannot devote his career to management, because when demoted he becomes an obsolete engineer. If he tries to keep up in engineering as a safeguard, he neglects management."

Providing a balanced view, a 50-year-old guidance and control systems engineer opines, "From a personal standpoint, I would prefer bumping. However, new lower-priced talent with the latest technological capability must also get its day if the company is to perpetuate and be able to compete."

Supervisors were asked how they choose those who are terminated in layoffs, and most list those with the lowest performance as of least value to the company, department, product line, or team effort. But 21% mention that they base termination on seniority and high salary, as well.

Taking a militant stand, a project manager for a California aerospace firm comments: "None of our jobs is really safe until engineers organize a professional association to protect ourselves from layoffs. We need an association that could also tell management how we want to be evaluated and when." □

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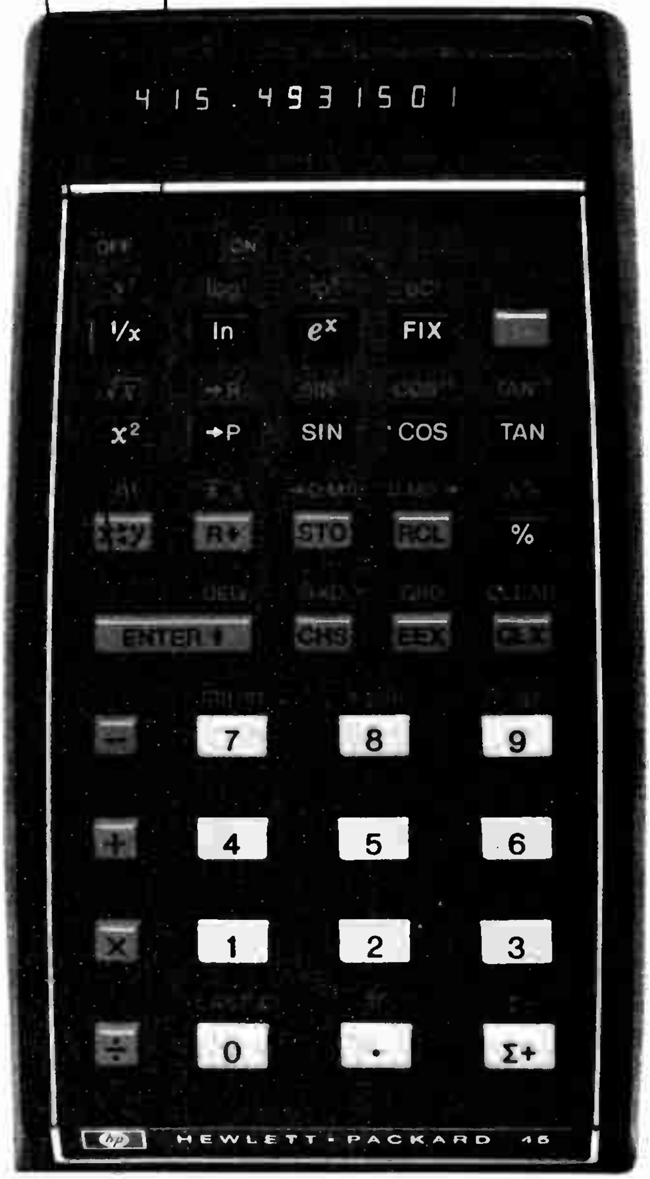

In 1928 a Polish mathematician, Dr. Jan Lukasiewicz, invented a parenthesis-free but unambiguous language. As it's evolved over the years it's come to be known as Reverse Polish Notation (RPN), and it's become a standard language of computer science.

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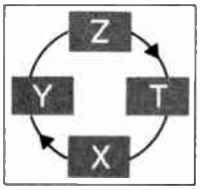

It offers a 4-Register Operational Stack that saves intermediate answers and automatically retrieves them when they are required in the calculation.

3.

It lets you store up to nine separate constants in its nine Addressable Memory Registers.

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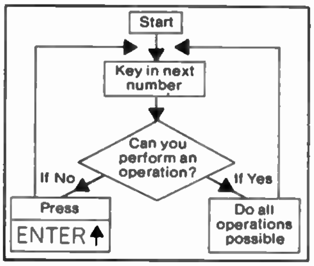

It demonstrates the superiority of Dr. Lukasiewicz' language by comparing it to other calculators' systems on a problem-by-problem basis, and it explains the algorithm shown left which lets you evaluate any expression on a calculator that uses RPN and an Operational Stack. This booklet is must reading for anyone seriously interested in owning a powerful pocket-sized calculator.

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THERMAL DESIGN PART 6

Network analog maps heat flow

Equivalent lumped-parameter calculations by the finite-difference method resolves thermal factors early in the design cycle

by Carl J. Feldmanis, *Air Force Flight Dynamics Laboratory, Wright-Paterson AFB, Ohio*

☐ It isn't easy to predict thermal conditions of an electronic system at the drawing-board stage. But knowledge of heat factors is crucial if a designer is to curtail the endless prototyping hours, which run up engineering costs. He must be confident that no temperature in the system will ever rise above some critical point. If it does, performance suffers, and devices fail. A well-engineered thermal system demands, then, that the designer have the analytical tools he needs to predict the thermal performance at every critical point.

A designer may approach thermal analysis from several directions. He may have designed a structure, has assumed a certain ambient temperature, and wants to check that no temperature in a device junction will exceed a critical value.

Or perhaps he may assume certain device temperatures and wants to compute the maximum thermal-resistance values that can be tolerated along certain thermal-resistance paths. Regardless of which variables are chosen as the dependent ones, the fundamental equations remain the same.

Fortunately, an effective method, called the finite-difference technique, is growing in popularity for solving such heat-transfer problems. The approach is to treat thermal relationships as analogs of electrical-network elements.

To proceed with this method of analysis, the designer first partitions the physical system into a number of subvolumes and places a node at the center of each volume element. Then he interconnects all nodes with the appropriate thermal impedances to simulate the flow of heat.

Thus, the thermal system takes on the appearance of an electrical network, and the designer can mobilize all the well-known methods for solving electrical networks, such as Cramer's rule, matrix inversion, and reduction by determinants.

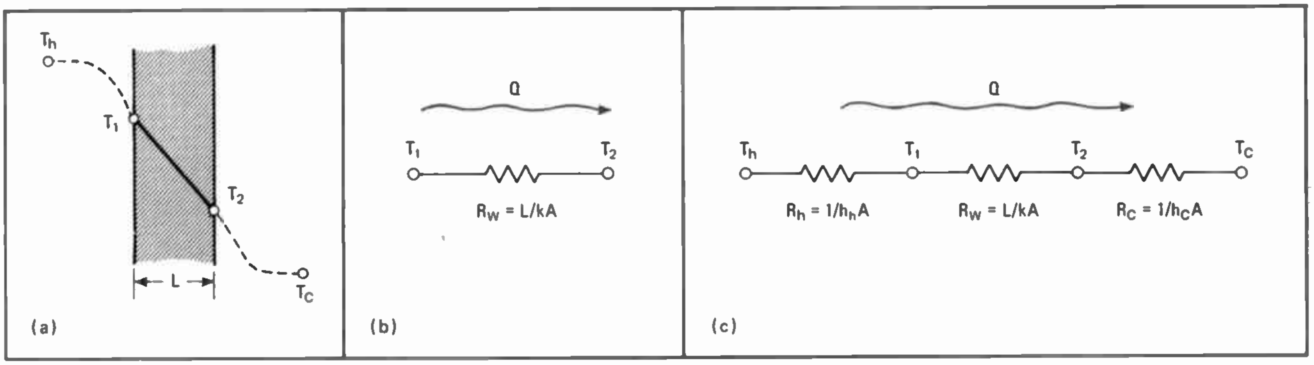
The strength of the finite-difference approach presented here is that it enables a designer to form a circuit model of this thermal system and then vary resistances, power levels, and temperatures at will to achieve a satisfactory design. The network model need not be planar. It is crucial, however, for the designer to make sure that enough temperature nodes are selected so that the model becomes a workable approximation of the actual thermal system.

Computer simplifies calculations

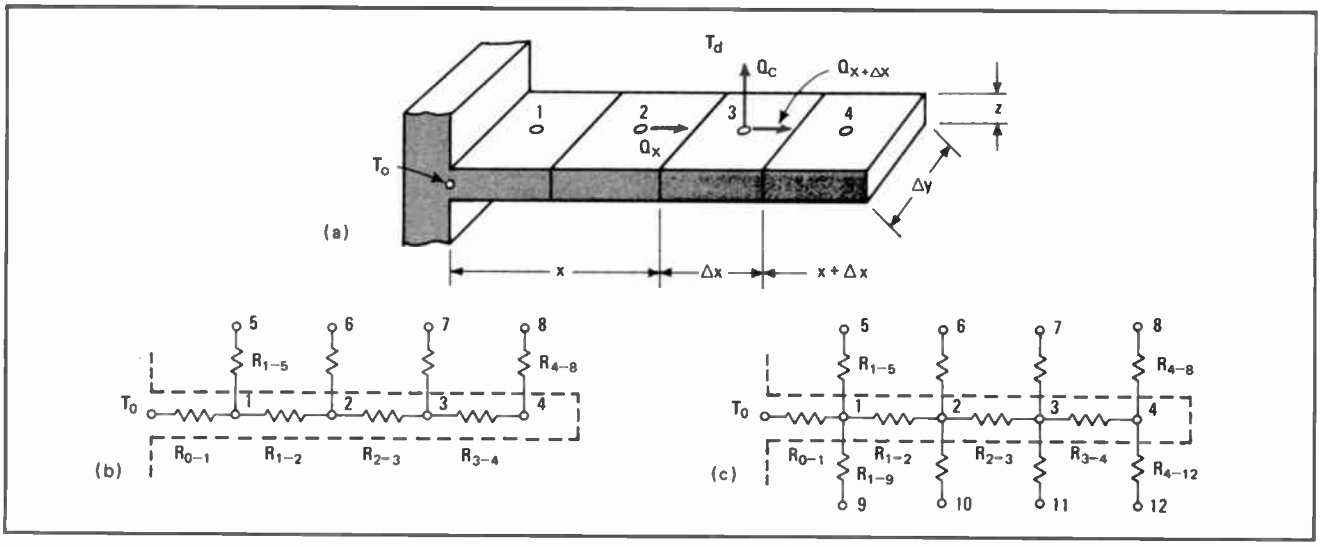
A computer solution begins by converting the physical system into a network consisting of nodes connected by thermal impedances.[1] All the resistances and capacitances of the system are calculated and then presented in a form acceptable to the particular computer program.

Using this lumping process implies that the lump or node is at a uniform average temperature. By proper selection of the node size, any degree of accuracy can be obtained.

Program capacity should be considered, as well as expected temperature gradients and machine time. Unfortunately, there are no general rules for assigning the right volumetric size to each node. This consideration, then, becomes a matter of engineering judgment that improves with experience.



1. Willing wall. A planar surface of arbitrary area and thickness is the simplest geometry encountered in heat transfer (a). A resistor becomes the equivalent circuit element (b). Adding resistors for the convective interfaces (c) completes the circuit to the adjoining ambients.



2. Fine fin. A thin wall projecting from a surface is an efficient convective interface (a). Network shown in (b) represents heat flow if convection occurs at top surface only. Adding resistors as in (c) simulates heat flow from top and bottom.

The heat-flow/current analog stems from a fundamental Kirchoff-law expression: the sum of the energy entering (or leaving) a node is zero:

$$\Sigma_i Q_i = 0$$

There are also terminal equations that relate the temperatures at the nodes to the heat flow between nodes. The flow is represented graphically by thermal impedances, or, in the steady-state case, thermal resistances are connected between the nodes.

The most time-consuming step is to convert the physical problem to a network equivalent, and a good starting place is to examine heat transfer in a simple geometric case—the plane wall.

Through the wall

Heat flow through a plane wall is analogous to current flow through a resistor. Figure 1 depicts flow from the warmer region at left to the cooler region at the right. The flow can be expressed as:

$$Q = (kA)(T_1 - T_2)/L$$

or

$$Q = (T_1-T_2)/(L/kA) = (T_1-T_2)/R$$

where Q is the heat-transfer rate in British thermal units per hour, k is the thermal conductivity in BTU/[(h)(ft)(°F)], T_1 and T_2 are the wall temperatures in °F, and L is the wall thickness in feet. L/kA is thermal resistance in (°F)(h/BTU).

Figure 1(b) is the circuit equivalent of the plane wall. In Fig. 1(c), two thermal resistors have been added to account for convection transfer at each wall. Note that the heat-transfer coefficients may be different (h_h, h_c), depending on the coolant flow and whether it is turbulent or laminar.

The convection-heat transfer to and from the wall can be expressed by the following equations:

$$Q = (T_h - T_1)/(1/h_hA) = (T_2 - T_c)/(1/h_cA)$$
$$= (T_h - T_1)/R_h = (T_2 - T_c)/R_c$$

Expression L/kA is called the conduction resistance, and expression 1/hA is called the convection resistance. In any case involving heat transfer between two points at temperatures T_1, T_2, where $T_1 - T_2 = \Delta T$, the heat flow (analogous to Ohm's law) can be expressed as the equation:

$$Q = \Delta T/R$$

The relationship between the temperatures and the heat flow, therefore, for the plain wall with convection can be expressed as follows.

$$Q = (T_h - T_c)/[(1/h_hA)+(L/kA)+(1/h_oA)]$$
$$= (T_h - T_c)/(R_h+R_w+R_c)$$

A thin fin

The fin geometry is common in both natural and forced convection-cooling hardware because it offers a large surface area for convective-heat transfer. A fin attached to a hot wall or some heat-generating source is shown in Fig. 2. Heat from the hot wall flows along the fin, and from there, by convection, to the ambient air or other ultimate heat sink. Under steady-state conditions, heat entering the element must equal the heat leaving the element, or:

$$Q_{in} = Q_{out}$$

and

$$Q_x = Q_{x+\Delta x} + Q_c.$$

where Q_c is heat lost by convection.

Heat entering the element at position x can be expressed in accordance with Fourier's law:

$$Q_x = -kA/\Delta x\,(T_b - T_a)$$

where $A = (Z)(\Delta y)$

Similarly, the heat leaving the element at position $x + \Delta x$ will be:

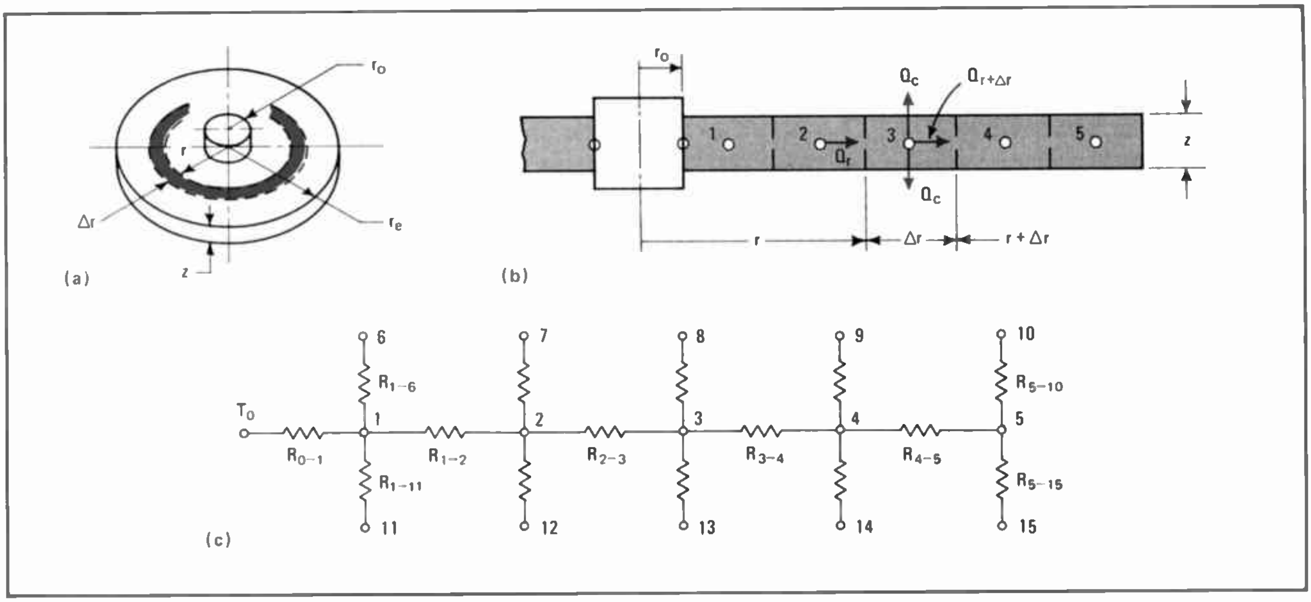
$$Q_{x+\Delta x} = -kA/\Delta x\,(T_c - T_b)$$

Heat leaving the element by convection will be

$$Q_c = (h\Delta A)(T_b - T_d$$

where $\Delta A = \Delta x(\Delta y)$.

A designer may want to solve such a problem for any



3. Cylindrical. Stacks of round, thin fins (a) dissipate heat efficiently. Analyzing designated concentric rings Δr wide (b) yields equivalent conduction resistors (horizontal) and convection resistors (vertical) arranged as shown in (c).

of several variables: heat flow in watts, temperature, or perhaps the heat-transfer coefficient (h). There are analytic techniques for the solution; however, solving a network analog is far simpler.

Figure 2(b) is the network representation of the fin when only one side of it takes part in transferring heat by convection; the other side and end are considered insulated.

Conduction resistances of the fin can be determined as follows:

$$R_{0\text{-}1} = \Delta x/2kA$$
$$R_{1\text{-}2} = R_{2\text{-}3} = R_{3\text{-}4} = \Delta x/kA$$

where $A = Z(\Delta Y)$.

Convection resistances are:

$$R_{1\text{-}5} = R_{2\text{-}6} = R_{3\text{-}7} = R_{4\text{-}8} = 1/hA$$

where $A = \Delta x(\Delta y)$.

If heat is dissipated by convection from both sides of the fin, then the circuit must be changed accordingly, as in Fig. 2(c). Thermal resistances are determined as in the previous example, except that half-thicknesses are assumed for determining the conduction resistances:

$$A = (Z/2)(\Delta y)$$

When heat is dissipated to the ambient air (assumed to be at constant uniform temperature) all the ambient nodes (5, 6, 7, 8, 9, 10, 11 and 12) can be combined into one node, which then represents the temperature of the ambient air.

A circular fin of rectangular cross section is another effective shape for transferring heat to a surrounding ambient. Its design ensures a large surface area for effective convection to the ambient.

Figure 3(a) shows such a fin with the heat source assumed to be located at its center. The easiest way to analyze the flow is to divide the fin into concentric cylindrical sections, or rings, with equal concentric thicknesses, Δr, as shown in Fig. 3_b. The network shown in Fig. 3(c) is a circuit equivalent when heat is convected from both the top and the bottom surfaces. Heat loss at the edge has been neglected. However, it could easily be included in the analysis.

A cold plate

The air-cooled plate has an excellent capability to sweep large quantities of heat away from board-mounted discrete devices. The plate shown in Fig. 4(a) consists of equipment-mounting surfaces with finned air-flow passages attached for forced-air cooling.

Figure 4(b) shows the network for both the plate section and the air stream. Note that resistors $R_{2\text{-}3}$, $R_{4\text{-}5}$, etc., have been drawn to account for the temperature rise of the moving air stream. The flow resistances are:

$$R_{2\text{-}3} = R_{4\text{-}5} = R_{6\text{-}7} \ldots = 1/c_p w$$

where c_p is the specific heat at constant pressure in BTU/lb/°F and w is the coolant flow rate in lb/h.

When the node regions are of equal size, then the convection resistances are:

$$R_{3\text{-}10} = R_{5\text{-}11} = R_{7\text{-}12} \ldots = 1/wc_p\,(e^{\beta}-1)$$

where $\beta = hA_c/wc_p$. If the plate had no fins, then:

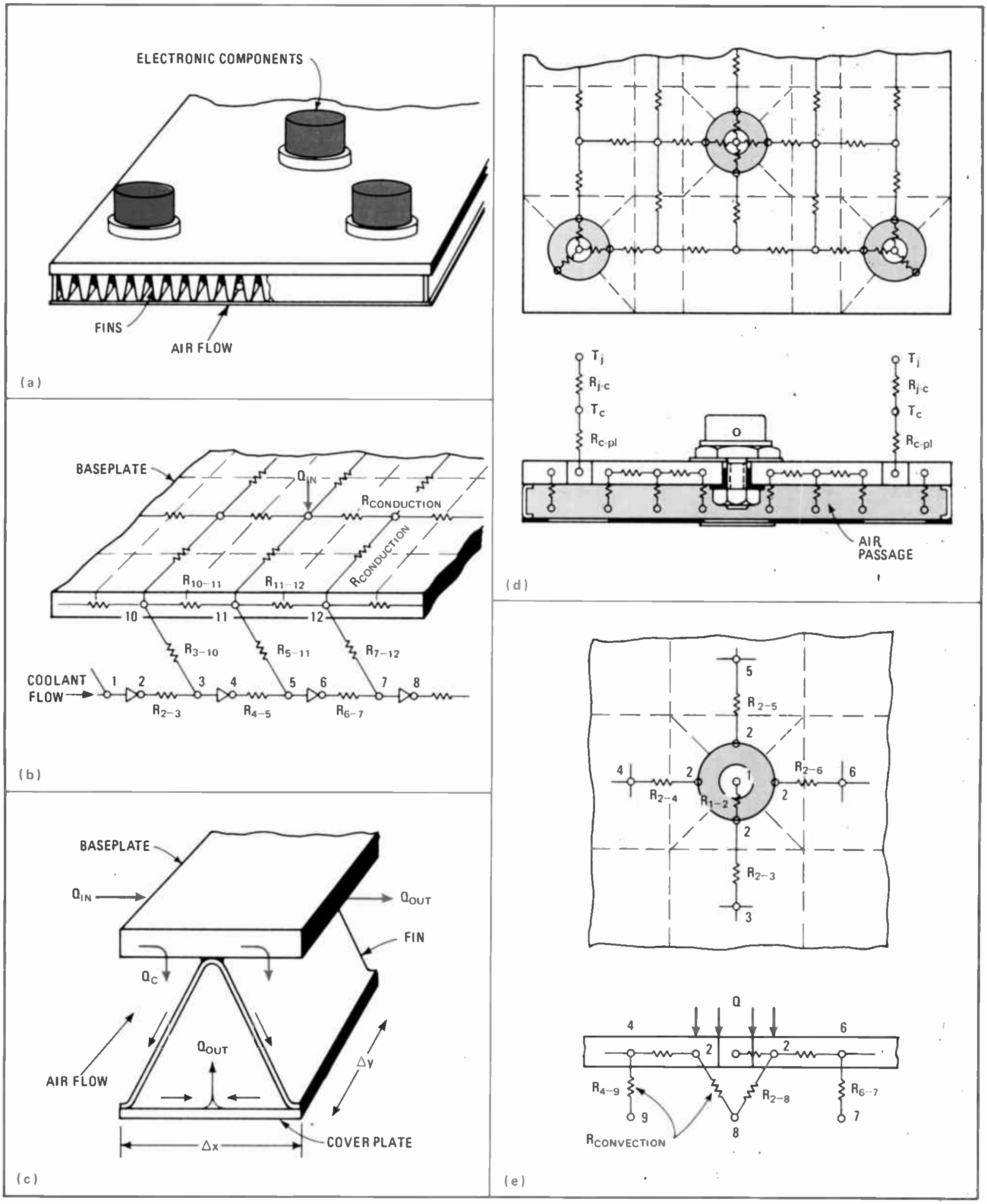
$$A_c = (\Delta x)(\Delta y)$$

However, since the air-flow passage has fins, the fin surface area must be added to the surface area of the plate. Figure 4(c) shows a section of finned plate. Note that heat from the baseplate flows along each fin that extends into the air stream, causing a temperature gradient to develop perpendicular to the flow. The gradient hinders effective heat transfer near the cover plate because convective transfer is dependent on temperature difference, and the difference between the cover plate and the coolant stream is quite small.

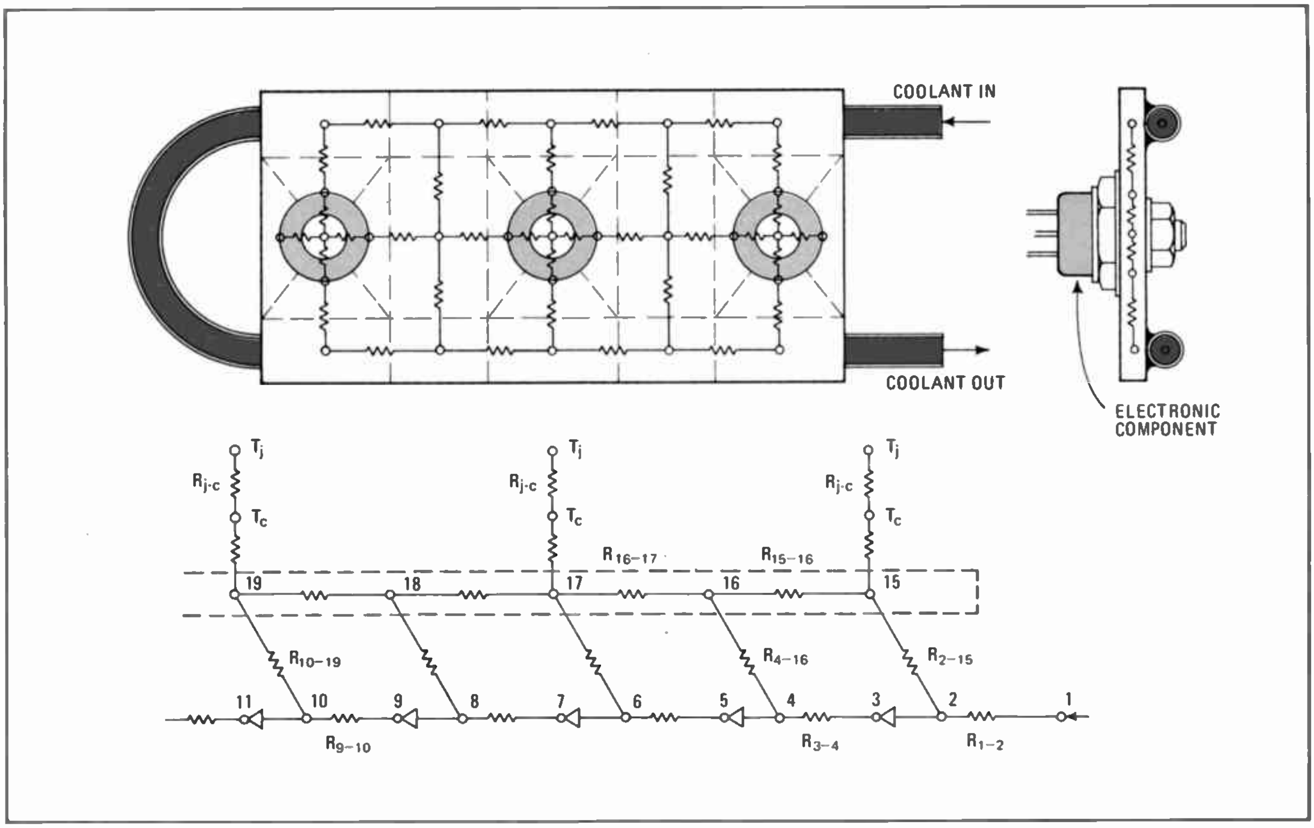
The term η is introduced to predict the convective heat-transfer capability of the structure. Then:

$$Q = hA\,\eta_0 \Delta T_m$$

where A is the total heat-transfer surface area.



4. Cold plate. Fastening components to a plate, then forcing air through finned passages effectively dissipates the heat (a). Circuit diagram accounts for heat flow along the surface, as well as convective transfer to the coolant flow (b). Cross section of the passage denotes the various thermal paths (c). Top view of the plate (d) shows the thermal-circuit paths along the surface. Convective coupling resistors to the flow stream are drawn in the profile view. Cross-hatched region (e) is a critical path between the device and the coolant base plate.



5. 'Round the bend. U-shaped coolant line attached to a plate forms a liquid-cooled cold plate. Circuit topography on surface is the same as that of air-cooled plate. Coupling resistors, drawn diagonally, represent heat flow from plate to coolant line.

For an asymetrically loaded cold plate, as shown in Fig. 4(a), the total heat-transfer surface area is expressed as:

$$A = A_b + A_f + A_c$$

where: A_b = baseplate surface, area, A_f = fin surface area, and A_c coverplate surface area

The over-all fin and cover-plate effectiveness can be determined from the following equation:

$$\eta_o = 1 - (A_f/A)(1 - \eta_f) - (A_c/A)(1 - \eta_c)$$

Where η_f and η_c are the effectiveness of the fin and base-plate, respectively.

Effectiveness of a flat, constant cross-section fin can be determined from an equation widely used in heat-exchanger design:

$$\eta_f = \tan h(ml)/(ml)$$

where $m = (2h/kz)^{1/2}$.

It is assumed here that the baseplate has an effectiveness of unity ($\eta_c = 1$) at each node.

Figure 4(d) is a network equivalent of a portion of the air-cooled plate. Once values are assigned to the known quantities, then network equations can be written. Techniques are covered in a number of volumes dealing with network analysis. The equations can then be solved by computer.

It may develop that such a network as is shown in Fig. 4(d) is not satisfactory for analyzing the configuration shown because it represents too crude an approximation. More nodes may be required.

Node count depends heavily on the thermal load placed upon the assembly. Concentrated high-heat loads may require more nodes, closely spaced around the component-mounting areas. If nodes are added to represent regions exposed to the cooling-air stream, they must be connected to the stream by convection resistances.

The boundary

A refinement that improves the accuracy of the network model is to model the thermal paths in the shaded region shown in Fig. 4(e). These paths are critical in the analysis because heat crosses the interface boundary along these surfaces and then develops a temperature gradient that lies in the plane of the baseplate. Four nodes have been assigned to the outer circle of the ring. However, these node points can be combined into a single node if the temperatures about the circle's circumference are assumed to be the same. When this is the case, this equation can be used to determine the thermal resistance of the annular region:

$$R_{1\text{-}2} = (r_2 - r_1)/(kA_m)$$

where A_m is a mean of the area defined as:

$$A_m = (A_2 - A_1)/[ln(A_2/A_1)]$$

The conduction resistances $R_{2\text{-}3}$, $R_{2\text{-}4}$, $R_{2\text{-}5}$, and $R_{2\text{-}6}$ are the sums of the trapezoidal and rectangular node regions shown in Fig. 4(e). As far as the convection resistance is concerned, the part of the ring (node 1) covered by the washer and nut will not participate in the convective transfer. The active transfer area exposed to convection-heat transfer is the total rectangular area

Why analyze?

A designer embarks on the thermal-analysis course to make sure that no component in his system will exceed its maximum operating temperature. First thought usually goes to heat producers—semiconductors and resistors. But equally as important are nearby components, wires, and circuit boards.

A useful analytic technique helps a designer answer the question: Is any critical temperature exceeded? If the answer is yes, he must alter parts placement and structural geometries; perhaps it may be necessary to substitute materials with lower thermal resistances so that heat transfer is improved.

What complicates packaging architecture is that the thermal requirements are only part of the packaging designer's responsibility. He must also satisfy mechanical, electrical, manufacturing, and maintainability requirements—a huge order, indeed.

minus the covered position. This is represented by:

$$R_{2\text{-}8} = 1/wc_p(e^{\beta}-1)$$

where $\beta = hA_2/wc_p$.

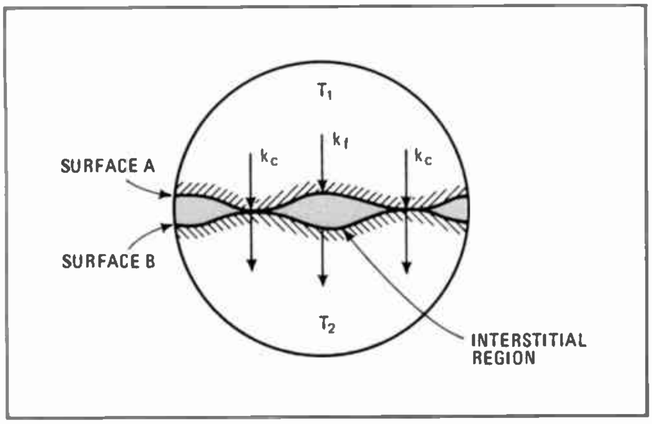
Natural convection and radiation also carry heat away from the external surfaces of the plate and the components, but they can be neglected if the forced-convection transfer coefficients are reasonably high.

Cooling with liquid

When powers levels soar into the kilowatt range, then designers often turn to liquid-cooling. This changes the analysis somewhat. Figure 5 shows a simple cold plate with three heat-dissipating components attached. Heat from the components enters the plate (shaded area) and travels to the liquid stream. Conduction resistances are determined in the same way as in the air-cooled systems. What differs is the convective-heat transfer. In an air-cooled plate, all nodes are exposed to forced-convection heat transfer, but in liquid-cooling, only the nodes adjacent to the coolant line connect to the coolant flow. In the network (Fig. 5b), the flow resistances are:

$$R_{1\text{-}2} = R_{3\text{-}4} = R_{5\text{-}6} = 1/wc_p$$

When temperature gradients through the coolant-line



6. Bridgehead. Heat flow across mating interface of two materials travels both through contacting points and interstitial regions. Thermal coefficients k_c and k_f account for thermal coupling.

wall can be neglected, then the coolant-coupling resistances are:

$$R_{2\text{-}15} = 1/hA_c$$

where A_c is the convection-heat-transfer area.

A figure of merit, η, is introduced to weight the effectiveness of the area A_c:

$$R_{2\text{-}15} = 1/hA_c\eta$$

Heat capacity of the liquid must also be considered, and this capacity can be determined from the following expression:

$$C = \rho c_v A \Delta x.$$

where A is the cross section of the tube, c_v is the specific heat at standard volume, and ρ is the density of the fluid used for cooling.

