MARCH 29, 1979

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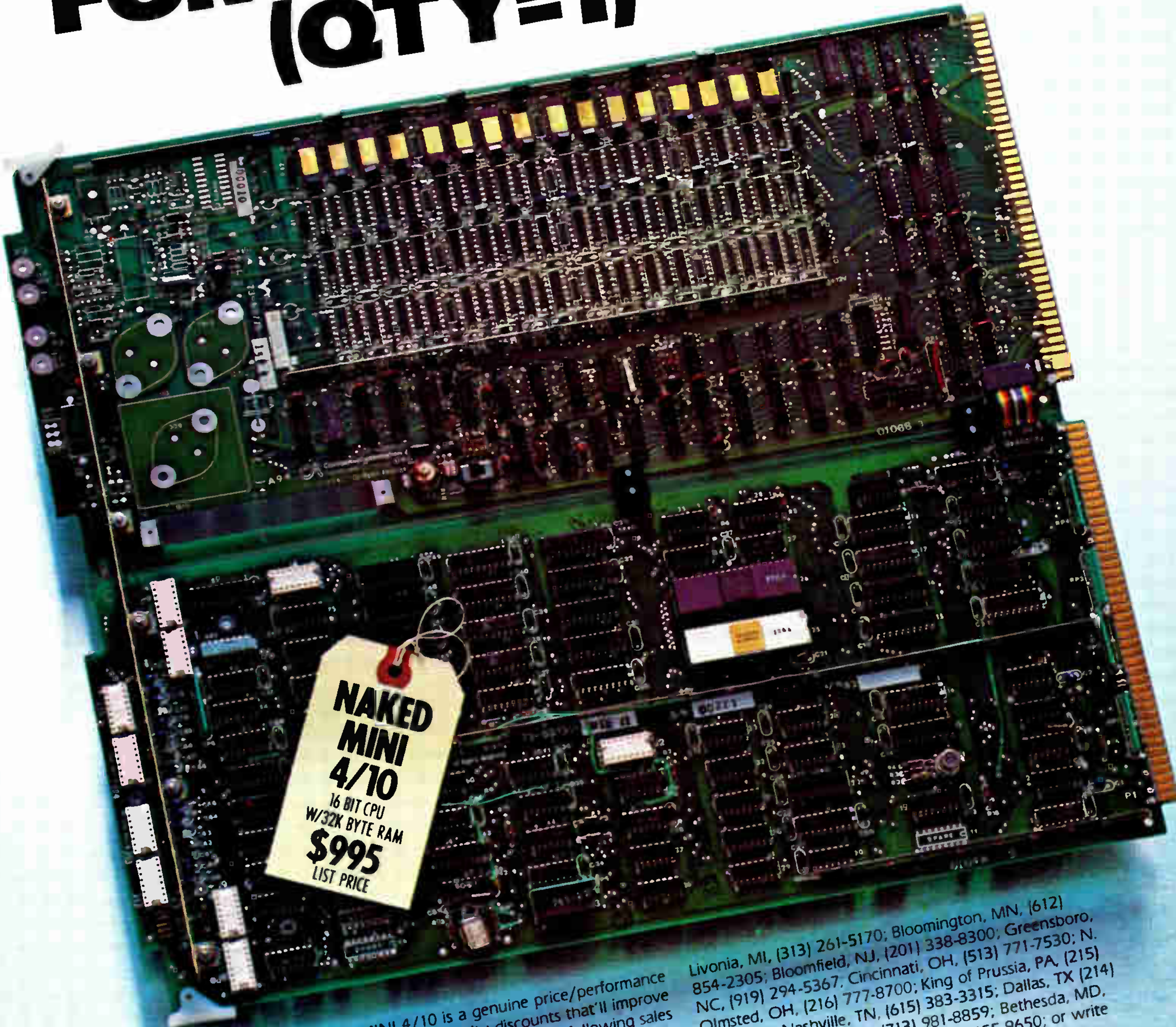

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Electronics
The International Magazine of Electronics Technology
Vol. 52, No. 7 • March 29, 1979

Highlights

Cover: Handling digital data by satellite, 91
The power limitations, long distances, and kinds of noise encountered in sending data by satellite impose strict bounds on the choice of multiplexing, modulating, and coding techniques.

Cover photograph is by Jerry Kresch.

Magnetic bubbles make two big breakthroughs, 80
At a recent conference in California, IBM Corp. announced a simpler, denser bubble-memory design, Bell Laboratories a simpler, faster one. If the two advances prove compatible, the last barriers to the widespread use of these memories may fall.

What's doing in logic timing analyzers, 103
Capable of synchronous or asynchronous operation, current models offer more channels, different speeds, and assorted triggering schemes in combinations that should meet almost every design need.

A new breed of linear ICs run on just 1 V, 115
A cadmium-nickel battery or even the residual voltages within a system are enough to power cleverly designed linear circuits built with standard bipolar technology. Altogether new applications open up.

. . . and in the next issue
Two special reports: VLSI lithography and a preview of Electro/79 . . . a programmable-memory–based controller.

Publisher's letter

Satellite data signal processing, the subject of the cover article (p. 91) by communications editor Harvey Hindin, brings together various technologies in a perfect example of effective systems engineering. It's a packaging job.

The special report describes how data is packaged for the most efficient transmission via communications satellites. The objective is to use the least bandwidth and the least power with the least number of errors.

"These techniques," comments Harvey, "will become more and more important as the satellite airwaves become more crowded. The theory and the basic concepts have been around for some time, but there was simply no need for their application in terrestial lines. Now satellites have forced theory, hardware, and software to bear on the problems."

The result: application of digital technology, large-scale integration, and signal-processing theory to the packaging of satellite data. These techniques, as a result, must be understood by the system user, the service operator, the hardware manufacturer, and even the builder of the birds, Harvey points out.

What's next in satellites? At some point, computers will communicate directly at their native bit rates with no special signal processing needed, Harvey predicts.

Key moments in electronics technologies are often marked by a particular symposium or colloquium. The Third International Conference on Magnetic Bubbles held earlier this month on the desert at Indian Wells, Calif., seems to be one of those landmarks.

As Larry Waller, Los Angeles bureau manager, who covered the sessions, observed, IBM and Bell Laboratories, which usually operate at low key, came out talking about their latest bubble-memory developments (p. 80). On short notice, publicity representatives held full-scale press conferences, something not previously done at the ICMB.

Another indication of the technological ferment was the increase in attendance, plus the appearance of high-level marketing personnel. "It's a sign that a technology is finally starting to take off," Larry remarks.

Typical of electronics technologies, one product improvement often forces another. Such is the case with the programmable pacemakers described on page 84 by Larry Marion of the Chicago bureau.

After the change to batteries to extend the pacer's operating life, it became necessary to make the new unit programmable to adjust performance to the patient's changing needs during that long period.

Although in the past the medical profession has often been slow to accept electronics innovations in patient care, this has not been the case with the new pacers. And that's what is known as progress.

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Meetings

International Symposium on Computer Architecture, IEEE, Marriott Hotel, Philadelphia, April 23–25.

16th Annual Rocky Mountain Bioengineering Symposium, IEEE, Fitzsimons Army Medical Center, Denver, Colo., April 23–25.

27th Annual Relay Conference, National Association of Relay Manufacturers (Elkhart, Ind.), Oklahoma State University, Stillwater, Okla., April 23–25.

1979 Photovoltaic Solar Energy Conference, IEEE and the Commission of the European Communities (Brussels), Kongresshalle, West Berlin, April 23–26.

Electro/79 Show and Convention, IEEE, Coliseum and Americana Hotel, New York, April 24–26.

Reliability Physics Symposium, IEEE, Airport Hilton Hotel, San Francisco, April 24–26.

International Microwave Symposium and Workshops, IEEE, Sheraton Twin Towers, Orlando, Fla., April 30–May 4.

Newcom—The 1979 Electronic Distribution Show, Electronic Industry Show Corp. (Chicago), Las Vegas Convention Center and Hilton Hotel, Las Vegas, Nev., May 1–4.

25th International Instrumentation Symposium, Instrument Society of America, Sheraton Hotel, Anaheim, Calif., May 7–10.

1979 SID International Symposium, Society for Information Display (Los Angeles), Chicago Marriott Hotel, Chicago, May 7–11.

ISS '79—International Switching Symposium, Colloque International de Commutation (Paris), PLM St. Jacques Hotel, Paris, May 7–11. For information in the U.S., contact A. E. Joel Jr., Bell Telephone Laboratories, Holmdel, N. J.

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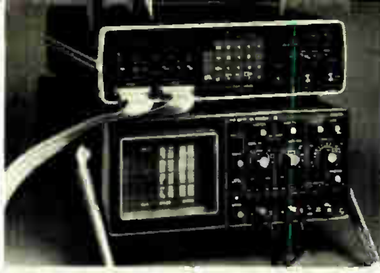

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Circle #7 for additional information

Circle #169 for demonstration

Meetings

ence, EIA and IEEE, Hyatt House, Cherry Hill, N. J., May 14–16.

Electrical and Electronic Measurement and Test Instrument Conference, IEEE, Skyline Hotel, Ottawa, May 15–17.

Naecon—National Aerospace and Electronics Conference, IEEE and Naecon (Dayton, Ohio), Dayton Convention Center, Dayton, May 15–17.

Huntsville Electro-Optical Technical Symposium and Workshop, Society of Photo-Optical Instrumentation Engineers (Bellingham, Wash.), Huntsville Hilton and Von Braun Civic Center, Huntsville, Ala., May 22–25.

Failure Avoidance Seminar, Integrated Circuit Engineering Corp. (Scottsdale, Ariz.), Hilton Inn, Jamaica, N. Y., May 23–24.

1979 International Summer Consumer Electronics Show, EIA, McCormick Place, Chicago, June 3–6.

Short courses

Spring and summer program from Integrated Computer Systems includes microprocessor hands-on workshop and courses on military and aerospace microprocessor applications, spread spectrum communication systems, and small computing systems. Courses begin in April and are given repeatedly in cities throughout the U.S. and Canada. For information, contact Kim D. Sanson, program manager, Integrated Computer Systems Inc., 3304 Pico Boulevard, P. O. Box 5339, Santa Monica, Calif. 90405.

Summer short courses at USC include reflector antenna theory, June 4–8; advanced microcomputer system development, Aug. 6–10; and modern communication systems: analysis and design, Aug. 6–10. For information, contact University of Southern California, Continuing Engineering Education, Powell Hall 216, University Park, Los Angeles, Calif. 90007.

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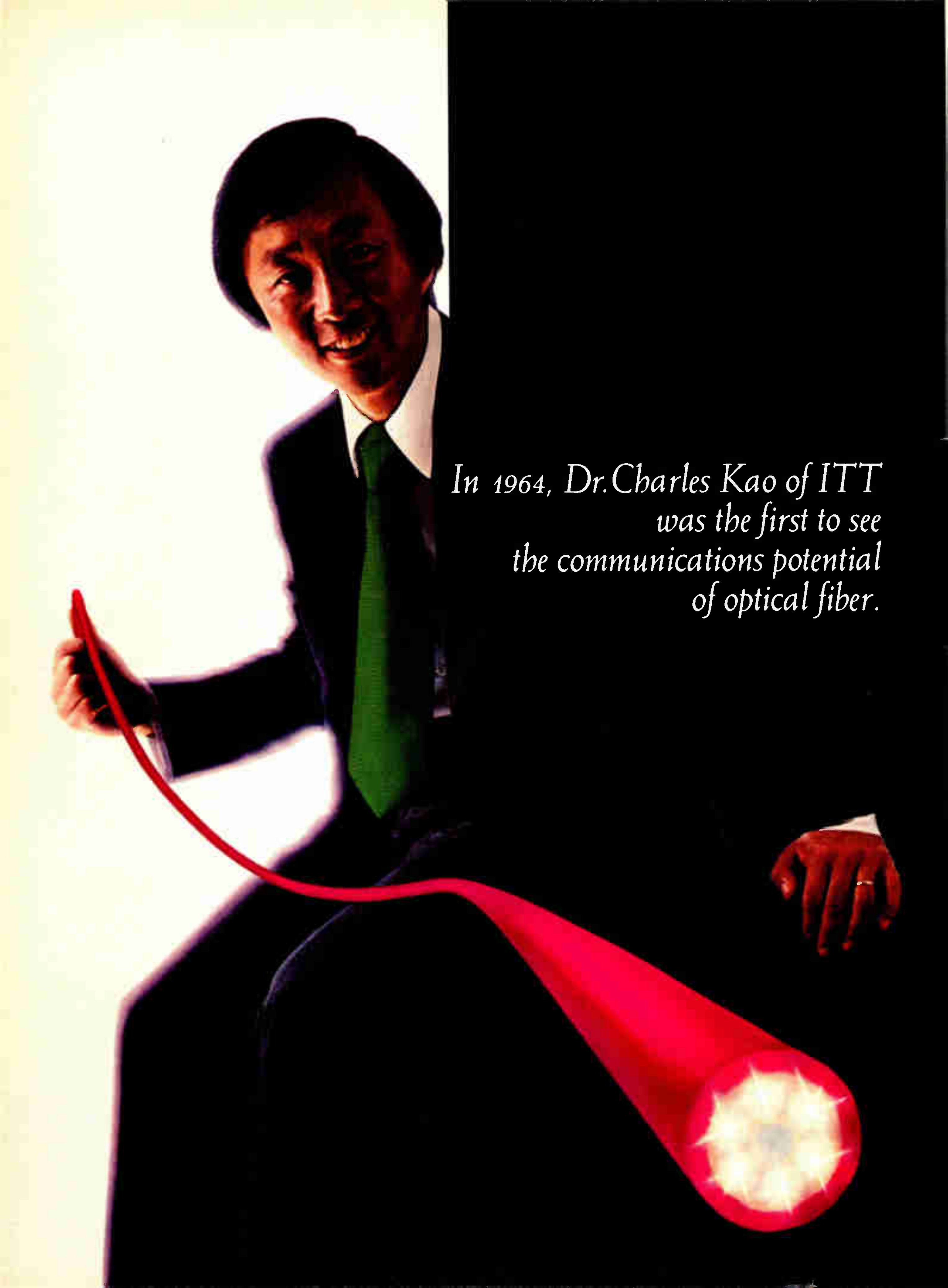
In 1964, Dr. Charles Kao of ITT
was the first to see
the communications potential
of optical fiber.

Editorial

The door is still open

Has the day of the venture-capital semiconductor start-up company—like Intel or Mostek—gone forever? Robert R. Noyce, Intel's chairman and a man who has been involved in his share of entrepreneurial endeavors, has some answers. He outlined them several weeks ago in London while accepting the Faraday Medal from Britain's Institution of Electrical Engineers.

The subject is particularly relevant for British audiences, which have seen their government put $100 million into a start-up semiconductor maker called Inmos and earmark another $800 million to push British industry into the microcomputer age. Noyce aimed some jabs at the United Kingdom's hostile tax climate, which deters private capital and makes government intervention on such a large scale necessary. "This is curing a symptom rather than a cause," he said. "A Band-Aid can only be effective if healing is going on underneath."

But Inmos has been started in the more hospitable American climate and has been staffed with a talented team of American semiconductor industry executives—so what are its chances of survival, and what indeed are the chances of any new company in the U. S. today? Said Noyce, "My philosophy for a start-up company is that it ought to do something no one else is doing" and that in targeting on memories and microprocessors Inmos "is not doing anything different."

One important key to semiconductor entrepreneurism is chip integration: how long will the process continue, creating start-up opportunities in its wake? In Noyce's view, the physical limits of very large-scale integration lie not in optical or X-ray resolution, but in thermal noise in the semiconductor device, where the signal levels have to be at least an order of magnitude higher than thermal noise-generating effects. That level, said Noyce in London, "would be reached by improvement of circuit densities within a further two orders of magnitude, by which time the supply voltage would be 0.5 volt and there would be between 10 and 100 million devices per chip." That equates with the largest computer to date, said Noyce. It also suggests a spectrum of opportunities bounded only by the human imagination and a benign tax climate.

Just the facts, please

Every so often we are reminded that the appearance of validity in data substitutes all too easily for the actuality. Current controversy surrounding overseas recruitment for engineering jobs in the U. S. aerospace industry is just such a reminder.

Companies can point to recruiting efforts that yielded nothing; engineers can point to their unemployed brethren; and both sides can present salary figures that seem not to deal with the same industry. But where are the facts?

One answer may be that the U. S. Department of Labor is falling down on its job; that it should be tracking engineers' salaries more closely. That's true—so far as it goes. The Labor Department does gather salary figures, and it will accept them from sources other than the employers (although it may not pursue them actively). But are the various engineering societies doing their part by surveying their members and reporting results to the agency? We think not.

The working engineer must also play his or her part—especially the jobless engineer. The best way to let the world know you are looking and you have a salary history is to register for unemployment compensation. You are not only paid, but your name also goes into computer banks that can service you and provide hard data on availability and salaries to the Labor Department.

National hires Heikes for European push

Pusher. Robert Heikes will be pushing National Semiconductor's product line.

The goal, says its president Charles Sporck, is for National Semiconductor Corp. to climb until it has the same market position in Europe that it has in the United States. This means he wants the Santa Clara, Calif., company to become the No. 2 supplier of integrated circuits in Europe, although its thrust will be across all its major product lines, both IC and discrete.

Experienced. Leading National's charge in Europe at its offices near Munich is Robert Heikes, who took over this month in the newly created position of international vice president. No stranger to Europe, he is reported to dote on travel on the Continent and French cooking.

For five years he was Motorola's managing director in Europe, where he helped set up manufacturing and marketing for Motorola Semiconductor. He returned to the U. S. in 1975 to become assistant general manager of Motorola's Semiconductor Group in Phoenix, a job he left last year [*Electronics*, Nov. 9, p. 46].

Lower down. National has a lot of catching up to do. Its sales in Europe last year are estimated to have been under $60 million, placing the company at about the No. 11 spot. The leader is Philips, with an estimated $350 million in sales, followed by Texas Instruments with $250 million, Siemens with $185 million, and Motorola with $135 million.

Heikes has some very definite ideas about making it in the European market. He plans to do more than go toe to toe against the other semiconductor firms.

Technologically, he feels that Europe is behind both the U. S. and Japan. National will benefit, therefore, by transferring technology to European companies, he says. The availability of new, high-performance devices will create larger markets, he reasons.

"What I want to do is in some way to cooperate effectively in several countries to help them in the high-technology business," says the 53-year-old executive and holder of a Ph.D. in physics. One example of what to expect is National's recent joint venture in France with Saint-Gobain, a French conglomerate, in which National will help establish production facilities for a metal-oxide-semiconductor plant with French government backing [*Electronics*, Dec. 7, p. 66].

To the top. If deals like this work out, "once we get into those markets, at worst we'll be the No. 1 second source," Heikes says. He expects to develop all of National's product line in the European market, from small-signal transistors to IBM-compatible mainframe computers.

National already owns production facilities in Greenock, Scotland. The plant, touted to be one of the most modern wafer fabrication units in Europe, also has a design group, and Heikes, who directed Westinghouse's Electric Corp. Research Laboratory during his 15 years with that company, is as yet unsure if he will need another.