Crossing the interface

Regardless of the mounting technique used, a thermal resistance always develops at the interface between a component and its mounting surface. There is a wealth of data available about idealized joints that have uniform pressure distribution, controlled flatness, and surface finish. However, since these ideal conditions are seldom realized, an analytical technique that considers these factors is required.[2,3,4]

Heat traveling across the boundary of two mating surfaces consists of the two components shown in Fig. 6. Heat flows through the contact points (k_c) and through the interstitial gaps (k_f). Therefore, the thermal conductivity is the sum of both terms:

$$K = k_c + k_f$$

The total heat transfer across the contact area is

$$Q = KA\Delta T = (T_1 - T_2)/(1/KA)$$

When only limited information about interface surface conditions is available, thermal conductance across the area of direct contact may be determined from the following expression:

$$K = 1.56k_A/(i_a + i_b) + 2n\bar{a}\,k_m$$

in which

$$k_m = (2k_1 k_2)/(k_1 + k_2)$$

where k_1 and k_2 are the thermal conductances of the mating materials, i_a and i_b are the root-mean-square values of surface irregularity (roughness plus waviness) for surfaces a and b, respectively, $\bar{a}$ is the average radius of the contact points, and n is the number of contact points per unit area.

If approximate values of i_a and i_b can be obtained, then $n\bar{a}$ values as a function of the stress distribution at the bolted interface may be determined from charts published several years ago.[3] □

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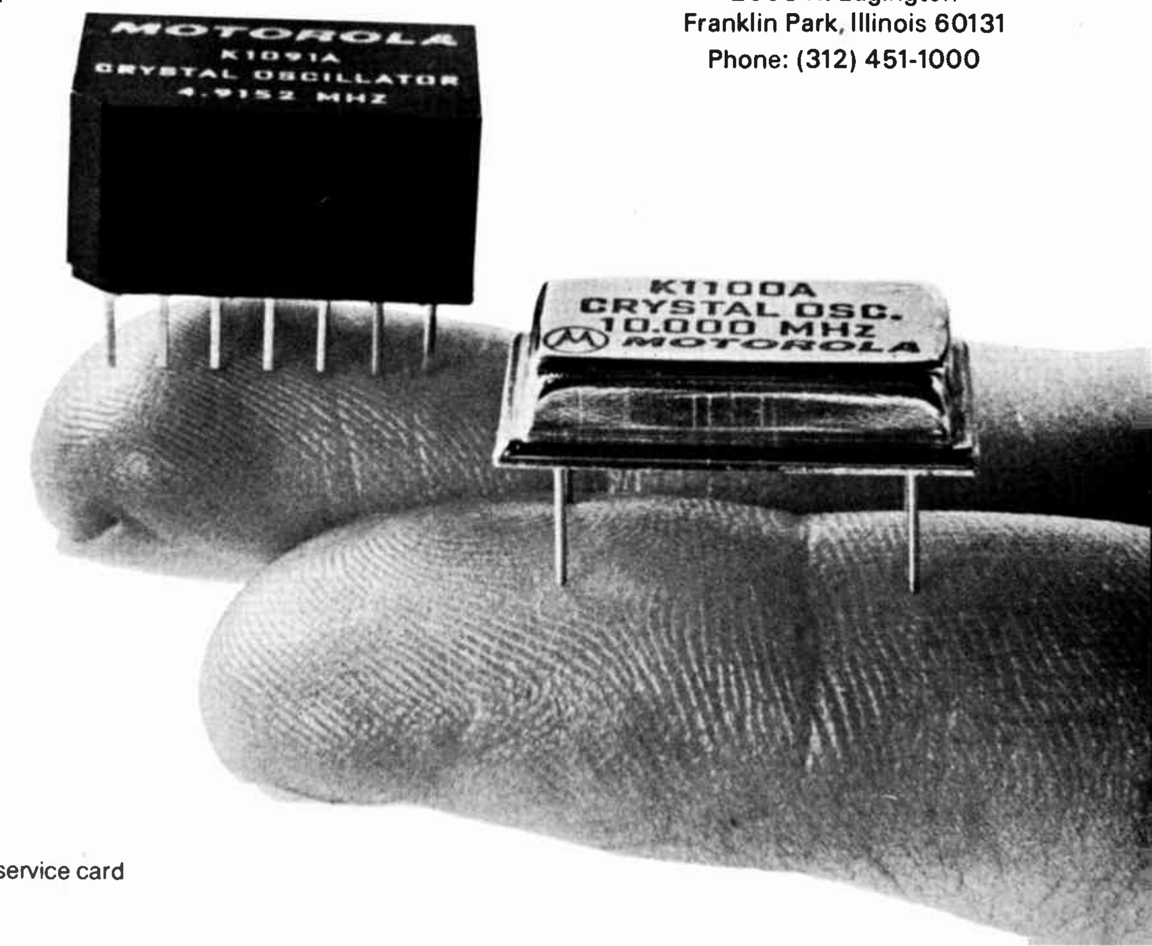


Active bandpass filter design is made easy with computer program

RCBAND time-shared software automatically determines the component values needed to build an active bandpass Butterworth or Chebyshev filter, in addition to predicting the circuit's frequency response

by Russell Kincaid and Frederick Shirley, *Sanders Associates Inc., Nashua, N.H.*

☐ With the assistance of a computer and the right program, the often tedious task of designing filters can be considerably simplified. The time-shared program presented here, for instance, lets the computer crank out all of the numbers needed for an active band-pass filter design.

The program, which is called RCBAND, accurately computes the component values needed to provide the desired frequency response and permits the engineer to modify his initial design easily. RCBAND can produce either a Butterworth or Chebyshev filter characteristic, and its output data can provide both a tabulation and a graph of the predicted frequency response. The program is available* without a surcharge from the User Program Library of Tymshare Inc., which is located in Palo Alto, Calif.

Program structure

RCBAND employs the state-variable bandpass filter (see "Examining the state-variable filter," p. 125) as the basic filter section that is cascaded to produce the desired filter response. Up to 20 of these sections can be synthesized. The program normally analyzes the design as a series of single-pole sections, but custom filters can also be analyzed if the engineer specifies each section individually.

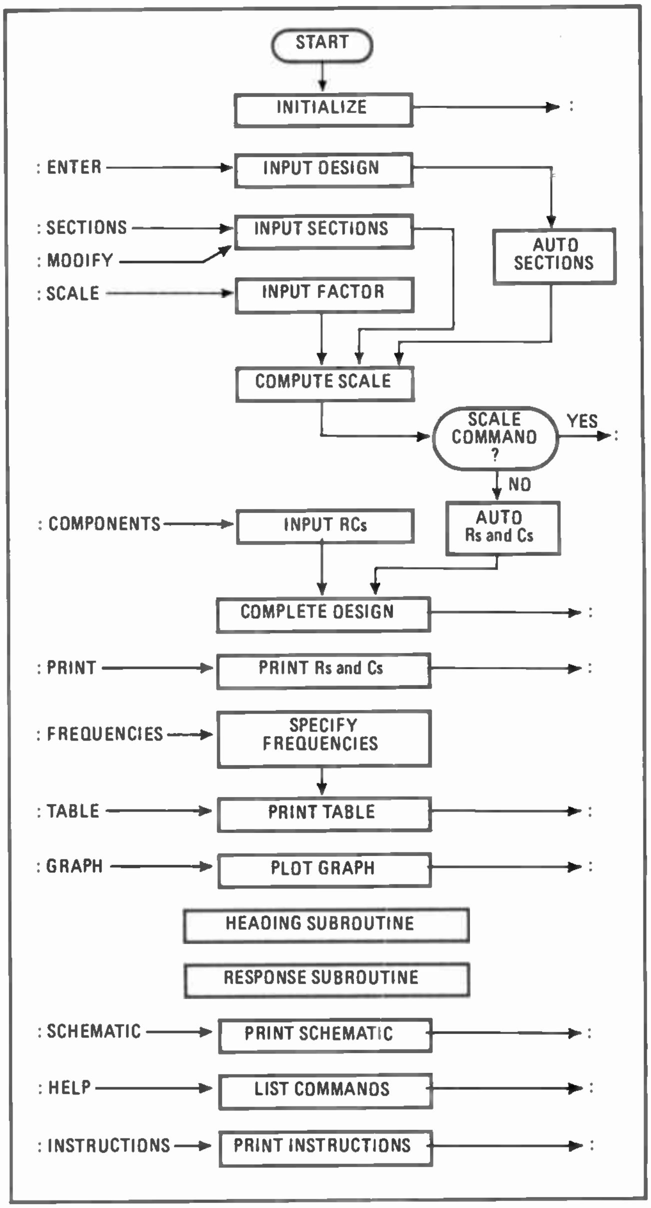
Only the basic filter specifications need be known to use the program—the number of poles desired, the type of filter characteristic, the center frequency, the bandwidth, and the gain. Or these inputs can be specified for each individual filter section, rather than for the entire filter.

The flow chart in Fig. 1 shows how RCBAND is structured. The program is written in NBASIC, the newest version of Tymshare's advanced SuperBASIC language. RCBAND is organized in a command-level format—that is, the computer prints a colon (:) and waits for further

*Copies of the RCBAND program listing can be obtained from Frederick Shirley, Sanders Associates Inc., 95 Canal St., M/S NCA1-6705, Nashua, N.H. 03060

Closing the loop

Readers who wish to discuss the RCBAND computer program with the authors may call Russell Kincaid at (603) 885-4633 or Frederick Shirley at (603) 885-6239, during business hours the week of May 20.



1. Filter design made easy. The RCBAND computer program designs active bandpass filters by using the three-amplifier state-variable filter as a basic building block. As this flow-diagram shows, program control is returned to the user after each subroutine instruction is completed. RCBAND automatically computes component values, predicts frequency response, and permits easy modification.

Designing bandpass filters

Bandpass filters can be made either by cascading low-pass and high-pass filter sections or by cascading stagger-tuned resonators. The low-pass/high-pass approach is best for wideband applications, while the stagger-tuned-resonator approach is best applied to narrowband filters.

The dividing line between the wide and narrowband approaches is determined by how much gain a section (a pole-pair) can provide and still have excess gain to operate the feedback loop. A two-resonator filter, for example, will have unity gain in the passband because the gain of one section offsets the skirt attenuation of the other. If the bandwidth of the over-all filter is increased by making the center frequency of one section higher or the center frequency of the other section lower, the filter gain will be decreased.

Another point to be considered in deciding between the two design approaches is the filter's skirt attenuation. For a resonator-type filter, the skirt attenuation is approximately 6 decibels per bandwidth octave, whereas for a low-pass/high-pass filter, the skirt attenuation is 6 dB per absolute octave. This means that a filter with a 2-kilohertz bandwidth centered at 10 kHz will provide an attenuation of 6 dB at 13 kHz if it's a one-resonator design. Or its attenuation will be 6 dB at 22 kHz if it's an equivalent low-pass/high-pass design.

The engineer must also choose between active and passive filter designs. Generally, an active filter is cheaper and lighter than a passive filter at low operating frequencies, specifically in the audio ranges, where an active filter works well. The frequency limitation of an active design lies in the amplifier.

The amplifier's performance can be estimated from its response curve of open-loop gain versus frequency. At those frequencies where amplifier gain is less than 60 dB, filter operation will be poor. And at higher frequencies, if amplifier gain is less than 40 dB, the filter will not work properly.

The low-pass pole existing in the amplifier tends to push the peak filter response to lower frequencies. Although this can be compensated for by trimming, the amplifier's pole frequency typically varies by 3:1 from unit to unit, so that trimming is difficult and rather temperature-sensitive.

Usually, the (Fairchild) 741-type operational amplifier will work well up to about 1 kHz, and the (National Semiconductor) LM101-type op amp, which has feed-forward compensation, will operate satisfactorily at frequencies up to around 10 kHz. Even higher frequencies can be handled by dielectrically isolated op amps such as the (Harris) HA2600-type unit.

The filter-circuit configuration chosen to implement a single filter section will also have some effect on performance. A filter section can contain one, two, or three op amps. Although it's the most expensive to build, the three-amplifier approach has two distinct advantages over the other two circuits—it is the least sensitive to component variations and the easiest to tune. This three-amplifier circuit is commonly referred to as the state-variable filter.

At least three parameters are needed to specify the response of a bandpass filter: center frequency, bandwidth, and gain. These parameters are functions of resistance and capacitance, as well as amplifier gain and bandwidth. For optimum performance, it is best to make the parameters depend on resistor ratios and RC products only. This is because the temperature tracking of resistors and RC products is controllable, but variations in amplifier gain and bandwidth are not.

When the filter's design frequency approaches the amplifier's upper limit (the frequency where the gain is down to 60 dB), the sensitivity of the circuit to amplifier gain and bandwidth becomes increasingly important. High-Q designs require more amplifier gain and are less tolerant of frequency shifts caused by amplifier-bandwidth limitations.

Filter sections can be arranged in any order without affecting the over-all filter response. Also, the gain of one section may be raised, and the gain of another section reduced by a corresponding amount. The Q of a filter section tends to be highest at the band edges, and odd-ordered filters generally contain a low-Q center-frequency section.

These simple considerations can be used to advantage in particular applications. For example, in a three-stage low-level preamplifier filter, the center-tuned section would be first, providing high gain to raise the signal above circuit noise. The remaining sections could then have reduced gain to avoid the undesirable condition of overdrive distortion.

---

directions from the user after completing each subtask. This format is indicated in the flow diagram by the command-level symbol (a colon) at the input and at the output of each subroutine function.

Since all the input specifications are stored, the user has maximum freedom to initiate, modify, or investigate a design in a truly interactive time-sharing mode. A byproduct of this type of organization is a set of aid commands that the user can call for at any time if he needs assistance in working with the program. Two of these aid commands—HELP and INSTRUCTIONS—are shown in Fig. 2.

The HELP subroutine prints a list of all the commands available through the program's input command routine, and the INSTRUCTIONS subroutine prints a brief explanation of the RCBAND program. Another subroutine that is included for user convenience is the SCHEMATIC listing, which is also shown in Fig. 2. It prints a circuit diagram of the standard state-variable filter section.

The front end of the program documents the run and initializes the variables, default actions, and user-defined number functions. Although initialization is not necessary in NBASIC, it does serve to increase computational efficiency if the program is to be compiled into a run-only machine-language version.

RCBAND is easy to use

The default conditions override the normal NBASIC error messages in case of input error or a program bug. This enables RCBAND to maintain complete control of the interaction between the user and the computer so that the user need never be aware of the NBASIC source language while working with the program.

There are three user-defined number functions—they present computer-output data and accept user-input data in formats that are meaningful to the engineer. One function rounds numbers to the number of places specified by the user so that the printout contains only the number of digits required, regardless of number magnitude. A second function interprets user input in either scientific (1.23E3) or engineering (1.23 K) units. And the third function presents output data in engineering units that are five digits in length (101.86 K rather than 1.0186327E+05).

Subroutines help the user

An input-command routine directs computation to one of several subroutines. At the completion of a subroutine, control is transferred back to the command level, the printer advances two lines, types a colon (:), and waits for the user to type an alphanumeric command like TABLE or GRAPH.

The ENTER subroutine prompts the user and accepts the input specifications he enters at his computer terminal. An alternate method of entering input data is provided by the SECTIONS subroutine, which permits the user to define a custom filter by specifying each resonator individually. This subroutine is also used when changing a section by the MODIFY command. The AUTO SECTIONS subroutine computes the specifications for each state-variable filter section from the over-all design objectives given through the ENTER subroutine.

The frequency scale for the table and graph printouts is controlled by the SCALE subroutine. The last portion of this subroutine is called by both the ENTER and SECTIONS subroutines for the initial selection of the frequency scale. The COMPONENTS subroutine permits the

Examining the state-variable filter

Although it requires three operational amplifiers, the state-variable active filter can operate at fairly high frequencies and can develop large values of Q. Moreover, the operating frequency, gain, and Q of this filter circuit are independent of each other, and the circuit itself is not overly sensitive to fluctuations in component values over the range of operation.

The state-variable filter consists of a summing amplifier (A_1) and two integrators (A_2 and A_3). The circuit's bandpass response is taken at the output of integrator A_2. The natural frequencies, ω_1 and ω_2, of integrators A_2 and A_3 are, respectively:

$$\omega_1 = 1/R_6C_1 \text{ and } \omega_2 = 1/R_7C_2$$

The transfer function of these integrators can be defined in terms of their natural frequencies (which are, of course, expressed in radians per second):

$$e_{out} = -\omega_1 e_1/s \text{ and } e_2 = -\omega_2 e_{out}/s$$

where s is complex frequency. Let three resistance ratios be defined for summer A_1:

$$\beta_1 = R_2/R_1 \text{ and } \beta_2 = R_2/R_3 \text{ and } \beta_3 = R_5/R_4$$

Then the transfer function of summer A_1 can be written as:

$$e_1 = -\beta_1 e_{in} - \beta_2 e_2 + [R_4/(R_4+R_5)]$$
$$[1 + R_2[(R_1+R_3)/(R_1R_3)]]e_{out}$$

Now the transfer function of the entire circuit can be expressed as:

$$e_{out}/e_{in} = \beta_1\omega_1 s/[s^2 + [(1+\beta_1+\beta_2)/(1+\beta_3)]\omega_1 s + \beta_2\omega_1\omega_2]$$

The principal filter specifications are center frequency (ω_o), damping factor (ζ), and gain constant (k):

$$\omega_o = (\beta_2\omega_1\omega_2)^{1/2}$$
$$\zeta = \tfrac{1}{2}[\omega_1/(\beta_2\omega_2)]^{1/2}[(1+\beta_1+\beta_2)/(1+\beta_3)]$$
$$k = \beta_1\omega_1$$

These variables permit the filter's transfer function to be written in the standard format of a second-order equation:

$$e_{out}/e_{in} = ks/(s^2 + 2\zeta\omega_o s + \omega_o^2)$$

The filter's 3-dB bandwidth (b_o) and center-frequency gain (g_o) can be computed from this last equation:

$$b_o = 2\zeta\omega_o = \omega_1[(1+\beta_1+\beta_2)/(1+\beta_3)]$$
$$g_o = \beta_1[(1+\beta_3)/(1+\beta_1+\beta_2)]$$

A multiple-pole bandpass filter can be built as a series of one-pole-pair sections like the one shown here. Each pole pair in the over all filter transfer function is used to specify the resistor and capacitor values in the corresponding circuit section. The frequency response of any section is completely determined by center frequency ω_o, 3-dB bandwidth b_o, and center-frequency gain g_o.

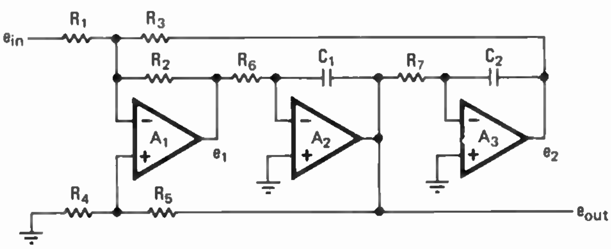
To simplify the computation, six of the nine unknown component values can be preset to reasonable values:

$$R_4 = 1 \text{ kilohm}$$
$$R_2 = R_3 = 10 \text{ kilohms}$$
$$C_1 = C_2 = 0.01 \text{ microfarad}$$
$$R_6 = R_7 \times C_2/C_1 \text{ ohms}$$

These are the computer-selected component default values used by the RCBAND design program. The remaining three resistor values can be determined from these preset component values and the three known filter parameters:

$$R_7 = [1/(\omega_o C_2)](R_2/R_3)^{1/2}$$
$$R_1 = [\omega_o/(b_o g_o)](R_2R_3)^{1/2}$$
$$R_5 = R_4[(\omega_o/b_o)(R_3/R_2)^{1/2}[1+(R_2/R_1)+(R_2/R_3)]-1]$$

The preselected values suggested for capacitors C_1 and C_2 are scaled by RCBAND to place the values of resistors R_6 and R_7 within the range of 10 kilohms to 100 kilohms. When necessary, the values of resistors R_2 and R_3 are also scaled, with resistor R_2 decreasing in value and resistor R_3 increasing in value so that resistor R_5 is always positive in value.



```
:HELP

COMMAND              DESCRIPTION
-------              -----------

ENTER                INPUTS FILTER SPECS
PRINT                PRINTS RC VALUES
SCHEMATIC            PRINTS SECTION SCHEMATIC
GRAPH (OR) PLOT      PLOTS RESPONSE GRAPH
TABLE                PRINTS RESPONSE DATA
FREQUENCIES          PRINTS DATA FOR SPECIFIED F'S
SCALE                EXPANDS FREQ SCALE
COMPONENTS           OVERRIDES PRESELECTED RC'S
SECTIONS             SPECIFIES FILTER SECTIONS
MODIFY               VARIES ONE FILTER SECTION
INSTRUCTIONS         DESCRIBES PROGRAM USE
QUIT                 RETURNS TO EXEC
HELP (OR) ?          REPRINTS THIS LIST
VERSION              LATEST UPDATE
CREDITS              PROGRAMER
CHARGES              ADDITIONAL COST

:
```

```
:INSTRUCTIONS

   THIS PROGRAM DESIGNS RC-ACTIVE BANDPASS FILTERS AS A
SERIES OF ONE-POLE SECTIONS.  BUTTERWORTH AND CHEBYSHEV
CHARACTERISTICS CAN BE SYNTHESIZED FOR A MAXIMUM OF 20
SECTIONS.  A CUSTOM FILTER MAY ALSO BE DESIGNED BY
SPECIFYING EACH SECTION INDIVIDUALLY.

INPUT COMMANDS:
   ENTER         --INPUTS THE FILTER SPECIFICATION (# OF
                   SECTIONS, TYPE, CENTER, WIDTH, AND GAIN)
   SECTIONS      --ALTERNATE INPUT METHOD BY SPECIFYING EACH
                   SECTION (CENTER, WIDTH, AND GAIN)
   MODIFY        --VARY ONE SECTION (CENTER, WIDTH, AND GAIN)
   COMPONENTS    --OVERRIDES COMPUTER-SELECTION OF INITIAL
                   RC VALUES (R2,R3,R4,C1 AND C2)

CIRCUIT COMMANDS:
   PRINT         --LISTS SECTIONS DATA (CENTER, WIDTH, GAIN,
                   AND COMPONENT VALUES)
   SCHEMATIC     --PRINTS SCHEMATIC OF STANDARD SECTION

RESPONSE COMMANDS:
   TABLE         --PRINTS GAIN, PHASE, AND TIME DELAY VS FREQ
   FREQUENCIES   --PRINTS TABLE AT USER-SELECTED F'S (36 MAX)
   GRAPH         --PLOTS GAIN, PHASE, OR TIME DELAY WITH
                   AUTOMATIC OR USER-SELECTED SCALE
   SCALE         --EXPANDS FREQ SCALE IN TABLE AND GRAPH

ANY COMMAND MAY BE ABBREVIATED TO ITS FIRST THREE LETTERS.
TO ABORT PRINTOUT AND RETURN TO ':' PRESS THE ESCAPE KEY.

:
```

```
:SCHEMATIC


E(IN)>-R1-*--R3-----------------------------:
          :                                 :
          *--R2--*--R6--*--C1--*--R7--*--C2--*
          :      :      :      :      :      :
          >-     :      >-     :      >-     :
            AMP1>:        AMP2>*        AMP3>:
          >+        GND>+      :    GND>+
          :                    :
   GND>-R4-*--R5----------------*---------------->E(OUT)


AMP = OPERATIONAL AMPLIFIER
GND = GROUND REFERENCE

:
```

2. Aid commands. The RCBAND user can ask for HELP, a call that produces a list of all the program's available commands. Or he can request INSTRUCTIONS to get a concise description of what RCBAND is all about. Another user-convenience call is SCHEMATIC, which gives the diagram of the filter section used by the program.

```
:PRINT

    CHEBYSHEV BANDPASS RC-ACTIVE FILTER

   1.0000 KHZ CENTER                4 POLES
   100.00  HZ WIDTH             6.02 DB GAIN
   .5   DB RIPPLE


SECTION  1:
   CENTER FREQ    = 1.0521 KHZ
   3DB BANDWIDTH  = 18.425  HZ
   CENTER GAIN    =  14.09  DB
   R1 = 112.75 K       R4 = 1.0000 K       R7 = 15.127 K
   R2 = 10.000 K       R5 = 118.27 K       C1 = 10.000 NF
   R3 = 10.000 K       R6 = 15.127 K       C2 = 10.000 NF

SECTION  2:
   CENTER FREQ    = 950.48  HZ
   3DB BANDWIDTH  = 16.645  HZ
   CENTER GAIN    =  14.97  DB
   R1 = 101.86 K       R4 = 1.0000 K       R7 = 16.745 K
   R2 = 10.000 K       R5 = 118.81 K       C1 = 10.000 NF
   R3 = 10.000 K       R6 = 16.745 K       C2 = 10.000 NF

SECTION  3:
   CENTER FREQ    = 1.0213 KHZ
   3DB BANDWIDTH  = 43.225  HZ
   CENTER GAIN    =   6.68  DB
   R1 = 109.45 K       R4 = 1.0000 K       R7 = 15.584 K
   R2 = 10.000 K       R5 = 46.413 K       C1 = 10.000 NF
   R3 = 10.000 K       R6 = 15.584 K       C2 = 10.000 NF

SECTION  4:
   CENTER FREQ    = 979.17  HZ
   3DB BANDWIDTH  = 41.443  HZ
   CENTER GAIN    =   7.05  DB
   R1 = 104.94 K       R4 = 1.0000 K       R7 = 16.254 K
   R2 = 10.000 K       R5 = 46.505 K       C1 = 10.000 NF
   R3 = 10.000 K       R6 = 16.254 K       C2 = 10.000 NF

:
```

3. A demonstration. In response to a PRINT command, RCBAND computes the component values for each section of a four-pole Chebyshev filter. The desired filter specifications are also printed out (at the top of the listing) with this command. The filter's frequency response can be obtained as either a tabulation (by using the TABLE command) or as a plot (by using the GRAPH command).

user to override the computer selection of the independent resistor and capacitor values in the individual filter sections. The AUTO COMPONENTS subroutine, which is called by the SCALE and COMPONENTS subroutines, computes the dependent resistor and capacitor values in each filter section.

In the PRINT subroutine, the section specifications and components values are tabulated for the entire filter. Additionally, the FREQUENCIES subroutine produces a table printout of the over-all filter's response for user-specified frequencies. The TABLE subroutine prints this filter-response data (gain, phase, and time delay versus frequency), and the GRAPH subroutine plots the filter response. Here, the user can specify the dependent axis, or he can accept the automatically computer-generated scaling for the plots.

The HEADING subroutine advances the printer to a new page and prints the over-all filter characteristics in a concise heading format. This subroutine is called at the beginning of the PRINT, TABLE, and GRAPH subroutines. The RESPONSE subroutine computes the filter-response data; it is called in before the printout command in the TABLE and GRAPH subroutines.

A four-pole Chebyshev filter will be designed to show how RCBAND works. The filter should have a center frequency of 1 kilohertz, a bandwidth of 100 hertz, a gain

:TABLE

CHEBYSHEV BAN[illegible]S RC-ACTIVE FILTER

1.0000 KHZ CENTER 4 POLES
100.00 HZ WIDTH 6.02 DB GAIN
.5 DB RIPPLE

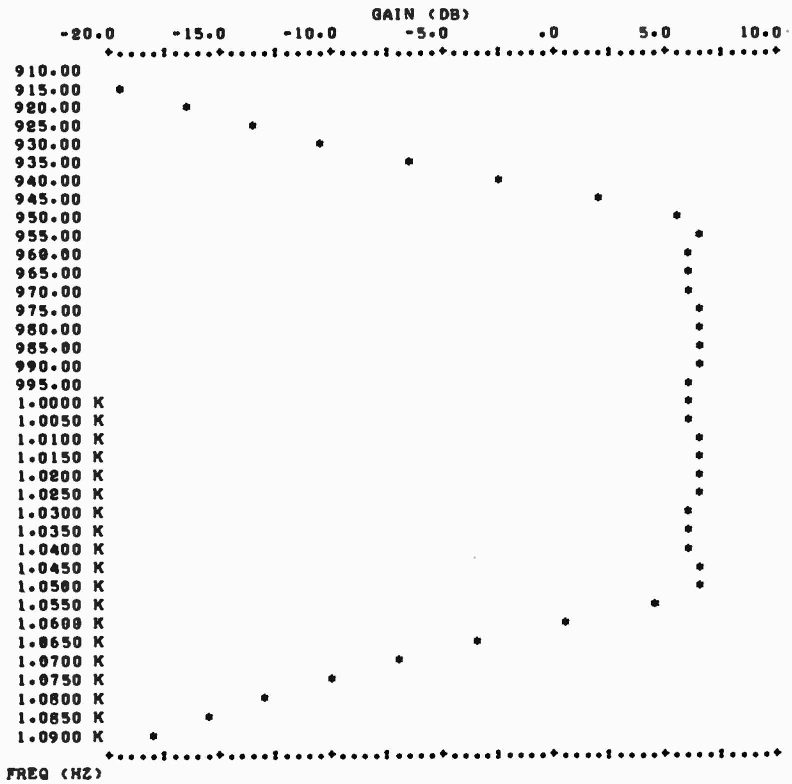
FREQ (HZ)	GAIN (DB)	PHASE (DEG)	DELAY (SEC)
910.00	-21.77	318.7	1757.3 U
915.00	-19.29	315.3	2103.7 U
920.00	-16.59	311.1	2583.7 U
925.00	-13.63	305.8	3284.9 U
930.00	-10.34	299.0	4381.5 U
935.00	-6.65	289.6	6259.8 U
940.00	-2.46	275.6	9737.5 U
945.00	1.98	252.7	16172. U
950.00	5.53	217.1	22439. U
955.00	6.52	178.6	18857. U
960.00	6.21	150.0	13417. U
965.00	6.02	128.3	11140. U
970.00	6.14	108.8	10741. U
975.00	6.38	89.3	10957. U
980.00	6.52	69.5	10944. U
985.00	6.46	50.2	10395. U
990.00	6.27	32.2	9568.6 U
995.00	6.09	15.7	8889.0 U
1.0000 K	6.02	.0	8611.3 U
1.0050 K	6.09	-15.6	8799.2 U
1.0100 K	6.27	-31.9	9365.8 U
1.0150 K	6.45	-49.4	10058. U
1.0200 K	6.52	-68.0	10496. U
1.0250 K	6.40	-86.9	10450. U
1.0300 K	6.18	-105.4	10145. U
1.0350 K	6.03	-123.6	10286. U
1.0400 K	6.12	-142.9	11487. U
1.0450 K	6.44	-166.3	15026. U
1.0500 K	6.31	-197.9	19825. U
1.0550 K	4.27	-233.7	18454. U
1.0600 K	.56	-261.4	12228. U
1.0650 K	-3.38	-279.0	7767.6 U
1.0700 K	-6.98	-290.5	5278.3 U
1.0750 K	-10.18	-298.6	3845.9 U
1.0800 K	-13.05	-304.7	2956.9 U
1.0850 K	-15.64	-309.5	2365.4 U
1.0900 K	-18.01	-313.3	1948.8 U

:

:GRAPH
GAIN, PHASE OR TIME DELAY? GAIN
AUTOMATIC SCALING? NO
DB PER PRINT POSITION? .5
DB MAXIMUM? 10

CHEBYSHEV BANDPASS RC-ACTIVE FILTER

1.0000 KHZ CENTER 4 POLES
100.00 HZ WIDTH 6.02 DB GAIN
.5 DB RIPPLE



:

of 6.02 decibels, and a passband ripple of 0.5 dB.

This data is given to RCBAND through the ENTER command. An unacceptable input—one that is ambiguous or out of range—is brought to the user's attention by an error routine so that corrected data can be re-entered immediately. This prevents a computer run from aborting needlessly.

Applying the program

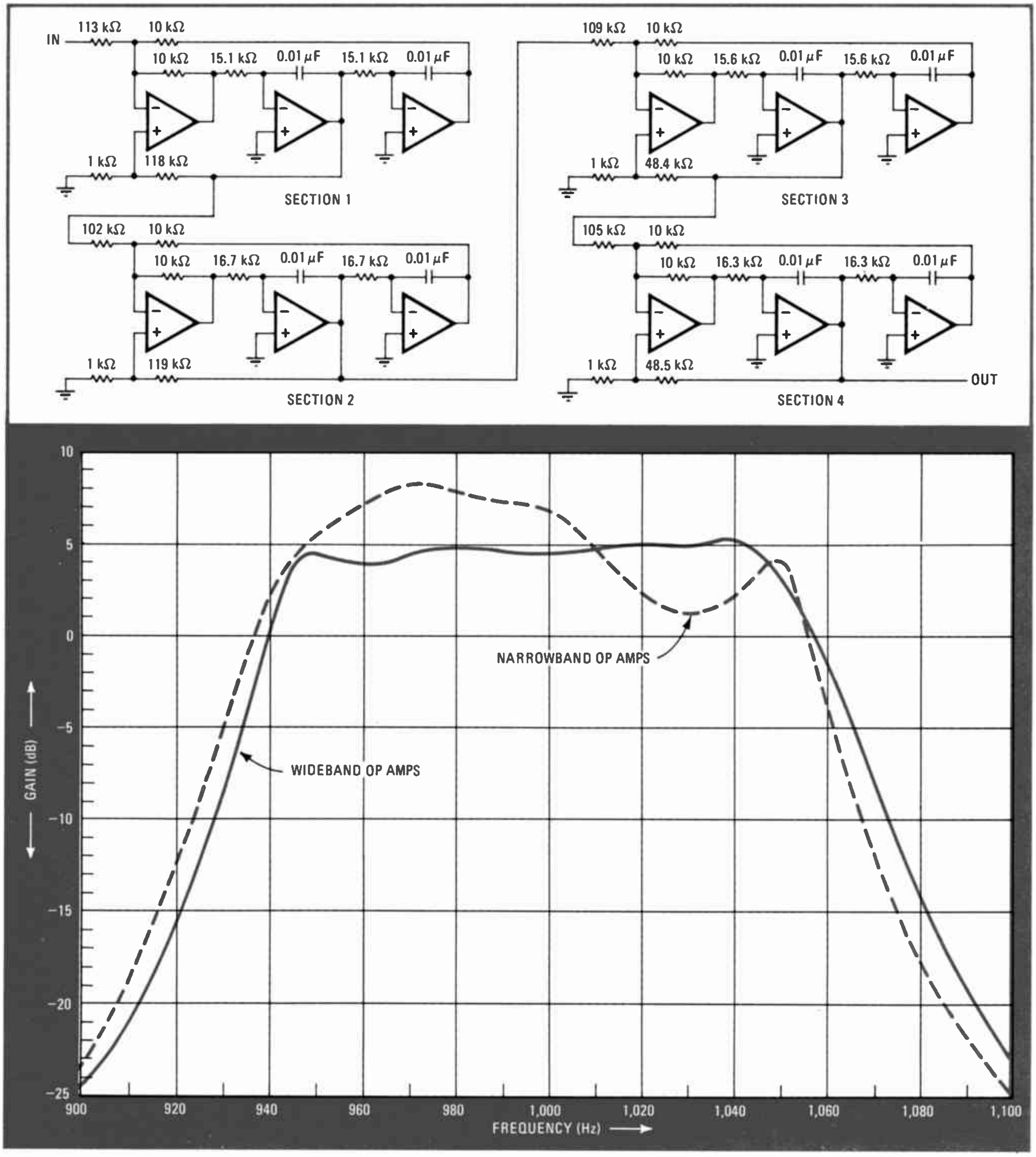
The PRINT command will provide a tabulation, as shown in Fig. 3, of the computed component values in each of the four filter sections. The section parameters (center frequency, bandwidth, and gain) are also printed to help the designer check and/or align the filter response. This printout, as well as the other major program printouts, are spaced on 8½-inch pages with a short heading on each page labeling the results. (The format is suitable for inclusion in engineering reports.) The data is presented in engineering units, rather than scientific notation, to make the printout easier for the engineer to interpret.