William Warner has a system that's worth whistling for

For William Warner, the design process probably began with a car accident almost five years ago. He woke up to find himself paralyzed from the waist down, in a room with three quadraplegics.

"I spent a lot of time with them and I saw what they needed," he says. "When I left the hospital I decided to build a control system for

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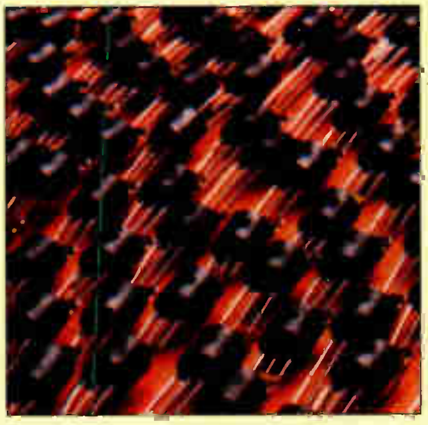

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People

Designer. A little intuition and logic helped William Warner design his controller.

them to help with everyday living."

The result is a control system that allows things like room lights and television sets to be turned on and off with a whistle (see p. 46) Warner, now 24 and in his junior year in the electrical engineering department at Massachusetts Institute of Technology in Cambridge, Mass., has built three of the systems and hopes to license manufacturing rights.

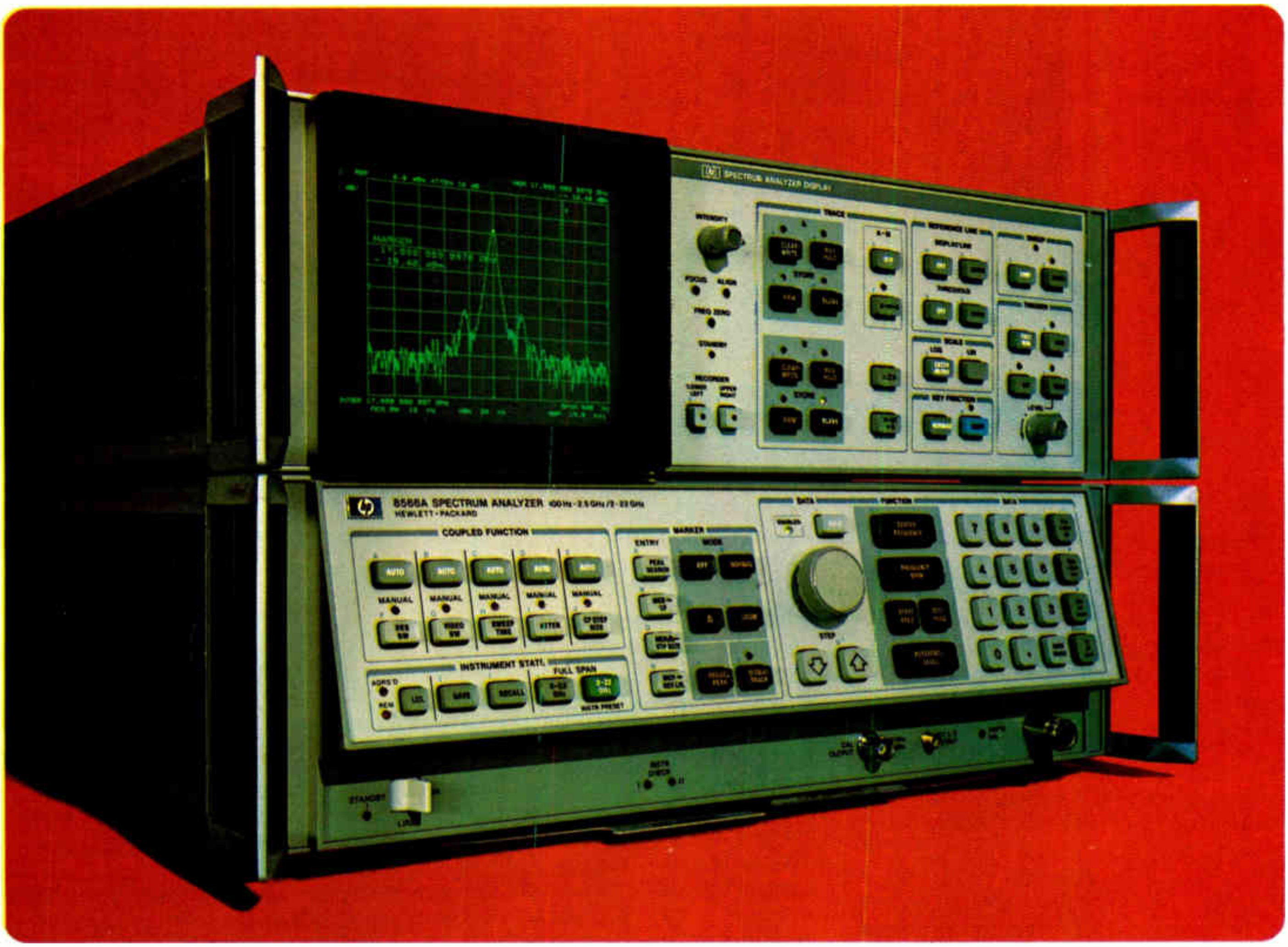
Quick. "I had no engineering background outside of Ohm's law," Warner says of when he began the design. "But the learning curve is fast in digital design. It's the physical design of things like printed-circuit boards that takes so long. Knowing even 96% of it isn't enough—the other 4% is tough."

Warner has been perfecting his device over several years and through three versions. He has been working with MIT Prof. Derek Rowell [*Electronics*, April 27, 1978, p. 14], to apply Motorola's 6800 microprocessor or possibly an 8080.

Warner has other design plans for the future, including redesign of his bamboo-framed, rickshaw-like tricycle, which he pedals using his arms: "It needs more arm and shoulder momentum—merely a mechanical problem." He wants to work eventually in computer graphic design, using his architectural and photographic skills to solve problems with moving and stationary objects. But in the forefront of his concern is seeing that the whistle system is available to the people who need it. □

MEASUREMENT COMPUTATION news
product advances from Hewlett-Packard

APRIL 1979



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New microwave spectrum analyzer features high resolution, high accuracy, plus automatic measurement capability

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These are just some of the performance highlights of the new HP 8566A 100 Hz to 22 GHz Spectrum Analyzer. Additonal performance features include *(continued on third page)*

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- Program storage in nonvolatile memory

Versatile

HP's new 3779 Primary Multiplex Analyzer provides within one instrument the capability to measure comprehensively the performance of primary level Pulse Code Modulation (PCM) terminal equipment. Separate tests of analog-digital (A-D) and digital-analog (D-A) performance can be made in addition to characterizing the analog-analog (A-A) performance of the PCM channel bank. The instrument may also be used to measure FDM terminal and TDM switching equipment, including single channel PCM codecs, and both discrete and LSI devices. The 3779 has been designed specifically to measure to CCITT, CEPT, and BELL recommendations and makes significant contributions in new measurement hardware and software.

Two Versions

Two versions of the Primary Multiplex Analyzer are available. The first, Model 3779A provides voice channel measurements to CEPT recommendations. With the digital option it will test PCM equipment, conforming to CCITT Recommendations G.711 and G.732, i.e., 30 voice channels/32 time slots encoded using the A-law and time-division multiplexed into a 2048 kb/s digital stream.

The second version, Model 3779B provides voice channel measurements to BELL recommendations. With the digital option it is designed to test PCM equipment conforming to CCITT Recommendations G.711 and G.733, i.e., 24 voice channels/24 time slots encoded using the μ-law and time-division multiplexed into a 1544 kb/s digital stream.

Automatic Measurement Execution

Organized around a microprocessor, the instrument can automatically sequence through a number of measurements to programmed limits, calculate and display results. A keyboard oriented towards voice channel measurements controls the 3779. Programming requires no special expertise, since all measurement execution is preprogrammed.

Conveniences

If required, the measurement parameters (test levels, frequencies, limits, etc.) may be modified via the keyboard. Once the 3779 is programmed, measurements may be assembled into a sequence which is stored in nonvolatile memory for future use. Indications of the status of the instrument, together with measurement parameters/results, are on an alphanumeric CRT display. A built-in self-test facilitates calibration and fault diagnosis. An electronic, keyboard-operated combination lock provides security for the stored programs.

For more information, check **B** *on the HP Reply Card.*

New state of the art spectrum analyzer

HP-IB

(continued from first page)

80 dB distortion-free dynamic range and extremely high sensitivity (−137 dBm to 1 GHz, −134 dBm to 5.8 GHz, −115 dBm to 22 GHz). The analyzer has built-in preselection from 2 to 22 GHz and the ability to scan this wide range repetitively. (Similarly, you can scan from 0 to 2.5 GHz).

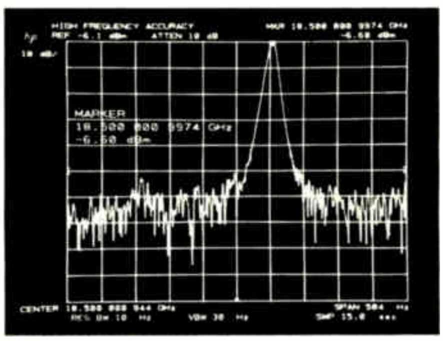
Operational Features

The 8566A's performance is matched by its powerful operational features. When operated manually, the analyzer's functions and operating state are keyboard selected, causing an internal microcomputer to administer controls, calculate and manipulate data (including correcting for hardware inaccuracies), and offer new operating features. Among these are tunable markers that greatly speed measurements, automatic peak search, automatic preselector peaking, automatic signal track, and complete CRT labeling of all pertinent operating conditions.

Remote Programmability

All of the keyboard functions are remotely programmable via the HP-Interface Bus. Combining the analyzer with a friendly controller like the HP 9825A desktop computer forms a powerful automatic measurement and analysis system. Applications well-suited for such a system include spectrum surveillance and automated production testing of sources and non linear devices.

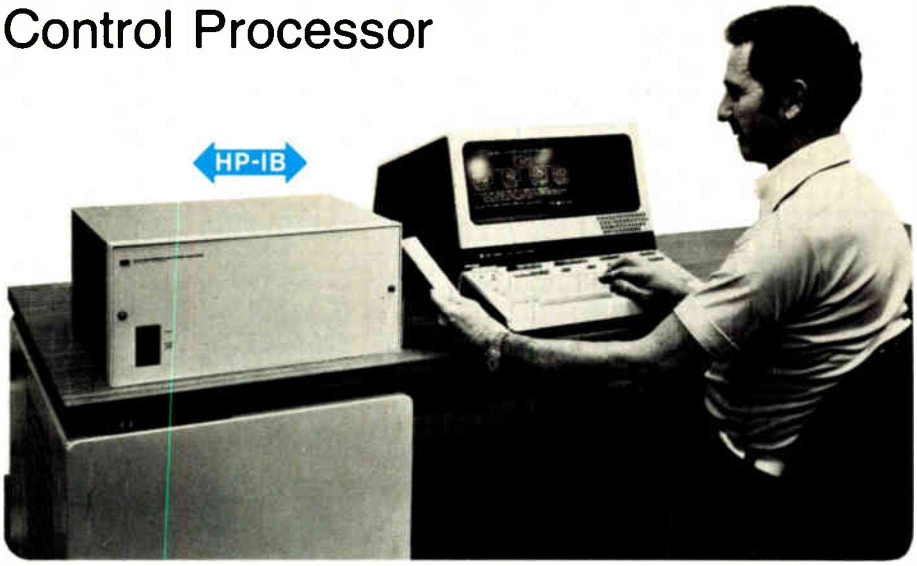
There is much more you will want to know about this analyzer; check **C** *on the HP Reply Card.*



HP 8566A Spectrum Analyzer uses its 10 Hz resolution bandwidth to display a stable 18.5 GHz signal.

New high-performance option now available for HP 2240A Measurement Control Processor

HP-IB



Widely used in product tests, and electromechanical equipment process and control, the HP 2240A Measurement Control Processor now offers even more extended data processing capabilities.

Three new high-performance capabilities are now available for the HP 2240A Measurement Control Processor, an intelligent front-end subsystem that executes measurement and control tasks by processing, conditioning, and controlling analog and digital signals. The 2240A can be interfaced to any HP 1000, 9825A/35/45 computer via the HP-IB interface.

The capabilities, available in an optional package, include two new modes of data acquisition. The first, continuous data acquisition, allows the 2240A to acquire analog and/or digital data and return it continuously to the computer at average rates of up to 10,000 readings/second. The second capability, history data acquisition mode, enables the 2240A to acquire data and subsequently discard it in the absence of an unpredictable but critical event. When the event occurs, (e.g., the closing of an alarm switch) data leading up to the event can be recovered, making the 2240A a good choice for many monitoring applications. IF-THEN decision-making capability has also been provided for in the 2240A. This allows it to alter its operation, based on the status of a digital input—independently of the computer! With the addition of these new capabilities, the HP 2240A's high level measurement and control commands now number more than fifty.

The Extended Performance Option can be ordered with an HP 2240A.

For complete information, check **D** *on the HP Reply Card.*

Analyze control systems on-line

Now there's a fast and easy way to characterize control systems—in many cases while they are in operation. Application Note 240-1, "Digital Signal Analysis - Feedback Control System Measurements," tells how HP's 5420A Digital Signal Analyzer does it.

Check **E** *on the HP Reply Card for a complimentary copy.*

New personality module for HP's 1611A offers flexibility to monitor activity on virtually any μP

HP's 1611A Logic State Analyzer now offers a general purpose personality module, Op. 001 (Model 10264A for field installation) which enables monitoring of virtually any μP. Multiple clocks allow monitoring of bus structures in either multiplexed or conventional architectures. The wide information display (up to 36 bits) accommodates either 8-bit or 16-bit μP formats.

HP's Model 1611A Logic State Analyzer can now be configured for measurements of microprocessors not covered by dedicated personality modules. A new general-purpose personality module now offers the flexibility to monitor activity on virtually any microprocessor. Seven clock inputs allow multiplexed information on common bus structures to be latched into the analyzer at times appropriate for display.

Each 8-bit half of a multiplexed 16-bit address bus may be separately clocked into the 1611A. Also, 8-bit bytes of a multiplexed 16-bit auxiliary bus can be clocked in separately. Furthermore, 4 auxiliary bits can be interrogated at yet another time nibble on a separate clock.

Multiple Clocks

The multiple clocks also allow viewing of activity across several buses during different time segments. For example, 16 bits of address, 8 bits of data, 8 bits for I/O, and 4 bits for other control lines such as MEMR, MEMW, I/OR, I/OW.

Display 36 Bits of Information

The ability to display 36 bits of information allows this module to monitor activity on address, data, and up to four control bits of 16-bit processors. Separate switches for the 4 auxiliary lines let you use them as part of the trigger specification.

Flexible Codes

Display listings with this module are in the absolute code being executed with respect to the established trace parameters. The displayed code for address and data may selected in hexadecimal or octal. The same code may be used to display external and auxiliary inputs or they may be displayed in binary. Connection to a system under test is through two pods with individual leads and probes for each of the data, clock, and qualifier inputs.

This module may be ordered separately for field installation as Model 10264A or as installed on a 1611A as the Model 1611A Option 001.

For complete information, check **H** *on the HP Reply Card.*

Stimulus/response instrumentation ends costly improvisation

Obtain fast, reliable characterization of digital logic-based circuits with new stimulus/response instrumentation from Hewlett-Packard.

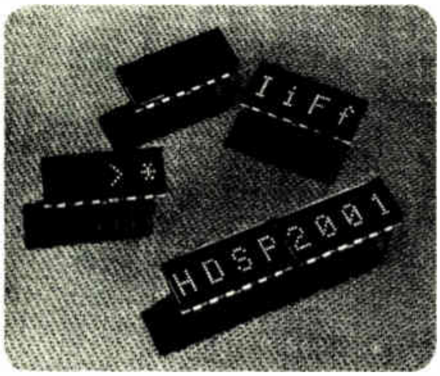
For testing RAM's or other IC's, the multichannel 8016A Word Generator and 1615 Logic Analyzer combination give you timing as well as functional test capability. Elsewhere, instruments specializing in serial data interfaces or parallel bus communication are also available. HP stimulus and response instruments offer programmable memory so that you can test different devices simply by changing the stored data. Rapid pattern loading is assured via HP-IB, and the addition of a controller provides a powerful, cost-effective test system.

For further information, check your test interest on the HP Reply Card: Multichannel devices, **I***; Serial data logic,* **J***; Parallel bus stimulation,* **K***; and CMOS component testing,* **L**.

The 8016A Word Generator with card reader option for easy truth table loading. The 1615A Logic Analyzer displays state and timing as well as capturing glitches.

HEWLETT-PACKARD COMPONENT NEWS

New dot matrix display has µP-based controller interface



The newly introduced HDSP-24XX Series dot matrix alphanumeric display system couples HP's proven HDSP-2000 LED display with a µP-based controller/interface to substantially reduce engineering development costs and time previously required for dot matrix displays.

Low voltage, compact size, and solid state features make the HDSP-24XX Series excellent for applications such as data entry terminals, instrumentation, electronic typewriters, and other products using 5×7 dot matrix alphanumeric display systems.

Each display system consists of two component parts:

1. **An alphanumeric display controller** with preprogrammed routines to accept, decode and display standard ASCII data. Four separate display formatting modes allow easy interface to the customer keyboard or µP-based system.

2. **A display panel** consisting of HDSP-2000 displays matched for luminous intensity and mounted on a low thermal resistance P.C. board.

Optional upper and lower case character fonts, programmed custom character sets, and single line 16-, 24-, 32-, or 40-character display lengths are available.

*To order, contact any HP component distributor or check **M** on the HP Reply Card for more information.*

HP's new YELLOW alphanumeric display is a color alternative to the red display

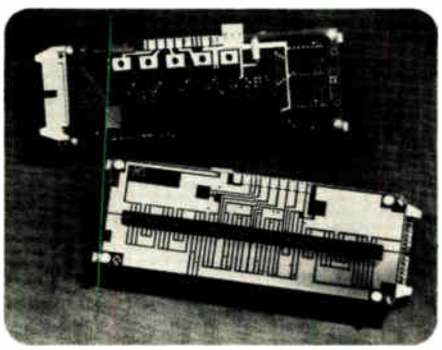
If your application requires small displays or prohibits the use of red displays, HP has the answer—the HDSP-2001. A YELLOW, four-character, solid state alphanumeric display, the HDSP-2001 offers the same reliable performance as the proven Hewlett-Packard HDSP-2000 red alphanumeric display.

In addition to its reliability, the HDSP-2001 has numerous other features including wide angle viewing, small size, uniform display appearance (segments are binned according to both color and intensity), TTL compatibility, integral shift registers, and constant-current drives.

Such attributes make these yellow displays an outstanding choice for applications such as flight instrumentation, office equipment, military fire control and communication systems. This new display may also be used in bright ambient environments with appropriate filtering.

Each HDSP-2001 character is formed with a 3.8 mm (0.15 in.), 5 × 7 dot matrix, capable of displaying the full ASCII code, lower-case, as well as upper-case letters, punctuation marks, mathematical and other symbols, plus numerals. Each four-character package measures 17.7 mm (0.699 in.) long by 7.25 mm (0.290 in.) high. Small, yellow HDSP-2001 alphanumeric displays are available in stock from HP distributors.