The TABLE and the GRAPH commands produce a tabulation and a plot, respectively, of the frequency response of the example filter. These two printouts, which are included in Fig. 3, give the response in engineering units—gain is in decibels, phase in degrees, time delay in seconds, and frequency in hertz.

The GRAPH subroutine used in RCBAND minimizes printout time by returning the printer carriage, once the actual data point is plotted, instead of wasting computer time by "printing" spaces all the way across the page. The user may select the scale for the gain axis, as done here, or he may let RCBAND determine it automatically. The scale for the frequency axis may also be user-selected through the SCALE command.

The schematic of the four-pole Chebyshev filter is drawn in Fig. 4, showing the final component values for all four filter sections. Needless to say, it still remains for the designer to select the operational amplifiers that are best for his application.

If narrowband 741-type operational amplifiers, which have a 60-dB bandwidth of 1 kHz, are used, the response



4. The real thing. Schematic shows the circuit configuration and component values of the four-pole Chebyshev filter described in the RCBAND printouts of Fig. 3. This filter's gain-versus-frequency response curve is closer to ideal when wideband op amps (like LM101-type units) are used than when narrowband op amps (like 741-type units) are used. Of course, the op amp chosen depends on the application.

curve drawn as a dashed color line in the gain-versus-frequency plot of Fig. 4 is obtained. On the other hand, if LM101-type operational amplifiers, which provide a 60-dB bandwidth of 10 kHz (with a 3-picofarad compensation capacitor), are used, the frequency response plotted by the solid color line results. Notice the similarity of the filter response predicted in the GRAPH printout of Fig. 3 to the filter response of the practical filter plotted in Fig. 4. □

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1. **SCRs**	18	6	12
2. **Heat Sinks**	21	9	12
3. **Clamps**	18	6	12
4. **Fuses**	18	6	12
5. **Balancing Reactors**	18	0	18
6. **Trigger Pulse Pwr. Amplifiers**	6	0	6
7. **Isolated Gate Drive Windings**	18	6	12
Totals	117	33	84

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All-electronic metronome provides accurate beat rate

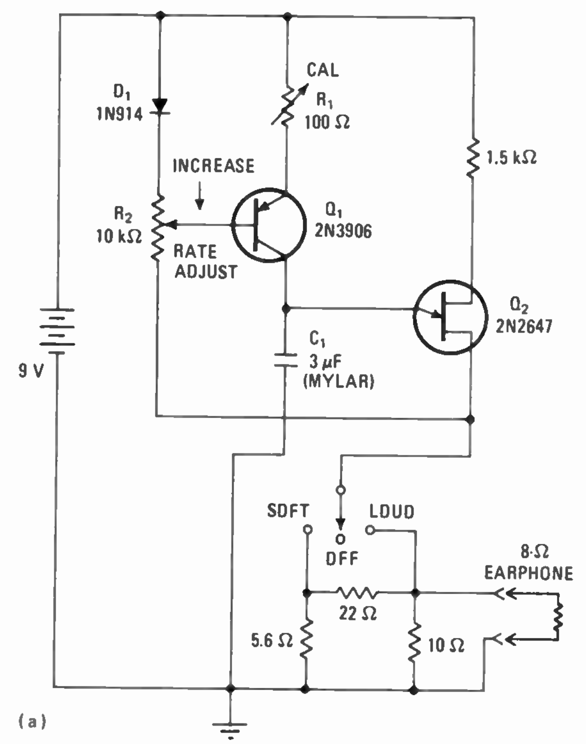
by Dennis R. Morgan
General Electric Co. Electronics Laboratory, Syracuse, N.Y.

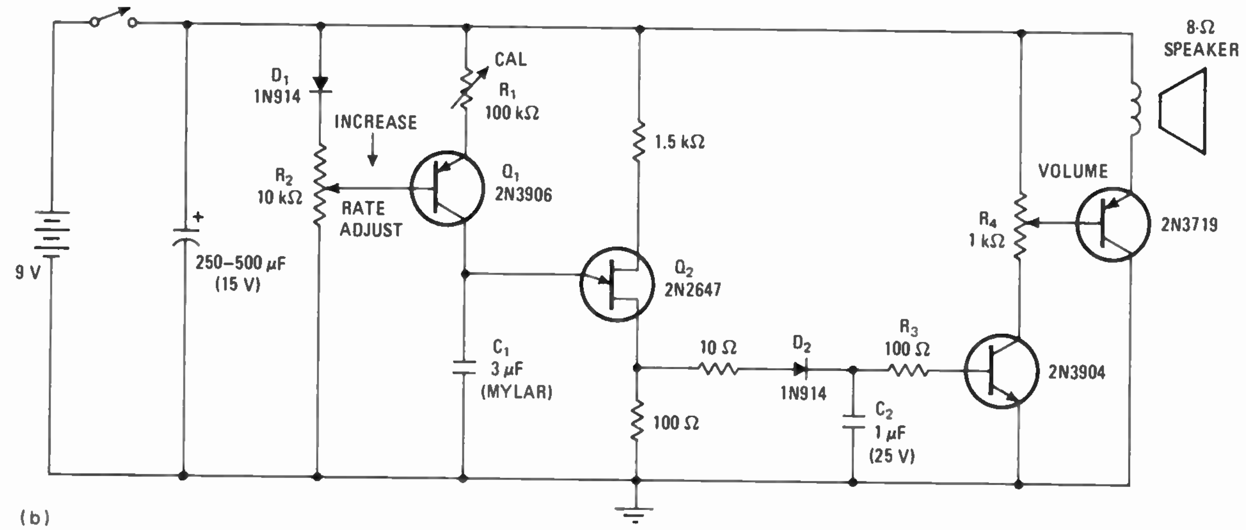
For the engineer who is also a music enthusiast, here is a precision electronic metronome that can be adjusted to the desired beat rate, is accurate to within 1 beat per minute, and can be assembled from standard parts. The circuit, which can be powered from any garden-variety 9-volt transistor-radio battery, can generate audible clicks (beats) even beyond the standard metronome range—from about 15 to 380 times a minute.

A 10-turn potentiometer that has a turns-counting dial is used to set the metronome's beat rate. The circuit can be calibrated so that the setting of this potentiometer is accurate to well within 1 beat per minute over the standard metronome range of 40 to 208 beats per minute. Furthermore, the circuit is relatively insensitive to variations in battery voltage, in particular to the reduced voltage that results from aging.

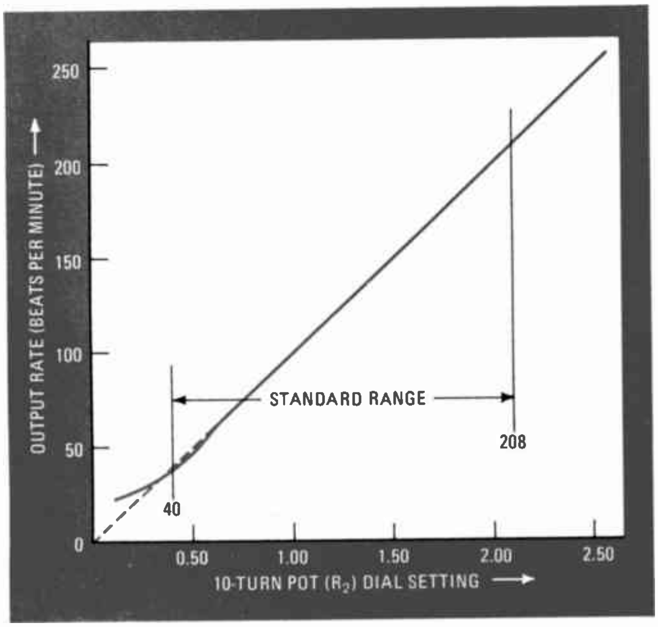
The figure shows two versions of the circuit—the one given in (a) is a pocket-sized metronome that has an 8-ohm earphone output, and the one given in (b) is a more powerful metronome with a regular 8-ohm speaker output. This latter circuit develops a hefty output power level of approximately 0.01 joule.

In both circuits, a constant-current generator (transistor Q_1) is used to charge capacitor C_1. When this capacitor's voltage reaches the firing point (above 6 V) of the





Rhythm reminder. Electronic metronome circuits are accurate to within 1 beat per minute over the standard metronome range of 40 to 208 beats per minute. Circuit (a) has an earphone output, while circuit (b) has a speaker output. In each case, a 10-turn potentiometer is used to set the beat rate. Both circuits are battery-operated. A typical calibration curve shows the linearity of the output beat rate.



unijunction transistor (Q_2), the capacitor is discharged and an output pulse is generated. The capacitor's charging current, and hence the operating frequency, is directly proportional to the voltage across variable resistor R_1, a voltage that varies linearly with the setting of potentiometer R_2. Diode D_1 compensates for the base-emitter drop of transistor Q_1.

Either circuit is calibrated by adjusting resistor R_1 to obtain the upper standard beat-rate limit (208 beats per minute) and then adjusting the stop on potentiometer R_2's turns-counting dial to get the lower standard limit (40 beats per minute). A typical calibration curve is given in the figure. (Plenty of patience and a good stopwatch are also needed for good calibration results.)

Metronome (a) includes a loud and soft control over volume within its on/off switch. Metronome (b) employs a pulse stretcher, made up of diode D_2, capacitor C_2, and resistor R_3, to increase the available energy from the 9-v battery. This circuit's volume control, resistor R_4, can be replaced with a fixed resistor to obtain maximum output, if desired. □

Different-color LEDs can switch each other

by F. Gerard Albers
University of Dayton, Dayton, Ohio

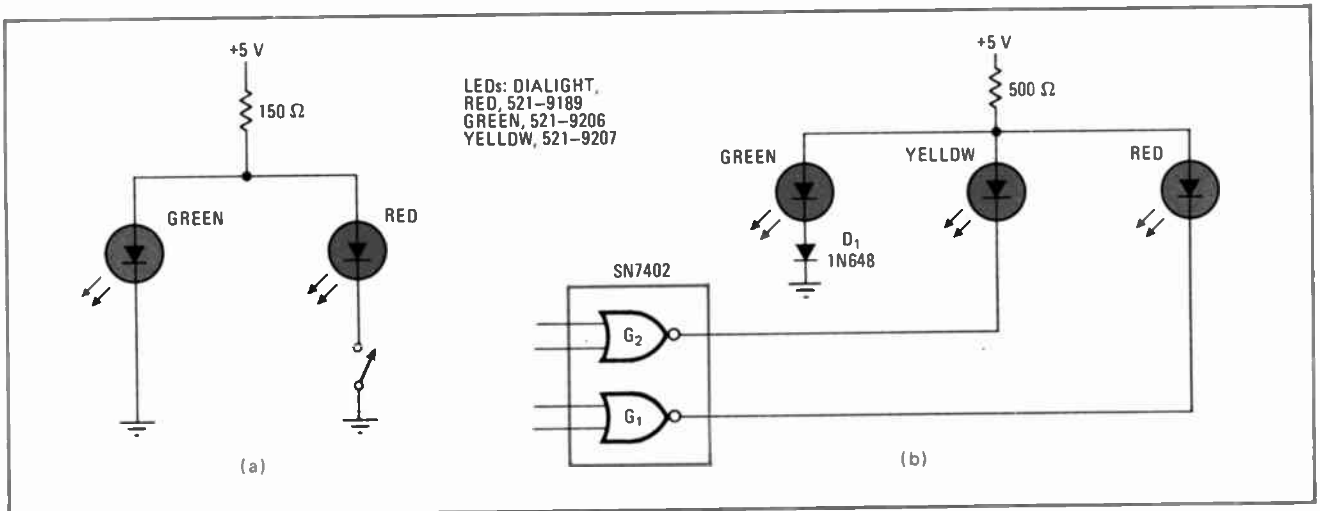
The inequality of threshold voltages of light-emitting diodes of differing colors can be used to minimize the circuitry needed for a display, especially if the application is not a critical one. The voltage drop across a LED that is conducting, therefore, can control another LED of a different color.

In the two-color display of (a), the green LED will light when the switch is open. But when the switch is closed, the red LED lights, producing a voltage drop of approximately 1.5 v, which is slightly below the threshold of the green LED. This lamp, then, goes out.

The concept can be expanded to multiple-unit displays, as in (b). The red LED, which is controlled by gate G_1, will disable the yellow and green LEDs when it is illuminated. If the red LED is not conducting, the display depends on the output of gate G_2.

When G_2's output is low, the yellow LED will conduct, producing approximately a 2.0-v drop at the resistor node. The green LED remains disabled because its threshold is now approximately 2.1 v because of diode D_1. When G_2's output is high, the yellow LED turns off and the green LED turns on.

The luminous intensity of such a display is quite acceptable, even in a well-lit room. And the difference in luminous intensity between the three LEDs is negligible. The 500-ohm resistor limits gate current and establishes the proper voltage drops for the LEDs □



Paring display circuitry to a minimum. The different threshold voltages of LEDs of differing colors can be used to select the colors in a display. For the two-color display of (a), only the green LED conducts when the switch is open, and only the red LED conducts when the switch is closed. Similarly, a three-color display (b) can be obtained by employing two switches (gates G_1 and G_2) and a diode (D_1).

Comparing the power of C-MOS with TTL

by Colin Crook
Motorola Semiconductor Products Inc., Phoenix, Ariz.

The low power dissipation of complementary-MOS circuitry is legendary by now. You've been told, time and time again, that it is lower—considerably lower—than equivalent TTL designs. How much lower is somewhat astonishing—as large as an order of magnitude or more.

Here is a set of tables that clearly demonstrates the vast difference in power requirements between C-MOS and TTL. This difference results in a significant saving in overhead for system-support needs, like power supplies and cooling equipment. The tables make a systems-level power comparison between C-MOS and TTL by examining a representative logic system—an industrial controller and sequencer.

This typical system consists of 500 IC packages: there are 200 quad NAND gates, 150 dual flip-flops, and 150 4-bit arithmetic logic units. Table 1 gives the device type numbers used for the C-MOS and TTL systems.

At medium frequencies, the dynamic power of C-MOS is significant compared to its dc power, so that certain loading and frequency conditions will be assumed. For this example, every output node of a gate package is loaded by 50 picofarads, every output node of a flip-flop package by 30 pF, and every output node (eight in all) of an arithmetic-logic-unit package by 15 pF. A reasonable assumption for the operating frequency is that

TABLE 1

LOGIC SYSTEM

Device	Number of packages	C-MOS type	TTL type
Quad NAND gate	200	MC14011CP	MC7400P
Dual flip-flop	150	MC14027CP	MC7473P
Arithmetic logic unit	150	MC14581CL	MC74181P

TABLE 2

DC POWER AT 5 VOLTS: C-MOS vs TTL

Device	Per-package power	System power
Gate	C-MOS: Typ = 25 nW Max = 75 μW	C-MOS: X 200 Typ = 5 μW Max = 15 mW
Gate	TTL: Typ = 40 mW Max = 110 mW	TTL: X 200 Typ = 8 W Max = 22 W
Flip-flop	C-MOS: Typ = 50 nW Max = 700 μW	C-MOS: X 150 Typ = 7.5 μW Max = 105 mW
Flip-flop	TTL: Typ = 80 mW Max = 200 mW	TTL: X 150 Typ = 12 W Max = 30 W
ALU	C-MOS: Typ = 250 nW Max = 3.5 mW	C-MOS: X 150 Typ = 37.5 μW Max = 525 mW
ALU	TTL: Typ = 470 mW Max = 750 mW	TTL: X 150 Typ = 70.5 W Max = 112.5 W

Total C-MOS system dc power

	Typ	Max
Gates	= 5 μW	15 mW
Flip-flops	= 7.5 μW	105 mW
ALUs	= 37.5 μW	525 mW
TOTAL	= 50 μW	645 mW
Current at 5 V	= 10 μA	129 mA

Total TTL system dc power

	Typ	Max
Gates	= 8 W	22 W
Flip-flops	= 12 W	30 W
ALUs	= 70.5 W	112.5 W
TOTAL	= 90.5 W	164.5 W
Current at 5 V	= 18.1 A	32.9 A

TABLE 3

C-MOS DYNAMIC POWER AT 5 VOLTS

Device	Per-package power	System power
Gate	At 200 kHz = 1.2 mW At 1 MHz = 6.0 mW	Average = 3.6 mW 200 X 3.6 mW = 720 mW
Flip-flop	At 200 kHz = 0.6 mW At 1 MHz = 3.0 mW	Average = 1.8 mW 150 X 1.8 mW = 270 mW
ALU	At 200 kHz = 0.4 mW At 1 MHz = 2.0 mW	Average = 1.2 mW 150 X 1.2 mW = 180 mW

Total system power

Gates	= 720 mW
Flip-flops	= 270 mW
ALUs	= 180 mW
TOTAL	= 1.170 W

half of all the nodes switch at 1 megahertz, and the other half switch at 200 kilohertz.

Because of its enhanced noise immunity at higher supply voltages, C-MOS is often operated at 10 volts. For this reason, we will compare the dc, as well as dynamic, power consumption of C-MOS at both 5- and 10-V supply voltages to the dc power of TTL at 5 V.

At operating frequencies of 1 MHz or less, the dynamic power of TTL is negligible compared to its dc power. In fact, TTL dynamic power does not become relevant until the operating frequency exceeds 10 MHz. Therefore, there is no real need to compute TTL's dynamic power separately.

Table 2 shows the dc power requirements of C-MOS and TTL when the system supply voltage is 5 V. As you can see, the entire C-MOS system consumes only 50 microwatts typically and 645 milliwatts maximum. In contrast, the same system built with TTL devices requires 90.5 watts typically and 164.5 W maximum.

In Table 3, the dynamic power of a 5-V C-MOS system is computed. Here, the total system power consumption is found to be 1.17W. Table 4 gives the total dc power for a 10-V C-MOS system; it is 190 μW typically and 2.58 W maximum. The total dynamic power for this same 10-V C-MOS system is evaluated in Table 5; it is 5.04 W average.

Table 6 summarizes the results of all the preceding tables. Roughly speaking, TTL consumes about 100 times more power than C-MOS, even when worst-case dynamic operating conditions are taken into consideration for the C-MOS system. □

Engineer's Notebook is a regular feature in Electronics. We invite readers to submit original design shortcuts, calculation aids, measurement and test techniques, and other ideas for saving engineering time or cost. We'll pay $50 for each item published.

TABLE 4

C-MOS DC POWER AT 10 VOLTS

Device	Per-package power	System power
Gate	Typ = 50 nW Max = 300 μW	X 200 Typ = 10 μW Max = 60 mW
Flip-flop	Typ = 200 μW Max = 2.8 mW	X 150 Typ = 30 μW Max = 420 mW
ALU	Typ = 1.0 μW Max = 14 mW	X 150 Typ = 150 μW Max = 2,100 mW

Total system power		Typ	Max
Gates	=	10 μW	60 mW
Flip-flops	=	30 μW	420 mW
ALUs	=	150 μW	2,100 mW
TOTAL	=	190 μW	2.58 W
Current at 10 V	=	19 μA	258 mA

TABLE 5

C-MOS DYNAMIC POWER AT 10 VOLTS

Device	Per-package power	System power
Gate	At 200 kHz = 4.8 mW At 1MHz = 24 mW	Average = 14.4 mW 200 X 14.4 mW = 2,880 mW
Flip-flop	At 200 kHz = 3.0 mW At 1 MHz = 15 mW	Average = 9.0 mW 150 X 9.0 mW = 1,350 mW
ALU	At 200 kHz = 1.8 mW At 1 MHz = 9.0 mW	Average = 5.4 mW 150 X 5.4 mW = 810 mW

Total system power		
Gates	=	2,800 mW
Flip-flops	=	1,350 mW
ALUs	=	810 mW
TOTAL	=	5.04 W

TABLE 6

TOTAL SYSTEM POWER: C-MOS vs TTL

Logic	Dc		Ac	Totals
	Typ	Max		
TTL	90.5 W 18.1 A at 5V	164.5 W 32.9 A at 5 V	Assume small compared with dc power	Max = 164.5 W Typ = 90.5 W Power supply average = 25.5 A at 5 V
5-volt C-MOS	50 μW 10 μA at 5 V	645 mW 129 mA at 5 V	1.170 W	Max = 1.82 W Typ = 1.17 W
10-volt C-MOS	190 μW 19 μA at 10 V	2.58 W 258 mA at 10 V	5.04 W	Max = 7.62 W Typ = 5.04 W

Engineer's newsletter

EE jobs: a return to the salad days?

After the nagging softness of the past few years, the EE job market is getting good again, at least for starting graduates. Despite the uncertainties about the economy, some 95% of the engineering schools surveyed by the Engineers Joint Council report that **demand for graduates is running 5% to 20% stronger this year than last.** Moreover, this year's graduating class of EEs is smaller than last year's, so there could be a return to the good old days of would-be employers scrambling to hire the personnel they need. **The specialty in greatest demand: semiconductor-device design.**

Heat helps you to fine-tune voltage-reference zeners

Determining the true zero-temperature-coefficient point of a voltage-reference zener can improve its stability, says James Williams, a senior engineer at the Instrumentation Laboratory of Massachusetts Institute of Technology, Cambridge, Mass. The zero-TC point of a temperature-compensated zener is always specified at some standard current, usually 7.5 milliamperes. Although a zener will meet the drift specified on its data sheet for this standard current, its performance can be enhanced by finding the actual bias point at which the zero-TC occurs.

To do this, the zener is biased by a constant-current source through a precision (±0.005%) 100-ohm resistor. Now, at the specified current (usually 7.5 mA), **hold a hot soldering iron about 1 inch away from the zener for around 5 seconds, and observe the drift on the voltmeter.** After the diode cools, adjust the current source a few tenths of a percent in either direction and repeat the process. **If the drift decreases, repeat the process until the zener is fine-tuned.** If the drift increases, the current source must be changed in the other direction. Finally, when you obtain minimum drift, read the voltage across the 100-ohm resistor and compute the current through it. This is the optimum zero-TC current for that particular zener.

Magnetize fluids to put them where you want them

Even EEs are occasionally faced by mechanical problems, such as lubricating and sealing the shaft on an adjusting knob, damping a meter movement, marking and sorting semiconductor chips, and so on. Such simple, yet frustrating, problems can sometimes be solved **by suspending magnetic particles in various liquids so that they can be shaped, retained, or moved by a magnetic field to the desired location.**

Several kits for use in mixing fluids for various applications are available at $100 each from Ferrofluidics Corp., 144 Middlesex Turnpike, Burlington, Mass. 01803. **The kits concentrate on such applications as lubrication, damping, printing, and general engineering design.** The company also makes the magnetic fluids in production quantities.

Reprint your own product designs

Is your production cycle hung up on delays in obtaining photostats of drawings? Print your own. For $150 you can buy a machine capable of **printing drawings as wide as 18 inches from blueprints, black-line prints, sepias, linens, or film.** For complex production jobs, a $675 machine handles drawings 42 in. wide. Write Teledyne Rotolite of 328 Essex St., Sterling, N.J. 07980.

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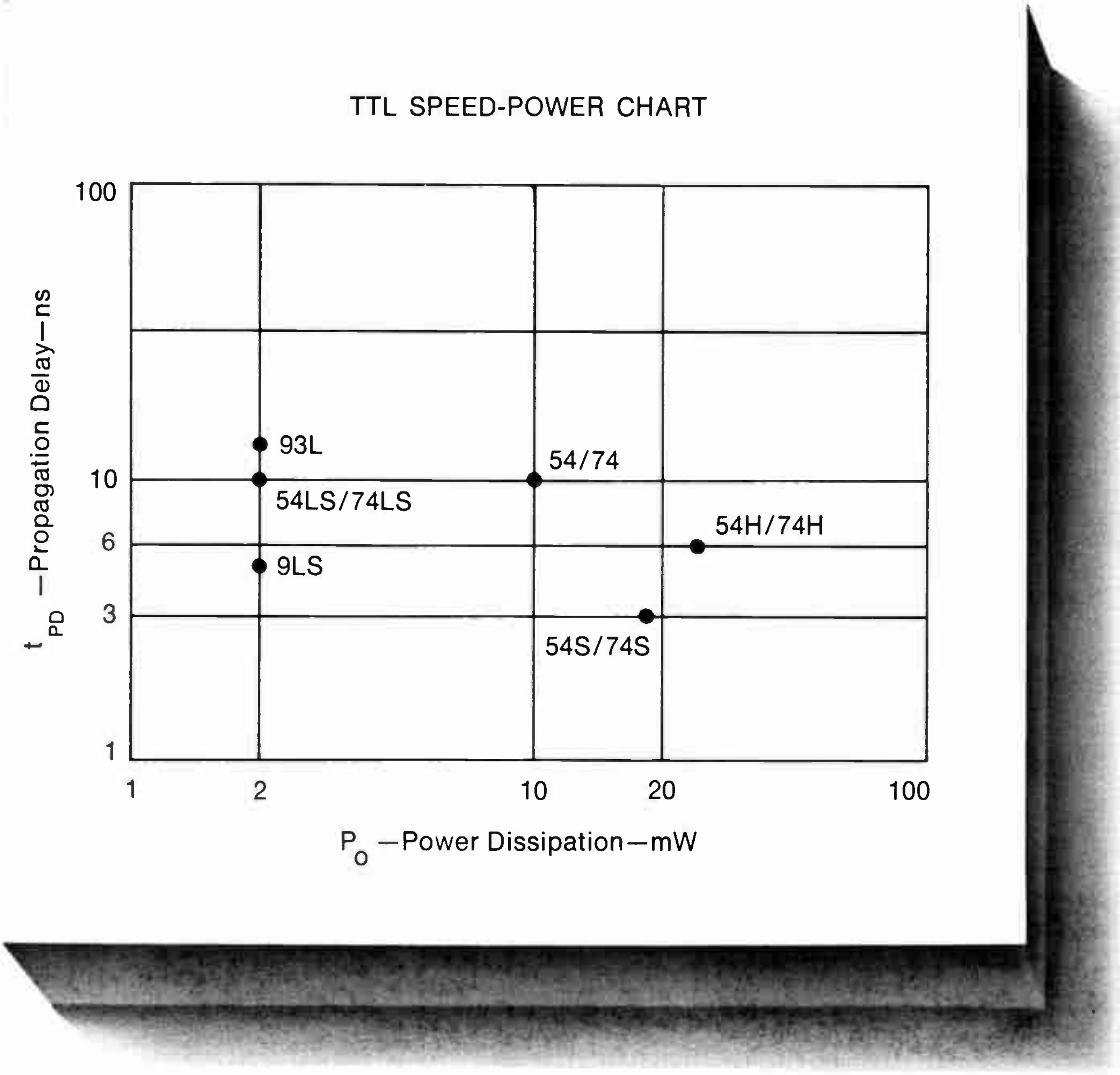

TTL SPEED-POWER CHART
100
10
6
3
1
t_{PD} —Propagation Delay—ns
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54LS/74LS
9LS
54/74
54H/74H
54S/74S
1
2
10
20
100
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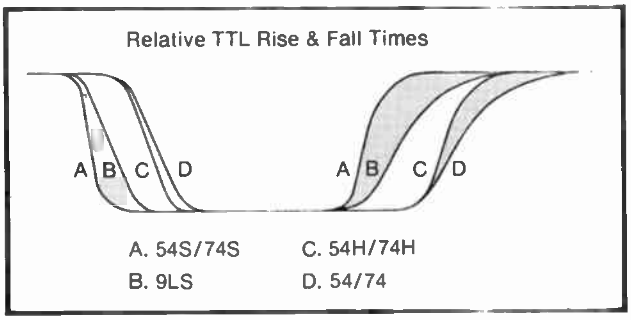

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9LS02	Quad 2-NOR Gate	.48
9LS03	Quad 2-NAND Gate (Open Collector)	.48
9LS04	Hex Inverter	.53
9LS05	Hex Inverter (Open Collector)	.53
9LS10	Triple 3-NAND Gate	.48
9LS11	Triple 3-AND Gate	.48
9LS15	Triple 3-AND Gate (Open Collector)	.48
9LS20	Dual 4-NAND Gate	.48
9LS22	Dual 4-NAND Gate (Open Collector)	.48
9LS32	Quad 2-OR Gate	.48
9LS74	Dual "D" Flip-Flop	.77
9LS109	Dual J$\bar{K}$ Edge Triggered Flip-Flop	.77
9LS112	Dual JK Edge Triggered Flip-Flop	**
9LS113	Dual JK Edge Triggered Flip-Flop	**
9LS114	Dual JK Edge Triggered Flip-Flop	**

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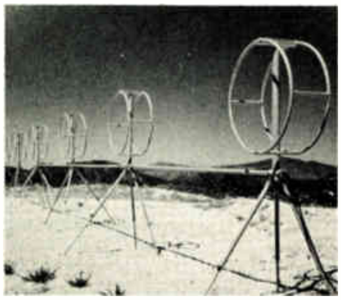

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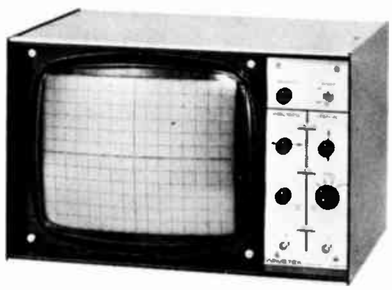


Plating process provides uniformity

Circuit boards' through-holes are electroplated with ductile copper of same thickness as on boards, enhancing strength of hole walls

by Stephen E. Grossman, Packaging & Production Editor

Plating a mere thousandth of an inch of high-quality copper in the holes of a printed-circuit board is a tough assignment. But MacDermid Inc. of Waterbury, Conn., has developed a dull-finish copper electroplating bath that does the job efficiently. What's more, the company claims it enables easier maintenance than other techniques.

Electroplating copper from a liquid bath is popular among printed-circuit-board manufacturers because it builds up copper rapidly on the circuit lines and in the through-holes. Once coated with copper, the plated-through holes provide electrical connections between the circuit patterns on both sides of the board.

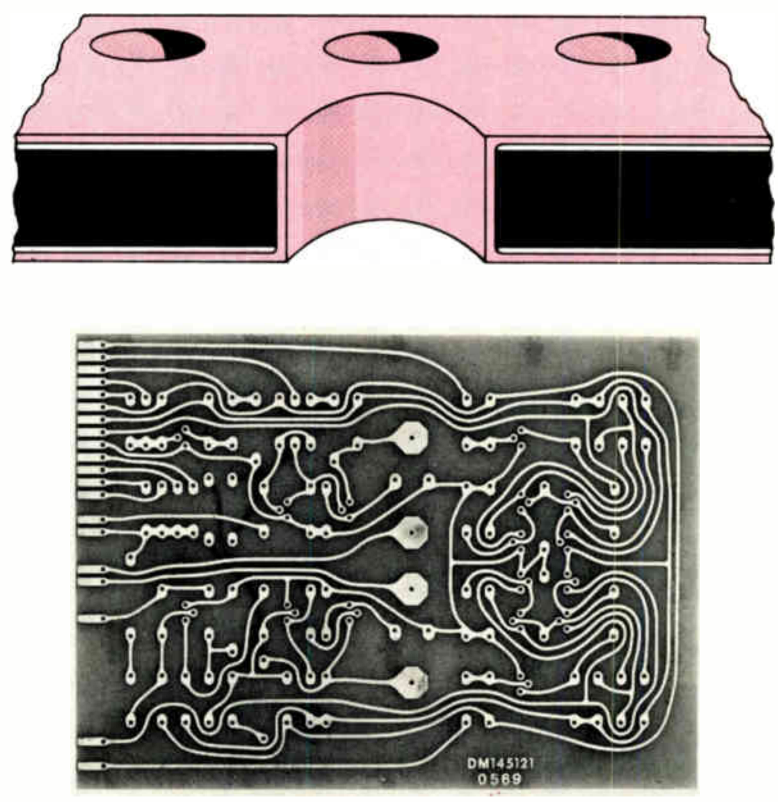
MacDermid, a chemical supplier, says that its plating bath has a high throwing power—better than one to one—which means that it plates out as much metal in the hole as it does on the board surface. The copper is unusually ductile, which is a vital property because the plated-through hole is subjected to severe elongation when the board passes through a hot soldering bath. In soldering, the board expands and contracts. The plating must survive such torture, adhering tightly to the hole wall without cracking.

While the quality of the deposited copper is important, it isn't the sole criterion. Another problem confronting electroplaters is maintaining the bath. According to Brian Mason, product manager at MacDermid, the new plating process enables the user to continuously filter his plating bath over carbon, thus ensuring that the bath is maintained free of contaminants. "The two addition agents used in the process," he says, "improve anode efficiency and control the grain structure of the deposited copper. But, unlike addition agents often used in bright-copper plating baths, they do not co-deposit with the copper and cause brittleness."

Conventional bright-acid and pyrophosphate plating baths deposit copper that has a high-gloss finish. MacDermid's material, called Hi-Spec Matte Acid Copper, has a satin sheen. This surface, the company says, offers a topography that is more compatible with electroless copper deposits and provides superior adhesion for photoresists and subsequent copper or tin-lead deposits in pattern plating.

Monitoring the bath is said to be easy, since the user needs do little more than analyze copper and sulfuric-acid levels by means of conventional titration methods.

MacDermid Inc., 50 Brookside Rd., Waterbury, Conn. 06720



Finished. With the MacDermid dull-finish electroplating approach, ductile copper builds up in through-holes at about same rate as on surface.

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Semiconductors

TRW launches rf power transistors

28-V parts withstand infinite VSWR, and thermal design ensures ruggedness

New vhf and uhf power transistors from TRW Semiconductors are priced low to help share in the growth of rf communications, one of the fastest growth areas in electronics. The new parts, rated to 50 watts vhf and 30 W uhf, represent the Lawndale, Calif., operation's new standard line of 28-volt parts for high-volume applications.

The transistors withstand infinite VSWR at all phase angles, and the latest advances in thermal design ensure ruggedness. All parts—even low-power ones—use emitter ballasting, which has often been restricted to high-power transistors.

The parts are packaged in low-parasitic ceramic packages, a move away from the molded plastic package that TRW has used in many products in the past. Product manager Robert Baughan says that the production cost is lower for ceramic packaging than it is for molded plastic packaging.

Metalization is gold rather than aluminum, to reduce metal migration in uhf devices. Migration has been a major cause of failure in uhf and microwave devices using the light metal. The gold also gives improved oxide-step coverage and better bonding strength to gold wire than does aluminum.

The company is aiming the rf-transistor line at a host of applications including use in aircraft, marine and tactical radios, radio relay, electronic countermeasures equipment and instrumentation. In the vhf range, devices are specified for output power of 4, 8, 15, 25, and 50 watts.

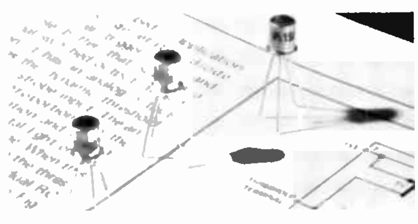
The output of TRW PT9731, for example, is rated at 25 W and a gain of 10 DB. The unit is priced at $13.85 each in quantities to 999. TRW PT9733, rated at 50 W and gain of 7 dB, is priced at $20.30 each in the same quantities.

In the uhf-transistor range, devices are specified for 4, 10, 20, and 30 W. As an example, TRW PT9704A is equivalent in performance to 2N6105A, with rated output power of 30 W and gain of 7.8 dB. The device is priced at $25 each in quantities from 1 to 999. All transistors in the line are available from stock.

TRW Semiconductor Operations, 14520 Aviation Blvd., Lawndale, Calif. [411]

Subminiature IC switch is light activated

The series IPI-15/17 light-activated switches are based on an MOS integrated circuit that includes a silicon



planar photodiode. The photodiode is integrated with a Schmitt trigger, buffer amplifier, and control circuitry on an MSI chip. In operation, the output is switched on when the incident illumination exceeds a selected upper threshold level and is switched off when the illumination falls below a lower threshold level.

Integrated Photomatrix Inc., 1101 Bristol Rd., Mountainside, N. J. 07092 [420]

Two DTL/TTL opto-isolators are placed in one package

A pair of inverting optically isolated gates, each with a light-emitting diode and an integrated detector, are available in a single package [*Electronics*, April 18, p. 25]. Designed to facilitate greater packing density on a printed-circuit board, maximum dc and ac circuit isolation between each input and output is maintained while DTL/TTL compatibility is achieved. Moreover, photons are collected in the detector by a photodiode, and are then amplified by a high-gain linear amplifier that drives a Schottky-clamped open-collector output transistor. Delay times of 50 nanoseconds can be obtained with this photon detector. The model 5082-4364 dual isolator is priced at $12.90 in 1 to 99 quantities and $9.90 for 100 to 999.

Hewlett-Packard Co., 1501 Page Mill Rd., Palo Alto, Calif. 94304 [414]

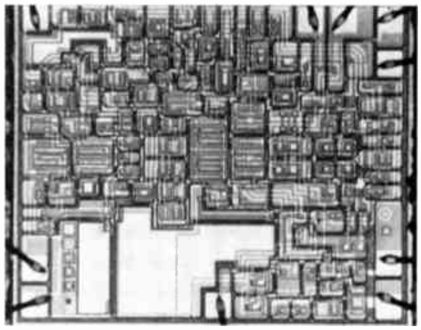
Display circuit integrates with microprocessor system

An LSI circuit is designed to integrate with the company's parallel-processing system microprocessor to extend the system's capability. The circuit, called a general-purpose keyboard and display device, is compatible with the control and bus structure of the microprocessor circuits and with TTL systems. The input-output characteristics of the circuit allow a wide range of displays to be used, as well as switches and keyboard functions. In operation, the input keys are sampled and the displays are refreshed at a rate of about once every 7 milliseconds.

Rockwell International, Microelectronics Group, Box 3669, 3430 Miraloma Ave., Anaheim, Calif. 92803 [415]

Sample-and-hold op-amp is priced as low as $14.85

A monolithic sample and hold operational amplifier, called the HA-2425, is designed to be less expensive than the modules or hybrids it replaces. The unit is priced at $14.85 in 100 lots. And, in addition to offering a slew-rate-to-droop-rate ratio of 5×10^6, the unit has a DTL/TTL-compatible control input, bandwidth of 2 MHz, 50-nanosecond aperture time and a slew rate of 5 V/μs. The design consists of an op amp with its output in series with an analog switch that features a leakage current of 1 nA maximum and 10 pC charge transfer. The switch is buffered by a MOS FET-input unity-gain amplifier. Connection of an external capacitor to the switch forms a sample-and-hold or track-and-hold circuit. With the switch closed the device functions as an op amp, and any of the standard op amp



feedback networks may be connected around the device, to control gain and frequency response, for example.

Harris Semiconductor, Box 883, Melbourne, Fla. 32901 [413]

4,096-bit RAMs access at 230 and 300 nanoseconds

Two n-channel MOS/LSI 4,096-bit dynamic random-access memories, designated the models MCM6605L and MCM6605L-1, provide access times of 230 and 300 nanoseconds, respectively. Both devices have TTL-compatible outputs and are intended for the replacement of core and smaller semiconductor memories in a wide range of computer applications. Developed jointly with American Microsystems Inc., the memories share common photomasks and processing with AMI 4,096-bit memories. Price ranges from $33.30 to $50, depending on type and quantity.

Motorola Semiconductor Products Inc., Box 20924, Phoenix, Ariz. 85036 [416]

Monolithic ICs control SCRs and triacs

The L120 and L121 monolithic integrated circuits each act as a complete control system for SCRs or

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By injection molding rotor and stator strips in Celanex thermoplastic polyester, instead of slower compression molding in alkyd resins formerly used, South American manufacturers cut finished part costs, speed production and improve performance of these TV tuners.

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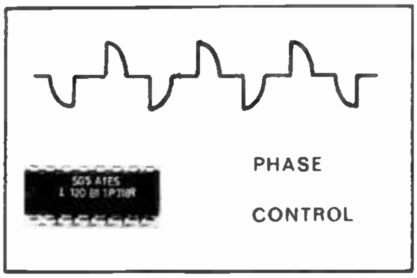
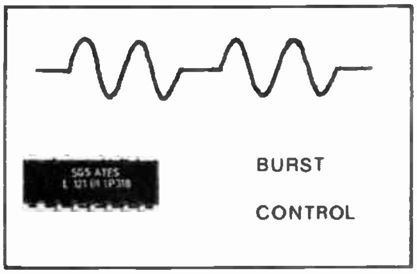
triacs. The L120 device is aimed at jobs in phase-type control systems. The firing angle of the SCR or triac can be varied continuously and linearly, between 0° and 180°. The output pulses have the same polarity as the power line. The L121 is designed for application in burst-type control systems. Its action determines the number of half cycles of output power to be transferred to the load in a set base-period. In each base-period, the duty cycle can be varied from 0 to 100% continuously. The firing pulses produced





have the same polarity as power line. Price for each of the devices is $6 for 1 to 99 pieces and $4 for 100 to 999 pieces.

SGS Ates Semiconductor Corp., 435 Newtonville Ave., Newtonville, Mass. 02160 [417]

Modulators are designed for telephone applications

The SL 10001A and SL 10001B bipolar monolithic integrated-circuit double-balanced modulators are designed primarily for use in telephone transmission equipment. The devices are also suitable for applications where a modulation function is required, and are conventional "tree configuration" multiplier circuits. Internal bias is provided, which allows direct bal-

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anced transformer input, or single-ended capacitor drive. The modulars/demodulators feature a carrier and signal suppression of 50 decibels, noise level of −112 dBm, intermodulation suppression of −58dB, and supply current of 4 milliamperes. Output is via a two-stage common-collector circuit providing a low output impedance. A pair of diodes are provided for optional limiting of the carrier input.

Plessey Semiconductors, 1674 McGaw Ave., Santa Ana. Calif. 92705 [418]

Static CMOS RAM offers 256 bits

Using silicon-on-sapphire techniques, a 256 × 1 random-access memory, designated the INS4200S, offers read cycle times of 180 nanoseconds, with write cycle times of 140 ns. Quiescent power dissipation is 40 microwatts. In the operational mode, power dissipation is 26 milliwatts. Input capacitance is rated at 6.5 pF at 25 C°, and supply voltage ranges from 5 to 15 volts. The INS4200S also offers a three-state TTL-compatible output, full address decoding and bipolar compatible pin-outs in a 16-pin dual in-line package. A minimum of additional components are required due to the three-chip selected inputs, especially when used with large memory arrays. Fully compatible with other C-MOS and TTL logic devices, the read-only memory is designed for use in scratch-pad, buffer, and main memory applications where high speed and low power are prime considerations. The device is priced as low as $26 when ordered in quantities of 100-999.

Inselek Inc., 743 Alexander Rd, Princeton, N.J. 08540 [419]

Why Parylene works where other microelectronic protection fails:

Crevice penetration in hybrids

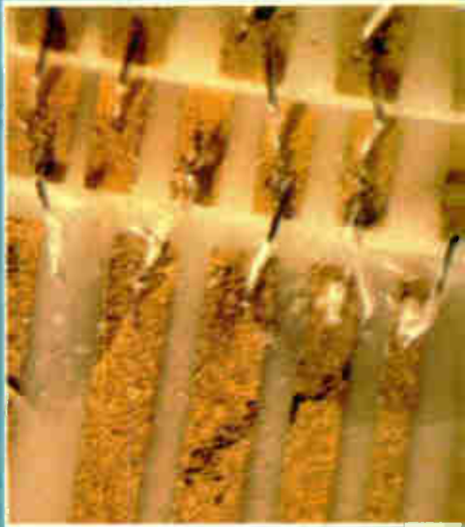
This beam lead has a 0.3 mil parylene coating all the way to the weld. Parylene penetrates deep within small crevices, maintaining clearance while putting a coherent coating under beam leaded chips and air bridges. No area is left unprotected, preventing shorts and allowing the designer great latitude in component spacing and sizing. And parylene secures loose debris while preventing breakoff of pigtails during shock and vibration loadings.

Controlled conformality

There's a uniform coating of parylene all the way around the half-mil tip of this phonograph needle. That's true conformality, and only parylene gives it, in precisely controlled thicknesses from .002 to 3 mils, in one step. Unlike spray or dip coatings, parylene won't bridge or puddle, or thin out at sharp edges, creating potential failure points. The parylene coating is completely uniform, no matter how dense or intricate the module. And because it's applied at room temperature, there's no component discomfort.

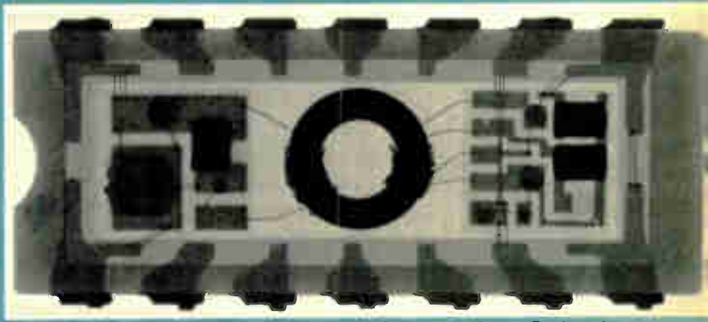
Lead Strengthening

It took up to 75 grams pull to break these 1 mil wires. Bare 1 mil aluminum wires, for instance, exhibit bond strengths of 3-5.5 grams; coated with 1 mil of parylene, pull strength increases by 60-70 grams. So wire and bond are stronger, and sideward shorts and loop collapse during extreme g-loads are prevented. Parylene coatings will penetrate the less than 1 mil clearance between beam lead bonded chips and the substrate, giving such strong coating coverage that the chip cannot be lifted without destroying it.

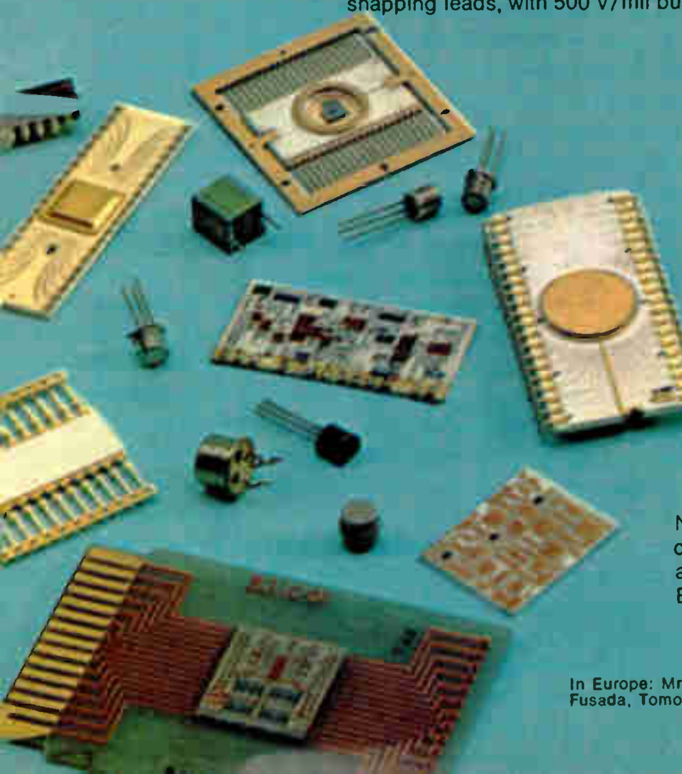


△200 C thermal shock protection

This hybrid microelectronics relay has undergone 200 45-minute cycles from −120 to 80°C, simulating earth-orbiting conditions. This X-ray shows all leads remain intact. Parylene protection was at work, on the transformer core and then the whole assembly before packaging (TO-116). There was no appearance of corona up to 5000 V_{dc}; leakage was reduced from 10μA to <.001μA at 1000V. RTV encapsulation suffered dimensional mismatch, straining and snapping leads, with 500 V/mil bulk breakdown.



X-ray courtesy NASA Lewis Research Center and Sterer Engineering



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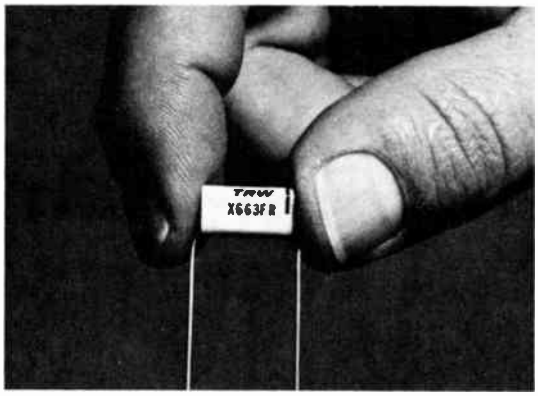
Fight chassis squeeze with these miniaturized "flat oval" capacitors



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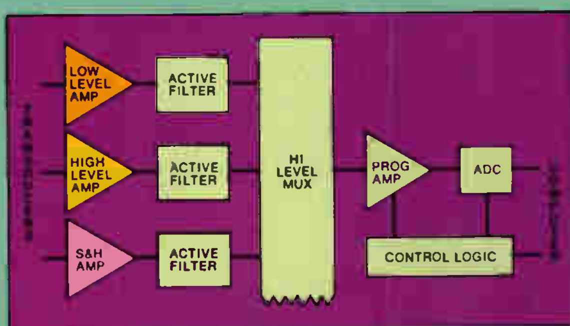

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Circle 155 on reader service card

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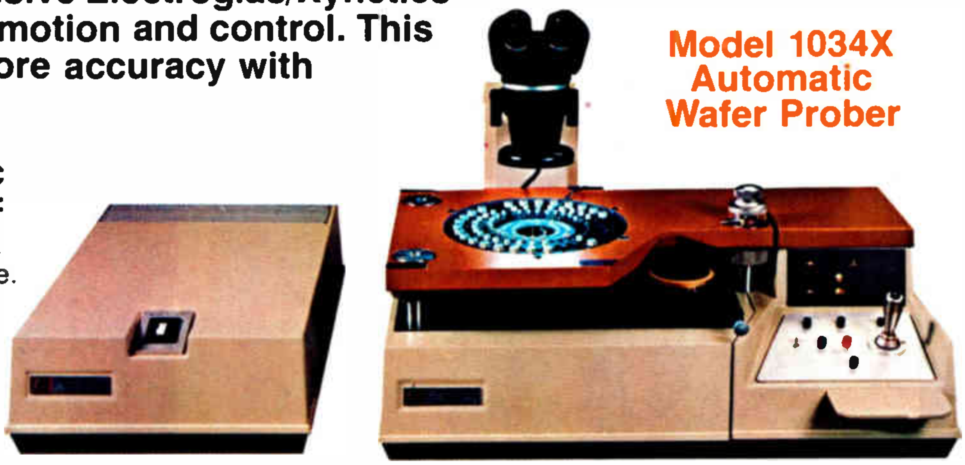
Electroglas's newest lines of Wafer Scribers and Wafer Probers incorporate the unique and exclusive Electroglas/Xynetics Linear Motor for X-Y motion and control. This new system gives more accuracy with maximum simplicity.



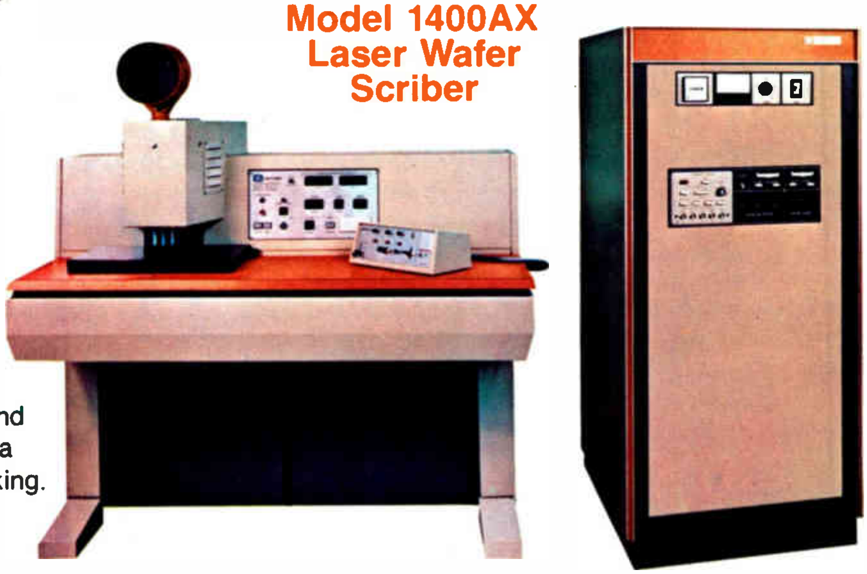
Model 1034X Automatic Wafer Prober

THE NEW 1034X AUTOMATIC WAFER PROBER FEATURES:

- High speed chuck with less than 20 mSec up/down time.
- Stage travel speed of 5.0" (127mm) per second.
- One G acceleration/ deceleration.
- Five by ten inch stage travel.

AT THE HEART OF THESE TWO NEW PRODUCTS is this linear motor. It has only one moving part — an electromagnetic forcer block which rides on a cushion of air and moves over a ferromagnetic platen with accuracy and stepping resolution of 0.5 mil or 10μ. All with NO FRICTION, NO WEAR.

Electroglas/Xynetics X-Y Motion System



Model 1400AX Laser Wafer Scriber

AN ADDITIONAL NEW FEATURE OF THE 1400 AX WAFER LASER SCRIBER is the most powerful commercially available YAG laser. It will scribe at better than 10" per second with a kerf width of less than .001" and a depth of .002", with no chipping or cracking.

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A XYNETICS COMPANY
2901 Coronado Drive Santa Clara, CA 95050 408/246-6500

See these two new systems at Semicon/West Booth No. 439

Instruments

Thermometers have wide range

One digital panel unit works with thermocouples, two with platinum probes

Three digital panel thermometers are being introduced to the U.S. market by Schneider Electronique of Rungis, France. The model TT 400, designed to work with thermocouples, gives digital linearization points for every 10°C change in temperature. The other two, the TT 2000 and TT 2120, which are for use with platinum probes, provide resolution of 0.1°C and 0.01°C.

The TT 400 is available with isolated binary-coded-decimal output or with a standard analog output card, which allows it to be used as a receiver to display temperature or as a generator in a regulation loop.

The TT 2000 and TT 2120 resistance thermometers, for industrial applications, have memorized display to facilitate reading. Outputs are coded for either digital recording or digital comparison; in the latter use, the unit can regulate temperature.

The TT 400 has an external cold junction that is fully compensated between -10°C and +80°C ambient temperature. The cold junction can connect directly on the rear panel of the TT 400 or near the thermocouple itself.

Digital linearization is used extensively; by incorporating large read-only memories, the company was able to include all points of the standard tables with a conformity of ±1°C. Depending on the thermocouple used, temperature range can be from 0°C to 800°C or -200°C to +1,370°C. Display rate is adjustable from 0.1 to 10 seconds. Input impediance is greater than 1,000 megohms, and offset current is less than 1 nanoampere. Rejection rate in normal mode is greater than 50 decibels at 50 hertz, and in common mode it is 140 dB in dc, and 120 dB at 50 Hz. Response time is 1 second. The unit has automatic zero-calibration and temperature stability of 10^{-4}/°C.

Temperature range of the TT 2000 is from -100 to +400°C, with resolution of 0.1°C and accuracy within ±1°C. Temperature coefficient is ±2°C with ±25°C of deviation. The TT 2120, with a temperature range of -120°C to +120°C, is accurate within ±0.2°C and has resolution of 0.01°C, while temperature coefficent is ±0.3°C for ±25°C of deviation.

Both units can take 10 readings per second and have a response time of 400 milliseconds. Normal-mode rejection is 50 dB at 50 Hz, while common-mode rejection is 100 dB at 50 Hz. Input impedance of the TT 2000 is greater than 100 megohms.

Price of the TT 400 is $375; the TT 2000, $375; and the TT 2120, $425.

Schneider Electronics Inc., 3 Hazel St., Peabody, Mass. [351]

Digital panel meters are easily customized

A continuing problem for firms that make relatively small quantities of instruments is obtaining satisfactorily labeled and specified digital panel meters with minimum cost and trouble. Tekelec Inc., has developed a meter and system that it feels will minimize the problem.

The company's 3½- and 4½-digit meters with liquid-crystal display can be specified with a wide variety of range and zero offset, plus any engineering units, all at only $29 over the cost of the basic meter in quantities of 100. Single quantity price is $59, and the meters themselves are a low $67.50 for a 3½-digit version or $98.50 for 4½-digit model, also in quantities of 100.

The Tekelec meters are in the TA 300 series, and use back-lit transmission field-effect displays, plus a single MOS and single bipolar chip. The range is set by a single external resistor. Because a precision wire-wound resistor with excellent temperature and time stability is required, so Tekelec maintains an inventory for models requiring 100 millivolt to 1,000 volt full scale and 100 nanoamperes to 10 amperes full scale. Likewise, a single resistor and a high-stability voltage source set the offset, and Tekelec inventories these parts for positive or negative offsets to 50% of full scale.

For many users, the label is even more of a problem than the electri-

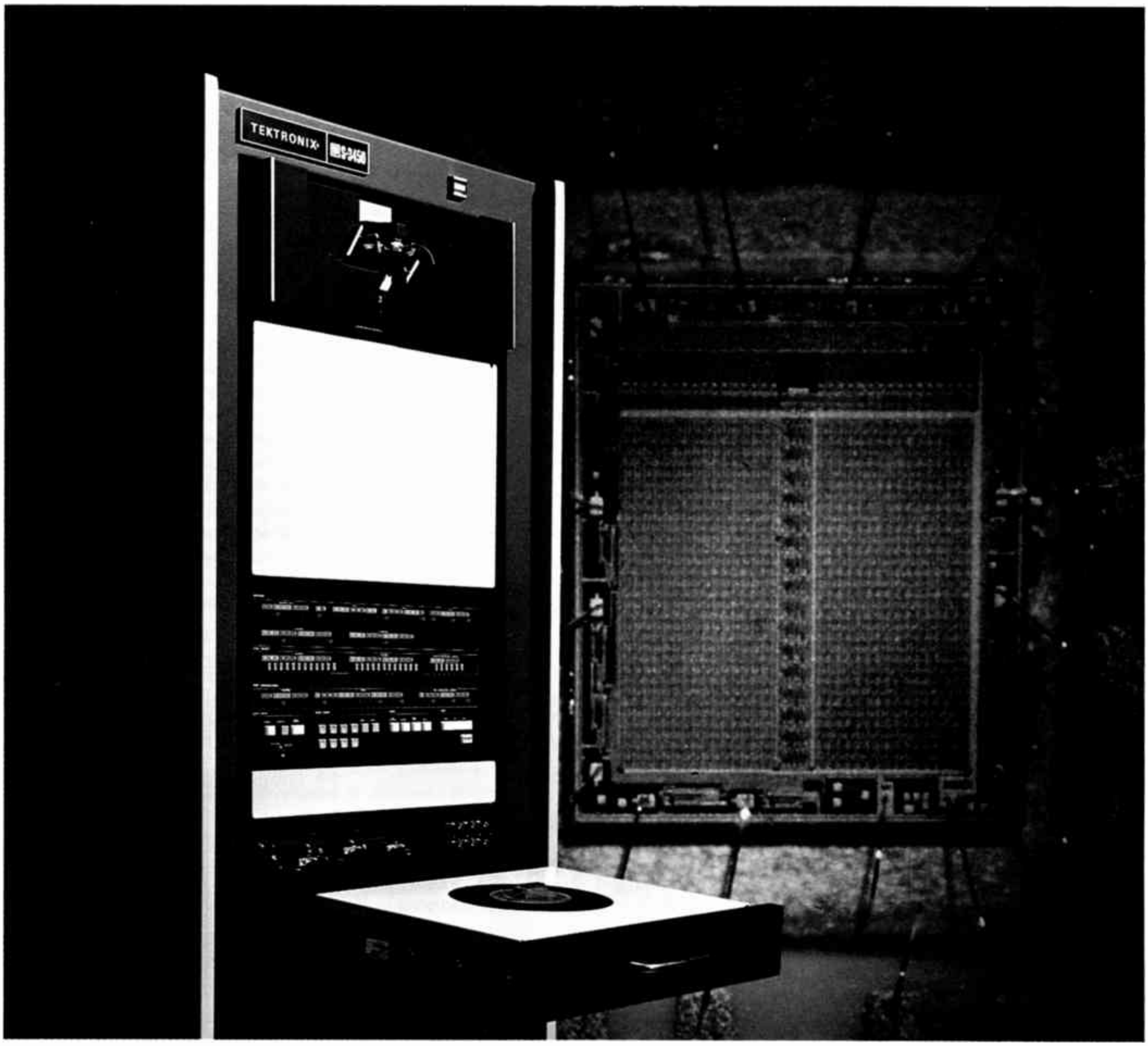
cal components. The company has a special machine that can make small quantities of labels without the usual high tooling cost, which is often $100 or more. The machine makes ¼-inch-high red, orange, or silver letters or numerals on a dark background. Up to 18 characters and spaces can be printed. Typical labels would be °C, gallons per hour, miles per hour and pounds/square inch.

Tekelec Inc., 31829 West La Tienda Drive, Westlake Village, Calif. 91361. [352]

Function generator operates from 2 Hz to 200 kilohertz

The model 30 function generator features 2 Hz to 200 kHz simultaneous sine, square and triangle waveforms with internal linear or logarithmic sweep capability. External capacitors may be added for unlimited frequency down ranging. Sweep mode and voltage-control mode give a frequency change of 1000:1, either linearly of logarithmically. Full voltage control of generator requires only 0 to 1 volt, either dc for programming discrete

TEKTRONIX HAS A NEW LINE TO TEST YOUR MEMORY



Meet the latest additions to the growing lines of TEKTRONIX Automated Test Equipment, the S-3400 Series of Semiconductor Memory Test Systems. These S-3400 systems are modularly constructed, fully programmable, stand alone semiconductor memory testers; capable of performing dc parametric, and functional tests on semiconductor memory devices.

The S-3400 systems have been designed and built to give you a system that can completely and effectively test all semiconductor memories. With interfaces available for wafer probers and automatic device handlers, a total package may be configured to supply you with a complete solution for your semiconductor memory testing requirements.

The S-3400 series joins with our S-3100 series and S-3260 Automated Test Systems to bring to you a wide range of test and measurement solutions. For more information contact the Systems Applications Engineer nearest you listed on the opposite page, circle the reader service card or write Box 500 A, Beaverton, OR 97005

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committed to technical excellence

frequencies or ac for fm operation.
Wavetek, Box 651, San Diego, Calif. 92112 [360]

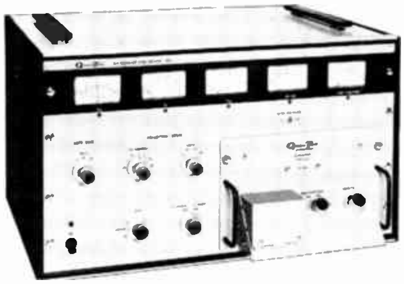
Digital rf power meter covers 1–18,000 MHz

A digital rf power meter for measurement of continuous-wave and swept rf power covers the range of from 1 to 18,000 megahertz. Called the model 4020, the meter features a wide dynamic range of +10 dBm to -40 dBm, without autoranging and

offers a fast response for real-time read out on oscilloscopes. The four-digit display provides direct information of power in both 50- and 75-ohm systems in dBm with a linearity of ±0.04 dB for any 10-dB range. Resolution is 0.01 dB over the full dynamic range. Price starts at $1,725.
Systron-Donner Corp., 735 Palomar Ave., Sunnyvale, Calif. 94086 [353]

Analyzer measures transistor noise

An rf transistor noise analyzer, the model 340B, directly measures transistor noise figure from 0 to 40 decibels. The instrument provides measurements for both bipolar and field-effect transistors, tested at frequencies between 1 and 60 megahertz. Operation of the instrument requires the use of the company's model 1340 front panel, frequency plug-in head, which is selected for one of the five test frequencies available. Each plug-in head contains a socket for the transistor under test, a selection switch, which determines



base resistance, a tuning control to compensate for base capacitance, and an sine wave oscillator for test calibration. Price is $2,500.
Quan-Tech division, Scientific-Atlanta Inc., Randolph Park West, Rte. 10, Randolph Township, N.J. 07801 [354]

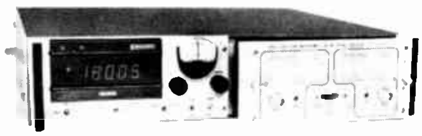
Semiconductor curve tracer permits scope display

For use with an oscilloscope, the model IT-1121 semiconductor curve tracer displays operating parameters

of almost all type of discrete semiconductors. These devices include bipolar transistors, diodes, SCRs, traics, and FETs. Extra leads are provided for testing larger devices or for in-circuit tests. All major controls are stepped in a 1,2,5 sequence. Price is $89.95.
Heath Co., Benton Harbor, Mich. 49022 [355]

Gain phase meter plug-in is accurate to within ±0.1°

The model 305-PA-3009 plug-in module is designed for insertion into the company's series 305 gain phase meters. With the addition of the module, the series 305 is able to make phase measurements with an accuracy to within ±0.1° in the signal frequency range of from 50 hertz to 50 kilohertz, ±25° from 2 Hz



to 500 kHz and from ±0.3° to ±2° out to 11 MHz. Further, the model 305-PA-3009 provides digital readout with a resolution of up to 0.01°.
Dranetz Engineering Laboratories Inc., 2385 S. Clinton Ave., S. Plainfield, N.J. [357]

Three phase wattmeter responds to any waveshape

Called the Digiwatt, a three-phase digital wattmeter incorporates transducers, which work as quarter square multipliers, in each phase. With this feature, the instrument

can respond to signals of any waveshape over a wide range of frequencies. The transducers are coupled to the circuits under test by toroidal transformers. Range of the Digiwatt is from 10 watts to 100 kilowatts, and voltage is from 1 V to 500 V rms.
Ormandy and Stollery, Regal Works, Station Rd., Brightlingsea, Essex, England [358]

Oscillographic recorder has seconds-to-minutes speeds

Offering a seconds-to-minutes chart-speed-reduction option, the model 7402A two-channel oscil-

The board nobody could test BUT Data General. And now us... in 1/24th the time.

Data General Corp. — the mini-computer star — really packs its PC boards. Typical is this 15″ x 15″ edition with 126 integrated circuits, 12 levels of logic, 15 time states.

Most test system companies just shook their heads. So Data General has been handling all its own circuit testing.

Until recently.

DGC brought 80 of these boards to us. Many doctored to incorporate particularly tough combinations of particularly troublesome faults. We ran them using the MIRCO 410 Logic-Circuit Test System and a test program developed with FLASH Test Generation Software. Result: fault isolation, on the average, in 1/24th the time.