*Check **N** on the HP Reply Card for full information.*



Microwave broadband mixer combines high isolation with rugged mechanical design

Rugged design in double balanced mixer provides excellent broadband performance and reliability.

The HMXR-5001 is a broadband double balanced mixer that holds conversion loss low and yet keeps isolation high across the full 2 to 12.4 GHz RF/LO band. Its IF band spans a 100:1 range, from 10 MHz to 1 GHz.

At frequencies up to 8 GHz, conversion loss is typically held to 7.5 dB and to 8.5 dB from 8 to 12.4 GHz. The device provides a typical isolation of 30 dB between its local oscillator and radio-frequency ports.

Hermetically sealed, high-performance Schottky diode beam lead quads are used in the HMXR-5001 instead of the chip diodes found in most microwave mixers. In addition, the unit is built with small semi-rigid cables as transmission lines, instead of the more common strip-line configurations. This combination assures the user that most of the important high frequency signals remain confined within these components for improved isolation.

Applications include frequency conversions in electronic surveillance systems, instrumentation, and measurement systems.

*For more information, check **O** on the HP Reply Card.*

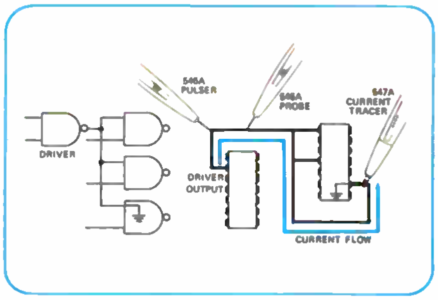
HP's IC Troubleshooters: fast, economical solutions to digital troubleshooting's basic problems

For most jobs, there are basic necessary tools to solve recurring problems economically and simply. For example, you reach for a screwdriver automatically when the need arises, and use it over and over without hesitation or concentration on the tool itself; you want to spend your time thinking about solving the problem at hand rather than how to use the tool.

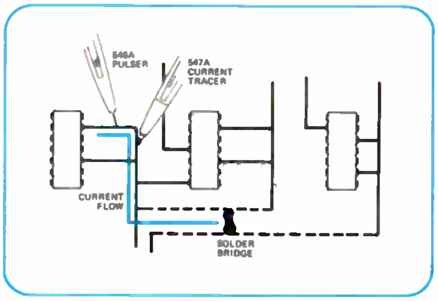
HP's IC Troubleshooters are basic tools just like the screwdriver: economical, ready for immediate use, simple to use and able to solve your basic digital troubleshooting problems over and over.

To clarify what this means, we've shown here two tough troubleshooting problems made simple by the IC Troubleshooters. In both cases, these tools indicate pulse activity, voltage or current, at the most basic circuit level—the node. You need these tools because your search for circuit faults must reveal the misbehaving node if you are to locate the faulty circuit element. And these tools are your best choice because they're low in cost, require no setup or similar attention, and show results through a lamp at probe's tip—eliminating the need to take your eye off the circuit you're tracing.

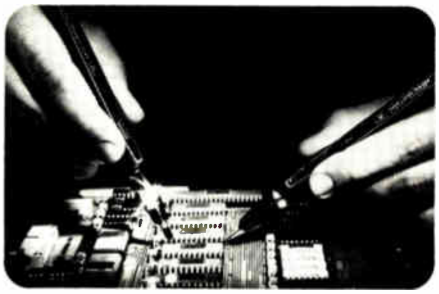
To learn more about these highly useful digital tools, just check **P** *on the HP Reply Card.*



Find Solder Bridges Quickly
- Pulse the driver output at desired pulse rate using HP 546A Logic Pulser.
- Adjust sensitivity of HP 547A Current Tracer at node driver output; use Current Tracer to follow current pulses to short circuit.
- Light on 547A Current Tracer will go out when solder bridge is passed.



Isolate Bad IC Input Quickly
- 545A Logic Probe and 546A Logic Pulser test node for logic state and determine if state can be changed. (Shorts to Vcc or Gnd cannot be overridden by pulsing)
- Pulsing the node with 546A Logic Pulser enables the user to follow current directly to the faulty input.



Here are the HP 546A Logic Pulser and 547A Current Tracer in action. HP Logic Probes resemble them closely. All items available in various combination "kits" complete with carrying case.

East-4 Choke Cherry Road, Rockville, MD 20850, Ph. (301) 258-2000
South-P.O. Box 10505, 450 Interstate North Pkwy., Atlanta, GA 30348, Ph. (404) 434-4000.
Midwest-5201 Tollview Dr., Rolling Meadows, IL 60008, Ph. (312) 255-9800.
West-3939 Lankershim Blvd, North Hollywood, CA 91604, Ph. (213) 877-1282.
Europe-Central Mailing Depot., P.O. Box 529, Amstelveen-1134, Netherlands, Ph. (020) 47 20 21.
Japan-Yokogawa-Hewlett-Packard Ltd., Ohashi 29-21 Takaido-Higashi 3-chome Suginami-ku, Tokyo 168, Ph. 03-331-6111.

HEWLETT hp PACKARD

MEASUREMENT COMPUTATION news
product advances from Hewlett-Packard

March/April 1979

New product information from
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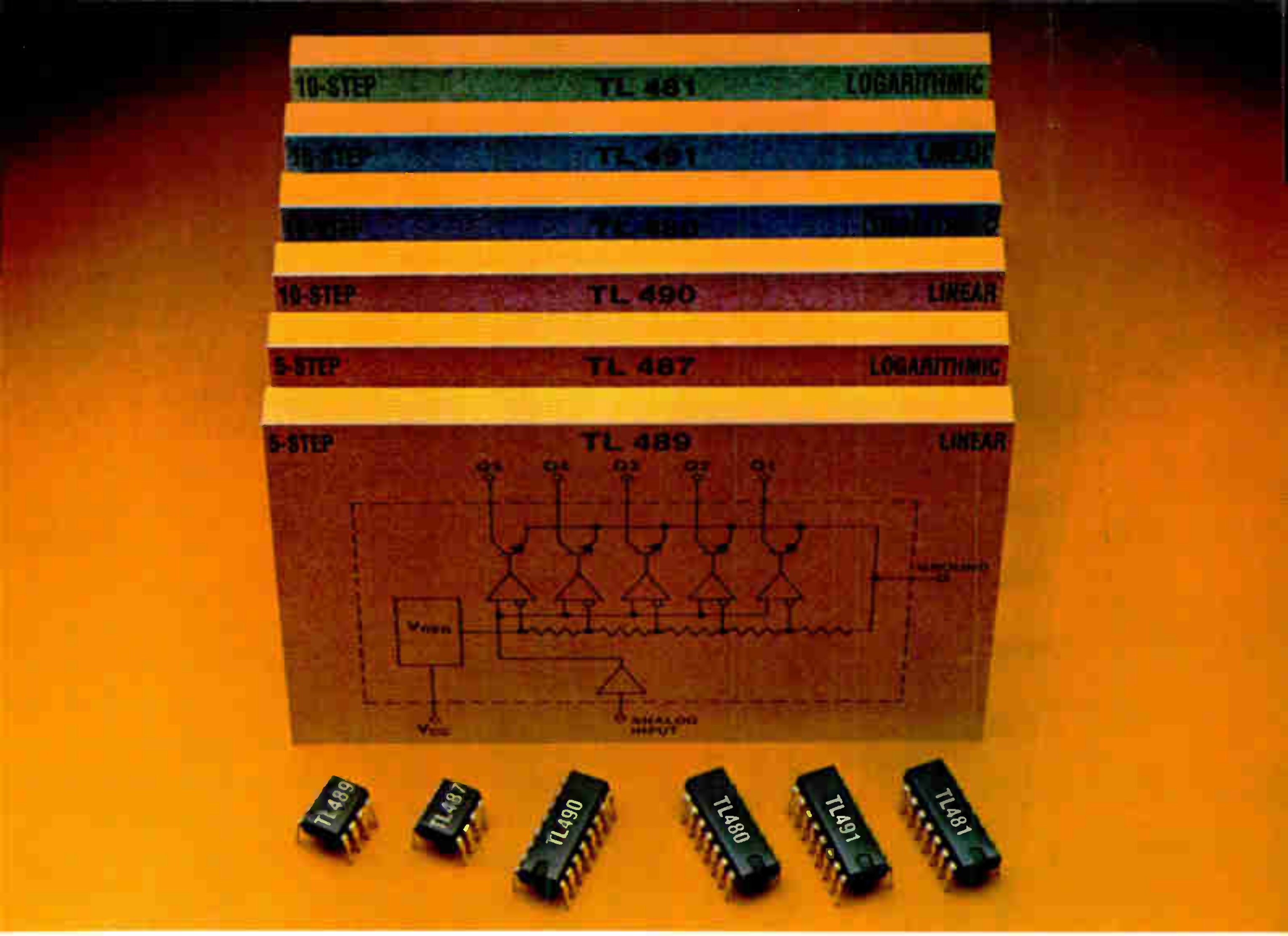


New analog level detectors. From Texas Instruments.

Our new line of monolithic analog level detectors is designed to meet all your cost/performance goals.

Each is unique. Because it combines a large number of components on a single chip—and sells for a fraction of the individual component cost.

Design flexibility

Now, for the first time, designers have more flexibility for a wider variety of applications.

Applications such as warning signal indicators, analog-to-digital converters, feedback regulators, industrial controls, audio level indicators—even light intensity and frequency detection.

Two degrees of resolution

TI analog level detectors are available as five and ten step detectors in both linear and logarithmic scale formats. For applications requiring greater resolution than 10 levels, the 10-step linear detectors can be cascaded to detect up to 150 levels.

Both open-collector and open-emitter output options are offered to yield an extremely versatile family of products capable of being custom-tailored to specific applications, using significantly less power than discrete versions.

Device	Input	Steps	Display Type	Price* 100 Pcs.
TL489	Linear	5	LED	$0.65
TL487	Logarithmic	5	LED	0.65
TL490	Linear	10	LED	1 08
TL480	Logarithmic	10	LED	1 20
TL491	Linear	10	VF	1 22
TL481	Logarithmic	10	VF	1 30

*Prices effective March, 1979.
Commercial temperature (0 C to 70 C) operating range versions in plastic dual-in-line packages

Analog level detectors from Texas Instruments. A simple, cost-effective solution to all your level-sensing applications.

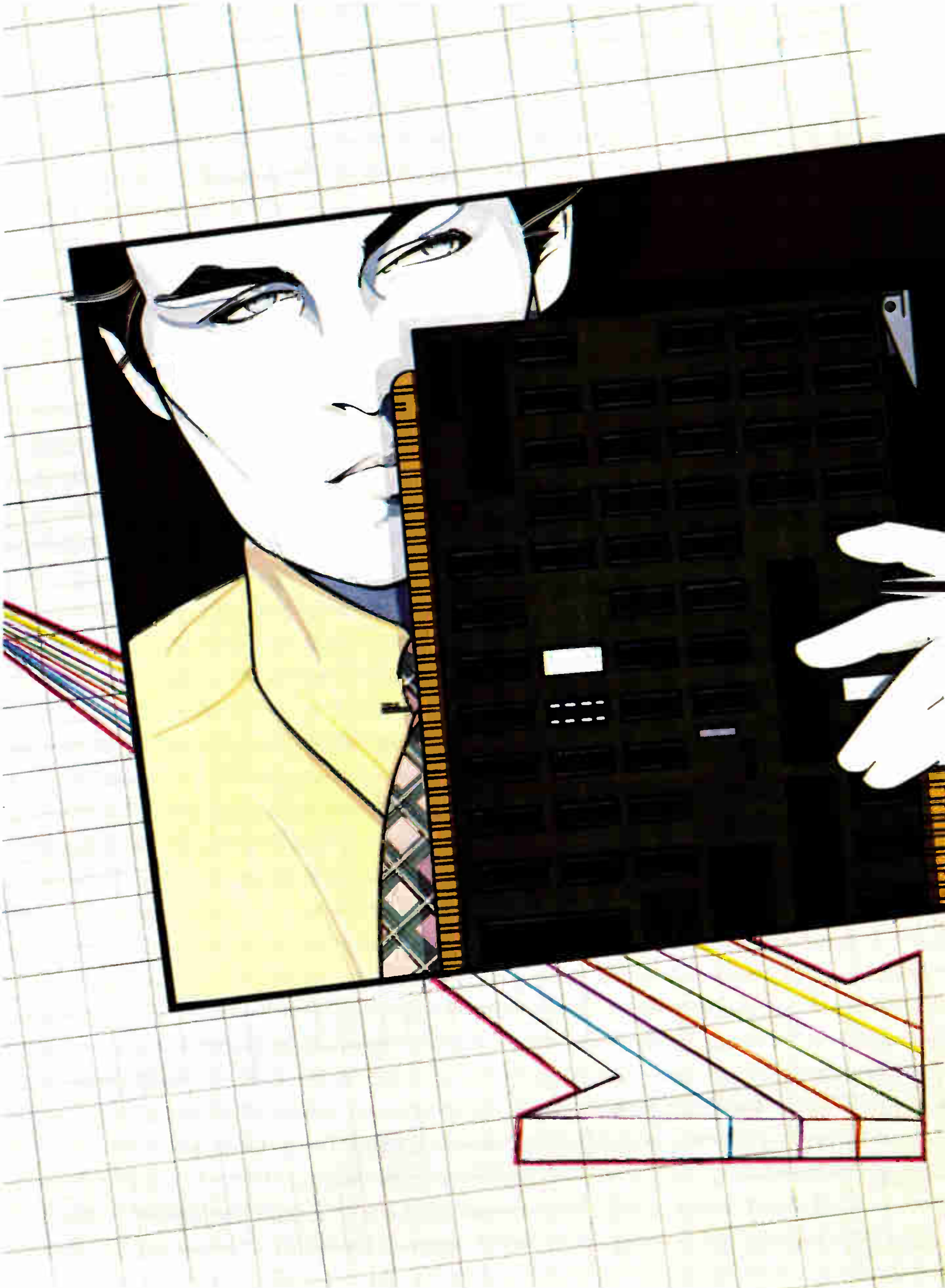
Free brochure

A new 12-page brochure (CL-410) gives full information on TI's line of monolithic analog level detectors and typical applications. Call your nearest authorized TI distributor, or write Texas Instruments Incorporated, P.O. Box 225012, M/S 308, Dallas, Texas 75265.

TEXAS INSTRUMENTS
INCORPORATED

82145

Circle 27 on reader service card



Shortcut to Success.

Introducing iSBC 86/12,™ the single board computer that brings the power of the 8086 to the Multibus™ standard.

There's no quicker way to implement designs with the new 8086 16 bit microprocessor than our new iSBC 86/12. It's dramatic evidence of the architectural capability of the 8086, with unprecedented computing power, memory and I/O capacity on a single board.

Multibus™ architecture ensures success.

The Multibus standard is your path to success with the iSBC 86/12 board. Since we introduced it in 1976 it has become the industry standard microcomputer bus. Even then we were looking forward to the 8086 and designed the Multibus architecture to support both 8- and 16-bit computers in single or multimaster systems, and a full megabyte of directly addressable memory.

That gives you unlimited design flexibility, with immediate access to the complete iSBC family of 8-bit computers, memory boards, analog and digital I/O, peripheral control and communications boards.

Plus over 100 additional expansion boards from more than 40 independent suppliers. And Multibus compatibility means you can preserve your design investment as your application requirements grow from 8 to 16 bits.

iSBC 86/12™ designed from experience.

We drew upon all our design experience to make the iSBC 86/12 board the most advanced 16-bit single board computer available.

At its heart is our 8086 CPU that gives the iSBC 86/12 board ten times the processing power of our 8-bit single board computers. We added 32K bytes of dual port RAM, fully accessible by all Multibus masters in shared memory designs. There are sockets for up to 16K bytes of EPROM. And the advanced architecture of the 8086 addressses up to a full megabyte of system memory.

The iSBC 86/12 board has a flexible I/O structure, with 24 programmable parallel I/O lines and a programmable synchronous/asynchronous communications channel with RS232C interface and programmable baud rate generator. In addition, the iSBC 86/12 architecture provides nine levels of vectored interrupt control and two programmable interval timers.

More than a shortcut.

The iSBC 86/12 board is a fully assembled and tested computer, dramatically reducing development time compared to component level design. More important, lower hardware costs enable you to incorporate the iSBC 86/12 board in hundreds of performance-dependent applications where the size and cost of larger computer systems would be prohibitive.

See us at Computer Caravan

And, with Intel, there's no penalty for success. When volume makes it more economical for you to build instead of buy your boards, we'll provide manufacturing drawings, pc artwork and a volume source for all the essential LSI components.

The same Intellec® Microcomputer Development System used with all Intel® microcomputers supports the iSBC 86/12 board with features such as ASM 86 assembler and PL/M 86 block-structured high level system programming language. You can debug your software right on your prototype system with ICE-86™ In Circuit Emulator or with the iSBC 957™ Interface and Execution package.

Attend an iSBC™ seminar in your area.

The best way to get started with this new-generation Single Board Computer is to attend the Intel iSBC seminar in your area. You'll learn about the iSBC 86/12 board and the rest of the iSBC product line. And we'll take you through the configuration and design cycle for several applications. For a seminar schedule and detailed information contact one of the Intel regional offices listed below.

And, for a free copy of our iSBC Configuration Planning Kit, or for on-site configuration or pricing assistance, write: Intel Corporation, Dept. 4-903, 3065 Bowers Avenue, Santa Clara, CA 95051.

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For configuration planning kit circle #28
For configuration pricing assistance circle #29

News update

■ John Locke is alive and well and living in Massachusetts—or at least a conception of his Social Contract is. The 89 member companies of the Massachusetts High Technology Council [*Electronics*, Jan. 5, 1978, p. 112] and the newly elected Governor of Massachusetts, Edward J. King, have signed what amounts to a new social contract.