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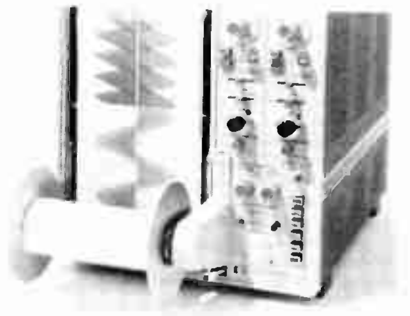
Circle 161 on reader service card

lographic recorder adds chart speeds of 125, 25, 5, and 1 millimeter per minute to the recorder's standard speeds of 125, 25, 5, and 1 millimeter per second. The instrument is suited for long-term measurements on a production line or for

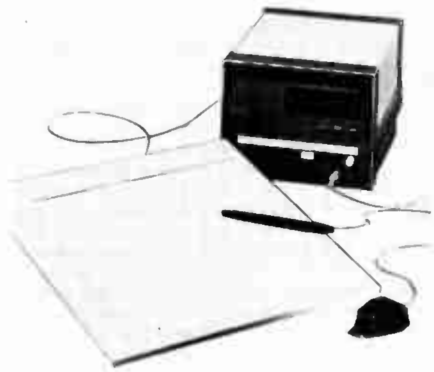


laboratory testing. The model 7402A is priced at $125, and the option is priced at $150.

Hewlett-Packard Co., 1501 Page Mill Rd., Palo Alto, Calif. 94304 [356]

Desk top digitizer has resolution to 0.001 inch

A graphics digitizer, called the Trak 200, converts drawings, maps, and other analog graphic data into computer compatible form, with resolu-



tions to 0.001 inch. The instrument has no moving parts except for the cursor, which requires no adjustment during the life of the equipment. The Trak 200 is available with either a binary or BCD controller. Price, which ranges from $5,000 to $50,000, includes software.

Electrak Corp., 11200 Lockwood Dr., Silver Spring, Md. 20904 [359]

A flexcircuit for "sunshine" calculators

We did it for Rockwell.

A better calculator for the money — Rockwell International's aim in the development of its new private label liquid crystal display calculator. To meet this goal, Rockwell designers developed a light-collecting prism for improved display read-out under varying light conditions, including sunlight.

And to facilitate this design improvement, Rockwell employed a Sheldahl flexcircuit. This flexcircuit makes 84 connections between the back-lighted prism-aided liquid crystal display and the calculator's driving logic. Flaps located on each side of the display aperture flex a full 180 degrees to form pressure pads for display connections.

Flexcircuitry's low bulk permits circuits to the upper edges of the display to be routed through limited space between the calculator case and the display ends. The back of the display is left completely open for light entry and prism placement. The flexcircuit has 132 plated-through holes to provide for a matrix that reduces 84 display connections to 28 logic connections.

Rockwell's calculator design is another case where flexcircuitry fits available space and can be produced in volume.

Perhaps Sheldahl flexcircuitry can help in your design problems. Just call or write Sheldahl for further information.

Sheldahl did it for Rockwell International.

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Electrical Products Division
Northfield, Minnesota 55057
Phone: (507) 645-5633

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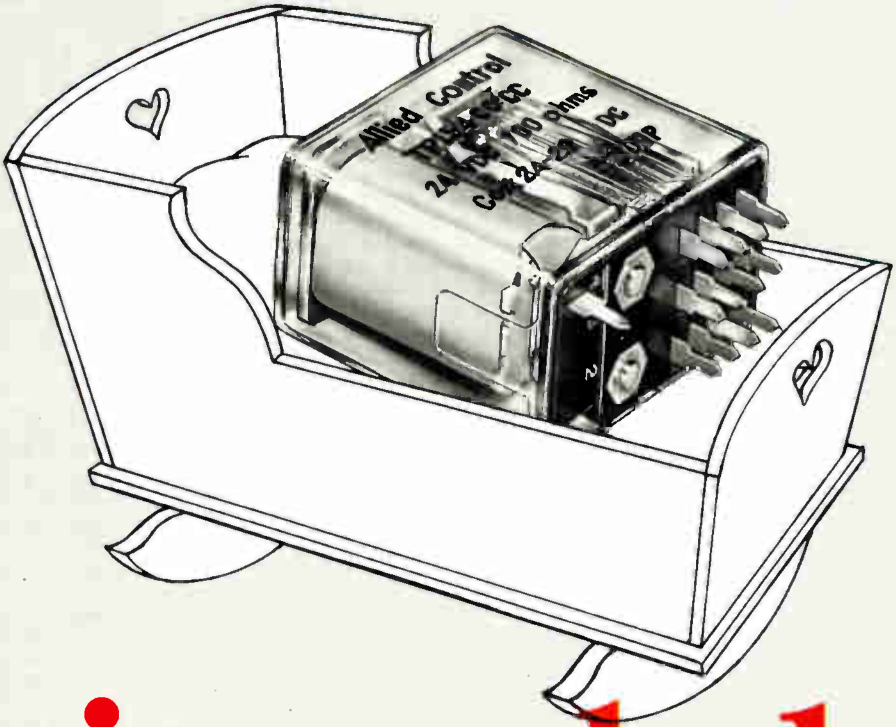

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2423 Northline Industrial Blvd.
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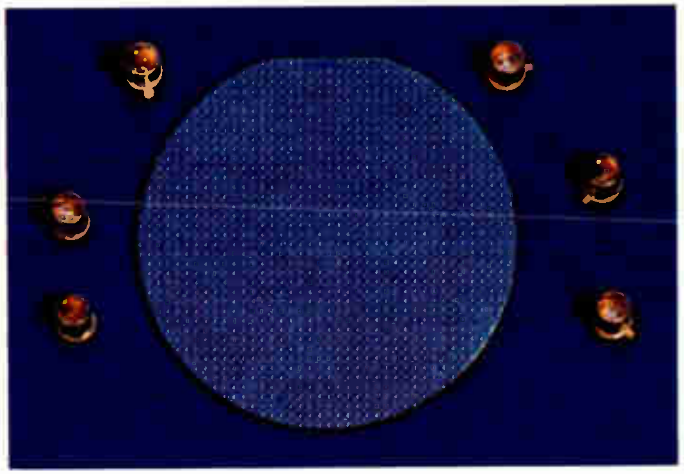
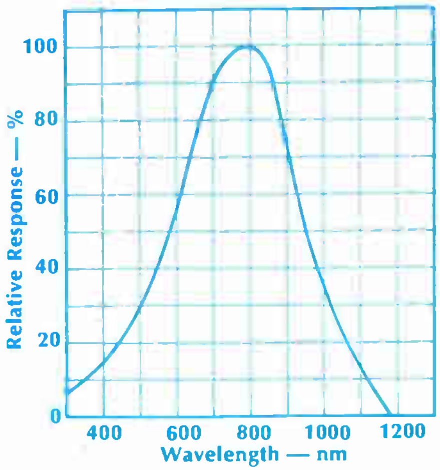
Vactec npn epitaxial large chip, high sensitivity phototransistor. An enlarged section of the wafer forms the colorful background.





Standard Vactec phototransistors provide very high sensitivity and good blue response. Liberal design flexibility is also offered with trade-off for some characteristics, including: light current; response time; spectral sensitivity; and breakdown voltage. Selection of packages are TO-18, co-axial, pill, non-hermetic TO-18 size and special arrays on 50-mil or 25-mil centers.

Custom design is practical for quantities as low as 10M per year. Masking charges are nominal. Our automatic test capability includes 100% sort (with light applied) for I_{CEO}, breakdown voltage and dark current. Vactec can also second-source practically anyone's phototransistors. Write for Bulletin VTTA-1 today.

Circle 165 on reader service card

Production Cleaning Problem?

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Branson systems, customized from standard modular generators and immersible transducers, pay off in precision, consistency, and efficiency.

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Franklin Lakes, N.J. 07417;
telephone: 201-891-9300.

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Circle 167 on reader service card

Data Handling

Microprocessor runs recorder

One of the first "smart" instruments is programable data-acquisition system

"Smart" terminals are already finding wide use in business data-processing applications. Now it looks as if the availability of microprocessor chips heralds the era of "smart" instruments and instrument accessory systems.

One of the first may well be a smart digital data-acquisition system developed by Doric Scientific. The multipoint Digitrend 220 recorder uses an Intel 8008 microprocessor control, plus semiconductor memory, and can scan and record 20 to 1,000 points at speeds to 20 points per second.

The points can be programed for up to six functions per system. Standard ranges and functions are four linear dc voltages with resolution to 1 microvolt and automatic ranging at high speed, six thermocouple inputs (J, K, T, E, S, and R) with built-in cold-junction compensation and digital linearization for direct temperature display in C° or F°, and two ranges of current transmitter inputs to handle process signals of 4–20 milliamperes and 10–50 mA.

Special functions, ranges, and scaling for standard or nonstandard transducers are available at an additional cost. Point skipping is included at no cost when point programing is ordered.

Group programing is available instead of point programing for a single function by groups of 10 points. This feature is extremely convenient for large systems where the first couple of hundred points can be point-by-point programed and the other hundreds can be group programed.

Time of day is displayed and recorded in hours, minutes, and seconds, also included is a power-failure indication. Precision self-test is a built-in feature.

Among the nine interface circuit cards that are available as options to couple to pheripheral equipment are: external alarm relays, computer access with parallel BDC output, serial output for 7-track or 9-track incremental magnetic tape recorder, serial output for paper-tape punch, serial output for Teletype, and output drive for modem.

A fixed data panel is available for entering data to be recorded prior to each scan. This feature is also available with an auto-calendar circuit, which automatically advances the date every 24 hours. Optional selective alarm provides up to 32 independent alarm points.

The use of plug-in read-only memories and programable ROMs in the Digitrend 220 permits selection of desired features and allows future expansion at a minimum additional cost. The base price is approximately $3,000 with 60 day delivery.

Doric Scientific Corp., 3883 Ruffin Road, San Diego, Calif. 92123. [361]

Magnetic-tape subsystem has up to eight transports

A magnetic-tape subsystem, which can include up to eight magnetic-tape transports, is available in seven- and nine-track models. The transports read and write tape at 75 inches per second, and have a data density of 556 and 800 bits per in. on the seven-track model, and 800 bits per in. on the nine-track model. The data transfer rate is 60,000 characters per second. The magnetic-tape units use a vacuum column for tape buffering and tension control, and a tape cleaner to maintain the integrity of the tape and read/write head. A read-after-write head checks the validity of data. The new transports rewind at a speed of 200 in. per second in the vacuum column. A 10½-in. reel can be rewound in 2 minutes. The first unit in a system is priced at $9,900. Any additional units the user may purchase cost $6,700.

Data General Corp., Southboro, Mass. 01772 [410]

Data-entry terminal transmits to 1,200 b/s

The model TR-10 data-entry and retrieval terminal offers a single-line 32-character buffered alphanumeric-display panel, and a double line of 64 characters is optional. Local and remote full or half-duplex operation is available at transmission rates of from 110 to 1,200

bits per second. The terminal also provides a 10-key keyboard and 10 additional keys are available as options. Portability is another feature; the TR-10 weighs only 10 lb. In addition, special formatting and interfaces are optional. Price of the TR-10 is $875, with quantity discounts available.

VMF Industries Inc., 216 N. Fehr Way, Bay Shore, N.Y. 11706 [365]

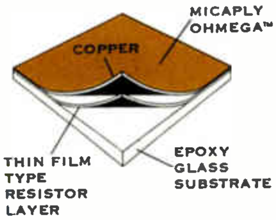
Low-speed modem offers high sensitivity

Operating at 303 bits per second and slower, series 3100 data modems have an active filter in the re-

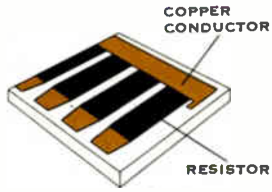
Micaply® Substrates and Circuits
For Thick/Thin Film Applications

Thick/thin film resistor-conductor circuits utilizing Micaply Ohmega™ Resistor-Conductor Laminates

Circuits of Micaply Ohmega™ offer designers a proven epoxy glass substrate with both the resistor and conductor layers completely covering the substrate on one or both sides. **Selective etching produces conductors complete with integral thin film type resistors as shown at the right.** The circuits shown above are examples of its use to replace more expensive thick/thin film resistor circuits and discrete resistor circuits.



Before Etching

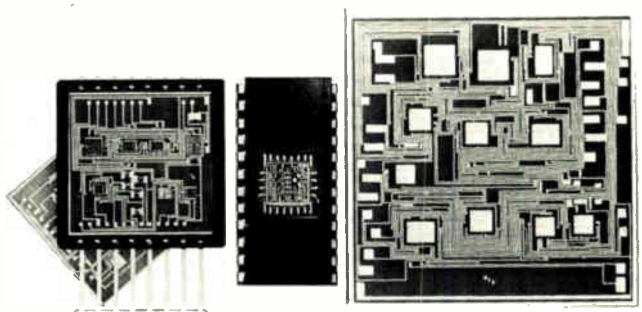


After Etching

Complete design assistance and circuit production are available. Contact us for an evaluation of your requirement and comprehensive technical literature. Find out how Micaply Ohmega™ can reduce your circuitry cost.

- Much lower cost than conventional materials and processing.
- 25 or 100 ohms-per-square sheet resistivity.
- Line widths consistent with thin film microelectronic techniques.
- Subtractive etching process — no screening, firing, or vacuum equipment required.
- 10" x 36" sheets for processing economy.
- Can be easily drilled and cut.
- Can be multilayered for higher density.
- Resistors can be laser trimmed.

Hybrid microcircuits utilizing Micro-Thin Copper Clad Laminates (a low cost ceramic substrate alternative)



Micaply® Micro-Thin Copper Clad Laminates make possible lower cost hybrid microcircuits. Epoxy glass microcircuits like the ones shown above eliminate the cost and costly processing of ceramic in many applications. Micro-Thin is an epoxy glass laminate completely clad on one or both sides with 100 microinches of copper. Using conventional etching techniques conductors with line widths as fine as two mils can be produced.

Complete design assistance and prototype service is available. Contact us for an evaluation of your requirement and for comprehensive technical literature. Find out how Micaply® Micro-Thin can reduce your microcircuit costs.

- Much lower cost than metal coated ceramic substrates.
- 100 microinch copper clad epoxy glass.
- Can be easily drilled and cut.
- 10" x 12" sheets for processing economy.
- Etched line widths as fine as two mils.
- Can be multilayered for higher density.
- Active and passive chips are easily bonded.
- No screening, firing, or vacuum equipment required.

Request complete literature on Micaply Ohmega™ and Micro-thin Copper Clad Laminate materials and production services.

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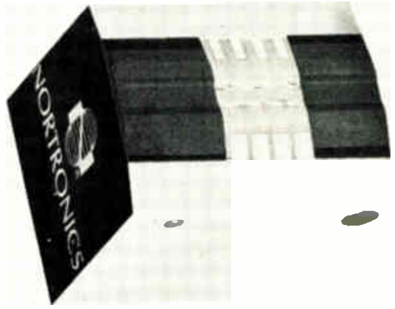
Micaply International, Ltd. Silloth, Cumberland, England, Silloth 571, Telex: 64120, Cable: Micaply Silloth ceiver section to provide telephone-line sensitivity to −50 dBm. The transmitter section of the modem is said to minimize transmission error by providing coherent frequency-shifting. Three basic models are available: originate acoustic, answer/originate acoustic, and answer acoustic. Users may specify that the units be equipped for use with data-access arrangements supplied by the telephone company. Options include EIA terminal interface cable, model 33 teletypewriter cable, and a second EIA connector to join two terminals to a single model 3100. Price is $230 to $300 each in lots of 50.

Novation Inc., 18664 Oxnard St., Tarzana, Calif. 91356 [364]

Magnetic head conforms to read-after-write format

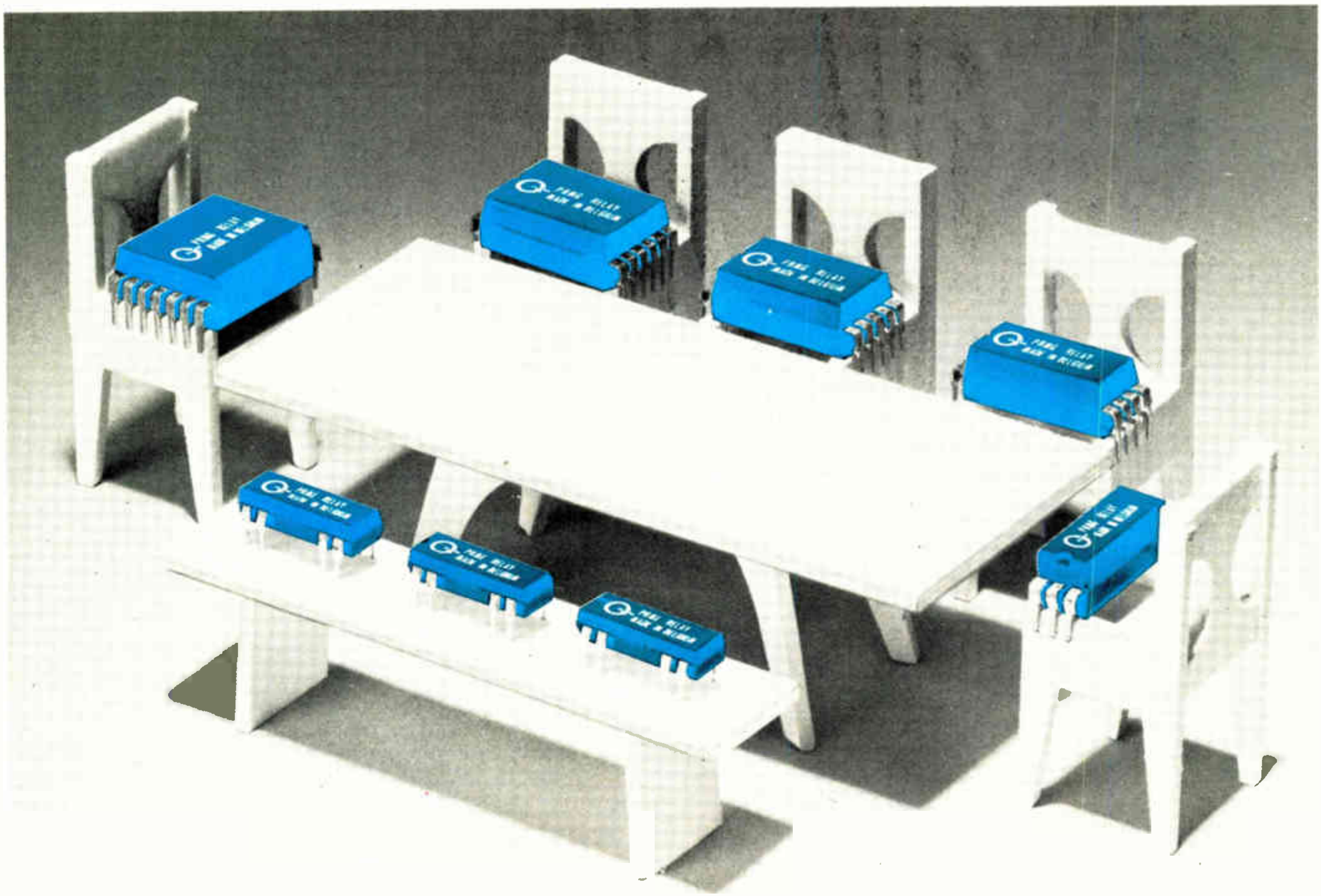
A ¼-inch digital magnetic head, constructed in a read-after-write format, meets standards proposed to ANSI by the Minnesota Mining & Manufacturing Co. and is compatible with the 3M cartridge system. The model DQ-42D dual-gap head offers block construction, which permits track-to-base dimensions with a tolerance of ±0.001 to be custom-tailored to individual needs. The head will operate to speeds of 90 inches per second.



Nortronics Co. Inc., 8101 Tenth Ave., N. Minneapolis, Minn. 55427 [366]

Tape reader is compatible with Intel microcomputer

The model R808 paper-tape reader is the first in a series of peripherals that are plug-for-plug compatible with the Intel Corp. Intellec series of microcomputers. The company says the R808 will permit users to load programs almost 12 times faster than is possible with a teletypewriter, providing a load rate of 3 minutes, compared to 35 minutes by the other method. The R808, which uses a photo-electric character-detector, is interfaced through



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A new family of low cost epoxy molded dry reed relays.

PRMG sealed contact reed relays provide switching performance with telecommunication reliability, offer load handling capability from low-level to 10 VA, versatile multipole contact arrangements from one to five contacts, rugged epoxy molded construction, and at economical prices.

Like the proven and demonstrated reliability of the Clare PRME, PRMG relays are rated for millions of operations, because we make every part ourselves... including the hermetically sealed capsules.

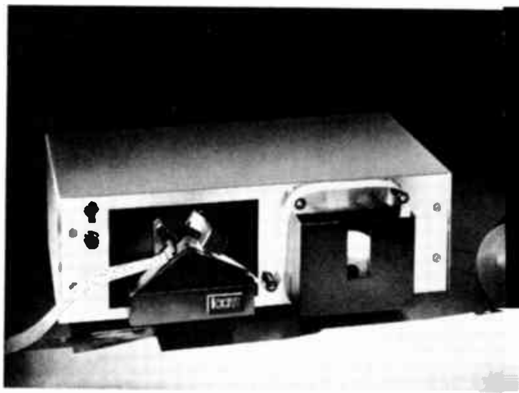
We manufacture our reed capsules on automated machines in a white-room environment.

PRMG relays have maximum switching ratings of 150 Vdc, 0.75 Amp. They are available with both in-line and staggered 10 M x 1 M (1 M = 2.54 mm, 0.100 inch) terminal patterns. The low profile PRMG package will permit 0.5 inch PCB centers.

For more information contact C.P. Clare & Co.
3101 West Pratt Blvd., Chicago, Illinois 60645.
Telephone (312) 262-7700 - Telex 25-3775.

C. P. CLARE & COMPANY a subsidiary of
GENERAL INSTRUMENT CORPORATION

two ribbon cables, tied directly to the Intellec I/O board. Additional microperipherals can be added by daisy-chaining the ribbon cables. The software driver routine for each microperipheral is located in one additional programable ROM memory, which is located in memory below the five system-monitor/PROM-writer chips sup-

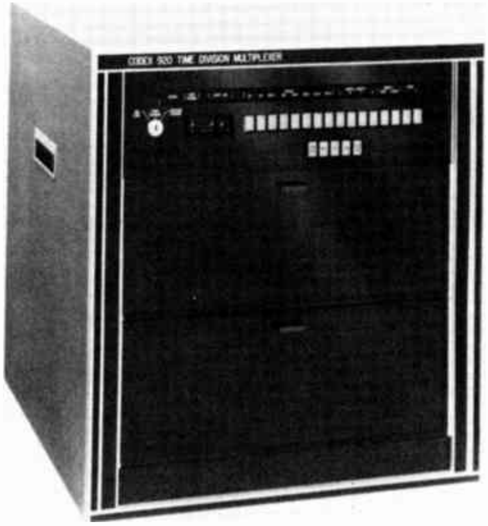


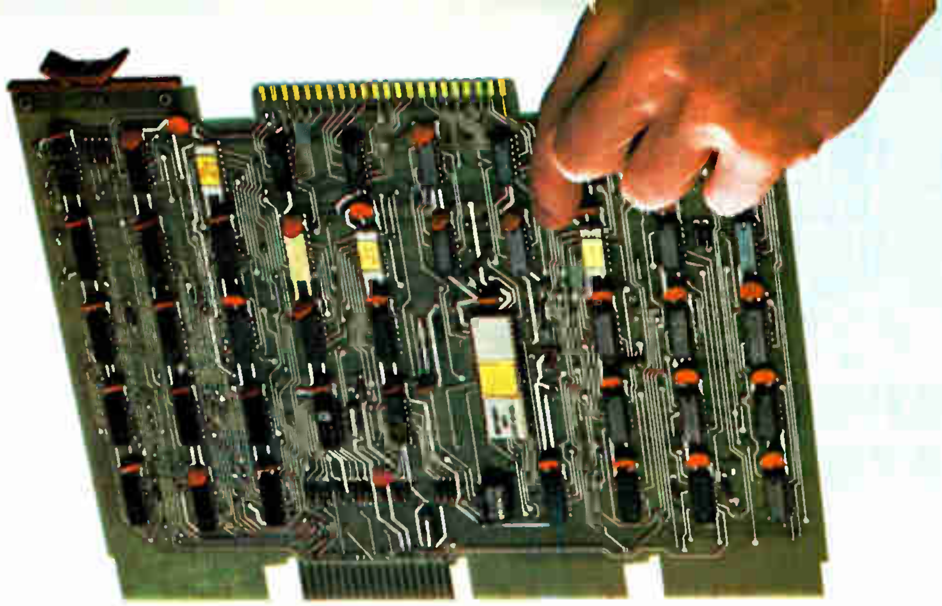
plied by Intel. Price of the model R808 is $995.

iCOM Inc., 21243 Ventura Blvd., Woodland Hills, Calif. 91364 [363]

Time-division multiplexers have stored programs

Three models of time-division multiplexers, called the 900 series, are designed for point-to-point and multipoint data-communications





Plug this in, and you've just designed a custom data acquisition interface.

Nothing to it.

Just plug in a few modules and tap in your instructions.

The new PDM70 programmable data mover will sample your sources, transmit your data in serial ASCII to a remote computer, and return control instructions to local devices. If you want, it can also communicate interactively, without computer intervention, between sources and local peripherals.

Off-the-shelf modules connect the PDM70 to any computer, to analog and digital input devices, and to such computer peripherals as Teletypes, X-Y recorders, storage oscilloscopes, printers, modems, and LED displays.

System prices start at $2000.

Write, and we'll tell you more.

We're Digital Equipment Corporation, Logic Products Group, Maynard, Mass. 01754. (617) 897-5111, extension 2785.

In Canada: P.O. Box 11500, Ottawa, Ontario, K2H 8K8. (613) 592-5111.

In Europe: 81 route de l'Aire, 1211 Geneva 26. Telephone: 42 79 50.

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digital

"Okay, okay. You tell me where we can find twenty thousand RAMs a week for that much less than the 2102 and I'll tell you where to find the Easter bunny."

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AMI
AMERICAN MICROSYSTEMS, INC.

Circle 176 on reader service card

its own acoustic coupler. Communications speed is 10,15, 30, or 120 characters per second, and transmission mode is either half or full duplex. Price of the terminal is $1,570 with a two-line display or $1,190 with a one-line display and a 500-character memory. The acoustic coupler is priced at $480. Delivery is from stock.

Termiflex Corp., Box 1123, 17 Airport Rd., Nashua, N.H. 03060 [368]

Tape reader is built for use with plotters

The Complot model MTR-3 magnetic-tape reader is designed specifically for use with the Complot plotter series. It is available as either a seven- or nine-track reader that offers a density of 200, 556, or 800 bits-per-inch. The plotter, buffered for off-line use, has such features as forward and reverse block advance and a hardware vector generator, which is said to reduce computer time.

Houston Instruments, 1 Houston Square, Austin, Texas 78753 [370]

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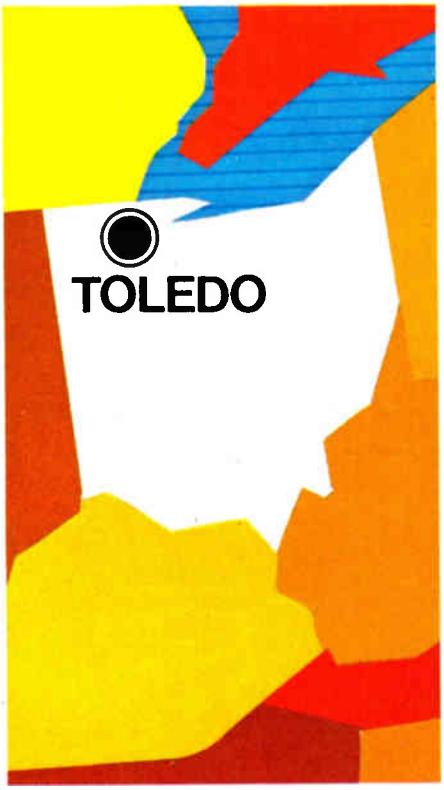

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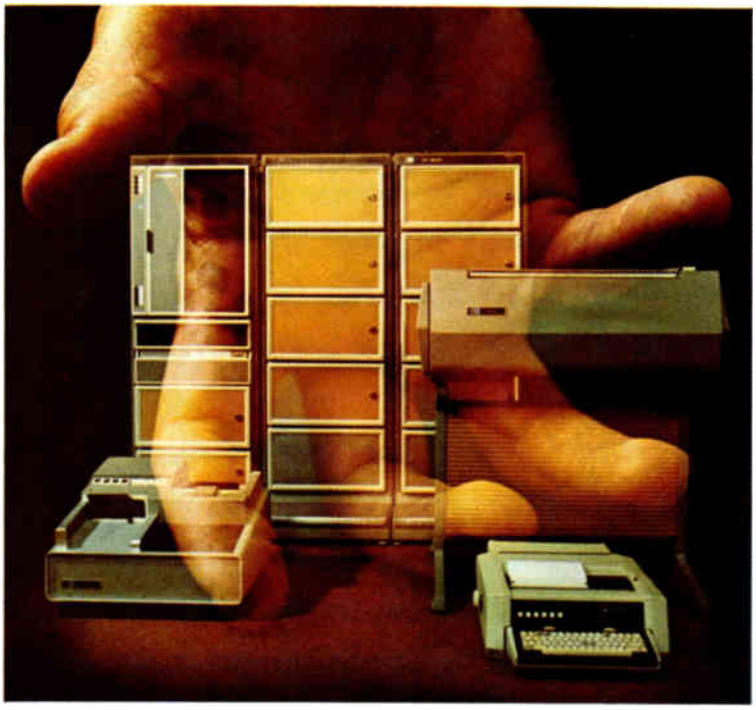

This $170,000*system gives you more computer access than any $300,000 system in existence.

HP's 3000 Minicomputer System gives you four languages: COBOL; BASIC; FORTRAN and HP's System Programming Language. A powerful Editor and File Manager. And concurrent accessibility from both terminals and batch peripherals.

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Packaging & Production

Tester checks microprocessors

Built-in computer checks devices, has flexibility to use future programs

The whole question of how to thoroughly test semiconductor-memory components hasn't been laid to rest yet, and already there's a component that promises an even bigger testing challenge—the microprocessor. It appears to require a completely different test approach from other semiconductor devices—one more akin to checking out a large computer than to testing logic or memory devices.

Macrodata Co. has developed a new test system, the MD-104M, to test microprocessors and related parts adequately. The tester is priced at $30,000 to $40,000, rather than the $150,000 to $200,000 now typically required for such a system.

The only adequate way to check a microprocessor, contends William C. W. Mow, Macrodata president, is to find out if the instruction set, which may have 75 or more instructions, works. Testing the part for its logic patterns as it's clocked won't ensure that the part is good, he says.

Microprocessors, like semiconductor memories, are pattern-sensitive; the sequence in which the instructions are programed can affect operation of the part and uncover subtle problems. Another problem is that so few microprocessor chips are in use that people can only guess at the most prevalent failure modes, says marketing vice president Joseph Rivlin.

Computer. The MD-104M includes a 10-megahertz special-purpose computer with 64 data bits (the MD-104 uses 16 bits for memory testing) plus parametric capability and interfaces to test microprocessors. An interface board is now offered with the system for the Intel 8080, and boards will be forthcoming for other parts that are or will be on the market.

Programing will be the key to testing the microprocessor, and, although the best techniques are not yet clear, Macrodata says the system is flexible enough to accommodate the programs that are ultimately proven optimum. The tester's computer, which can perform such exercises as loops and branches, address 65,000 addresses directly, and it can be expanded to several million. In this way, the MD-104M can, in effect, simulate the operation of the computer in a real environment.

Modular. The parametric capability of the system is provided in modular form, with the test operation able to choose up to the five or six parameters that are deemed most critical. Typical examples for a device manufacturer would be probe continuity, leakage, a unique dynamic test for drain current while the device is being clocked, and breakdown. The device user might choose thresholds and input and output leakage. These tests, on plug-in cards, would also provide the capability for classification into categories.

Timing tests are also possible, but Rivlin suspects they won't be considered vital for microprocessors. The system also tests memories and other parts. Testing time, however, may be very important. Mow says it may run about ½ minute because of the enormous number of steps required. The MD-104M is designed to support two test heads, and four of the MD-104M's can be controlled by a single MD-1041 controller, so that eight positions can be run simultaneously.

Macrodata Co., 6203 Variel Ave., Woodland Hills, Calif. 91364 [391]

Marking system prints up to 20,000 components/hour

A marking machine that prints identification marks on magnetic or nonmagnetic axial-lead components operates at speeds of up to 20,000 components per hour. The U-1220 series provides manual or automatic

feed. When the devices are printed they are dried and cured in an infrared oven that consumes 2 kilowatts of power. Components may vary from 2⅜ inches to 3⅜ in. in length including leads. The component body may measure up to 1 in. in length to 0.200 in. in diameter. The leads must be straightened and centered to alignment with the body's outside diameter to within ±0.0312 in.

Markem Corp., 150 Congress St., Keene, N.H. 03431 [394]

Turret bobbin winder can produce 550 coils/hour

Designed for small shops requiring the advantages of automated winding equipment, without the expense of large-scale machinery, the model 315-RT coil-winding machine handles all types of random-wound bobbin coils, solenoids, repeater

coils, and insulating linen for relay coils. Output is determined by coil configuration and operator efficiency. However, typically, at 300 turns, 550 coils an hour can be produced. At 500 turns, 370 coils per hour can be produced, and at 700 turns, 285 coils per hour can be wound. Maximum coil diameter and coil length that can be handled are to 2½ inches, wire sizes handled are 22 to 40, and winding speeds are provided up to 4,000 rpm. By eliminating bench, cutter ejector, and wax applicator found on many turret-type machines, the cost of the 315-RT is kept down; price is $6,900.

Geo. Stevens Manufacturing Co. Inc., 6001 N. Keystone Ave., Chicago, Ill. 60646 [393]

Bubble tester checks for leaks in hermetic seals

The model 481 gross-leak bubble tester checks for leaks in semiconductors, microelectronic devices and other hermetically sealed components. The unit features a tank with a transparent front and a lid that minimizes the loss of fluorinert vapor. The unit plugs into any 120 v outlet, offers a solid-state temperature-controlled immersion heater, and a built-in timer. Price is $285.

Trio-Tech Inc., 2435 N. Naomi St., Burbank, Calif. 91504 [395]

Packaging panels are offered in metric size

The 8136-MG16, 8136-MG17, and 8136-UMG2 are metric packaging panels measuring 100 millimeters

Chances are you own a continuously tunable electronic filter. So by now you probably realize that continuously tunable filters are low performance instruments with, at best, 5% accuracy. And with poor reproducibility of settings, poor frequency accuracy and poor phase drift characteristics. And although continuously tunable filters provide infinite resolution, most users find infinite resolution neither important nor desirable unless there's corresponding accuracy.