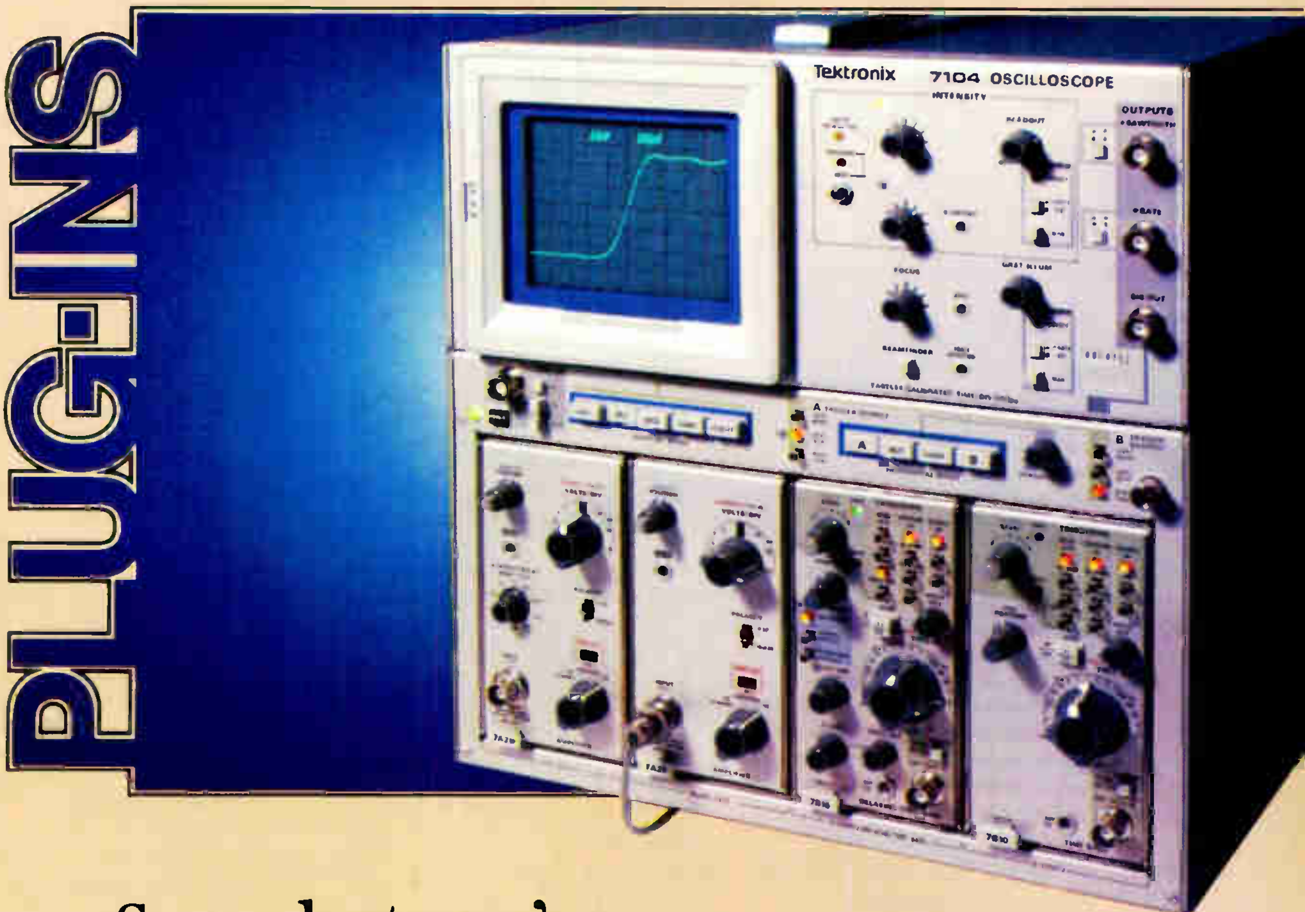
Under the terms of the contract, total state and local taxes would be reduced from 17.6% of personal income to 15.3% by 1982. In return, the member companies have pledged to create 60,000 jobs within the commonwealth over the next four years. "Council member companies alone will directly and indirectly generate 150,000 new jobs over the next four years. These jobs will generate $2 billion of additional personal income per year and $300 million of additional tax revenues per year," observes Ray Stata, president of the council and president of Analog Devices Inc., Norwood, Mass. Stata also notes that the companies are not seeking corporate tax breaks or other direct benefits for themselves, other than relief for their employees.

If this social contract succeeds, the Sun Belt may once again have to compete with the commonwealth for jobs. **Pamela Hamilton**

■ The Canadian Radio-Television and Telecommunications Commission has refused to reconsider its previous ruling that Bell Canada's profit from $1.02 billion Saudi Arabian connection be treated as ordinary revenue. Although Bell fought the ruling vigorously [*Electronics*, Nov. 9, 1978, p. 8], claiming among other things that potential investors in the company would be discouraged by such procedures, the regulatory agency said that not enough evidence had been given to justify a review of its decision.

Insisting that it doesn't pay to go into risky foreign ventures if the income is treated the same as home-grown money, Bell is not giving up and may appeal to the prime minister's office. **Harvey J. Hindin**

ONE GIGAHERTZ
REAL-TIME BANDWIDTH



See what you've never seen before.

Now Tektronix proudly announces its new 1 GHz real-time scope, the 7104. Rise time: 350 ps. Plus a 10mV/div - 1V/div vertical sensitivity, and a 20 cm/ns writing rate so any signal, single-shot or repetitive, can be seen and photographed. A window into a world previously invisible.

As part of the Tektronix Plug-In family, the 7104 is compatible with 7000-Series plug-in units. Including several new ones that take the 7104 to the limits of its specifications. In addition, the 7104 opens a whole new world of technology, both in circuit design and crt operation.

Throughout the history of science, important discoveries have been made possible by similar advances in instrumentation. We believe the 7104 represents such an advance.

The Tektronix 7104 Plug-In Oscilloscope. See what you've never seen before.

See the 7104 at Electro-New York

Tektronix®
COMMITTED TO EXCELLENCE

For literature, call (800) 547-1512 toll free.

For Technical Data circle 31 on Reader Service Card
For Demonstration circle 173 on Reader Service Card

The Mostek 16K

5 volt systems, the easy way.

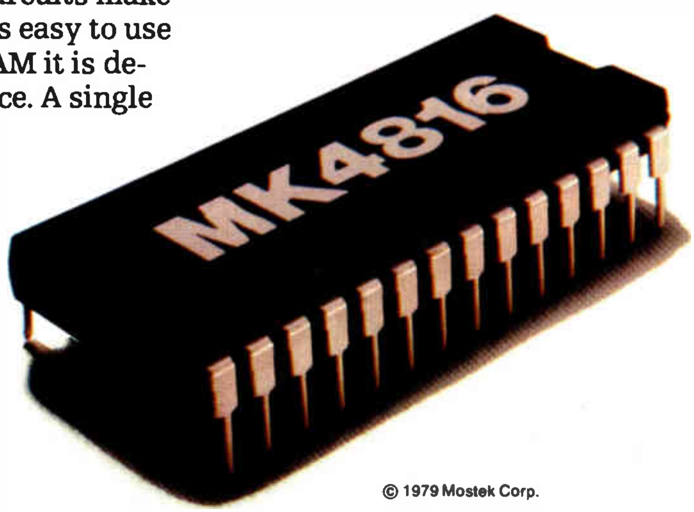
Now there's a total solution to 5 volt microcomputer systems. Mostek's new 4816 makes it easy. It's 5 volt only. It's 2K x 8. It's a compatible Micro Memory™ from Mostek.

Easy as static.

The 4816 is as easy to use as static RAMs, but offers all the performance and cost advantages of dynamic RAMs. The 4816 uses a dynamic cell and dynamic periphery to reduce die size to just 31,000 mils² as well as power dissipation to only 25 mW standby and 150 mW active. Access time of 150ns and cycle time of 270ns meet the needs of all microprocessor sockets.

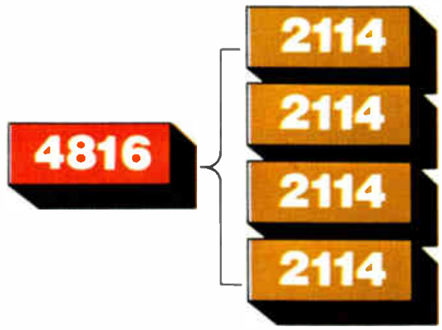
Easy to refresh.

On-chip logic, refresh and interface circuits make the 16K RAM as easy to use as the static RAM it is designed to replace. A single refresh pin allows flexible control of refresh, or automatic refresh in battery back-up mode. The timing of the refresh pulse is so flexible that it can occur during an active cycle or standby mode. In most 8-bit microprocessor systems as well as the new generation 16-bit microprocessors, the refresh pulse may be conveniently generated from the processor's output controls. In the Mostek system solution, our Z80 provides a refresh output signal that connects directly to the refresh input of the 4816. The 4816 appears totally static to the system.



Easy to upgrade.

Upgrading your system is as easy as replacing four 2114s or two newer generation 8K static RAMs with a single MK4816 to improve speed and density while reducing power and costs.



The 4816 is totally compatible with standard ROMs, PROMS, and EPROMs as well as next generation Micro Memories from Mostek.

Just call 214-245-0266 for more information. Mostek Corporation, 1215 West Crosby Road, Carrollton, Texas 75006. In Europe, contact Mostek Brussels; phone (32)02/660.25.68.

MOSTEK®

New CMOS microprocessor kit: You get the terminal, power supply plus all this from RCA for only $325.

Why is RCA offering such a terrific bargain?

Answer: To demonstrate the low power consumption and easy programming of our CMOS microprocessors.

For just $325 (optional with distributors), you get everything you need to build a microprocessor evaluation system: CPU, RAM's, ROM's, I/O's, passive components, p.c. board, hardware, even a microterminal. And we're throwing in the power supply free.

With the kit, you can discover how the RCA COSMAC architecture and a repertoire of 91 easy to use instructions give maximum performance with minimal memory.

You can also use the kit to learn about basic system design, hardware interfacing, and programming. Or for breadboarding and prototyping your own COSMAC Evaluation System (CDP 18S025).

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

Or contact RCA Solid State headquarters in Somerville, New Jersey. Brussels, Belgium. Tokyo, Japan.

The power supply for an NMOS system would have to be far more complex and much larger (as shown by the transparent box) than the one needed for a CMOS system.

Circle 34 on reader service card

RCA laser features linear input/output up to 5 to 10 mW

A flurry of activity in solid-state laser development will result in the appearance of new models from three companies—RCA Electro-Optics and Devices in Lancaster, Pa., Laser Diode Laboratories Inc. in Metuchen, N. J., and Hitachi America Ltd. in Arlington Heights, Ill. RCA's David Sarnoff Research Center in Princeton, N. J., has developed a device that will become available later this year. Described as having an "adequate" lifetime, the single-mode GaAs-AlGaAs laser will have an input/output characteristic that is linear up to power outputs of 5 to 10 mW, with stable coupling efficiencies up to 70%. **This makes possible heavy modulation and use in optical communications systems requiring wide dynamic range.** The 820-to-860-nm–wavelength light is emitted in a narrower beam than previously available so the diode energy can more efficiently couple into thin fibers. The light is monochromatic.

At Laser Diode, the lasers going to market have wavelengths of 1.15 to 1.30 μm, lambdas that can cut attenuation losses of some fibers below that for outputs in the 830-nm range. Pulsed- and continuous-wave versions are available; the latter starts pumping at 250 mA and can deliver up to 8 mW for $1,500. And Hitachi has added a new series, the 3000, to its buried heterostructure HLP laser line. The units combine a low threshold current of only 35 mA and moderate power output of 6 mW. In four package styles, the devices cost $1,650 to $3,465.

Two more bubble memory testers due out soon

As magnetic-bubble memory systems begin advancing into the marketplace, the automatic tester end of the business is starting to inflate. **Megatest Corp. of Santa Clara, Calif., is expected to announce a tester next month, and the test systems department of Watkins-Johnson Co. of Palo Alto, Calif., is due to follow with another.** Megatest's system will handle both engineering and production testing; Watkins-Johnson will offer an Adate 1450 model for engineering and production and a 1475 for production only. Both the $100,000 systems use Digital Equipment Corp. PDP-11/V03 minicomputers, extended Pascal software, plus emitter-coupled logic for the timing circuitry, and are capable of parallel testing. The Xincom division of Fairchild Camera and Instrument Corp.'s Test Systems Group also has a tester scheduled for a spring debut [*Electronics*, March 15, p. 33]. Pacific Western Systems Inc. of Mountain View, Calif., is also working on a system.

18-bit hybrid d-a converter to bow at Paris

What is billed as the first 18-bit hybrid digital-to-analog converter will be announced by Hybrid Systems Corp., Bedford, Mass., at the International Electronic Components Exposition in Paris, April 2–5. The new DAC 374 packs 18-bit resolution and 0.0008%—equivalent to 17-bit—linearity into a 1.77-by-0.9-in. oversized dual in-line package. Until now, the smallest available converters have been modular units, according to Hybrid Systems' director of corporate planning, Michael J. Fields. **Settling time is 50 μs, faster than that of many 16-bit converters.** Applications for the new unit might include wide-dynamic-range measurements, precise graphics with above-average gray-scale requirements, and high-accuracy references. Hybrid Systems expects units meeting military specifications to sell for $375 to $400 in lots of 1 to 10; these will be followed shortly by a commercial version priced at $275. Delivery for both is in 10 to 12 weeks.

TI to add Pascal to its FS990 development unit

Look for Texas Instruments Inc. to announce the availability of Pascal on its floppy-disk–based FS990 development system around midyear. **The move will continue the TI thrust to strengthen Pascal as the primary high-level language for its 9900 family** of 16-bit microprocessors and associated high-level development systems. Pascal has been available on the Dallas company's hard-disk–based DS990 minicomputer since last April. Various step function improvements in the language are expected with the extension of its use to the lower-priced FS990.

NEC maps entry into market for small computers

NEC Information Systems Inc. will unveil on April 9 a comprehensive small computer system aimed at the small business, electronic office, and distributed-processing markets. Not only does the Lexington, Mass., firm claim performance equal to that of Digital Equipment Corp.'s new LSI-11/23 [*Electronics*, March 1, 1979, p. 34], **but the Astra system may mark the boldest thrust yet into these markets by a Japanese company.**

Based on a 16-bit "business-dedicated" microprocessor chip designed by parent Nippon Electric Co., NEC's Astra can support up to 32 stand-alone intelligent cathode-ray-tube terminals, each with its own MOS random-access and read-only memory, plus a microprocessor to handle preprocessing, screen management, and keyboard management. Communication with the central processing unit is via a direct-memory-access link at up to a megabit per second. Several types of disk storage are available, and there is a range of printers. The smallest Astra, with a single terminal and printer, would sell for about $13,000. The largest, the 270, would be about $150,000. Deliveries are scheduled for June.

Dolby goes after video tape recorder market

At this week's National Association of Broadcasters convention in Dallas, Dolby Laboratories Inc., designers of the much-used industry-standard noise-reduction system, is slated to announce a noise-suppression system specifically for professional video tape recorders. Called the NRU-10 (for noise-reduction unit), the dual-channel unit, which contains two Dolby A system cards, **fits onto the audio front end of studio quality VTRs.** Expected out in the fourth quarter for under $3,000, the production model is designed to control audio noise only. But the San Francisco, Calif., company says it is investigating video noise reduction.

64-K RAM from Hitachi due at midyear

Hitachi America Ltd.'s Electronic Devices division in Arlington Heights, Ill., will begin shipping prototype quantities of its 64-K dynamic random-access memory chip in midyear. The n-MOS, 16-pin chip will use a 5-V single power supply, which Hitachi officials hope will become the worldwide standard. **The new chip will not be made at its new Irving, Texas, fabrication facility, but be imported from Japan.** Its new plant will be out next month, producing 16-K n-MOS chips initially and later expanding into other MOS memories.

Meanwhile, Hitachi will second-source Motorola Semiconductor Group's 16-bit microprocessor line. Sources say Hitachi is committing itself to the 68000 family with a production schedule that as yet remains to be determined.

"Sure, the big companies They can afford it."

True. For many of the Fortune 500, custom LSI is a way of life. We've been making circuits for Whirlpool since 1968. And putting companies like IBM, Singer and Hewlett-Packard in the chips almost that long.

More recently, Ford, Burroughs, Northern Telecom and ITT have swelled our blue-chip customer list.

But suppose you don't have their resources for developing new products. How can you afford to compete with their dazzling new sewing machines, computers, hand-held calculators, communication systems, appliances and instrumentation?

You do it the way hundreds of smaller companies have done it: with an imaginative product and custom circuits from AMI.

A little LSI goes a long way.

We have scores of case histories showing how emerging, innovative companies have forged to the front with the help of our custom microcircuits. Without going into hock to do it.

A case in point. A manufacturer of low-speed modems wanted to enter the 9600 bps modem market. So the firm came to AMI for a custom solution. The result: a modem with an order of magnitude fewer components, superior performance and at less than half the going price. It catapulted the company to the forefront of this market.

Two custom AMI chips have made another customer's DTMF (dual-tone-multiple-frequency) receiver the most popular circuit of its kind in modern telephone systems. Another firm has stolen a march on everyone with its high-security cryptographic communication system. (Our chips, again.) And our circuits are helping another company open more garage doors than anyone else.

As different as these companies are, they have one thing in common. None of them sat back and relaxed after getting their first custom circuit. Because they all know this:

You're only as good as your next product.

A custom LSI circuit could put you a year ahead of your competition. That can be the difference between success and failure. And, while your competitors are figuring out how you did it, you move on

...use a lot of custom LSI.

to the next generation product.

We've helped our customers stay ahead this way in a number of fields—EDP terminals, TV games, PABXs, facsimile transceivers, burglar alarms and avionics navigation equipment, to name a few.

The beauty of upgrading your product is that it's usually much easier once you have the first custom circuit. And a rapport is built between us. We understand your application and requirements, and you understand what we need to know to make the design changes. Often you work with the same engineers on every project, exploring ways to pack more performance onto the chip. And that again reduces development time and cost.

Which brings us back to that concern.

Doesn't it cost an arm and a leg?

It really doesn't. Although there are initial design and engineering costs, a custom circuit often turns out to be more economical than using standard parts. That's because a custom circuit is a completely integrated system, usually on a single chip. And it comes ready to drop right into your product.

If you build with standard parts, you may be dealing with more expensive components or a larger number of circuits, perhaps providing more capability than your application requires. And remember, components aren't the only costs involved. Assembly and board overhead can run you as much as 50% of your parts price, not to mention the time and money spent on testing and, for microprocessor systems, software development.

We also fabricate a great number of custom circuits along with our catalog products. This increase in volume leads to even more competitive prices, making custom a very attractive way to go. But it's by no means the only way.

Some other alternatives to consider.

As we also build the S2000 (4-bit), S6800 (8-bit) and S9900 (16-bit) microprocessor circuits, we obviously have no axe to grind with the standard approach. We'll steer you that way if it really makes more sense. Or maybe we'll work out a system based on a standard microprocessor with custom peripherals. A lot of our customers have found this the best solution, because many functions, such as A/D conversion, special display drives and high-speed calculations, can't be handled by standard circuits.

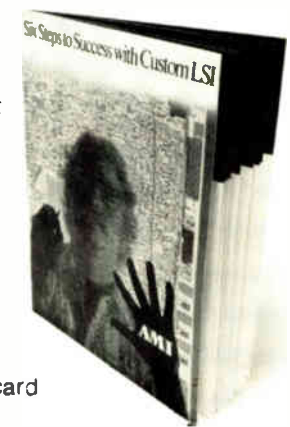
While we're talking about alternatives, remember that AMI gives you more custom choices than anyone else. We offer 25 variations of four MOS processes to get you the right speed and power dissipation you need. And we're happy to work with you in any of three basic roles. First, as a complete design and manufacturing service. Second, as a manufacturer only, with you supplying designs created by your company or an independent design house. Third, we could get involved in a joint development program where our circuit designers and your systems engineers work together on a family of circuits for you.

Our new books show you what steps to take.

We've just published two new brochures titled "MOS Systems Solutions: A Dozen Case Histories" and "Six Steps to Success with Custom LSI." They cover the most important factors to consider in choosing a custom LSI supplier. When you see what AMI offers compared with other custom houses, you'll see why we're the leader in this complex field.

So write or call AMI Custom III Marketing, 3800 Homestead Road, Santa Clara, CA 95051. Phone (408) 246-0330. Or one of these regional sales offices: California, (213) 595-4768; Florida, (305) 830-8889; Illinois (312) 437-6496; Indiana, (317) 773-6330; Massachusetts, (617) 762-0726; Michigan, (313) 478-9339; New York, (914) 352-5333; Pennsylvania, (215) 643-0217; Texas, (214) 231-5721; Washington, (206) 687-3101.

We'll send you our brochures. Or, if you prefer, give you a 30-minute presentation right in your office. With the help of custom LSI, you could be right up there with the big companies.



AMI®
AMERICAN MICROSYSTEMS, INC.

Circle 39 on reader service card

TWELVE REASONS WHY THE L135 IS THE MOST PRODUCTIVE LSI BOARD TEST SYSTEM YOU CAN OWN.

To compare productivity in LSI board testers, take their three common operations: diagnosing, testing, and programming. Now, to each operation apply the basic measures of productivity: cost, throughput, and quality of testing.

The L135 has the highest diagnostic throughput, the lowest operating cost. No other test system comes even close.

1. The L135 finds bad LSI devices on long buses.

The Electronic Knife does it. It takes just a few more probes after regular guided probing finds the failing bus. Without the Electronic Knife, you're faced with trial and error replacement of LSI chips. Or skilled technicians tying up the system for an hour or more per bad IC.

2. The L135 makes fewer diagnostic probes – by an order of magnitude.

State-sensitive trace does it. Most LSI boards are loaded with multi-input LSI chips linked through "wired-and" bidirectional buses. These often require hundreds of diagnostic probes per fault. State-sensitive trace cuts the number dramatically.

3. The L135 produces immediate probe commands.

The on-line circuit model with a large random-access memory does it. With circuit structure immediately accessible, the operator does not wait for commands between probes. Other test systems that use fault dictionaries often delay each command several seconds, adding minutes to each diagnosis.

4. The L135 mechanizes probing.

The M150 Automatic Prober does it. Seven to ten times faster than a human operator, the M150 speeds up board diagnosis even more because its operation is both error-free and fatigue-free.

The L135 delivers the highest quality of testing, thereby slashing costs for diagnosis later at systems test and service out in the field.

5. The L135 emulates LSI-board operating environments.

5-MHz clock-rate testing does it. To ensure adequate board quality, you usually have to run LSI boards at clock rates as the last step in testing. Only the L135 provides test rates of up to 5-MHz, the speed of many microprocessors seen in today's products.

6. The L135 emulates and tests CPU sets.

Multiple drive/compare phase control does it. During clock-rate testing, the test system must first replace the CPU set and then test it at speed. The associated microprocessors usually receive multi-phase inputs and generate multi-phase outputs. The L135 provides the necessary, easy-to-program, precise phase controls over driver inputs and comparator strobing.

7. The L135 tests and diagnoses analog circuits.

Integrated ac-dc-parametric capability does it. The L135 offers many analog force-and-measure functions through matrix connections, all completely integrated into system hardware and software. If these capabilities aren't integrated into the test system, they must often be added to accommodate the increasing analog content of LSI boards. That prolongs test time and slows diagnosis considerably.

8. The L135 tests at dc and clock-rate on the same channel.

All-speed pin compatibility does it. In clock-rate testing, high-speed tests are usually applied on the same pins tested earlier with dc. The L135 allows you to apply both types of tests at the same system channel, eliminating the need for awkward switching or extra channel capacity.

9. The L135 has enough clock-rate channel capacity for the big jobs.

432 I/O pins does it. Big LSI boards have upwards of 250 edge-connector pins, all active. In addition, you need simultaneous access to dozens of internal test points and devices invisible to the edge connector. The L135 offers the highest clock-rate channel capacity, enough for all foreseeable LSI boards.

10. The L135 cuts total programming time.

The P400 Automatic Programming System does it. The P400 automatically generates all the dc patterns and diagnostic data for the toughest part of most LSI boards: the jungle of random digital logic, as well as those portions containing modeled LSI devices. Total programming time is shorter. The best of the so-called "automated test generation" techniques offered by other systems still require manual pattern-writing. That takes longer and costs much more.

The L135 cuts the time needed to get products into the production line and out to the market place.

11. The L135 cuts system time for debugging.

Immediate-response debug software does it. During test-plan debugging, the L135 responds to the test engineer's commands and displays results immediately. Total debugging time is cut to a fraction because the test engineer is not distracted by system delays; he can concentrate on his circuit and his test plan.

12. The L135 readily assembles the many parts of LSI test plans.

Structure-merge programming does it. Test plans originate in many places: manual patterns and circuit models, learned data from known good boards, circuit and device simulators, automatic pattern generators, etc. The L135's structure-merge software and its straightforward protocol assembles them all into a coherent package, saving your engineers hours of tedious and costly work.

For more information on these and other L135 features, contact your local Teradyne Sales Office or call any of the numbers listed below.

CHICAGO (312) 298-8610/BOSTON (617) 969-6300/SUNNYVALE (408) 732-8770
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TERADYNE

Circle 41 on reader service card

A-d converter hits 8 gigahertz with GaAs device

by Larry Waller, Los Angeles bureau manager

Experimental 5-bit unit developed by TRW applies transferred-electron device in serial conversion technique

TRW Inc. is setting exceptional new records for high-speed analog-to-digital conversion. It is now fabricating a 5-bit converter built around a gallium-arsenide device heretofore considered mainly a microwave-frequency oscillator.

"The converter will sample and digitize an analog signal at a variable rate of anywhere up to 8 gigasamples a second," says Thomas G. Mills, manager of compound semiconductors and microwave products at TRW's Microelectronics Center of the Defense and Space Systems Group, Redondo Beach, Calif. He directs the converter project, which is partly sponsored by the Office of Naval Research. "In contrast, present commercial converters [including board modules, hybrids, and chips] operate at fixed rates which are usually well under a gigasample a second," he adds.

TED. At the heart of the converter is a logic element built around a transferred-electron device, or TED [*Electronics*, Jan. 22, 1976, p. 83]. The device resembles a Gunn-effect diode—a three-layer device with n^+, n, and n^+ regions that relies most of the time on the tunneling effect of electrons through the thin region to oscillate at microwave frequencies.

To the conventional Gunn diode TRW adds a gate on the n channel, Mills explains. The gate can produce oscillations by fast trigger pulses. Also, the gate allows the device to have a threshold voltage that can be made to range between values of 0 and 3.75 volts.

Moreover, the single gate can be biased to within 95% of the threshold voltage. And importantly, a dual-gate design can also be built with a clock bias supplied to one gate and a signal to the other.

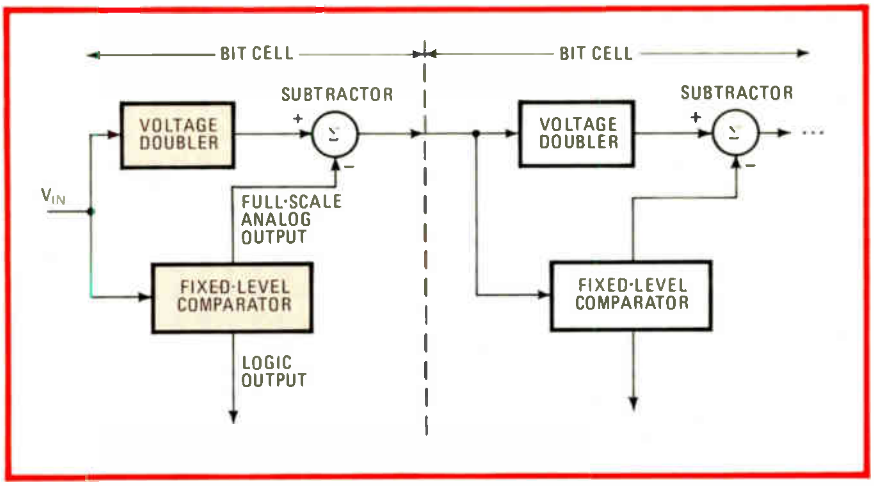
The converters can get their very high sample rates because the TEDs can be built to generate an output pulse of less than 25 picoseconds and pulse widths of less than 50 ps.

Simple. To make best use of the TEDs' properties, TRW puts the devices into what are called bit cells, each of which is dedicated to a single bit of the digital converter output. With only five active devices per cell (two TEDs and three field-effect transistors), the bit cell is a very simple device. Furthermore, when organized in a successive-approximation conversion system, the resulting a-d unit can attain high speed and accuracy, Mills says.

In comparison, "without the TED to work with, a conventional successive-approximation converter is slow in terms of silicon technology." Also, the device can become very complicated: it needs a sample-and-hold circuit, a comparator, a d-a converter, an n-bit register with conversion logic, a dc reference, a timing circuit, and an output register.

TRW's converter consists of a string of five bit cells connected in cascade, as shown in the diagram below. The input signal is applied to the first bit cell, which compares it to the $V_{FS}/2$, where V_{FS} is the full-scale voltage of the converter. If the input exceeds $V_{FS}/2$, the cell's logic output then goes high. The successive-approximation process then repeats in subsequent cells.

In each, a dual-gate TED level detector functions as a comparator and a single-gate TED provides the clocked input. One FET operates as a current source and two FETs to-



Fast mover. Successive-approximation converter (shown in simplified form) uses five bit cells in cascade. Extremely fast comparator is built around a dual-gate TED.

gether as a differential amplifier that provides a gain of 2 in the feed-forward step.

Better. With dc power dissipation of 330 milliwatts per cell, the part is far under the best high-speed silicon a-d converters, which can run above 1,000 mW per bit, he claims. A bit cell measures 84 by 112 mils, already small, but will get even smaller in a 5-bit package because fewer pads will be needed.

Since full performance specifications await finished converter testing, planned for later in the year, how the unit measures up exactly in such factors as accuracy remains to be determined. But Mills sees no reason why it should not work at least as well as present converters. Any commercial fallout—it is too fast for most jobs in this area—is years away, he says.

Mills expresses only one concern about the future of the device: "It bears so little resemblance to conventional converters," he says, "that users might tend to back off." □

Automotive

TI quiets interference by switching loads using fiber-optic interconnections

Surge currents in automobile ignition and control wiring may create more than static on the car radio. Car designers have recently been concerned about possible electromagnetic interference (emi) in newfangled engine control systems built around low-current devices such as microprocessors and complementary metal oxide semiconductors.

Recognizing this, engineers at Texas Instruments Inc. in Dallas have shown how to contain and reduce emi generated during the switching of heavy automotive loads like headlights and power-window motors. Their two-part solution substitutes emi-free fiber-optic cables for copper wiring, which radiates interference, and uses solid-state switching circuits in place of arc-prone electromechanical relays.

"We wanted to demonstrate that a low-cost, low-power drive circuit using a fiber-optic link can switch 20-ampere loads," reports Joe Mings, who described the system at this week's Vehicular Technology Conference in Arlington Heights, Ill. He and co-designer Joe Bremmer, who has left TI since the completion of the work, add that reduced electrical interference is not the only advantage of their circuit. They also make claim to greater reliability, savings in power and weight, and improved electrical isolation.

TI's circuit, shown in the figure, relies on infrared-light emitters linked by fiber optics to IR sensors and on high-input-impedance amplifiers that switch current in either of two windings in a dc motor of the kind that controls a power window.

Open and shut. Closing switch S_1 causes an infrared-emitting diode of gallium aluminum arsenide to send 3 microwatts of light at 7,900 angstroms down a 30-foot length of commercially available Dupont Crofon fiber. At the far end, the light, attenuated to 300 nanowatts, turns on a high-gain IR transistor.

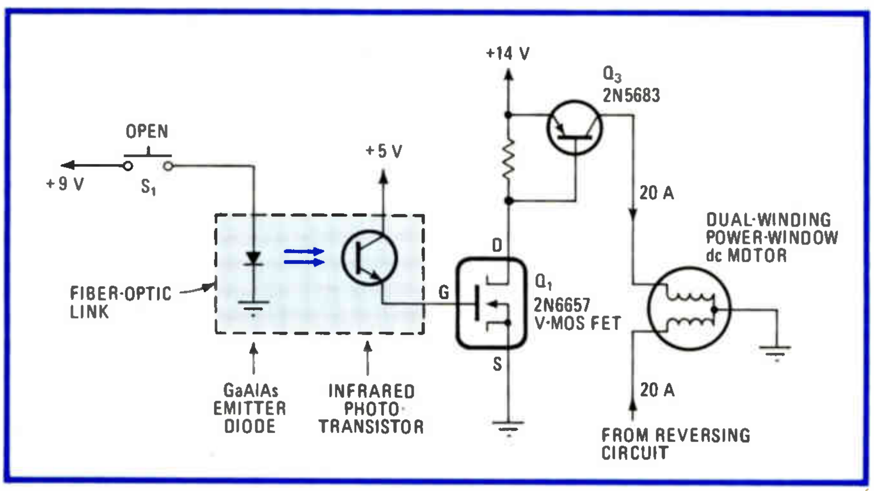
(Actually, TI uses two identical circuits—one controls the current in one winding, the second, not shown, controls it in a second winding).

Trying to cut costs, Mings and Bremmer originally used an inexpensive red-light–emitting diode as the light source. But they found that its metalization pattern focused much of its output laterally rather than through its top into the fiber. That problem and the phototransistor's poor response to visible light forced them to switch to the more expensive infrared emitter.

Isolating. When the phototransistor turns on, 5 volts is applied to the gate of Q_1, a V-groove MOS power field-effect transistor, turning it on. A FET, a 2N6657, was chosen for its high input impedance, which adds to the electrical isolation provided by the fiber. When Q_1 conducts, its drain voltage goes low and turns on pnp bipolar power transistor Q_2, driving one winding of the motor at 20 A to open the window. Q_2, a 2N5683, was selected for its low collector-emitter voltage drop (1 V) at a collector current of 20 A.

What's next? With proof that the concept works, TI hopes to sell it to automobile and aircraft manufacturers seeking a way to reduce weight while increasing the reliability of their electronics. Mings says the firm is already talking to Detroit about the system, but he will not yet reveal to whom.

Nor will he hint at the circuit's cost, though he is counting on the price of fiber-optic cable falling



Light switch. Simplified schematic of control circuit shows how light signals over an interference-free fiber link activate solid-state switches and a high-power dc motor.

rapidly in the near future. In addition, he says TI is developing a line of fiber-optic connectors that should cut the cost of making terminations significantly. -John Javetski

Careers

Overseas hiring stirs aerospace dispute

Booming business in the U. S. aerospace industry is expanding engineers' job opportunities—yet a chorus of protest is rising. Its theme: jobless American engineers are being bypassed in favor of their overseas counterparts, who are being hired at wages under the prevailing rates.

The focal point of the protest is the U. S. Department of Labor's division of labor certification, which is responding with a temporary halt to the certification, based on company need, that allows U. S. firms to hire foreign engineers.

The division reports a jump in requests for certification from almost zero to 600 or 700 in the past six months—mostly from agencies supplying temporary workers to the aerospace industry, but also for some 50 positions at Emerson Electric Co., the St. Louis-based maker of electrical and electronics equipment. Irwin Feerst, petition candidate for the IEEE presidency, has protested vigorously to the Labor Department on the Emerson situation.

Figures. Charges that aerospace employers are feeding the Department of Labor false figures on availability of U. S. engineers and prevailing wages come primarily from an ad hoc group called the American Engineers Association. In the same corner is the Council of Engineers and Scientists Organizations (CESO), the federation of bargaining units for engineers and technicians at big aerospace firms.

Richard L. Hurwitz, head of the ad hoc group, says ads have appeared recently in publications aimed at English engineers. The ads have been placed by "job shops," which contract engineers for temporary jobs in the aerospace industry. Hurwitz says that in his specialty—stress engineering—engineers imported for West Coast assignments are earning $3 an hour less than job shops are paying U. S. counterparts.

However, there are no firm figures on the number of job openings and of available U. S. engineers, or on how many foreign engineers are coming in and at what wages. The regional offices of the Division of Labor Certification get their information either from employers applying to import engineers or from government resources, which depend ultimately on information from local unemployment offices.

One major problem is that engineers and other professionals tend to bypass the unemployment offices, says Nandor Kertai, assistant division chief of the certifying unit. At a March 12 meeting in Washington, the ad hoc group reported it had a list of 150 aerospace engineers actively seeking employment, and perhaps four times that number out of the industry but available.

While exploring the possibility of using such sources of information as the ad hoc organization's list, the certifying office has imposed the temporary ban, Kertai says. It also wants to check the disputed wage data; figures will be supplied by the CESO, and perhaps by others.

Few of the jobs (or job announcements) in the controversy are for electronics engineers, but the situation may be different at Emerson Electric, which started hiring in England almost a year ago. The shortage of EEs in the U. S. is generally accepted, but Emerson has refused to respond to Feerst's charges that it started paying the English employees at rates below prevailing wages. -Ben Mason

Industrial

Japan, producing 7,000 robots yearly, leads world with 30,000 installations

While Western nations struggle to catch up, Japan is running hard and fast to develop industrial robots. These will automate a wide variety of production processes from integrated circuits to automobiles.

Some 120 Japanese robot manufacturers turned out about 7,000 units last year, raising the number of installations to 30,000, says Kanji Yonemoto, executive director of the Japan Industrial Robot Association. This number is 10 times that of the United States, according to John J. Wallace, president of the Robot Institute of America, and Japan's annual output is well ahead of the estimated 4,500 robots now in use in the U. S. and Western Europe, where applications are limited largely to heavy industries like the automotive.

"Japan is very much the leader in robot applications, whereas the U. S. has been extremely slow," concedes Wallace, who is also president of Prab Conveyors Inc., a Kalamazoo, Mich., robot manufacturer.

No one challenged Yonemoto's numbers, revealed for the first time

Estimator. Japan has roughly 10 times the number of robot installations as the United States, according to John J. Wallace, president of the Robot Institute of America.

in the U. S., or Wallace's assessment of the developing world markets for robotics at last month's three-day international symposium in Washington sponsored by the RIA. "It's getting to sound like an old story," said J. F. Engelberger, president of Unimation Inc., Danbury, Conn. He contends that "Japan's banks are more patient and willing to live with a smaller return on capital investment" in the early years of a growing industry. In the U. S., however, there are no significant tax incentives or depreciation allowances on old production equipment to stimulate investment in automation, RIA's Wallace says.

NEC's move. Nippon Electric Co. demonstrated one area of innovation in industrial robot use by detailing at the meeting how it has automated the wire bonding of integrated circuits. NEC developers say their present system of bonding large-scale chips employs an image-processing unit controlled by a microcomputer to run five work stations. Each has a 256-element photodiode linear sensor to scan the chips and a microcomputer to carry out the bonding sequence.

The microcomputer, with 10 kilobytes of read-only memory and 6 kilobytes of random-access memory, takes data from the scanners to determine the orientation of the ICs at each work station after the operator manually aligns the initial circuit's electrodes with the tool. The bonding sequence becomes automatic thereafter, regardless of the orientation of subsequent chips. The image processor detects the locations on each chip to be wire-bonded to the external leads.