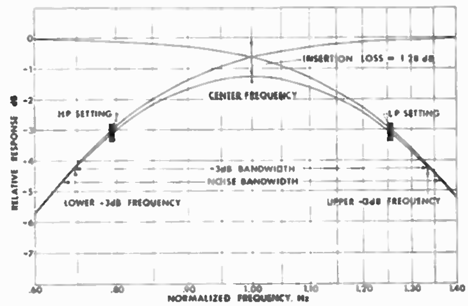
But all this isn't why we say "junk it."

WHAT YOU SET, ISN'T WHAT YOU GET.

Take a look at the graph. As you can see, the front panel filter settings don't tell you the -3dB cutoff frequencies, the bandwidth, the noise bandwidth, and the center frequency. Or the insertion loss. You have to measure them — a time consuming, costly procedure.

THERE'S A BETTER WAY.

Ithaco offers two types of filters with switch selectable frequency settings. One type has 3 decimal digit frequency resolution for the user who not only needs resolution but also wants to know where he is without measuring.



Normalized gain, attenuation, phase, and pulse response curves are printed on top of the filter. The other type uses the internationally accepted 1/10 decade [1/3 octave] frequency step — so you can operate with octave, decade and other convenient band pass settings, and still have sufficient frequency resolution for general lab and data acquisition applications. These filters have all the information shown on the graph printed on top — for all filter settings. And that's why we say "take your laboratory filter and junk it."

MORE NAILS IN YOUR FILTER'S COFFIN . . .

Standard accuracy of all Ithaco filters is ±1% in frequency, ±2° in phase, and ±.1dB insertion loss — all at least twice as good as the best the competition can offer. Plus, output drift is an order of magnitude lower than the competition. And self-noise is minimal. Best of all, Ithaco filters are competitively priced.

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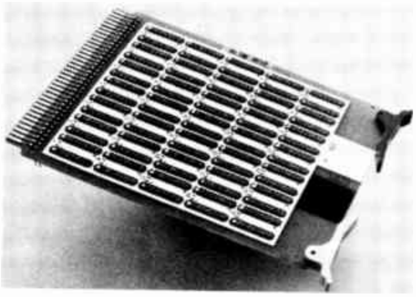
Take your laboratory filter and junk it.

ITHACO

Circle 185 on reader service card

New products

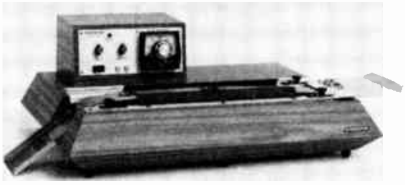


by 160 mm. The panels are 1/16-inch double-sided versions with collector voltage and ground-connection planes at preselected positions adjacent to the IC rows. The MG16 version contains 14-pin patterns, the MG17 16-pin patterns, and the UMG2 contains 12 rows with 49 contact assemblies per row. The panels also contain two-piece machined contact assemblies available with either tin- or gold-plated outer sleeves.

Augat Inc., 33 Perry Ave., Attleboro, Mass. 02703 [396]

Soldering system handles ceramic hybrid circuits

The model BR-8, belt reflow soldering system, is designed for high speed production soldering of ceramic hybrid circuits. The compact bench-top instrument uses back-side heating through a thin Teflon-coated fiberglass transfer belt. Circuits placed on the belt travel over



two temperature-controlled heating stages and then move through a high-speed cooling zone. Unlike other hybrid soldering processes that apply heat equally to both components and substrates, this system maintains low component temperatures with very rapid heating cycles. The 2½-inch wide belt, which travels at up to 40 in. per minute, will

If you're testing 1K RAM's or 4K RAM's without an MD-100 or MD-104...

YOU'RE KIDDING YOURSELF!

Reliability—With more than 300 stand-alone MD-100/104 systems in use throughout the world today, Macrodata has set the industry standards for memory testers—and these two systems still provide the only way you can test memories effectively and obtain valid data.

Pattern Sensitivity—If one of those "it's no problem" guys has been telling you that a few hardwired patterns are all you need to test RAM's, watch out! They have decided that RAM's aren't really pattern sensitive, so they don't bother to fully explore worst-case pattern conditions for these devices. They say that it's not necessary, but you know better.

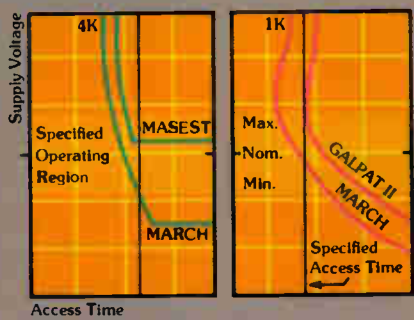
Pattern Sensitivity Tests

The adjacent curves are plots of individual device access times at different supply voltages. Each curve represents a different test pattern. Over the specified operating regions of the devices, these shmoo plots show the pattern sensitivities of the 1K and 4K RAMS. For example, while MARCH would make one think that the 4K device is operational, notice that the chip does not work during a portion of its MASEST curve. A MARCH test also indicates that the 1K device passes its access time specification at nominal voltage, but a GALPAT II test demonstrates much slower access time characteristics and that the 1K chip does not really pass at nominal voltage.

Here's Why You Need MD-100/104 Capability

Example #1: In a recent test, six devices from separate lots from the same manufacturer all failed under different unique patterns with identical set-up conditions of voltage, timing, etc.

Example #2: In another test, one device passed on all patterns for approximately 10 seconds and then failed due to heating problems. After being rehabilitated by coolant spray, the device again ran and passed until heat produced failure.



Example #3: For typical pattern sensitivity of 1K and 4K RAM's, see the chart of V. vs. Access Time.

Let's Make A Deal—If someone tells you that your semiconductor memory is not pattern sensitive and all you need are fixed patterns to solve your test problems, send your device to us for the moment of truth. If we're right, aren't you just kidding yourself until you get an MD-100/104 on line? For action, call or send for a free brochure today.

Macrodata

MACRODATA ®

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Circle 187 on reader service card

accommodate over 1,000 2-inch-square substrates per hour. Solder reflow temperatures up to 400°C are maintained within 2°C.

Browne Corp., 203 Chapala St., Santa Barbara, Calif. 93101 [397]

Ultrasonic assembler also checks switch contacts

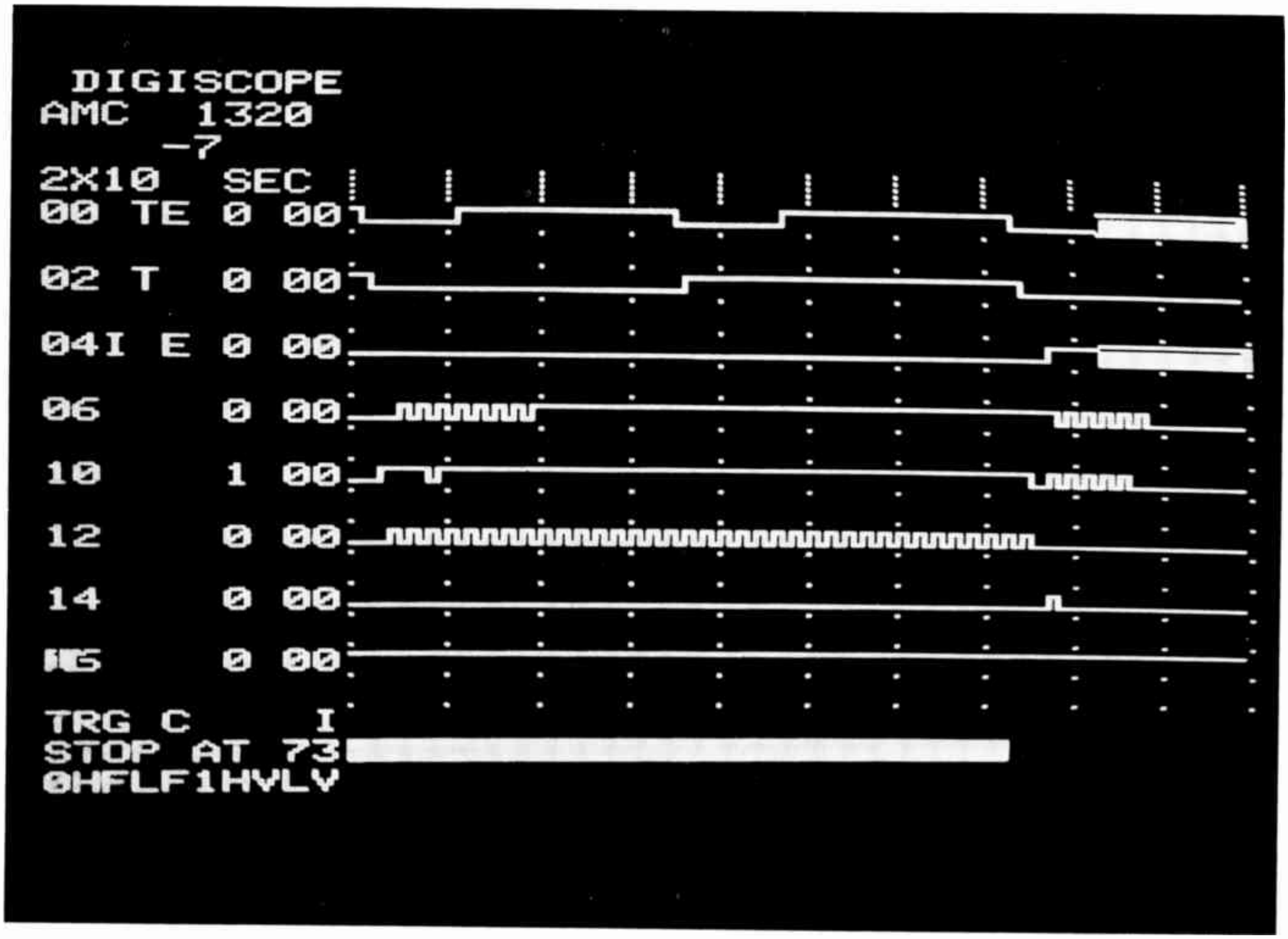
An ultrasonic assembly system stakes plastic and metal switch assemblies together, and also checks the position of the switch contacts automatically before accepting them. Parts are manually loaded on the rotary system at the front work table, then ultrasonically staked together. After assembly, the switch contacts are checked by an electrical sensing circuit to see if any are too high. A similar test is used to determine if any of the contacts are too low. Switch slide assemblies with high or low contacts are air ejected immediately after the test station. Good parts remain on the rotary table until they reach the accept chute.

Sonics & Materials Inc., Kenosia Ave., Danbury, Conn. 66810 [398]

Panel rack assemblies handle 26 positions

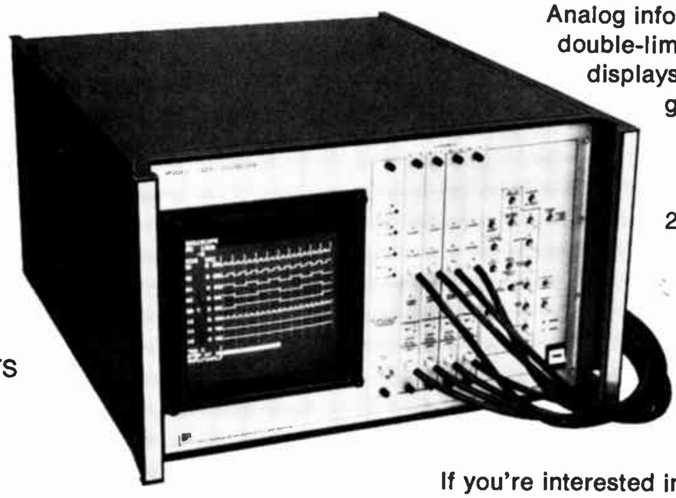
A family of panel rack assemblies and accessories are designed to complement the company's 324 family of wire-wrapping panels. The rack assemblies are available with either ⅛-inch thick standard Retma end plates or 3/32-in.-thick flush end plates. The racks are available in six positions and 13 positions spaced on 1.2 in. centers, and may be expanded to 11 positions and 26 positions on 0.6-in, centers. Connectors may be removed from the power panel without having to desolder, and the power panel may be removed for automatic or semiautomatic wrapping. Price in quantities of 10, with 26 connectors and 2 power panels mounted, is $329.

Mupac Corp., 646 Summer St., Brockton, Mass. 02402 [399]



Digital timing, analog problems–only the Digiscope shows you both

"A radically new logic state analyzer from E-H Research gives you the equivalent of an 8 or 16 gun, 50 MHz, real time scope display of logic timing. It lets you see such analog parameters as glitches, ringing, rise and fall times, and voltage levels."
— Jerome Lyman, ELECTRONIC PRODUCTS Magazine, 1/19/74



The Digiscope gives you eight channels of digital data simultaneously acquired at 50 MHz, up to 100 bits of pre-trigger lookback, and single shot measurements without sacrificing critical analog information in the signals.

Now Digiscope lets you see such anomalies as glitches (Channel 14), slow rise times (Channel 6), low "one" levels (Channel 12), high "zero" levels and ringing (Channel 10) that are often the cause of mysterious system failures.

Analog information is preserved with unique, double-limit threshold comparators. Screen displays all instrument settings for photographic recording.

You can trigger on any logical combination of the eight inputs. Probe impedance is greater than 20 megohms, shunted by less than 8pF, so you don't have to worry about a probe loading the circuit.

We think when you see it, you'll agree: Digiscope is the most efficient, error-free test instrument ever made for designing, debugging, and maintaining digital electronic equipment.

If you're interested in the whole story about this radically new logic state analyzer, let us know. We'll send you the AMC 1320 Digiscope brochure immediately.

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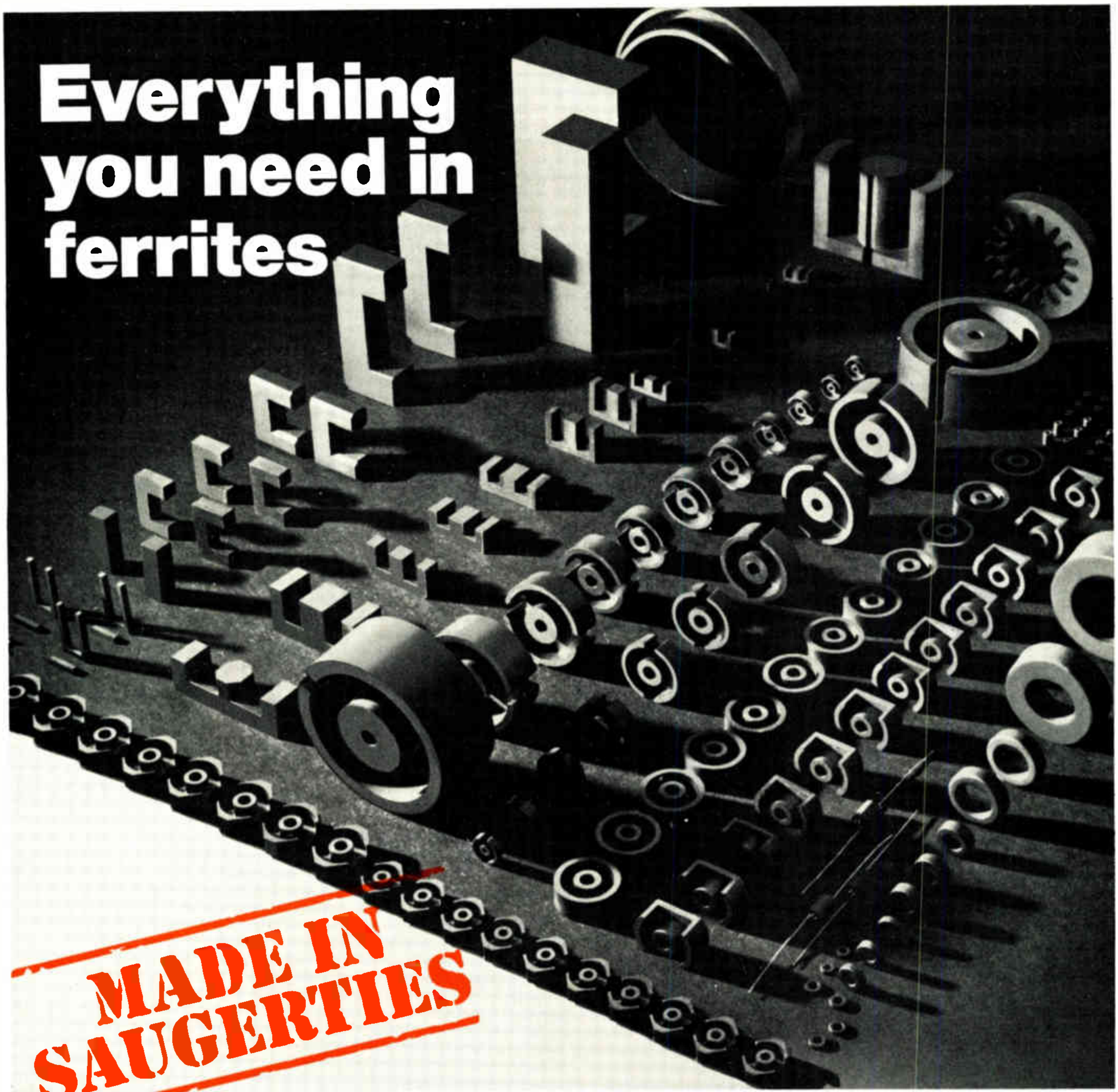

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Circle 191 on reader service card

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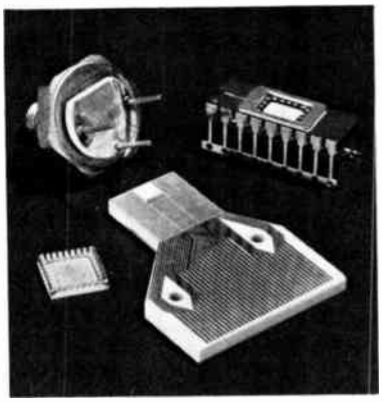

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Circle 193 on reader service card

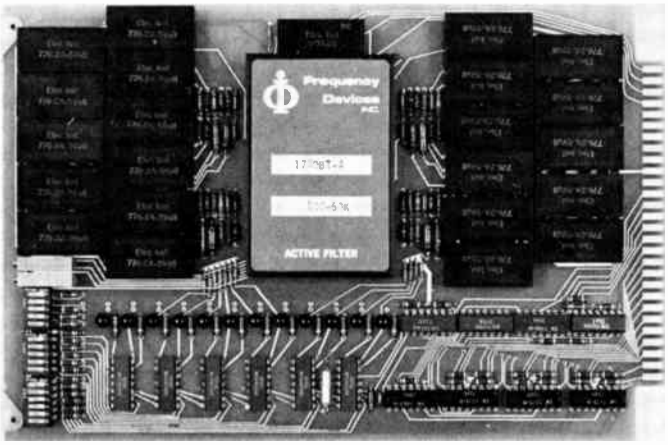
Subassemblies

Interface cards link systems

'Universal' programing system on a card fits into data-acquisition rack

Large instruments can interface a computer with signal-processing modules, such as active filters and oscillators. The user can make his own interface with filters, reed relays, or resistors, but few small interface subsystems are available. Frequency Devices Inc. describes its FC-103 Universal Programing Card System as "a system on a card with a memory" that can fill the gap in this market.

A line of four-pole low-pass Butterworth and Bessel filters is available with it now, and high-pass, bandpass, and band-reject filters, as well as elliptic filters and low-distortion quadrature sine-wave oscillators will be available in the future. The 2-by-3-inch modules can be plugged directly into a socket on the 6-by-9 ⅛-inch card, which fits into a data-acquisition rack.



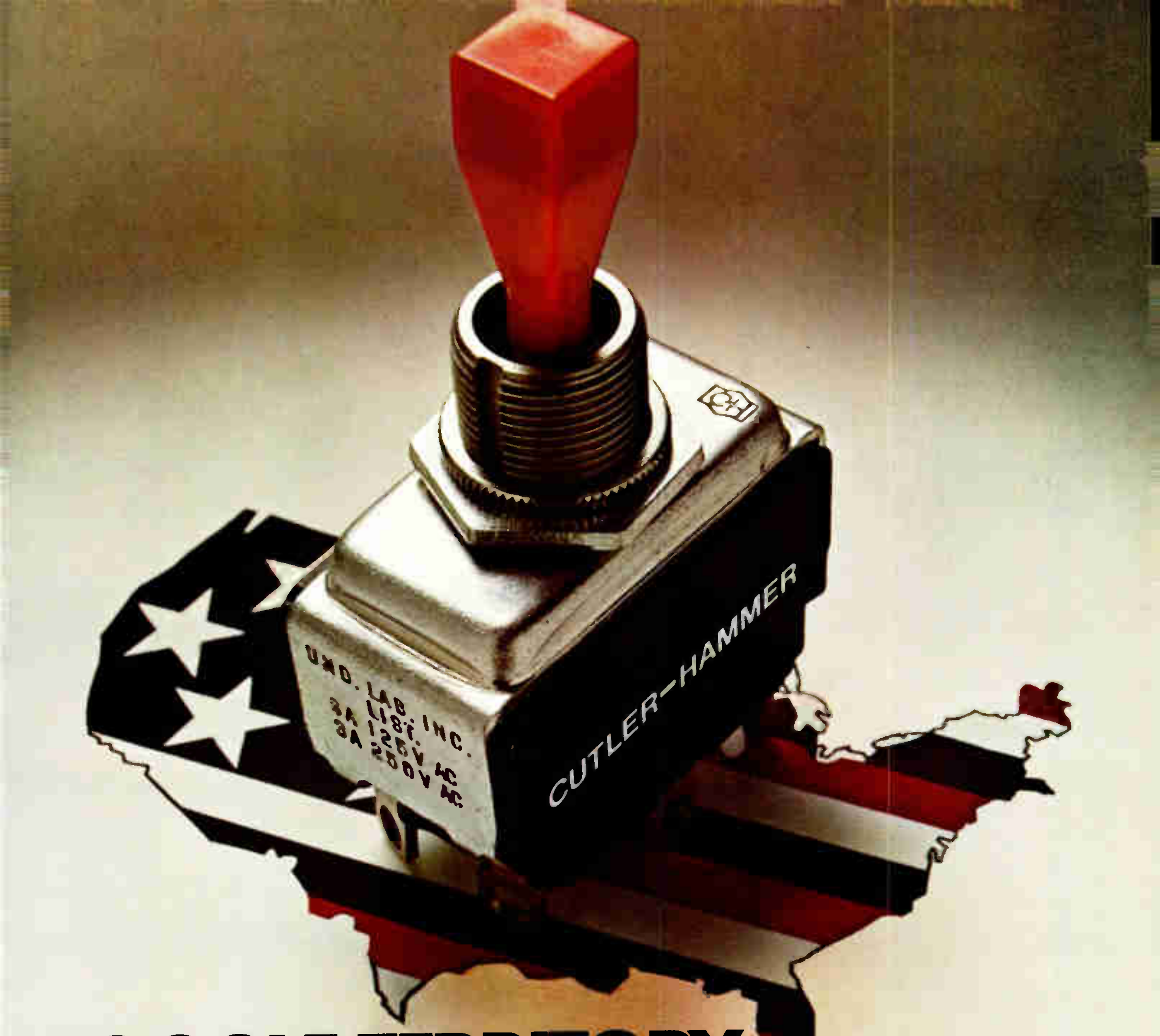
The FC-103 can program the frequency of a module over a 5,000-to-1 range in 500 equal increments. Four models cover ranges of 0.1 to 50 hertz, 1 to 500 Hz, 10 Hz to 5 kilohertz, and 100 Hz to 50 kHz. The FC-103 is frequency-programed with 11-bit binary-coded decimal, while the 103B is programed with 9-bit binary coding.

Dual in-line switches can program data locally; and local, on-card data or remote data can be selected from the computer or through a local dual in-line switch. On-card dual in-line switches can set up to 16 address values; the correct value must be present on the four address lines to access the card. The card can also bypass the filter completely.

Reed-relay switches, shielded for maximum isolation between the analog and digital grounds, interface between the analog and digital segments. Frequency Devices says that the use of relays eliminates the problems of on-resistance and leakage current that is inherent in semiconductor switches. The state of the filter, including its frequency, bypass mode, and a flag indicating whether or not the address is accepted, are monitored by data-indicator lines.

Address-decoding to facilitate the programing of several cards on a single data bus, on-card programing, filter bypass, and memory are available as delete options. They can be added to an existing card at any time.

The FC-103 is aimed at computer-controlled data acquisition and processing in such applications as spectral analysis, prefilters for digital filters, and domain filtering, or in dedicated systems, it is designed to function like the front end of a Fourier fast-transform analyzer. The company claims that the unit can also vary the frequency of the analog filter with a minimum of software in applications where sam-



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Circle 113 on reader service card

pling rates vary as a function of time.

The FC-103 is priced from $254 to $350 for one to nine units, depending on options selected. Prices range from $160 to $225 each for 100 units. The 1740BT Butterworth filters and 1740LT Bessel filters cost $69 each for one to nine units and $46 for 100 units. Evaluation quantities are available in two to four weeks.

Frequency Devices Inc., 25 Locust St., Haverhill, Mass. 01830 [381]

Dc-to-dc converters provide dual output with low noise

The D15 series of dc-to-dc converters provide dual outputs of ±15 volts dc at ±100 milliamperes, regulated to 0.01% with an 11-millivolt noise content. The standard input is a single 5-volt dc or a 12-v dc input;

both offer an efficiency of 65%. Further, all six sides of the miniature module are tightly shielded by a continuous conductively coated copper layer. Transfer isolation is 80 picofarads and 10^9 ohms. Price of the converter in quantities of one to nine is $69 each.

Hybrid Systems Corp., 87 Second Ave., Burlington, Mass. 01803 [383]

Analog-to-digital converters are priced at $48 each

Two analog-to-digital converters, designated the models 4116 and 4117, are priced at $48 each, an

Dialight sees a need:

(**Need:** The right switch for the right price.)

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For the switch buyer, choice of function and esthetics, reliability, ease of mounting, and low cost are his prime concerns. He may need a pushbutton switch for panel, sub-panel or snap-in mounting. He may need a choice of bezels with or without barriers in black, gray, dark gray or white. He may need a legend that's positive, negative, or hidden until energized . . . one that's white when "off" and red, green, amber, blue or light yellow when "on" . . . or colored both "on" and "off." He may need a highly reliable switch proven in thousands of installations. Matching indicators with same front-of-panel appearance are also available. Obtainable from our world-wide distributor network.

The cap has a metal insert designed for proper heat dissipation. Cap is illuminated by a T-1 ¾ incandescent lamp in voltage range to 28V. Lamp can be easily replaced without special tools from front of panel.

Bezels available in black, gray, dark gray or white and in round, square or rectangular shapes.

Fingertip grip simplifies insertion or replacement of pushbutton cap.

More than 12 colors available in round, square, or rectangular shapes in six basic sizes—½" to 1½". Choice of engraved, hot stamped or replaceable film legends with positive or negative presentations.

Stainless-steel clips lock switch into panel on four sides. No tools or additional hardware required for installing. Panel mounting switches come with required hardware for panel or sub panel mounting.

Available with or without bezels. Bezel allows for simple snap-in mounting. Without bezel, switch can be used for panel or sub-panel mounting.

Alternate, momentary, and snap-action contacts with ratings to 5 amps. All switch contacts are gold plated for high reliability. Normally open, normally closed, and two-circuit (one N.O., and one N.C.). Totally enclosed within anodized aluminum housing. Low level and D.P.D.T. snap action, and contactless solid state switches also available.

Terminals are gold plated for oxidized free solderability, and come in choice of solder blade or pc terminations.

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DIALIGHT

Dialight Corporation, A North American Philips Company • 60 Stewart Avenue, Brooklyn, N.Y. 11237 (212) 497-7600

Circle 197 on reader service card

amount that decreases to $40 for quantities of 100. The model 4116 is an eight-bit binary converter, while the model 4117 is a 2½-digit BCD version. Differential nonlinearity for both models is specified at a guaranteed maximum of ±0.1 least-significant bit. Overrange capability is also offered.

Teledyne Philbrick, Allied Dr. at Rte. 128, Dedham, Mass. 02026 [384]

Regulated power supplies have three dc outputs

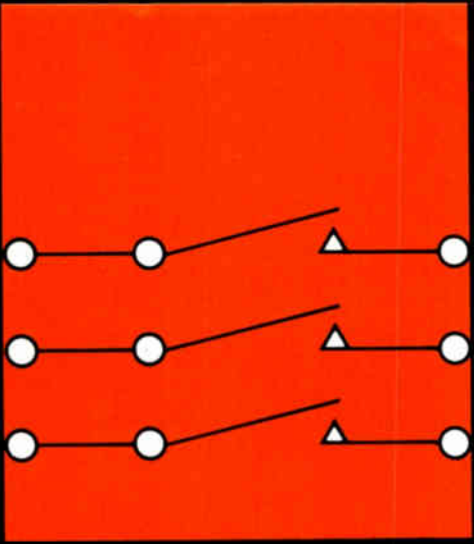
A series of 300-watt switching-regulated power supplies that feature three dc outputs measure 5.05 inches wide by 3.65 in. high by 16.12 in. long. The units provide 5 volts at 50 amperes, regulated primary output, and ±12 V, ±15 V or

±18 V semiregulated at 8 A each for the remaining two outputs. Designated the LH300T series, the supplies offer 75% efficiency on all three outputs, and overvoltage protection is provided on the 5-V channel. Price is $460, plus $30 if regulation is needed on the secondary outputs.

LH Research Inc., 2052 S. Grand Ave., Santa Ana, Calif. 92705 [385]

Low-pass active filters operate over 50:1 range

A series of four- and six-pole low-pass filters operate over a 50-to-1 tuning range and require a single transistor per pole for tuning. Resistor value is determined from a tuning formula and is the same value for all poles. Using 1% metal-film resistors, the cut-off frequency can be set within ±3% and is stable



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The most complete line anywhere.
Intersil's line of analog switches includes more functions, more technologies and a wider range of prices than that of any other semiconductor manufacturer. Delivery is off-the-shelf for most devices, available in commercial, industrial and military versions. We make all three basic types:

1. Low cost J-FET analog gates.
At less than $1 per channel, the IH5009-thru-5038 series replaces reed relays in multiplexing, gain-ranging and similar applications. Gates are available in "virtual-ground" versions, with effective R_{ON} from 5 to 50 ohms, and positive-signal versions. Configurations range from SPST and SPDT through 4PST.

2. Floating-body monolithic CMOS analog gates.
Low power IH5040 series CMOS gates are free from latch-up and channel-to-channel shorting. They come in commercial and military temperature ranges, with configurations from SPST and SPDT through 4PST.

3. DG-type switches, D-type drivers and G-type gates.
For years, Intersil has been making these devices, and is currently shipping the complete line of these driver-switch combinations you can't get anywhere else. DG111 through DG164 analog gates are available in all popular package types, as well as in high-reliability versions.

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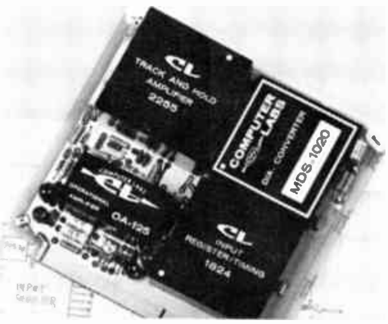
Circle 199 on reader service card

to ±0.05%/°C with temperature. Either Butterworth or Bessel-type response functions are available. Other specifications include cut off frequencies, extending from 1 hertz to 50 kilohertz, gain internally set to + 1, and an initial output offset voltage of ±2 millivolts, which can be adjusted to zero by means of an external trimming potentiometer. Price of four-pole models is $79, and six-pole models are priced at $109.

Datel Systems Inc, 1020 Turnpike St., Canton, Mass. 02021 [387]

D-a converters include deglitching circuit

The RDA-series digital-to-analog converters are for use in reconstructing TV and other video signals. The 8-bit and 10-bit converters include a



deglitching circuit to remove spike discontinuities from the analog output. Input word rates of 15-MHz are possible, and output amplifiers for applications requiring greater drive are optional. Prices on the 5½-by-6-inch edge-connector modules range from $850 to $950.