The scanning-field size is variable, NEC says, to a maximum of 2.56 millimeters (0.1 in.) on the vertical plane and 8 millimeters (0.3 in.) on the horizontal. The scanner can detect elements as small as 0.4 mil.

Successful. If the image processor fails to detect the circuit's position, the system will recycle until three failures occur. It then signals the operator. NEC engineers say the system, with a typical detection time of 0.9 second, is successful "more than 99.9% of the time."

Without specifying numbers, NEC claims to have "many installations running in a number of plants," where bonding quality is improved and the necessity of finding and training skilled labor reduced sharply. Bonding system operators now need only be trained to change lead-frame circuit cassettes and maintain the equipment **-Ray Connolly**

Industrial

TI fills out its industrial line

Board-level products for industrial control applications continue to attract semiconductor manufacturers. Now it's Texas Instruments Inc., the biggest semiconductor maker of all, weighing in with a series of new products designed to make its TM 990 series of 16-bit microcomputer modules easier to use in signal-conditioning and actuator applications by plant engineers with little computer experience.

TI's Houston operation is putting together a selection of interfaces for the TM 990 boards. Some are bought on the outside; others are already being made by TI's Industrial Controls division in Attleboro, Mass., and in the case of several brand-new products, by TI Houston.

TI joins Intel Corp. and Motorola Inc., two other semiconductor giants that have introduced board-level products for industrial control [*Electronics*, March 1, p. 50].

Purchases. In a departure from its usual policy of building its own, TI is buying the complete lines of 990 bus-compatible analog-to-digital and digital-to-analog interface modules from Analog Devices Inc., Norwood, Mass., and Analogic Corp., Wakefield, Mass. The nine boards will be offered to fill out the line.

For connecting high-voltage industrial lines to digital computer control, TI Houston will offer the ac and dc input/output modules—the 5MT series—made by the Attleboro division. In addition, TI Houston is coming out with its own combination memory and I/O board with optical isolation—needed in an industrial environment. It has 32 isolated I/O lines and memory expandability to 32 kilobytes for use in a two-board system with the TM 990/100M and 101M central-processor boards.

In place. More than 1 million 5MT units are currently in place, ready for non-computer-controlled plant applications, so it is certainly possible that inexperienced users may already be familiar with that hardware, notes Tom Miller, TI's strategic marketing manager for metal-oxide-semiconductor microprocessors in Houston.

Besides the new hardware, added support for the company's move into the industrial market comes from new low-cost development systems brought out late last year and its Power Basic software introduced last June. An extension of standard Dartmouth Basic that TI has tuned specifically for industrial applications, Power Basic offers the inexperienced user much simpler programming than with assembly language, Miller notes.

The firm will shortly be adding mass-storage capability to the product line in the form of a bubble-memory board and a floppy-disk controller. A typical industrial system using the newly available equipment could cost from $2,000 to $2,500, he says. **-Wesley R. Iversen**

Medical

Whistle system lends quadriplegics a hand

For people who have lost the use of limbs, even simple acts are impossible. To help them turn on a light, or flip the pages of a book, or dial a phone, an energetic young man at Massachusetts Institute of Technology, Cambridge, Mass., has developed a control system for quadriplegics activated by a whistle.

"I chose whistling because almost everyone whistles, and, if not, it's not hard to learn," says William J.

Helper. Electronic aid for the handicapped senses a whistle signal, then activates the appliance corresponding to the number shown on the unit's light-emitting-diode display.

Warner, a junior in the electrical engineering department at MIT and himself a paraplegic. "You don't need an external input device such as a button or breath-pressure switch."

Warner's system, called the Whistle System 3, can turn lights, television, or stereo on or off; sound a buzzer to call a nurse; change TV channels; and, with a speakerphone, answer the telephone and dial the operator. The switch controlling each device plugs into a jack at the back of the system, which is about the size of a stereo amplifier.

Take a number. Warner's idea is to assign a number to each appliance and then display the numbers sequentially on a light-emitting diode on the front panel. The user merely whistles when the number corresponding to the task to be performed comes up. The system senses the whistle and switches the appliance on. To switch it off, the user whistles when the same number appears again.

The whistle frequency to which the system responds can be adjusted between 800 and 2,500 hertz by turning a dial on the front panel. This range will accommodate most people, Warner says. The length of time the whistle must last is also adjustable: about 3/4 second is optimum, lasting longer than most stray noise in the room, he says.

"Most noise won't trigger the system, but sometimes the television—especially dramatic background music—will," he explains. He has built a defense against this: when the TV is on, only whistles in sequence trigger the system.

The system is built around a Signetics Corp. 567 integrated circuit, which is a combination tone decoder and phase-locked loop. The whistle tone is applied to the phase-locked loop, which responds only to signals within its bandwidth. If the tone is the right pitch, it is applied to an internal transistor that saturates if the tone lasts long enough. The saturated transistor then toggles a flip-flop that controls the relay for the selected appliance, in this way turning it on or off.

A random-access memory board with 1 kilobit of RAM is also available to store such things as telephone numbers. Numbers can be read out of the memory through whistled signals and dialed automatically into the phone system.

Warner is currently adding microprocessor technology. "Using a microprocessor and software, I'll have a more flexible approach. Adding more logic creates many more options, and software control will add more refinements," he notes.

He has sold three systems for $950 each, but does not expect to build more in the near future. Instead, he has applied for a patent and hopes to license manufacturing rights. He figures that a stripped-down microprocessor-based version with no more than five controls might eventually sell for as little as $30 or $40. **-Pamela Hamilton**

Software

CDC aims at hierarchical memory

As computers become more powerful, their link to peripheral memory devices can become a bottleneck that limits their overall performance. This has stimulated recent work in both specialized hardware and software toward better management of memory systems, especially as the hierarchy of storage devices varies in capacity, retrieval speed, and cost.

Control Data Corp., the Minneapolis computer maker that is also a major marketer of IBM-compatible peripherals, is making what it calls the first move toward true hierarchical storage with its Storage Management System software. Designed to work with IBM System/370 mainframes and operating systems, the SMS controls the flow of data files between direct-access storage devices such as disk and tape drives and Control Data's Mass Storage System—a huge tape cartridge file intended primarily as an archive. To be delivered in August, the software will cost $20,000.

Doing more. According to Gordon Brown, senior vice president for marketing and planning at CDC's Peripherals Products group, the new software does more "memory management than currently available packages. For example, if data on a disk drive has not been used for a certain amount of time it can be automatically moved to mass storage and later to tape."

In addition to this so-called migration function, the SMS also keeps backup copies of data files, and handles storage and restoration of archival files. Although some form of data management software is offered by virtually all computer manufacturers today, and by a number of software houses such as Cullinane Corp., MRI Systems Corp., and University Computing Corp., Control Data is one of the first peripherals makers to offer it.

Brown says this software could be

a forerunner of a special data base processor—a concept that is gaining popularity but is not yet a commercial reality. "A company with the resources and ability to put together such a back-end processor will have an opportunity to attach peripherals to IBM computers, including the new 4300s." -Anthony Durniak

Military

Bendix to build bit-slice computer

Bendix Flight Systems division, Teterboro, N. J., will produce an advanced bit-slice microprocessor emulation of its existing BDX-900 series of digital flight computers for use in the latest phase of the U. S. Air Force Flight Dynamics Laboratory's Advanced Fighter Technology Integration (AFTI) program.

In competition with Lear Siegler and Honeywell, Bendix was selected by General Dynamics Corp.'s Fort Worth (Texas) division last month to provide digital computers and associated hardware for the AFTI/F-16 project. General Dynamics was awarded the $34.3 million contract last December. Sponsored jointly by the Air Force, the Navy, and the National Aeronautics and Space Administration, the project is managed by the Flight Dynamics Laboratory, Wright-Patterson Air Force Base, Ohio.

Using flight computers provided by Bendix, GD will modify one of its F-16 fighters as a demonstration testbed for such developments as triplex-redundant digital flight control, multimode mission capabilities, and integration of fire and flight controls. The amount of the Bendix contract was not revealed.

A breadboard version of the new Bendix computer—to include a new processor called the BDX-930—is scheduled for delivery in December. Discrete medium- and large-scale integrated microcircuitry used in previous 900, 910, and 920 Bendix machines will be replaced by four AMD-2901 4-bit-slice microprocessors. The microprocessors in the 930 will have improved microcode and advanced pipeline architecture for improved performance in the emulation version of the earlier machines, says Erwin Naumann, Bendix program manager for the project. With a microcycle time of 250 nanoseconds, the 38-square-inch single-card 930 will be faster, smaller and less

News briefs

NTT drops fiber loss again

The Nippon Telegraph and Telephone Public Corp. researchers who developed it call it the ultimate low-loss single-mode fiber. Operating at the theoretical minimum-loss wavelength of 1.55 micrometers, the silica-based optical glass fiber has an attenuation of 0.20 decibels per kilometer, compared with the previous NTT record of 0.66 dB/km [*Electronics*, Oct. 26, 1978, p. 184.] Careful processing of the raw fiber materials is the key to its low loss and core purity has been kept at a heretofore unheard-of 99.9999%.

TI second-sources Intel codec

As expected, Texas Instruments Inc. announced plans last week to second-source Intel Corp.'s 2910/11 codec [*Electronics*, March 15, 1979, p. 34]. Though other semiconductor firms are said to be close to establishing second-source arrangements of their own, the TI-Intel codec marriage is the first involving such large companies. In a field crowded with manufacturers hoping to take advantage of the promised vast market in telecommunications for codec parts, TI, by failing to introduce a part of its own design, has been noticeably absent. But the Dallas company's agreement with Intel is seen by observers as aimed at gaining it a major chunk of the action by making the Intel part an industry standard.

Few details of the agreement involving the n-channel metal-oxide-semiconductor codec were revealed. TI says only that it "will develop this second-source capability in cooperation with Intel." Production samples of the 2910/11, which will be pin-for-pin compatible with the Santa Clara, Calif., company's part, will be available during the fourth quarter.

IEEE's April showers are election petitions

Members of the Institute of Electrical and Electronics Engineers can look forward to a spring full of petitions to get constitutional amendments and candidates on the ballot. A campaign to elect instead of appoint the vice president of professional activities is being spearheaded by Robert Bruce, former chairman of the Long Island Professional Activities Committee. The circulation of petitions for a member-elected nominations and appointments committee is just getting under way, with Harry M. Cronson of the Boston section heading the drive. Both campaigns come from the membership wing favoring greater activity by individual members on job-related issues, and Bruce's amendment is similar to a proposal by the institute's current president, Jerome J. Suran. On the candidate front, petitions for the presidency are circulating for the current executive vice president, Leo Young, and four-time candidate Irwin Feerst. Their target is the board's presidential candidate, Burkhard H. Schneider; efforts to find a petition candidate to oppose the board's executive vice-presidential nominee, C. Lester Hogan, have been unavailing.

Technology whiz leaves Biomation

David Blecki, formerly its vice president of marketing, is the new general manager of the Biomation division of Gould Inc., Santa Clara, Calif. He succeeds B. J. Moore, who is leaving on an extended vacation before starting his own electronics consulting business. Blecki joined Biomation in 1971 from Hewlett-Packard, where he had held several marketing and sales posts in the U. S. and Europe. Moore has been president since 1971, pursuing an innovative course in the development of test and recording instruments. He was an originator of the logic analyzer, for which he shared *Electronics'* 1977 Award for Achievement [*Electronics*, Oct. 27, 1977, p. 82].

power-consuming than its predecessors, Naumann observes.

Such improvements fit well with AFTI program goals. Most current production fighters—including the F-16—use analog computer flight control in place of older mechanical control systems. But the current thrust of military technology is toward digital flight control. Because of its inherent self-testing ability, the digital approach is seen as a way to reduce required system redundancy to the triplex level, compared with the quad-redundant approach that achieves the needed reliability with analog systems, says Larry Lydick, chief engineer at General Dynamics for the AFTI/F-16 project.

Another digital system advantage lies in software programming: different flight control laws optimized for flight modes such as air-to-air and air-to-ground combat can be made available to the pilot. Comparable multimode capabilities with an analog system require additional hardware, and thus added weight and size. And with their higher number-crunching power, digital systems are also better suited to integrating other functions such as fire control into the flight-control system.

The AFTI program, begun in 1973, has explored various promising flight technologies. The latest award to General Dynamics is a five-year, two-phase program aimed at integrating into one F-16 testbed those technologies that may be used in fighters in the mid-1980s.

The first phase of AFTI/F-16 flight testing of the triplex digital flight control system and up to 20 multimode flight capabilities is scheduled for June 1981. The second phase, with integrated fire and flight control, will begin June 1982.

Delivery of Bendix's breadboard system in December will be followed from Oct. 1980 to April 1981 by three "flyable systems," Naumann says. Each will consist of three flight computers and one actuator interface unit designed to handle less critical flight functions. Software will be developed jointly by General Dynamics and Bendix. -**Wesley R. Iversen**

Communications

Analog method decodes satellite data

The word that describes most high-data-rate communications equipment nowadays is "digital." But, in a reversal of form, Bell Laboratories' engineers are investigating high-speed analog techniques to process data received via digital satellite communications links. The purpose: to detect errors and correct them.

The analog technique—a version of the so-called Viterbi method of decoding—could be more cost-effective than the digital parallel processing technique of error correction used until now, says Anthony Acampora at the Bell facility in Holmdel, N. J. In particular, Acampora and his group want to decode at data rates of 200 to 300 megabauds, rates at which the Bell System expects to handle data on its satellite systems of the future.

Digital parallel processing, the usual solution, is costly, requiring considerable circuitry, much of it custom-designed. It turns out that analog microwave circuitry using discrete transistors not only is fast enough but is available commercially and is cheaper.

Both approaches can implement the Viterbi algorithm—an efficient and commonly used decoding scheme that detects and corrects errors. The hangup in a digital implementation of the Viterbi algorithm is the sample-and-hold circuitry. It is hard to make fast sample-and-hold circuitry inexpensively at these data rates. Enter the analog approach.

Hung up. Acampora designs the sample-and-hold circuits with discrete bipolar and gallium-arsenide metal-oxide-semiconductor field-effect transistors. His group has built an experimental analog decoder to operate at 50 megabits per second, or 100 megabauds (see "Bits vs bauds," p. 50).

(In contrast, the maximum data rate accommodated without costly

Bits vs bauds

Computer engineers evaluate transmission-channel capacity according to the maximum number of information bits that may be sent in a specified time (usually bits per second). Communications engineers, on the other hand, evaluate the channel by expressing the modulation rate in bauds. A baud is a measure of signaling speed and is found by taking the reciprocal of the length (in seconds) of the shortest pulse used in a system.

A further complication is the presence of bits that represent not data but address codes or synchronization information. These lower the effective bit or baud rate because they are not "raw" data.

parallel processing is about 10 megabauds using transistor-transistor logic and 30 megabauds using emitter-coupled logic, Acampora says.)

As for his analog system, Acampora says that "devices for operation at 200 to 300 megabauds are already available, but we intended to evaluate the effects of analog implementation error rather than demonstrate ultimate speed capabilities of analog decoding."

So far, the evaluation is favorable. The measured bit-error rate is within ½ decibel of the ideal, Acampora says. The next step will be to build a system that operates at still higher baud rates. **-Harvey J. Hindin**

Fiber optics

Bell Labs tests offer promise of extremely fast transmission rate

Fiber-optic transmission of digital information up to the unheard-of rate of 200 gigabits per second? That's what has been indicated by recent experiments at Bell Laboratories in Holmdel, N. J. And it's been done over a 760-meter-long single-mode fiber whose core is only 9 micrometers in diameter.

Which is not to say that multimode-propagation, larger-diameter fiber or coaxial cable have been superceded yet: the new system is strictly for demonstrating the tremendous bandwidth capability of single-mode fibers. For example, the experimental fiber has a capacity 2,000 times greater than the one used in AT&T's recent experiment in Chicago with fiber-optic telephone-transmission.

Not ready. Another reason that the system is far from commercial use, of course, is that practical components such as laser sources and photodetectors in the 1.28-micrometer wavelength region of the fiber are not yet available.

Operation at 1.28 μm was chosen because at that wavelength the pulses can propagate through the fiber with almost zero distortion or smearing. This low distortion is necessary in a practical system so that data error rates can be kept to a minimum.

In the Holmdel experiment, researchers David M. Bloom, Leon F. Mollenauer, and Chinlon Lin used a laboratory laser that generated 1-watt pulses only 5 picoseconds wide. These pulses propagated through the germanium-doped silica fiber with no broadening at all until laser power was stepped up to about 60 W peak. Then, stability problems in the laser, not in the fiber, showed up as pulse smearing at the fiber's output. **-H. J. H.**

A little squeeze alters optical-power phase

Researcher Stuart Kingsley has been squeezing a lot of single-mode fiber-optic cables lately. The variations in fiber length, diameter, and refractive index that result all phase-modulate the light traveling through them.

The effect, though small, is enough to be both measured and controlled. Such a phenomenon is generally undesirable because modulation not induced by a transmitter is usually equivalent to noise. Yet the phase-modulation effect could be applicable to a device that resembles a hydrophone—an underwater electro-acoustic sensor typically used to listen for enemy submarines. Light transmitted through a fiber-optic surface would be phase-modulated by passing submarines.

In his work at University College, London, Kingsley found that, at a wavelength of 0.6328 micrometer, the pressure sensitivity of a glass fiber results in a phase modulation of 6.4 radians per meter of interaction length between the pressure and the fiber, per bar of applied pressure.

Doubling. What's more, the effect doubles for each bar of pressure applied. Similar effects occur when the fibers are stressed along their lengths. After taking into account unavoidable experimental errors in his acoustic pressure generator and his optical phase-modulation detector, Kingsley "considers that the experimental and theoretical results are in reasonable agreement."

Much work, not the least of which is to understand fully how the modulation processes operate, remains to be done before a real system is practical. The calculations are, however, promising. If the pressure sensitivity of a silica fiber is 6 radians per meter for each bar of pressure, then a kilometer-long hydrophone operating with 2 milliwatts of optical power will generate a modulating signal equivalent to 32 decibels below the threshold of hearing.