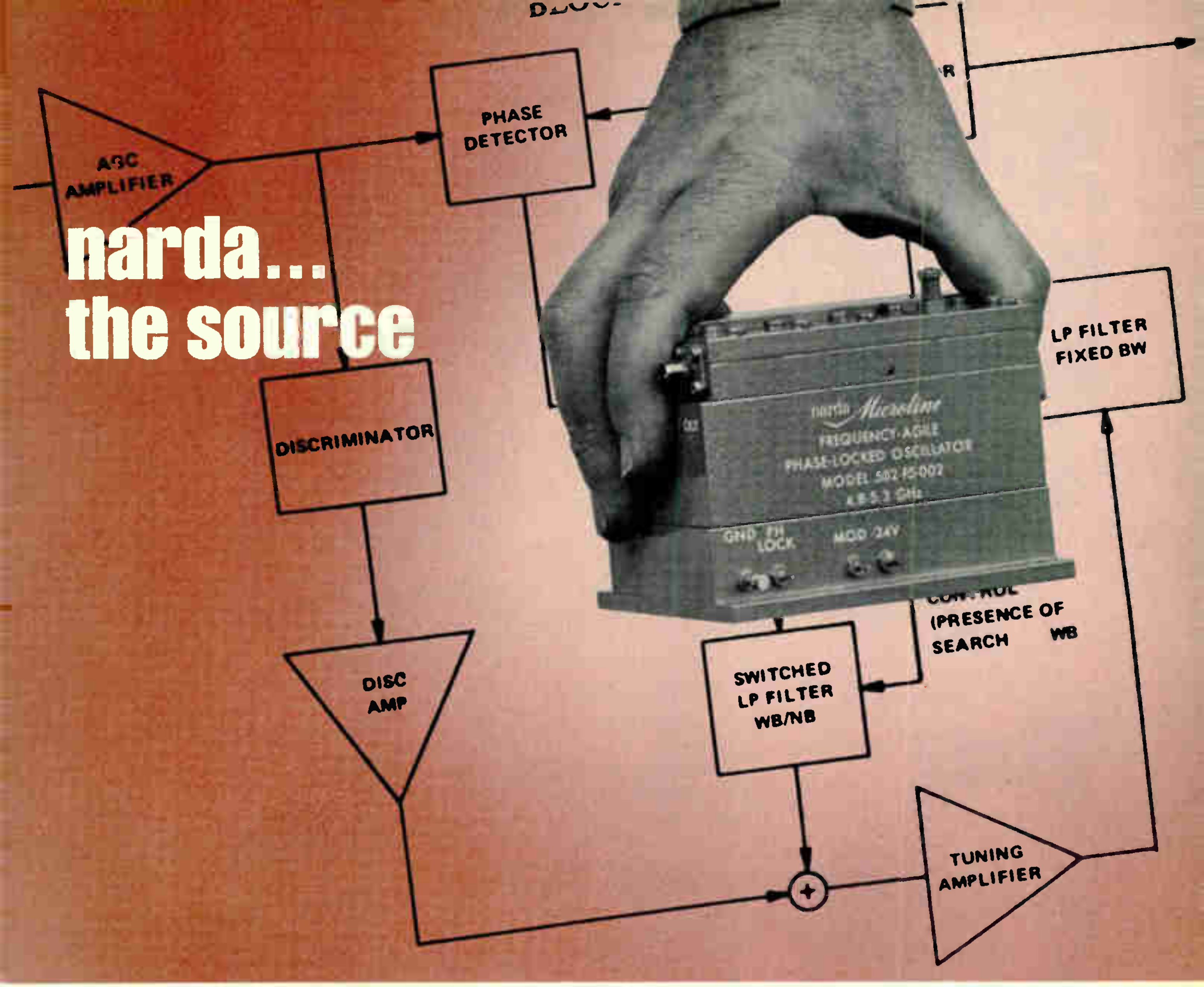
Computer Labs, 1109 South Chapman St., Greensboro, N.C. [386]

Filter-duplexer operates like passive switching device

Designated the model SB-A100, a solid-state filter-duplexer is designed for the Tacan Frequency range. The unit operates like a passive switching device, diverting receiver and transmitter signals to and from a common antenna without

 Circle 200 on reader service card

Circle 273 on reader service card



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- **Wide Frequency Range (500 MHz)**

Circle 201 on reader service card

Narda's Solid State Signal Sources automatically adjust to a changing input reference signal. The source will track a sweeping input signal, or if switched to a new input will lock to it within 0.1 second, in sequential frequency commands in any increment.

These devices are particularly well suited for applications which require exceptional operating stability and outstanding spectral purity such as: microwave radio transmitters, receivers in communications systems, transmitter exciters, receiver local oscillators, doppler radar frequency references and frequency reference standards for laboratory experiments.

Write for complete information . . . Model 461-F5-001 from 4.5 to 4.8 GHz, Model 502-F5-002 from 4.8 to 5.3 GHz.

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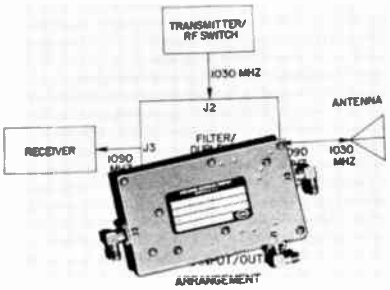
New products



external bias or switching. Out-of-band or unwanted-signal rejection is provided with internal filtering and receiver-limiter protection. Transmitter frequency is 1,030 MHz ±0.2 MHz, and receiver frequency is 1,090 MHz ±0.2 MHz.

Engelmann Microwave Co., Skyline Dr., Montville, N.J. 07045 [388]

Amplifier will drive any three-wire synchro

A synchro amplifier called model C70 3718 005 is designed for driving multiple synchro loads with impedance as low as 50 ohms, line-to-line. The unit is suitable for use where available synchro information does not have the power to drive additional instruments or where the synchro information available cannot accept errors caused by excessive loading. The amplifier requires power of 115 v, 400 hertz, and generates all other necessary power requirements.

Kearfott division, The Singer Co., 1150 McBride Ave., Little Falls, N.J. 07424 [389]

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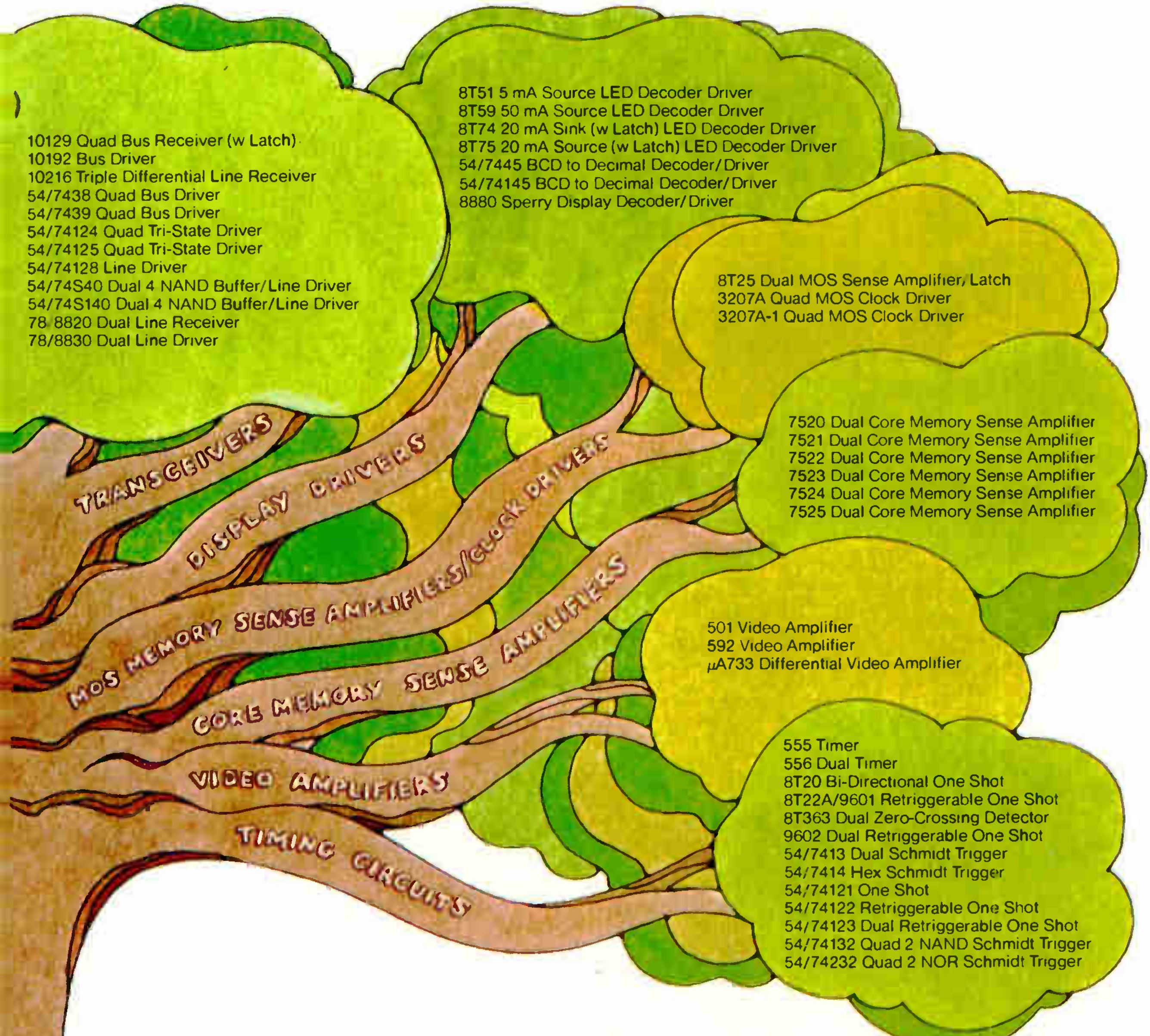

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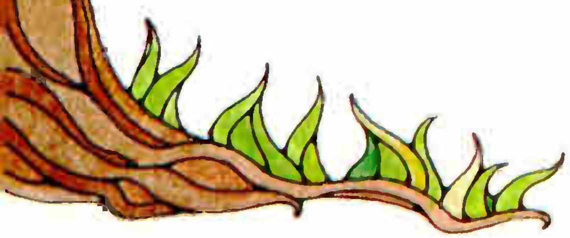

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NOAA's new SMS/GOES Synchronous Meteorological Satellite will usher in a new era in satellite borne weather instrumentation. Once in orbit NOAA will commence processing and distributing weather data from the new Visible/Infrared Spin-Scan Radiometer (VISSR), which produces improved pictures of the earth's cloud cover. At the heart of VISSR are eight EMR Integrated Photoelectric Sensors. On earth the data from VISSR is processed by EMR Digital Interface Electronics using the latest PSK demodulation and bit synchronization techniques.

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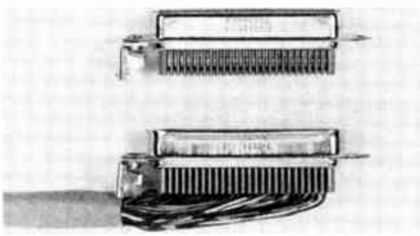
Components

Connector works in the field

Micro-Pierce designed to move termination process out of plant

As the telephone industry seeks replacements for hard-wired connections to keep spiraling labor and operating costs under control, the Amphenol Industrial division is introducing a solderless connector



that can be terminated in the field. Essentially a replacement for the Amphenol-patented Micro-Ribbon connector for push-button telephones, the new Micro-Pierce series is available at equivalent prices.

Applications. Amphenol believes that, besides opening new applications for telephones—especially installing connectors on all telephone equipment in central offices—the solderless termination will be popular in other applications, including business machines, computers and peripherals, data communications, and instrumentation. "With more than 250 Micro-Ribbon connectors in the field, it's the biggest single connector utilized in the telephone industry," says James L. Pratt Jr., the firm's telecommunications marketing manager.

Cables in use now are terminated in the manufacturing plant; installers are forced either to use standard cable lengths or order specific lengths from the factory. "What we're trying to do," Pratt explains, "is to move the termination process from the factory to the field."

To apply the connector in the field, the conductor is guided and pressed into the termination end of the connector. A cutting surface on the connector shears the insulation at four contact points, and a curved surface makes electrical contact by displacing the conductor material without cutting it—important for maintaining the tensile strength of the conductor.

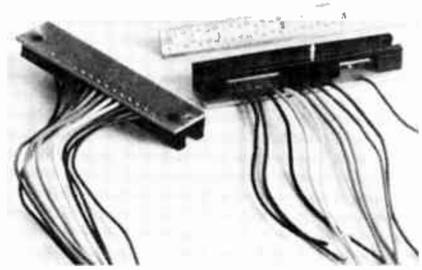
"When the conductor is seated in the contact trough, electrical contact is made at four points, and the displaced insulation provides a gas-tight seal," Pratt says. The dielectric extends beyond the back of the connector, helping to hold the wire for termination and relieving the strain on each connector.

System. Amphenol has also developed a complete termination system for applying the connector to the cable, which it will sell or lease to customers. Included are two hand tools that will terminate from one to 50 contacts at a time, a semiautomated bench-mounted tool for factory installation of 50 contacts at once, and a conversion unit to convert factory soldering equipment to insulation-piercing type.

Amphenol Industrial Division, 1830 S. 54th Ave., Chicago, Ill. 60650 [391]

Selector switch offers 11 discrete positions

A linear slide-selector switch with 11 discrete positions is called the Swift Action Switch because of its fast snap-detent action. Actuation force from position is a minimum of 10 ounces with 0.150 inch of travel. Contact rating is 20 volts dc maximum, while current rating is 1 to 10 milliamperes and maximum capacitance is 60 picofarads between the

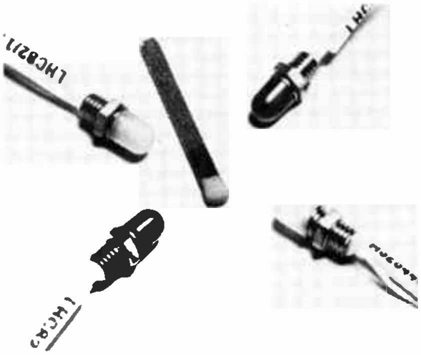


common and switching circuits. Tests show the unit has a life expectancy of 25,000 cycles, the company says.

Sonitronic Inc., 32-02 Linden Pl., Flushing, N.Y. 11354 [343]

Subminiature indicator need little mounting area

The 252 series of subsubminiature indicator lights using T-1 incandescent lamps requires only a 0.193-inch panel-mounting clearance hole. Connections are brought out as flex-

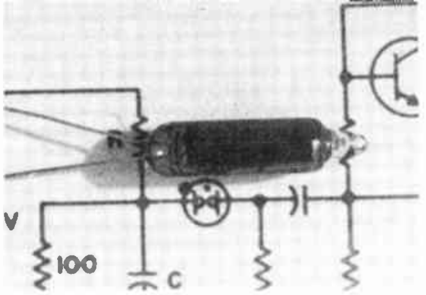


ible wire leads, and the opening is sealed so that the unit is moisture- and dustproof. Life of the lamp is rated at 60,000 hours at 5 volts. A variety of materials and finishes is available. The devices conform to military specifications. Price is $2.09 in 1,000-lots.

Dialight, 203 Harrison Place, Brooklyn, N.Y. 11237 [345]

Cold-cathode circuit monitors TV-tube voltage

A neon cold-cathode-circuit component, called the A-401, is designed to monitor and shut down the picture-tube voltage in a TV set when excessive voltage is detected. The unit may also be used to monitor the capacitor voltage in medical-electronic equipment. When the critical voltage is reached, the component directly triggers an SCR crowbar circuit, thus protecting the capacitor. Initial breakdown voltage of the A-401 is 100 to 110 V dc, mea-



sured in the dark. Breakdown stability is ±3 V of initial, and life is 100 hours continuous at 2.5 milliamperes dc.

Signalite, 1933 Heck Ave., Neptune, N.J. [344]

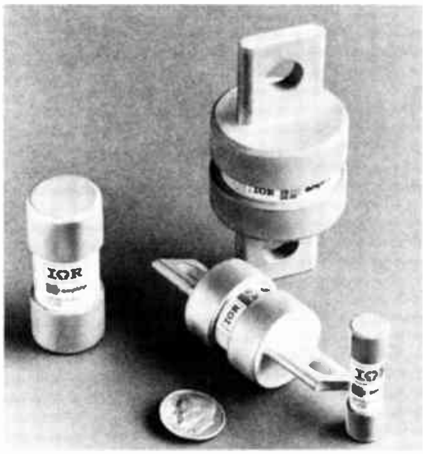
Time switch provides 24-hour on-off control

Designed to provide 24-hour on-off control in a variety of applications, including process equipment and such home appliances as fans, the series 2400 time switch has 96 self-contained clips offering on-off operation in 15-minute increments or multiples. No tools are needed to change the schedule. The single-pole, double-throw snap-action contacts are rated at 20 amperes, noninductive to 480 V ac. The unit can be supplied with an optional time delay for use where many time switches control large quantities of motors.

Zenith Controls Inc., 830 W. 40th St., Chicago, Ill. 60609 [346]

Semiconductor fuses come in fire-resistant packages

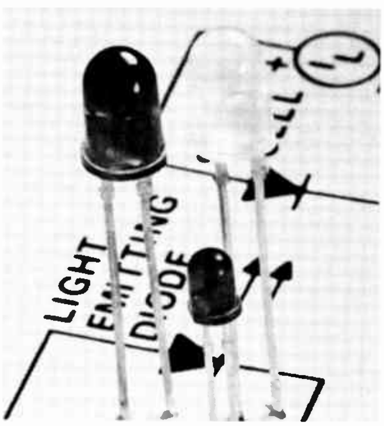
Semiconductor protective fuses with ratings of 130 volts, 10 to 800 amperes, are designated the SF13X series. The line of devices use fire-



resistant metal-ceramic packages, permitting higher case temperatures without the effects of thermal fatigue. Maximum peak voltage is 183 v, and maximum arc voltage is 220 v. Price for a 130-v, 100-A version is $4.20 in small quantities.
International Rectifier Corp., 233 Kansas St., El Segundo, Calif. 90245 [347]

Green LED glows with 800-microcandela intensity

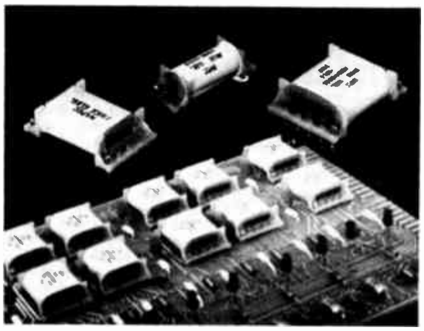
Three green light-emitting diodes, designated the TIL211, 222, and 223, are priced in 100-lots, at 46 cents, 48 cents, and 48 cents, respectively. The 211 features a 0.120-inch nominal lens diameter, a forward



current of 25 milliamperes, and a minimum luminous intensity of 800 microcandelas. The models 222 and 223 emit a minimum luminous intensity of 1 millicandela when forward-biased at 25 milliamperes. The 222 has a filled-epoxy lens, while the 223 has a clear diffused lens.
Texas Instruments Incorporated, Box 5012, M/S 308, Dallas, Texas 75222 [348]

Miniature reed relays offer contact combinations

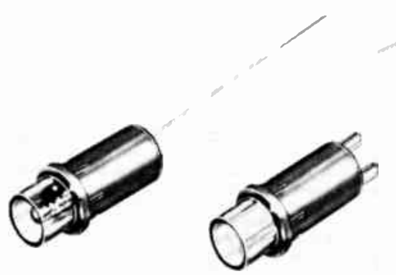
With an over-all length of 1.14 inch, series 46 open-type miniature reed relays can be densely mounted on pc boards. A newly designed terminal, spaced on 1-in. centers with a 0.150-in. grid, offers good accessibility and protection against dam-



age. Five different coil forms provide a multiplicity of contact combinations. Included are form A, B, and C dry-reed contacts and form A and B mercury-wetted contacts. Magnetic latching relays are available with 1A and 2A contact combinations. Magnetic shielding is available on all relays. Contact ratings for form A and B mercury-wetted relays is 50 watts; for form A and B dry reed relays, 10W; for form C dry-reed relays, 2.8 w. Delivery is from stock.
North American Philips Controls Corp., Cheshire, Conn. 06410 [349]

Miniature lights require no mounting hardware

A series of miniature lights for commercial and industrial applications, designated Rib-Loc, install from the front of the equipment panel and require no mounting hardware. The units feature polyamid-molded ribbed housings that fit into 0.312-inch punched holes. Other features include heat-resistant polycarbonate lenses in a variety of colors, two lens-cap styles, and T-1¾ incandescent or neon lamps.
Eldema Division, Genico Technology Corp., 18435 Susan Rd., Compton, Calif. 90221 [350]



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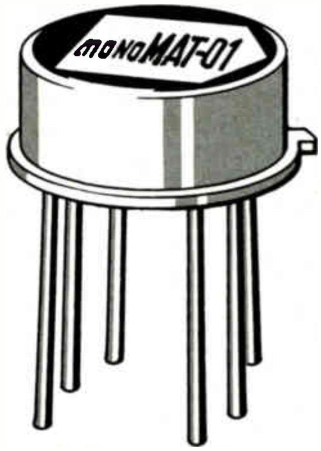

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h_{FE} @ I_C = 10μA	500	330	250	250	•
I_{OS} @ I_C = 10μA	0.6	0.8	3.2	3.2	nA
TCI_{OS} (−55° to +125°C)	90	110	150	150	pA/°C
I_B @ I_C = 10μA	20	30	40	40	nA
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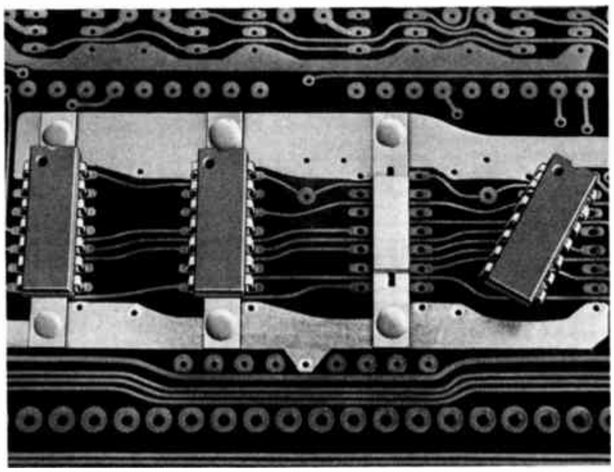
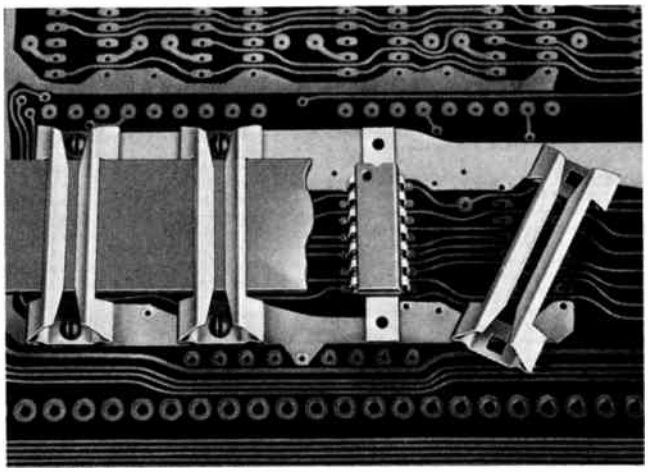
If you've got a problem with hot DIP's one of these ideas will probably solve it

No. 14 of a Series

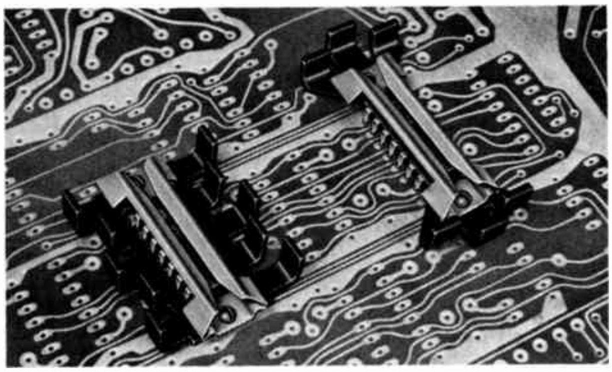
Heat build-up in DIP circuits can degrade performance, ruin reliability and in some cases, it can get completely out of control, (such as when many digital DIP IC's are jammed together on high-density boards). Whether you are using digital DIP's or high-powered linears like big op amps or voltage regulators, there's an IERC DIP-cooling system that will provide just the amount of power dissipation you need for good circuit performance, reliability and economy. In fact, the four ideas shown here will solve most DIP cooling problems. Dissipators are coated with Insulube® 448 (500-V. dielectric); can be mounted directly onto p-c lines.



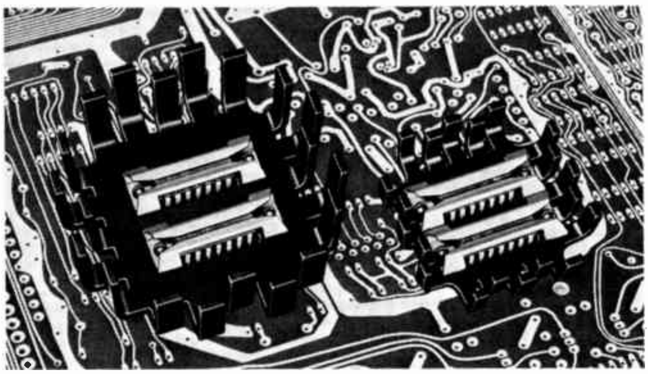
Thermal runaway is a worry when DIP density gets high such as on digital boards. One cheap solution is IERC conduction bases soldered to plated lands or ground planes. Bases control runaway by providing heat path from hot DIP bellies to lands or planes. Expect 75 to 125 mw more power with the same substrate temperature rise above ambient, or about 10°C cooler temperature with same power.



Forced air cooling for your high-density power IC DIP boards may look like the only answer, but IERC DIP conduction bases and retainer clips could make you forget it. Base gets heat from DIP bottom, clip from top and payoff is 200 mw improvement in power handling capability on G-10 boards. Solder bases to lands or ground planes and you get even more. Copper strip helps equalize DIP temperature differentials for more predictable performance and gives a little extra dissipation to boot.



Tear up the data sheet on many op amps and other power linear IC's in DIP packages unless you use thermal management or more circuits. They just won't operate that way without overheating. But clip those DIP's in our LIC or PB1 Staggered Finger dissipators with our retainer and you'll get specified performance and more. For instance, a DIP in our LIC is worth two bare devices (100% power increase), and the shorter PB1 will give you about 400 mw, or 57% more power than a bare DIP with the same substrate temperature rise.



Finding happiness together in our HP1 dissipator are Darlington amplifier and resistor network that replaced discrete resistors and several amplifiers. HP1, capable of dissipating about 10 watts, gives Darlington five times the power handling capability while it lets designer use a versatile, convenient resistor net in a power circuit without fretting over fast aging and premature failure. Smaller UP using half the board area permits operating two DIP's at four times the power possible with bare devices.

For more information
on heat sinks and dissipators for milliwatts to kilowatts, send for the IERC Short Form Catalog today. It covers the most complete line of thermal problem solving devices available anywhere.

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Heat Sinks/Dissipators

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Monsanto's new HT Series (High Technology) instruments designed specifically for communications, is the 8700 family of Frequency Counters. As a part of Monsanto's ongoing R & D program to produce digital instrumentation of optimum reliability and performance, these counters offer outstanding specifications. Only through the judicious use of tested technology, human engineering principles, and state-of-the-art circuitry and components, could the demanding standards of this series be accomplished. To further fulfill the promise of the series, each instrument is housed and protected in a contemporary, designer-styled aluminum enclosure that facilitates calibration and maintenance while providing an appearance as advanced as the technological innovations it contains.

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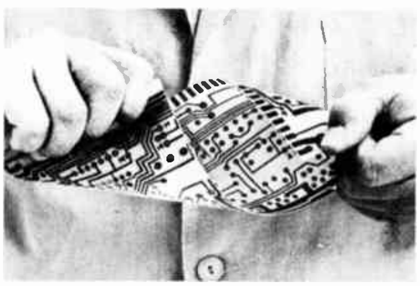
A chromium for microelectronics applications is produced by a chemical vapor-deposition process that yields a metal 99.996% pure. Called Marz, the metal is made into coarse granules, nominally a −10 to +18 mesh, which can be used as an adhesive. Another application is in the production of photomasks. The company says the chromium has a typical life expectancy 10 times higher than that of photo emulsions. Price ranges from $150 to $225 per pound, depending on mesh size and amount.

Material Research Corp., Rte. 303, Orangeburg, N.Y. 10962 [476]

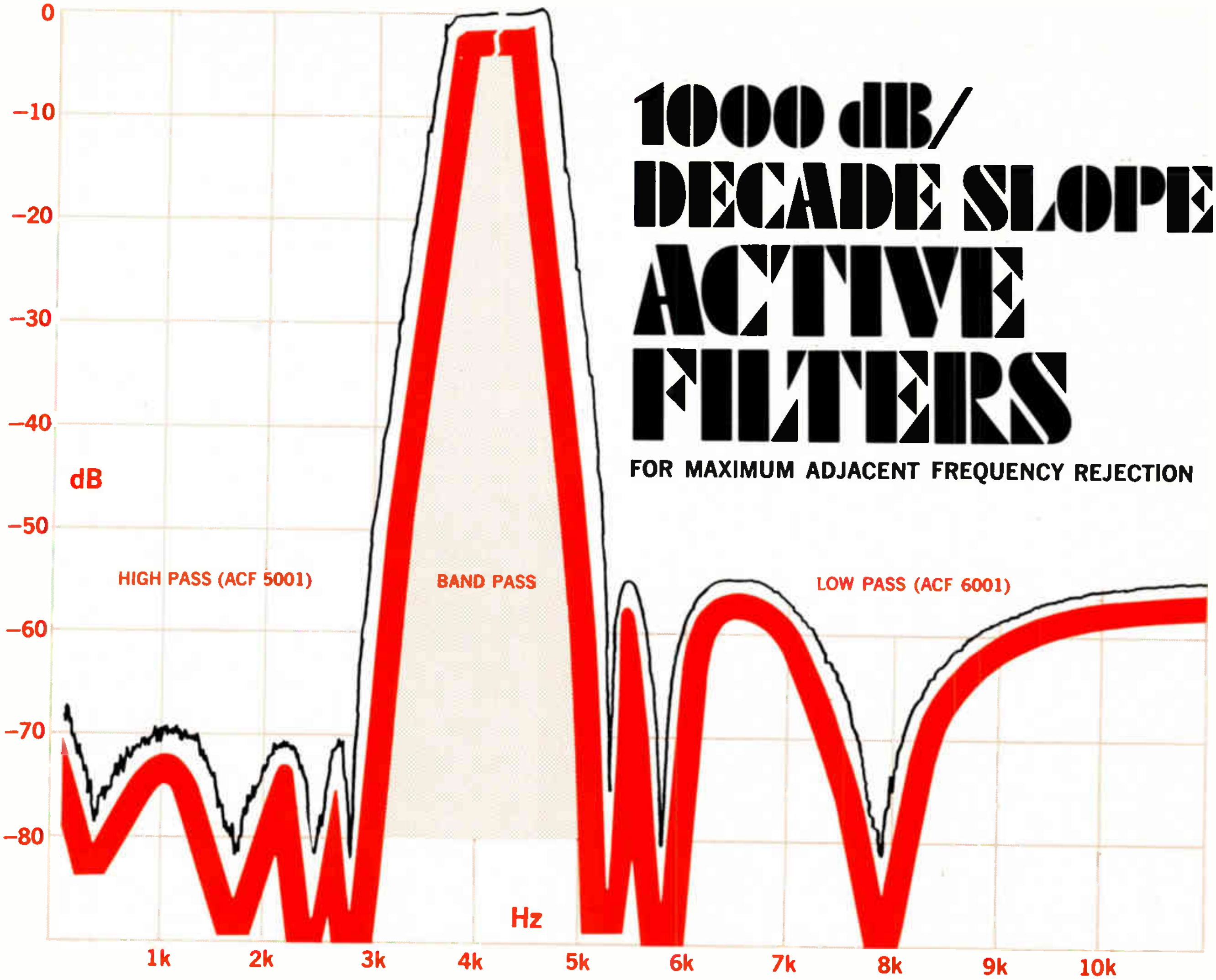
A glass-epoxy copper-clad laminate has been formulated to reduce tool wear in punching and stack-drilling operations. Firebran 670P has a mat core to minimize abrasiveness and is said to eliminate halos around punched or drilled holes, problems that often occur with conventional glass-fabric laminates. Price is about $1.80 per square foot.

Synthane-Taylor, Valley Forge, Pa. 19482 [477]

A woven-glass fabric and epoxy-resin copper-clad laminate, designated G-10 Flexible, can be folded around corners or shaped into tubes



(Continued on page 220)



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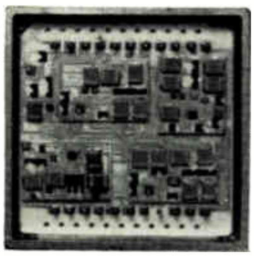

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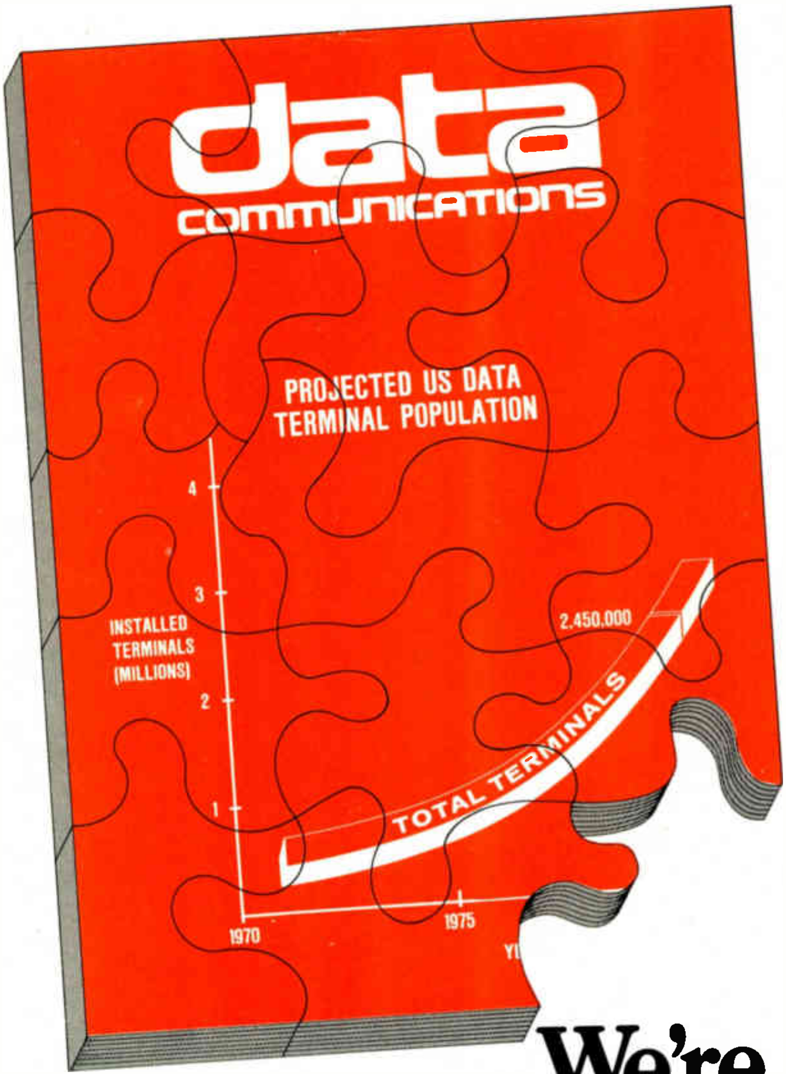

Data communications is indeed a puzzle to most of the people working in the market. In fact, many don't realize that they have data communications needs or what their needs are.

The people responsible for planning a data communications system for their company must decide alternative systems approaches, carriers, hardware, and vendors—all in the context of economics, government regulation, and future technology development.

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At Brand-Rex, we're committed to filling every order we take. On time, or as close as it is humanly possible to be. Any time we do have a problem, we'll let you know what it is and what it's going to mean to you. And we'll do everything we can to make it less of a burden.

That's our pledge. It's a lot to live up to, but we think it's the least we can do. As time goes by, we'll try to find even better ways to serve you. And if I'm sure of anything, it's this: We *can* do it.

Harry Wasiele, Jr.

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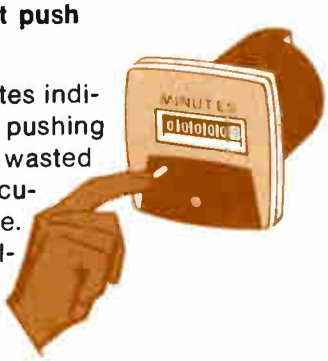

Reset your hours or minutes indicator to zero simply by pushing the button. No knobs. No wasted motion. Just fast and accurate resetting every time. Push-button reset is available on Type 240 in behind-panel or BIG LOOK® style in 2½" and 3½".

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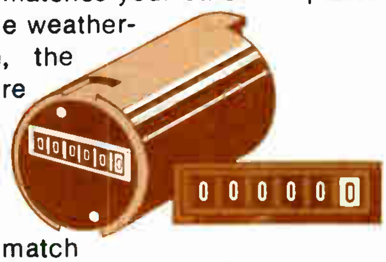


For a catalog of GE's full line of panel meters, contact your nearby authorized GE Distributor, Modification Center, or GE Sales Office. Or write to General Electric Company, Section 592-46, One River Road, Schenectady, N.Y. 12345.

Specify General Electric... just for good measure.

to adjust to space limitations. The unetched laminate passes a solder dip test of 400°F for 20 seconds and retains shear and tear qualities at operating temperatures of 300°F.
Norplex, 1300 Norplex Dr., LaCrosse, Wis. 54601 [478]

Epo-Tek H61 is a thermally conductive and electrically insulating epoxy for use with hybrid and optoelectronic devices. The 100%-solids material can be used to coat active chip and wire devices and to bond chip components in devices where electrical conductivity is not required. The material, in flowable paste form, is screen-printable. A 3-ounce evaluation kit is priced at $15.
Epoxy Technology Inc., 65 Grove St., Watertown, Mass. 02172 [479]

A silicon-core iron for making core stops in relays is said to eliminate hard spots and inconsistencies in machining, thus boosting production rates by as much as 30%. Called B-FM, it is also for use in solenoid switches and armatures and meets

the requirements of the National Association of Relay Manufacturers Specification 102, Issue I.
Carpenter Technology Corp., 101 W. Bern St., Reading, Pa. [480]

A solder mask for printed-circuit applications cures with ultraviolet light, instead of heat. Called Dynacure SM-15, the 100%-solids material is screen-printable, contains no solvents, and cures to a hard scratch-resistant finish in 3 to 6 seconds. The second side of two-sided work can be screened and cured almost immediately after processing the first side.
Dynachem Corp., Santa Fe Springs, Calif. [401]

A new glass, called IP745, is used to passivate high-voltage diodes and forms the structural package for each device. The glass is applied to a rotating, brazed subassembly in a deionized water slurry. The rotation forms a bead, which maintains its forms by surface tension during the conveyor furnace firing. The glass will act as a permanent barrier to ion-migration. IP745 is specifically designed to increase yield to 98% or 99% over 60 V, reduce snapback, and tighten voltage distribution. Moreover, IP745 permits thicker plating on leads, since it is chemically strong, which in turn increases solderability and yield on the board. In production quantities, price can be as low as $45 per kilogram.
Innotech, 181 Main St., Norwalk, Conn. 06851 [402]

Data conversion. A reference for the data-conscious engineer has been published by Hybrid Systems Corp., 87 Second Ave., Burlington, Mass. 01803. The softbound handbook discusses a variety of data-handling modules and binary codes. It describes various types of digital-to-analog and analog-to-digital converters available, the meanings of their specifications, and ways to test them. There are also chapters on sample-and-hold modules and analog multiplexers. Price is $1.50. Circle 421 on reader service card.

Oscilloscope. Scientific & Industrial Instruments Co., B-14 Industrial Estate, Pologround, Indore-3, India. A data sheet gives specifications and general information on solid-state oscilloscope model EE 601. [422]

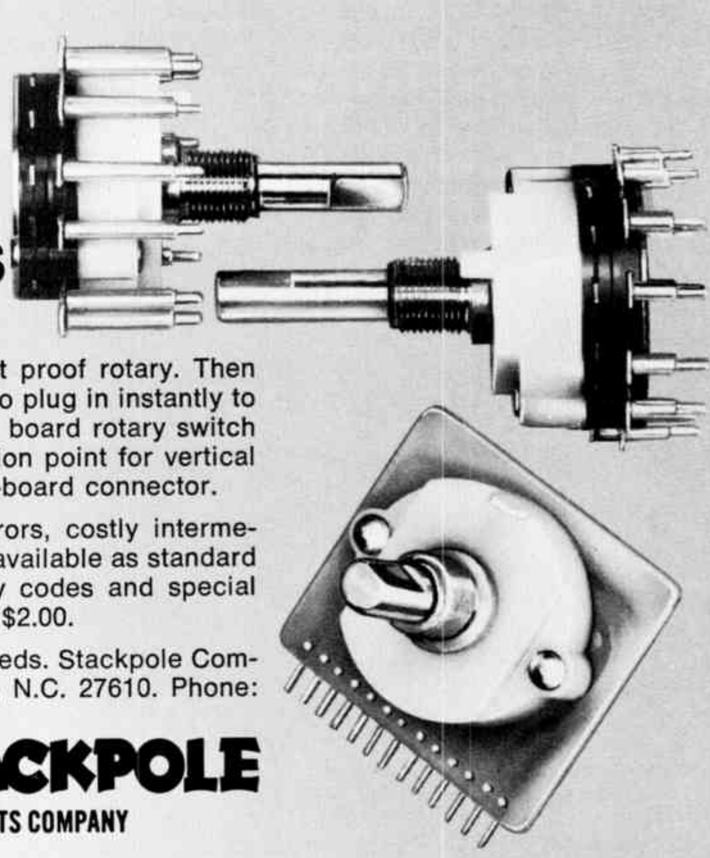
Capacitors. American Technical Ceramics, 1 Norden Lane, Huntington Station, N.Y. 11746, has published a 16-page catalog on uhf microwave-capacitor kits and a 200-page rf-capacitor handbook, which discusses the design and uses of miniature chip and leaded capacitors. [423]

Terminal. A brochure providing information on the Keyview CRT display and data-entry terminal, which dials in data in increments of 10 bits per second from 10 to 9,990 b/s, has been released by Information Design Inc., Civil Air Terminal, Bedford, Mass. 01730. [425]

Communications monitors. A 10-page technical bulletin from Cushman Electronics Inc., 830 Stewart Dr., Sunnyvale, Calif. 94086, describes the company's line of communications-service monitors for testing and maintaining two-way radios and microwave radios below 1 gigahertz. [426]

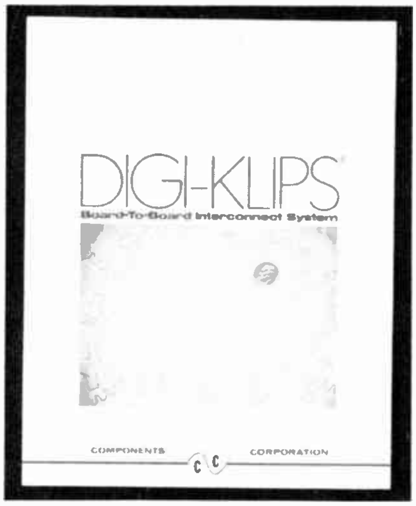
Etcher. Chemcut Corp. 500 Science Park, State College, Pa. 16801. A two-page technical sheet provides information on the system 547 spray ether, which handles circuit boards measuring from 6 by 6 inches to 40 inches by any length. [435]

Photoresist stripping. An applications note on the use of plasma in-



strumentation for removal of photoresist from aluminum substrates is available from Tegal Corp., 860 Wharf St., Richmond, Calif. 94804. [436]

Connectors. Components Corp., Denville, N.J., has published a short-form catalog providing information on the Digi-Klip line of board-to-board connectors, which allows designers to configure mother and daughter boards according to individual requirements. [427]



Signal capture. Macrodyne, 1900 Maxon Rd., Schenectady, N.Y. 12301, is offering a bulletin that discusses Erdac III, a four-channel transient-signal-capture and tape-recording system. [437]

Mixers. Anaren Microwave Inc., 185 Ainsley Dr., Syracuse N.Y. 13205. A 12-page specifications bulletin provides information on the family of 22 biased and unbiased mixers covering from 0.5 to 18 GHz in 11 overlapping ranges. [438]

Programs. Wang Laboratories, 836 North St., Tewksbury, Mass. 01876, is offering complimentary copies of the company's Programmer magazine, a publication aimed at users of calculator and computer products. [428]

Modems. Modems, frequency-division multiplexers, and diagnositic testers are the subject of a 12-page brochure being offered by DataStat Inc., 246 Sobrante Way, Sunnyvale, Calif. 94086. [429]

Resistors. Vishay Resistor Products, 63 Lincoln Highway, Malvern, Pa. 19355. Bulletin AB-104 describes how its Bulk-Metal resistors reduce size and improve specifications of a-d converters. [430]

Power systems. Time Mark Corp., Box 15127, Tulsa, Okla. A 12-page applications guide is available to advise designers on the installation of phase loss, low-voltage, and phase-reversal protection in three-phase power systems. [431]

Couplers. Elgin Electronics Inc, Walnut St., Waterford, Pa. 16441, has announced an eight-page applications guide featuring 25 different coupler models. The guide also provides installers with a reference to voice-connecting and data-access-arrangement services offered for use with customer-provided equipment. [432]

Cathode-ray tubes. Thorn Radio Valves & Tubes Ltd., Mollison Ave., Brinsdown, Enfield, Middlesex, England, An industrial cathode-ray-tube catalog provides information on oscilloscope, radar, display, and monitor tubes. It also provides charts and comparative information. [433]

Process control. A brochure from Data General Corp., Southboro, Mass. 01772, describes the modules—computers, programing, peripherals—that make up process-control equipment specifically built around small computers. A typical system using a backup computer is

explained and diagramed. [434]

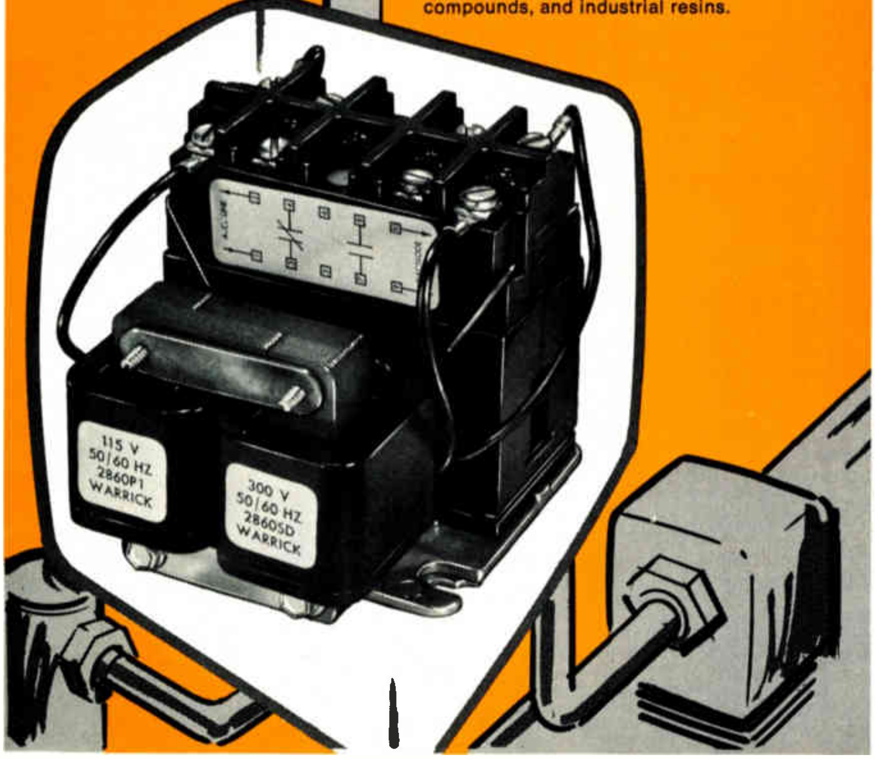
Spectrum analyzers. Federal Scientific Corp., 615 W. 131st St., N.Y. 10027. A four-page catalog provides information on how to use on-line real-time spectrum analyzers to test and service high-quality tape recorders. [371]

Directional couplers. Hyletronics Corp., Newtown Rd., Littleton, Mass. 01460, has published a brochure describing the line of 3 dB, 90° directional couplers. The line covers from 0.25 to 18 GHz in octave bandwidths. [372]

Multiplying d-a converter. A six-page catalog describes the model 869 four-quadrant multipling digital-to-analog converter. Block and functional diagrams, illustrations of the four quadrant and multiplier modes, charts, and specifications are provided. [373]

Rf and i-f components. A 32-page catalog on rf and i-f components, including microwave mixers, modulators, and amplifiers, is available from Varian, Beverly division, Salem Rd., Beverly, Mass. 01915 [374]

Sensors. Sensor Technology Co., 905 Dexter Ave. North, Seattle, Wash. 98019. An illustrated catalog describes the company's ultrasonic noncontact product line and provides information on each of its sensing devices. [375]



New books

Environmental Control in Electronics Manufacture, P.W. Morrison, Van Nostrand Reinhold Co., New York, 1973, 474 pp., $23.95.

Written by Western Electric engineers and members of the technical staff of Bell Laboratories, this book presents a systematic approach to the identification and control of contaminants in microelectronics manufacture. It should be of interest to the process engineer striving to improve his production line.

Although aimed primarily at microelectronics, this volume should prove valuable to engineers engaged in the manufacture of any precision devices.

The authors define a product contaminant as a substance or energy that can adversely affect the product; they then go on to classify a contaminant as physical matter, organic or inorganic chemical, or a viable organism. The reader learns both the origin of contaminants and their means of transport.

Contaminants are discussed in the light of how they threaten yield and reliability of semiconductor and thin-film fabrication processes. One case history, for example, describes a bit of sleuthing that enabled engineers to track down a malfunction in a tantalum capacitor. Current leakage was traced to tantalum-carbide inclusions in the oxide layer. The culprit was carbon, supplied by pump oils that had back-streamed into the sputtering chamber.

Chapters 3 and 4 explain how to use instrumental analysis and microscopy to identify contaminants. The principles in the beginning chapters are then applied to actual manufacturing situations.

Clean rooms, vital to controlling manufacturing environments, are covered in detail; so is their design, the materials used for clean-room construction, and floor-space requirements, plus the economics of building and operating a controlled-environment facility.

With demands growing for stricter pollution control, chapter 15 is must reading because it provides a clear and concise approach to identifying and treating liquid and airborne-waste products. There are

also some helpful diagrams of various waste-treatment systems.

—Peter E. Kukanskis,
MacDermid Inc.

MOS **Field-Effect Transistors and Integrated Circuits,** Paul Richman, Wiley Interscience, 1973, $14.95

Transistors have come a long way since 1970. At that time, a good field-effect (both junction and MOS) transistor textbook was published, Richard Cobbold's "Theory and Application of Field-Effect Transistors." Cobbold's remains a useful text, but Paul Richman's new book illustrates the maturing of a technology as it moves from the research laboratory to the production environment.

Richman's book provides a good summary of MOS theory and technology before 1973. Although billed as a textbook, the problems included are generally of the discussion type, and he provides no specific "answers." His is a "pedagogic monograph," rather than a self-study-type text.

By covering devices and processing, the text brings the novice up to snuff in most aspects of today's MOS technology. The approach is standard; he considers surface-state theory and MOS transistors before getting into technology.

This volume is basically oriented toward devices and processing. Previous texts in field-effect transistors had a stronger emphasis on hooking up MOS transistors and on circuit analysis. A good mixture of the two approaches is used in Cobbold's book, which also is very strong on detailing assumptions behind derivations.

Richman's book discusses such current topics as parasitic-MOS-substrate devices, silicon-on-sapphire technology, local-oxidation technology and metalization systems. It has mainly qualitative discussions of nitrate insulators and MNOS technology. Although weak on actual MOS circuitry and integrated-circuit structures, especially complementary-MOS technology, Richman provides a good introduction to MOS technology for those interested in device physics and processing.

—Joel Dubow, Components Editor

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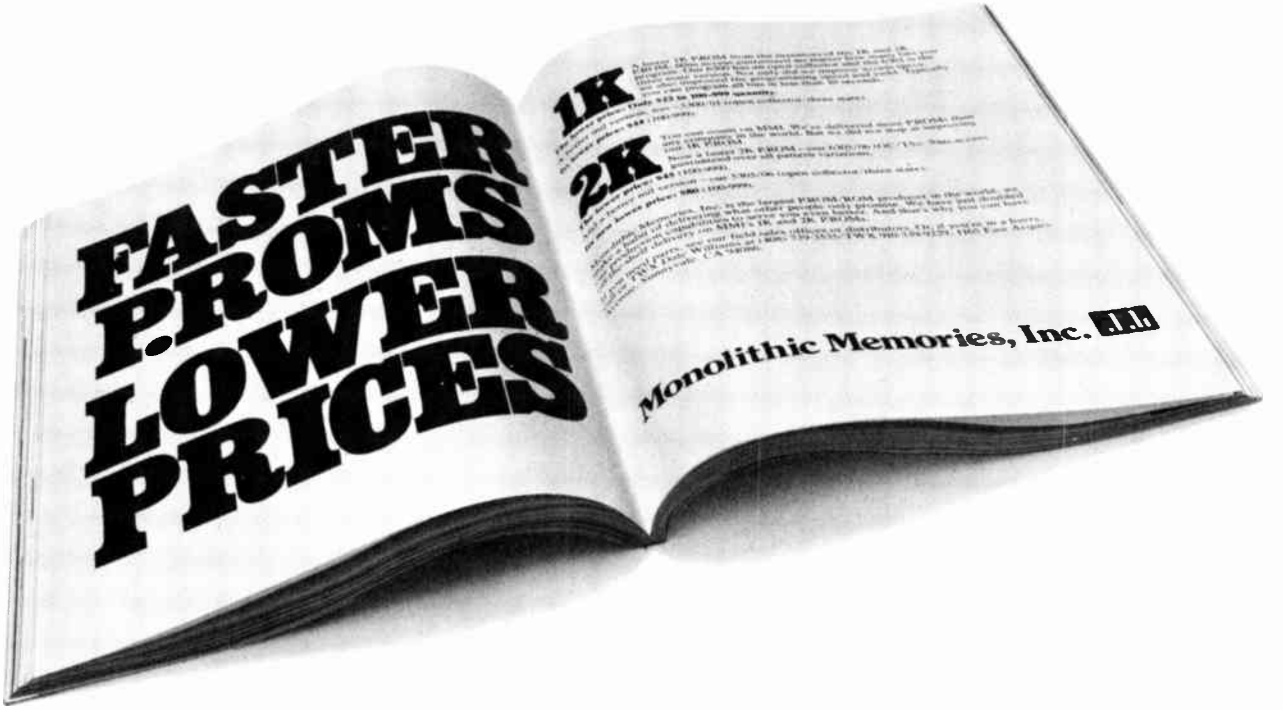

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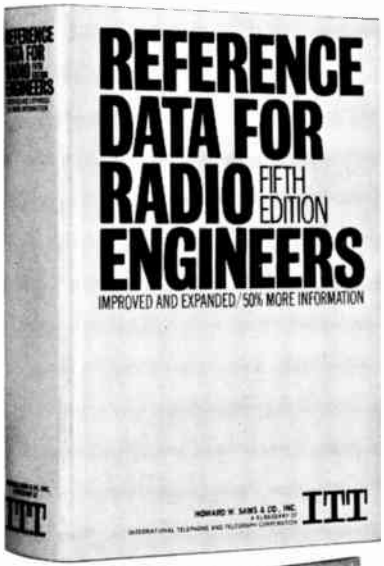

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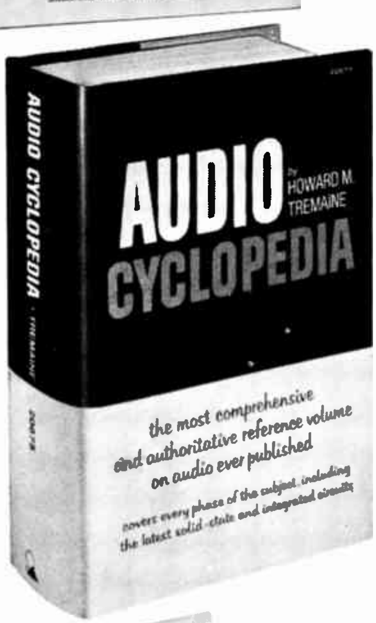

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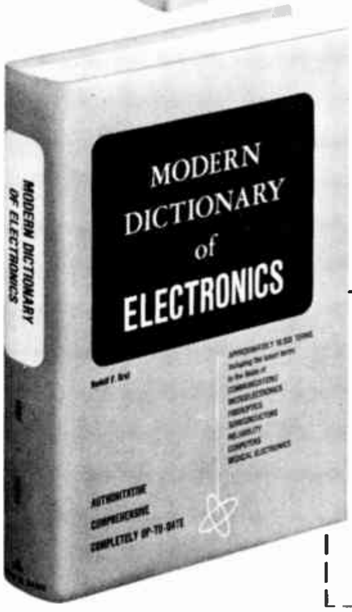

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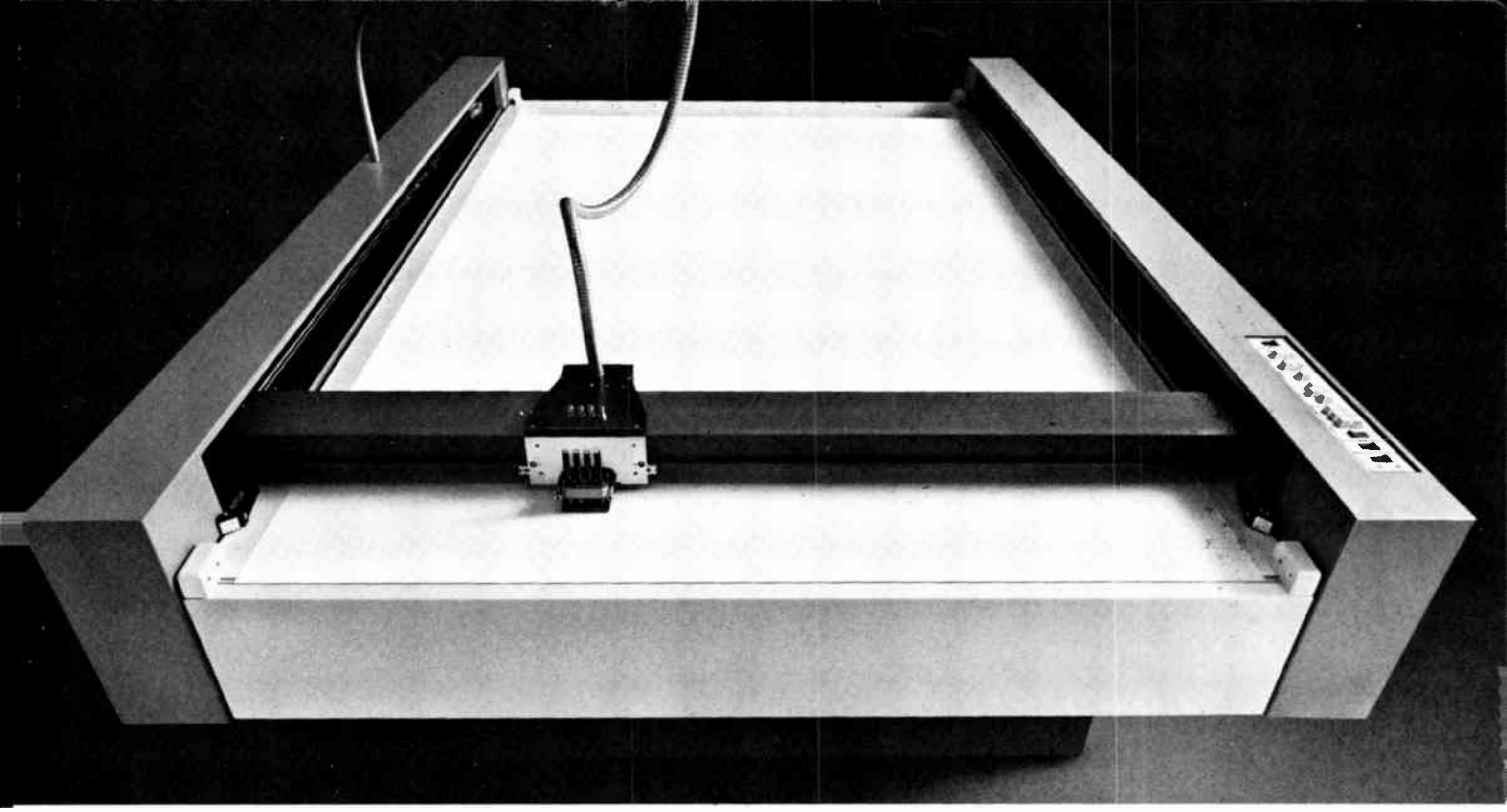

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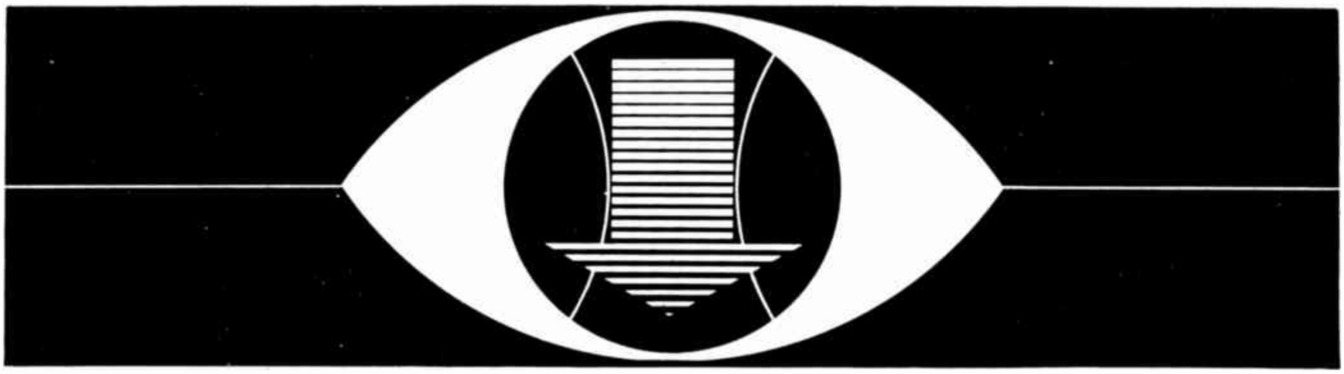

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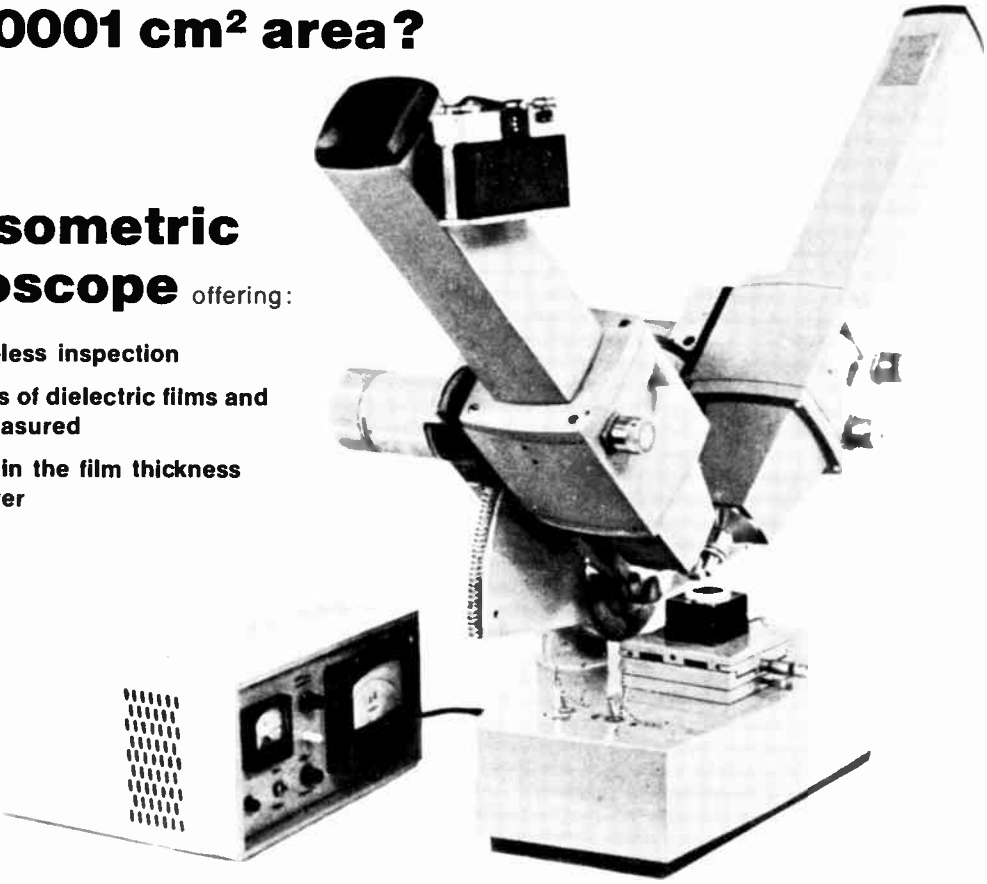

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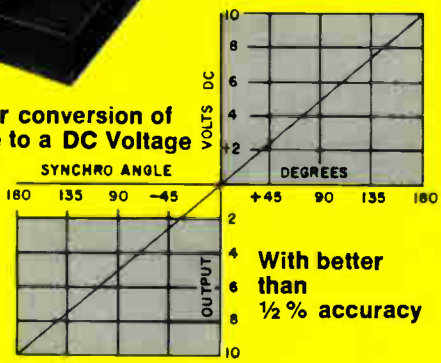
#MAC 1422-1

Provides a linear conversion of a synchro angle to a DC Voltage



With better than ½% accuracy

Specifications

Accuracy: ±1% over temperature range
Input: 11.8V, 400 HZ line to line 3 wire synchro voltage
Output Impedance: less than 10 Ohms
Input Impedance: 10K minimum line to line
Reference: 26V ±10% 400HZ (Unit can be altered to accommodate 115V if available at no extra cost)
Operating temp. range: −25°C to +85°C
Storage temp. range: −55°C to +100°C
DC power: ±15V ±1% @ 75ma (approx.)
Case material: High permeability Nickel Alloy
Weight: 6 Ozs. Size: 3.6″ x 2.5″ x 0.6″

A.C. LINE REGULATION

A new method has been developed which allows us to provide a low distortion highly regulated AC waveform without using tuned circuits or solid state active filters of any kind.

The result is a frequency independent AC output regulated to 0.1% for line and load with greater than 20% line variations over a wide temperature range.

Features:

- *0.1% total line and load regulation*
- *Independent of ±20% frequency fluctuation*
- *1 watt output*
- *Extremely small size*
- *Isolation between input and output*

Specifications: Model MLR 1476-1
AC Line Voltage: 26V ±20% @ 400Hz ±20%
Output: 26V ±1% for set point
Load: 0 to 40ma
Total Regulation: +0.1%
Distortion: 0.5% maximum rms
Temperature Range: −55°C to +125°C
Size: 2.0″ x 1.8″ x 0.5″

Other units are available at different power and voltage levels as well as wider temperature ranges. Information will be furnished upon request.

SOLID STATE SINE-COSINE SYNCHRO CONVERTER - NON VARIANT

This new encapsulated circuit converts a 3 wire synchro input to a pair of dc outputs proportional to the sine and cosine of the synchro angle independent of a-c line fluctuations.

- Complete solid state construction.
- Operates over a wide temperature range.
- Independent of reference line fluctuations.
- Conversion accuracy — 6 minutes.
- Reference and synchro inputs isolated from ground.

Specifications Model DMD 1508-2

Accuracy: Overall conversion accuracy 6 minutes. Absolute value of sine and cosine outputs accurate to ±30MV
Temperature Range:
Operating −40°C to +85°C
Storage −55°C to +125°C
Synchro Input: 90V RMS ±5%LL 400Hz ±5%
DC Power: ±15V DC ±10% @ 50MA
Reference: 115VRMS ±5% 400Hz ±5%
Output: 10V DC full scale output on either channel @ 5ma load
Temperature coefficient of accuracy:
±15 seconds/°C avg. on conversion accuracy
±1 MV/ °C on absolute output voltages
Size: 2.0″ x 1.5″ x 2.5″

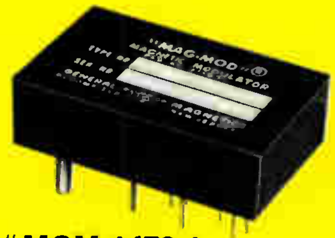
Units are available with wider temperature ranges and 11.8V LL, 26V reference synchro inputs. Information will be supplied upon request.

4 QUADRANT MAGNETIC ANALOG MULTIPLIER

DC x DC = DC OUTPUT

Product Accuracy is ±½% of all theoretical product output readings over Full Temperature Range of −55°C to +125°C.

Maximum Output Error for Either
X = 0, Y = 10V
Y = 0, X = 10V
X = 0, Y = 0
would be ±2 MV over Entire Temperature Range.



#MCM 1478-1

Specifications Include:

Transfer Equation: E = XY/10
X & Y Input Signal Ranges: 0 to ±10V peak
Maximum Static and Dynamic Product Error: ½% of point or 2MV, whichever is greater, over entire temperature range
Input Impedance: X = 10K, Y = 10K
Full Scale Output: ±10V peak
Minimum Load for Full Scale Output: 2000 ohms
Output Impedance: Less than 10 ohms
Bandwidth: 1000Hz
DC Power: ±15V, unless otherwise required, at 20ma
Size: 1.3″ x 1.8″ x 0.5″
Output is short circuit protected

There is No Substitute for Reliability

Circle 901 on reader service card

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