This is the same as 50 dB below zero sea-state noise—a calm sea. Although this level would be difficult to detect for ordinary sonar with human listeners, it is quite another matter in these days of digital signal processing and computer echo enhancement. So the effect is under study at Kingsley's lab and at others around the world. **-H. J. H.**

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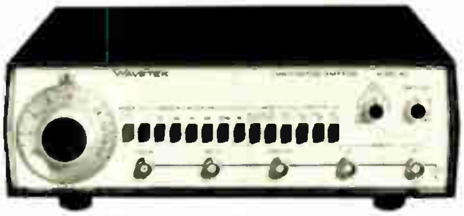

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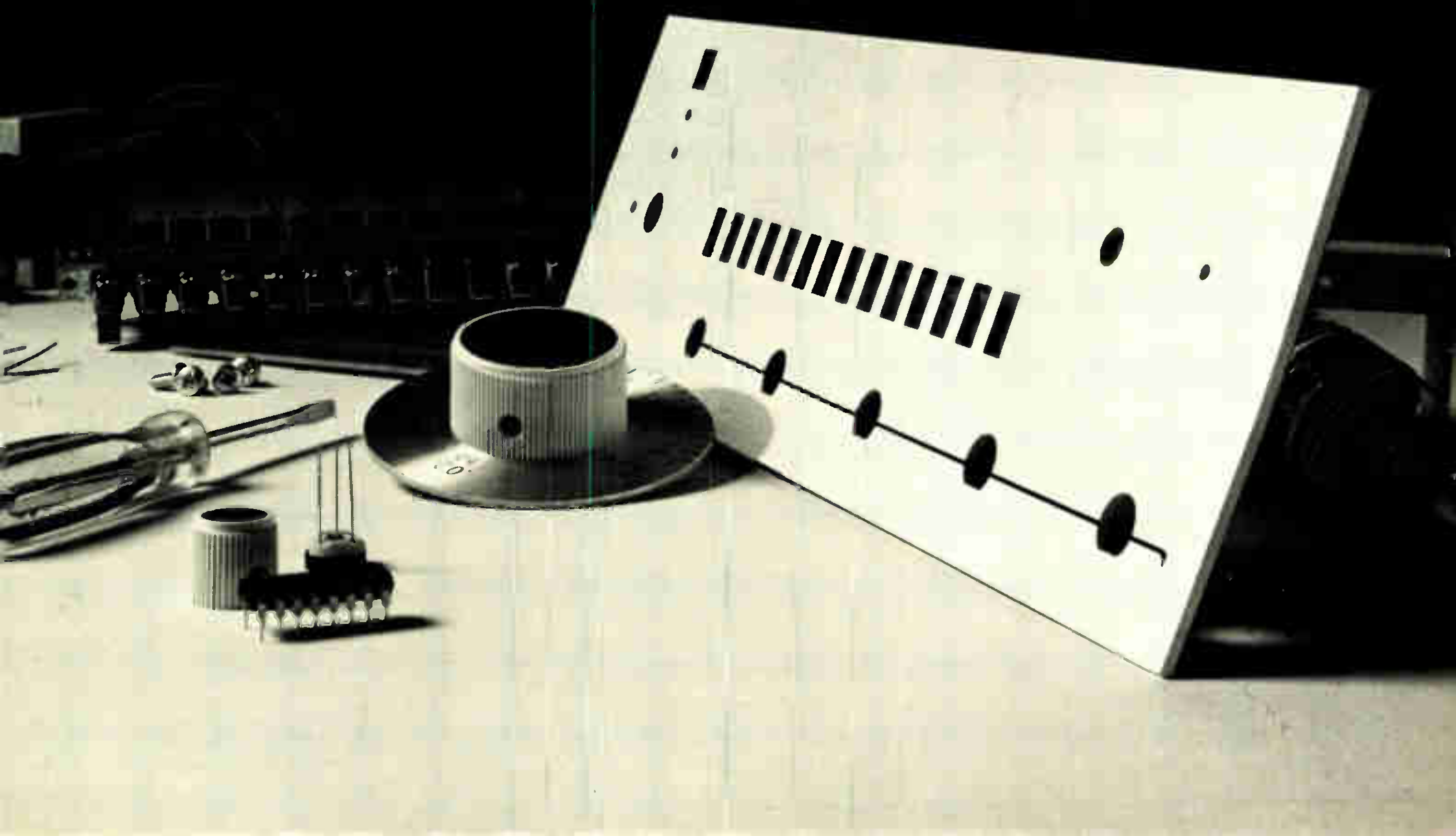

King Carl XVI Gustav of Sweden—on the right in these photos—presents the 1978 Nobel Prize in Physics to Bell Laboratories scientists Robert Wilson (top photo) and Arno Penzias.

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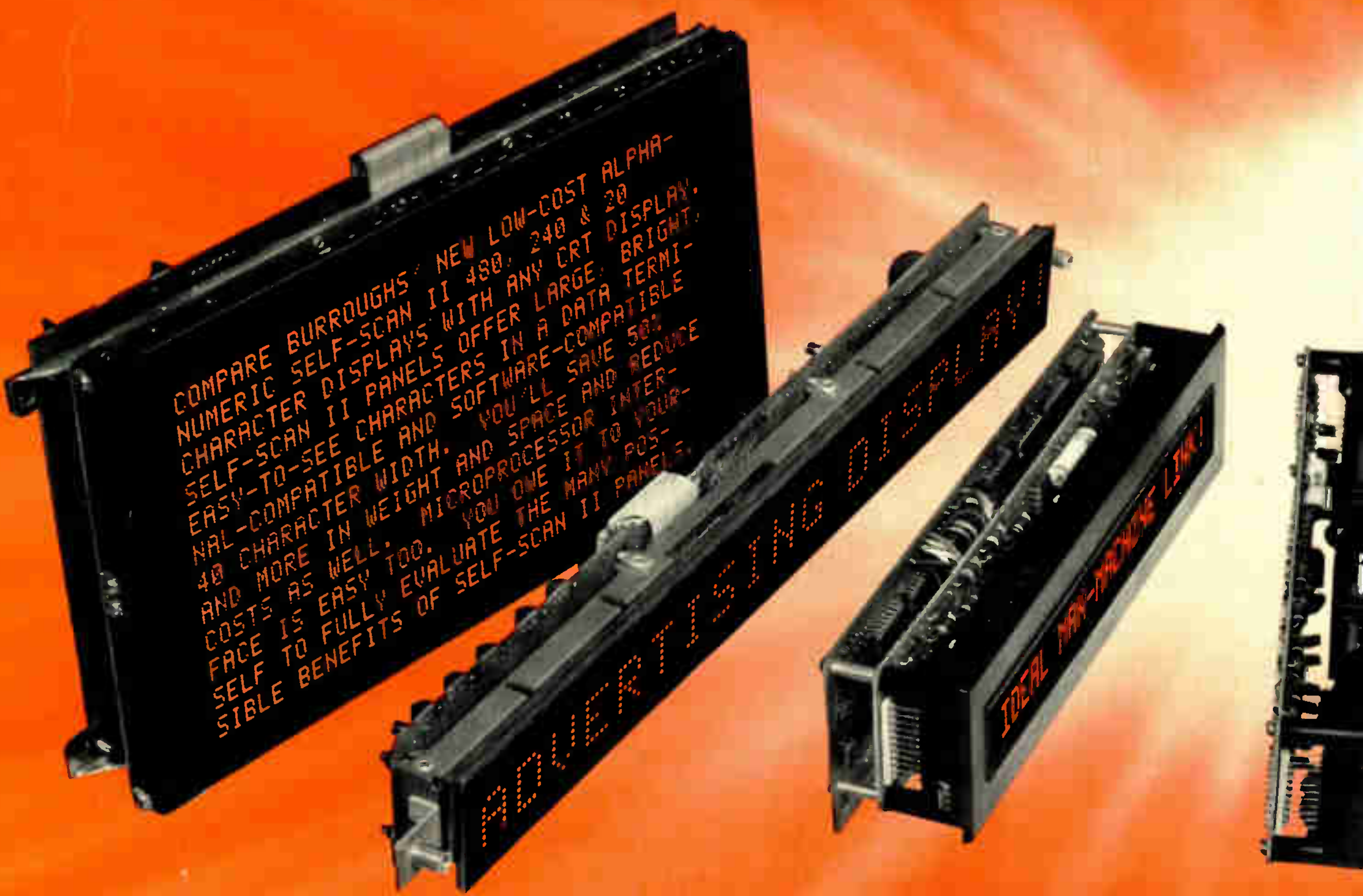

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Washington newsletter

New flexible transducer material reported by NRL

A new composite material developed by two Naval Research Laboratory scientists has resulted in a flexible electro-acoustical transducer that can be formed into almost any shape and used to replace the brittle piezoelectric ceramics of conventional transducers. NRL researchers Roy Rice and Robert Pohanka report that their new flexible composite **combines ferroelectric, piezoelectric, and/or electrorestrictive materials with a polymer** such as silicone or polyvinylidene fluoride. The new composite can be made into different shapes to conform to that of another body to which it would be attached. The composite "shows excellent response to uniaxial pressure signals," the researchers report.

Loran-C receiver improves location accuracy 500%

The accuracy of shipboard position fixes using Loran-C navigation has been improved by a factor of five—to within 30 meters—by a new computer-controlled receiving system developed by Johns Hopkins University's Applied Physics Laboratory for the Navy. The Laurel, Md., lab says the new Loran navigation receiving system, called Lonars, employs a statistical processing technique to track 100-kHz pulsed signals from up to eight stations simultaneously in as many Loran-C chains and then selects three low-noise signals for position fixing. "Serious noise in the Loran band is intermittent," explains APL's Lonars project engineer Leo Fehlner. "Therefore some Loran signals are contaminated and others are not. **If you use only the uncontaminated signals you can base your position fix on signals of textbook quality.** This is the advantage Lonars provides." It eliminates interference from atmospheric sources, like lightning, as well as interference from other Loran signals.

Carter trade policies generating opposition in Congress

Pressure in Congress is growing to get the White House to increase domestic market protection for small and minority businesses in the new Multilateral Trade Negotiation by restoring provisions that set aside certain Government contracts for small businesses. As part of the negotiation, foreign producers would be permitted to bid on some Federal contracts. **In return, Japan and European nations would open more of their procurement to U. S. companies.** But House small-business subcommittee chairman John LaFalce (D., N. Y.) warns that congressional approval of the trade pact, scheduled for completion later this year, will be hard to obtain unless the provision protecting contracts set aside for small businesses from foreign competition is restored.

VCR sales continue to soar in February; other markets mixed

Consumer electronic product sales to dealers provided a mixed picture in February with **home video cassette recorders more than double the 1978 level** while color TV receivers increased only fractionally, home radios of all types declined, and auto radios advanced. The Electronic Industries Association reports that February VCR totals of 32,881 were nearly 120% ahead of 1978, putting the first eight weeks of 1979 more than 97% ahead of the same 1978 interval. Color TV sales of 711,411 sets in the month were 1.3% ahead of last year, but the first eight weeks' total was less than 1% above a year ago. Monochrome receiver sales, however, gained 16.2% in February, rising to nearly 465,000 and putting the two-month total 13.5% ahead of 1978. A-m/fm radio sales slipped 23% to 1.3 million units for the month, pulling the total for the year to date down 13.4% from this time last year.

Senator Hollings rings a bell with S. 611

Senator Ernest Hollings was not yet born when a young Winston Churchill remarked in 1920 that war and politics, despite their similar excitements, had one distinctive difference. "In war," the British leader observed, "you can be killed only once, but in politics many times." The South Carolina Democrat seems to have had that maxim in mind while drafting his bill to amend the 1934 Communications Act. The Hollings bill, S. 611, moves neatly between the shellholes left from last year, when a barrage of criticism from industry and Government sorely damaged its House counterpart sponsored by California Democrat Lionel Van Deerlin [*Electronics*, June 22, 1978, p. 58].

Van Deerlin proposed a sweeping rewrite of U.S. telecommunications regulation that was long on Utopian principles but weak on their implementation. Hollings less immoderately wants major changes in the existing structure implemented with reasonable speed, the pace being set by both the developing competitive marketplace and the public interest.

A rational compromise

Van Deerlin's staff, which is nearly finished with its revisions to last year's bill, could learn from the Hollings proposals that successful politics is the art of the possible. Initial assessments by forces for and against competition agree that the 115-page Hollings draft is a bill that could pass and still be recognizable before the 96th Congress adjourns for the 1980 elections. "No bill is perfect, but this one is the best I have seen," says one telecommunications lobbyist who is an advocate of competition in this area. "I'm not altogether happy with it, of course, but it represents as good a compromise as any of us are likely to get."

As chairmen of the communications subcommittees in their respective chambers, both Sen. Hollings and Rep. Van Deerlin strongly support substitution of competition for Government regulation. Yet their approaches to this goal are vastly different.

Some examples: Hollings would leave the Federal Communications Commission intact, rather than replace it, but require it to complete action on rulings within 180 days at the outside, rather than the years it may now take. Instead of opening markets quickly to competition and eliminating the requirement that the FCC weigh the public interest in its actions, Hollings would phase in competition and phase out regulation so that AT&T could not quickly swallow up new and competitive markets. Where Van Deerlin's bill put forth no public interest requirements, Hollings retains them, arguing that "increased competition is a means to an end; it is not an end in itself. Where an important public goal is not well served by competition, regulatory tools must still be available."

One of Van Deerlin's most controversial requirements was that AT&T be required to spin off its Western Electric manufacturing arm. Hollings rejects that, but would require Western and any other Bell component to be operated as a "fully separated subsidiary" if it chose to enter a competitive market. While AT&T would be freed from the constraints of its 1956 antitrust consent decree and enter any market it wished—including unregulated information or data-processing services—it would have to do so in each case through a subsidiary with a separate financial structure, facilities, directors, officers, and employees, and then be obliged to deal with AT&T on an arm's length basis like any unaffiliated company. This separation requirement is now being construed to include any Bell System telephone affiliate that chooses to compete in regional intercity markets, where the FCC's jurisdiction would be substituted for that of a state. States, however, would retain control of intracity telecommunications.

Flexibility in numbers

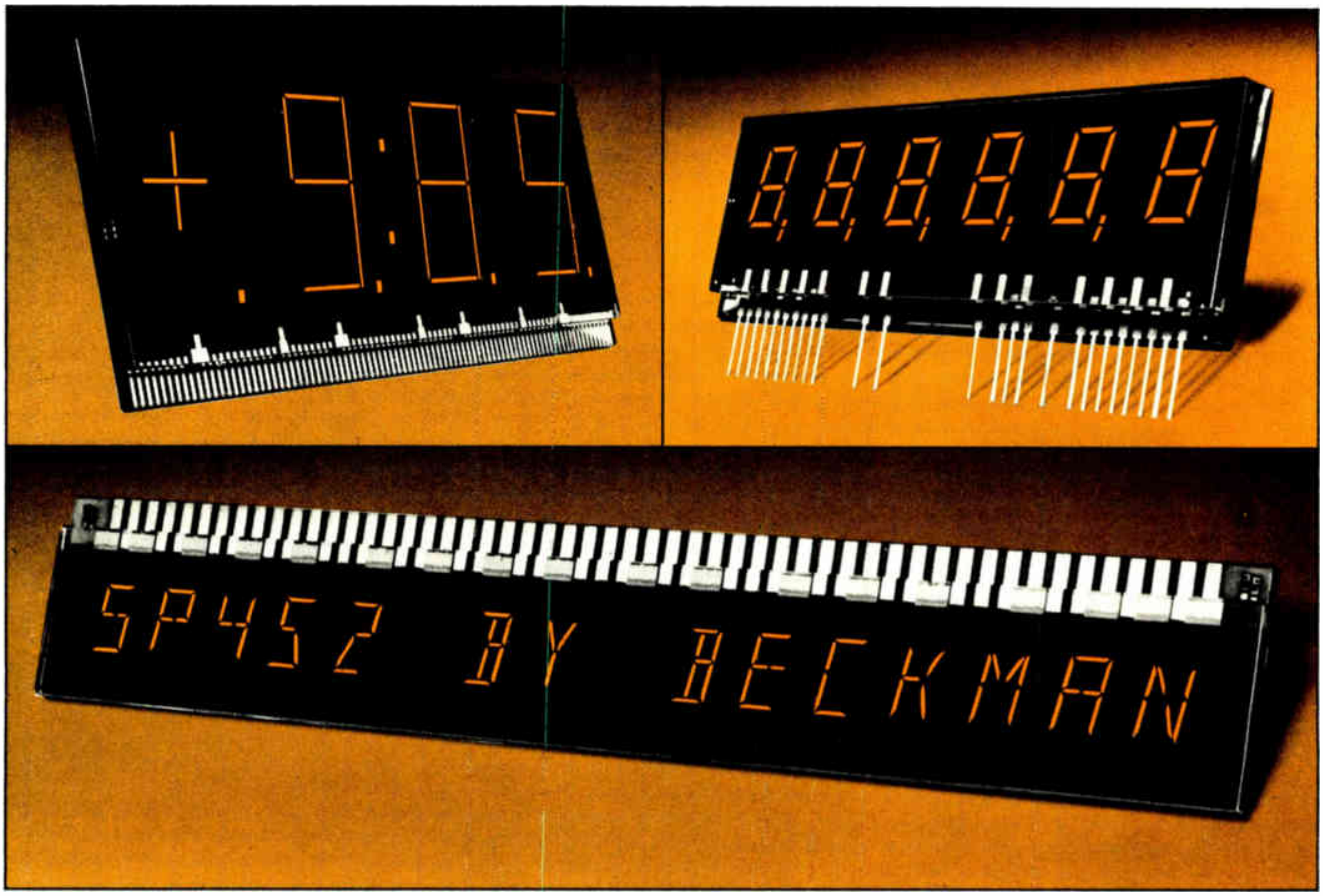
Concerning his domestic telecommunications proposals, the senator argues that "a skeptic might say this bill amounts to a giant handicapping scheme. To which one would reply, that is exactly what is needed. The telecommunications markets are such that one cannot simply declare 'there should be competition' and expect it to occur overnight. Indeed, if one were to remove all regulation, the probable result would be a speedy end to the budding competition that has begun to emerge. An intelligent, flexible handicapping system with built-in mechanisms for tightening or loosening the restraints as competition flourishes or flounders in each market is precisely what the telecommunications industry most needs during the next one or two decades of transition to a state of what we hope will be full competition."

It is as appropriate as it is coincidental that the number assigned to the Hollings bill is the one most Americans must dial for telephone repairs. For S. 611 holds more promise than any legislation to have come along so far for fixing a national telecommunications system so that it can respond quickly to new technology and its innovators.

Ray Connolly

This 7-segment numeric Screened Image Display is designed for use in applications requiring display of four digits (or, end-stackable multiples of four) at viewing distances up to 100 feet. The SP-431 can be used in either the Pulsed DC or multiplexed mode. Readability is assured by the 2.0-inch digit height and by 180 footlamberts of neon-orange brightness. Further application of the SP-431 is enhanced by a plus and minus symbol in the most significant digit; and, a colon between the second and third digits.

The SP-491 is a standard Screened Image Display that is ideally suited for point-of-sale equipment, instrumentation and electronic games. Readability is assured at distances up to 50 feet by the 0.7-inch height of the six digits and 210 foot-lamberts of brightness. The SP-491 is a 7-segment display that is designed for multiplexed operation. It offers a wide, 130° angle of visibility; and, has a decimal point and comma in five digit positions.



Here's a vivid demonstration of the suitability of the Screened Image Technology for producing large fields of versatile, 14-segment characters. The SP-452 provides 16 characters, each with its own decimal point and comma. The half-inch size is ideal for point-of-sale equipment and in other applications where large field, alphanumeric capability is needed. The 14-segment format makes possible a display set of the ten numerals and the alphabet plus special symbols — providing a character set that can be as versatile as you want to make it.

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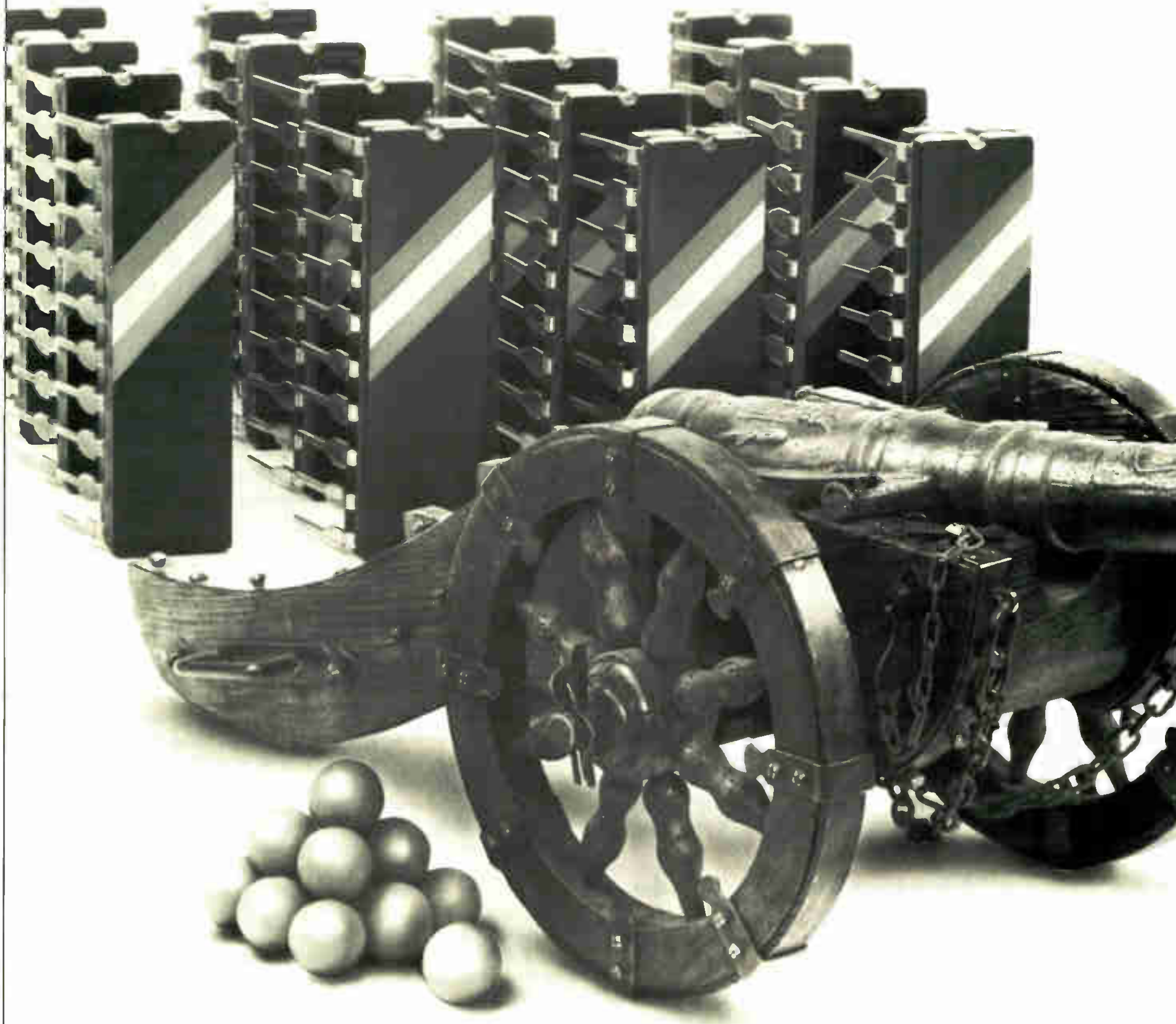

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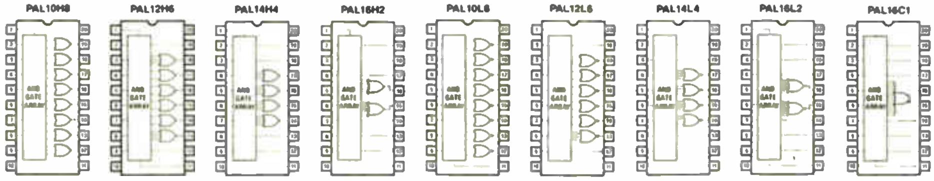

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PAL12H6	12	6			AND/OR Gate Array	Now
PAL14H4	14	4			AND/OR Gate Array	Now
PAL16H2	16	2			AND/OR Gate Array	Now
PAL10L8	10	8			AND/NOR Gate Array	Now
PAL12L6	12	6			AND/NOR Gate Array	Now
PAL14L4	14	4			AND/NOR Gate Array	Now
PAL16L2	16	2			AND/NOR Gate Array	Now
PAL16C1	16	2			AND/OR/NOR Gate Array	Now
PAL16L8	10	2	6		AND/NOR Gate Array	3rd Q79
PAL16R8	8			8	AND/NOR Array w/Reg's.	3rd Q79
PAL16R6	8		2	6	AND/NOR Array w/Reg's.	3rd Q79
PAL16R4	8		4	4	AND/NOR Array w/Reg's.	3rd Q79
PAL16X4	8		4	4	AND/NOR/XOR Array w/Reg's.	4th Q79
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International newsletter

Electronics goods look good for 1987, Arthur Little says

A bullish outlook for electronics-based goods amounting to $30 billion by 1987 in the U. S. and Europe in the automotive, consumer, business, communications, and industrial sectors is the verdict of a two-year study completed by Arthur D. Little Inc., the Cambridge, Mass., management consultant firm. The $2 million study, sponsored by more than 60 clients from governments and industries in the United States, the Far East, and Europe, also predicts that **worldwide shipments of microprocessor-based modules will reach 400 million units by 1987.** Text processors, another key area considered, are expected to increase from $1.5 billion in 1977 to a possible $3 billion by 1987. By 1982, the study says, nearly all new cars in the U. S. and Europe will have intelligent electronic engine controllers.

Japanese firm builds 16-K static RAM with 90-ns access time

Samples of a static 16-K random-access memory will be supplied by Oki Electric Industry Co. starting in September. The MSM2128 is made to 3-μm design rules and features a gate length of only 3 μm. It operates from a single 5-V power supply, with an access time of 90 ns. **Power consumption is a low 520 mW.** Organized as 2-K by 8 bits, the chip is only 5.0 by 6.2 mm and comes in a 24-pin dual in-line package pin-compatible with popular ultraviolet-light–erasable programmable read-only memories of the same capacity. The memory cell consists of four transistors and two high-resistance polysilicon transistors. The MOS RAM is made from masks fabricated by electron-beam exposure.

Canada lets firms run their own TV earth stations

Canadian cable television companies, broadcasters, and common carriers can now buy and operate their own television-signal receive-only earth stations under a new policy of Canada's Department of Communications. Until now, only Telesat Canada, the Crown corporation responsible for the Canadian satellite network, has been issued licenses. The new rules, which also allow reception of the 12-GHz signals from the Anik-C satellite to be launched in 1981, are expected to increase the use of television signals in remote areas. They do not, however, permit the reception of signals from U. S. satellites, which are specifically excluded. Several Canadian companies are already tooling up to meet the demand, and **Micro-Sat Communications Ltd., Toronto, for one, is offering a 4-GHz receive-only station** made under license from Hughes Microwave Communications Products of Torrence, Calif.

Fast GaAs circuits being tried out in French lab

Although RTC–La Radiotechnique-Compélec is just getting into volume production of 100-K emitter-coupled-logic circuits with a propagation time of 0.75 ns [*Electronics*, March 15, p. 68], its sister research and development company in the NV Philips Gloeilampenfabrieken group, Laboratoires d'Electronique et de Physique Appliquée, has already moved into its second generation of even faster gallium-arsenide integrated circuits. LEP's first generation of **GaAs field-effect transistors has gate delays of 65 to 150 ps.** But the consumption is relatively high—as much as 50 mW at fast speed. Since these circuits hold promise only for applications where a few gates will do, LEP has started work on a second generation with power consumption low enough for complex circuits. In an early try with ion-implanted GaAs FETs, a NOR gate with a fanout of two dissipated 13.5 mW at a propagation time of 102 ps. LEP expects to cut the consumption considerably, with little loss of speed.

PAL decoder joins brightness processor on a single chip

Valvo, the West German components-producing subsidiary of NV Philips Gloeilampenfabrieken of the Netherlands, is about to unveil a single chip containing a complete PAL decoder and a luminance-signal processor. The TDA3560 thus **handles all the steps necessary to process the composite video signal** into the red, green, and blue signals that drive the video modulator. It can also process the color inputs coming from external sources like a video recorder or a teletext unit. Only 10 square millimeters, the chip integrates some 750 elements. It operates off 12 V and consumes 1 W. The TDA3560 will be shown at the Hanover fair in West Germany next month.

Siemens expands its 100-K ECL family with LSI and more MSI chips

Supplementing the 100-K family of small- and medium-scale integrated emitter-coupled logic already on the market, Siemens AG, Munich, is now coming out with a line of 10 standard large-scale integrated ECL devices and 4 additional MSI ECL parts. The circuits will bow at the Paris components show next month. **The LSI range contains devices with gate delays down to 0.5 ns.** The parts, incorporating from 450 to 700 gate functions, consume from 2 to 3 W. The range includes a multiplexer, a register, a counter, a parity generator, and a sequencer. The four MSI devices are a converter and three circuits for use in computer applications; gate delay is down to 0.7 ns.

Ion implantation makes bipolar process versatile

All the components needed for high-performance signal processing in applications such as analog-to-digital converters, for example, have been packaged together in a low-power process developed at Plessey Ltd.'s Allen Clark Research Centre, Caswell, Northants. The process produces planar npn and pnp transistors and an n-channel junction field-effect transistor by extensive use of ion implantation. The f_t unity gain point for the npn transistor is 2 GHz; **for the pnp transistor, it is over 200 MHz—some 20 times better** than that achievable by a conventional lateral pnp device. Developed to meet an unspecified military requirement, the process could be used commercially to integrate complementary linear functions now produced in multichip hybrid packages, but Plessey is unlikely to have the resources to push in that direction.

VW plans to acquire a majority share of small-computer firm

It looks as though West Germany's big auto maker, Volkswagenwerk AG, in its efforts to diversify into different product areas, has finally found the first company willing to enter a partnership—the Nuremberg small-computer and office-equipment producer Triumph/Adler, part of the Litton Industries group of the U. S. The partnership, which must still be approved by Litton's and VW's supervisory boards, as well as by West Germany's Cartel Office, provides for **VW to take over 55% of T/A's stock from Litton for an estimated $200 million,** leaving Litton with 19% (the remaining 26% is owned by several other firms).

T/A rates as one of the most successful of West Germany's small-computer makers. During the past 10 years, it has increased its sales from $130 million to more than $600 million. With VW backing, the company is expected to intensify its marketing efforts in the U. S.

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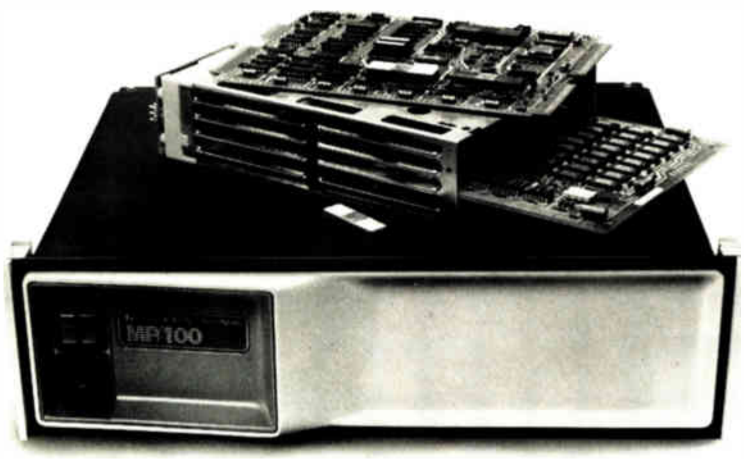

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Continuous addressing makes LCD bright and flicker-free

Technique is employed in an experimental compact storage scope that needs only 500 mW

A miniature storage oscilloscope with a liquid-crystal display and a minuscule power consumption of 500 milliwatts could be just around the corner, thanks to a novel display addressing technique developed at the Royal Signals and Radar Establishment in Malvern, England.

It has already been used in a prototype storage scope that displays analog waveforms as a dark trace on a bright background using a 100-by-100-element X-Y matrix [*Electronics*, Feb. 15, p. 68]. The instrument is approximately 7 inches wide by 7 in. long by 3.5 in. deep and weighs 4.5 pounds including battery; the display is 2.5 by 2.5 in.

The new addressing mode results in a bright, flicker-free display over the entire temperature range of the liquid crystal used. For currently available twisted nematic LCDs, this range is from −10°C to 70°C.

Instead of rapidly addressing rows and columns serially in a multiplexed arrangement, binary signal sequences are applied continuously to all row and column electrodes. The effective potential at any matrix node is thus the difference between row and column signatures.

Black lines. "When there is a high correlation between the two signals," says Ian A. Shanks, who developed the technique, "the effective potential is zero and the liquid-crystal sandwich remains in a nontransmissive state." But when there is no correlation, a 5-volt root-mean-square voltage develops across the twisted nematic liquid crystal and it switches into the transmissive mode. As a result, the analog waveform appears as a black trace on a light background that is readily photographed and highly visible even in low or zero ambient lighting, according to Shanks.

Shanks, though, is reluctant to say much about the details of the addressing method, which will be presented at the Society for Information Display's 1979 International Symposium to be held in Chicago May 8–10. But he is confident that the technique can be extended to displays of 1,000 by 1,000 elements.

Full resolution is possible only when a single trace is displayed. However, dual-trace operation has been successfully demonstrated at reduced resolution by displaying one waveform on all the odd-numbered columns and the other on all the even-numbered columns.

Storing. Data for the display is stored in two 256-by-4-bit complementary-metal-oxide-semiconductor static random-access memories organized as 128 words of 7 bits. The analog signal to be displayed is sampled and digitized by an analog-to-digital converter, and the samples are stored in the RAM. The memory is then read out repetitively and the stored binary numbers are used to determine the position of the addressed element in each column of the display matrix.

The system can operate in either an update mode with repetitive triggering or a storage mode with a single-shot trigger. The latter, Shanks says, is the most valuable feature of the scope, providing "infinite persistence for as long as the supply is maintained."

Speedup. The prototype system has a bandwidth of 5 kilohertz, but this figure can be increased to 2.5 megahertz for the storage mode by adding a charge-coupled-device delay line before the a-d converter and may possibly be extended to about 50 MHz, Shanks believes.

For the immediate future, Shanks is upgrading the store and has a 128-by-256-element display under way. Further out, he states, other LCD phenomena may be considered that would improve brightness, enlarge the viewing angle, and make dynamic response faster.

One novel application Shanks sees for the LCD is as a projection display. Here, the rear reflector is removed and the LCD is used as a transparency in a conventional projector. Such a projection scope could be useful to teachers. □

Japan

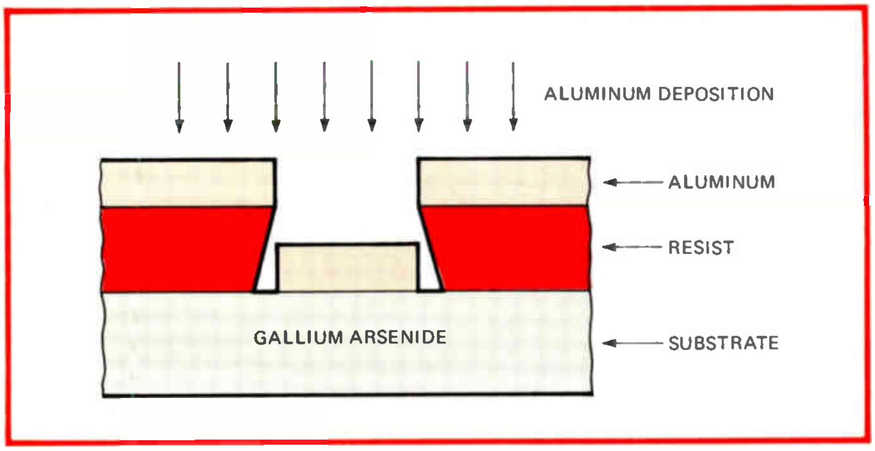
E-beam and liftoff produce finer lines

Gallium-arsenide field-effect transistors with submicrometer gate lengths show great promise both as discrete low-noise K-band devices and for ultrahigh-speed, low-power, very large-scale integrated logic. To fabricate such devices for use in receiving 12-gigahertz satellite transmissions and in dividers counting down from 1 GHz. Matsushita Electronics Corp. employs electron-beam exposure and a metal liftoff process, and has even come up with a two-layer resist.

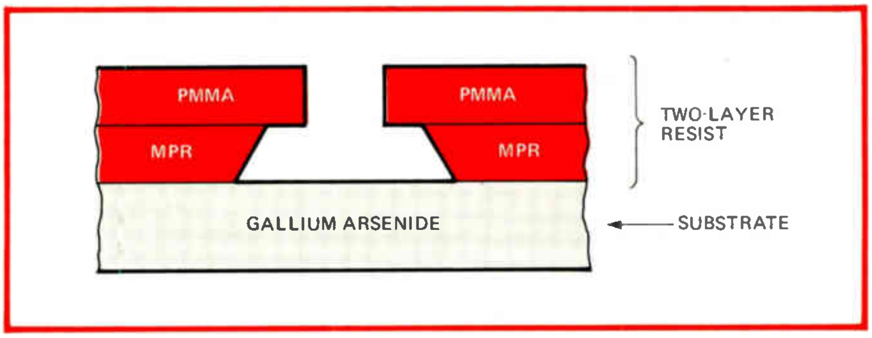
The company has thus been able to make a low-noise FET that operates at 12 GHz and a nine-stage ring oscillator with a gate propagation delay of 150 picoseconds. The typical gate length for both is 0.8 micrometer, though devices with 0.5-μm gate lengths have been made.

Direct electron-beam exposure of a positive resist is the most attractive method for fabricating such fine features. Electron beams, of course, offer higher resolution than optical lithography, and the liftoff made possible by using a positive resist yields much sharper lines than would a negative resist and an etchant.

Exposure and development of the positive resist strips it away from those areas where metalization is to be applied. Metal is deposited directly on the wafer only in the desired locations; elsewhere it overlies the resist. If the process is done properly, there is a clean break between the metal on the wafer and the metal overlying the resist (see the upper of the two diagrams).



Cut away. Electron-beam exposure yields desired undercutting (above), resulting in sharply defined lines when the remaining resist is dissolved and the unwanted metal floated free. Use of two layers of resist with slightly different sensitivities increases undercutting (below).



Sharp. The resist is then dissolved in an organic solvent, lifting off the undesired metal and leaving a sharply defined pattern whose height can be several times the line width. For example, line widths as small as 0.2 μm with a height of 0.5 μm have been fabricated.

Liftoff is also aided by applying the vaporized metal from a point source far from the chip. The vapors that reach the wafer travel in a direction perpendicular to the surface and therefore do not get into the crevices formed by undercutting.

Another advantage of electron-beam exposure is that electrons passing through the resist and striking the substrate ricochet off it, causing additional exposure close to the substrate. The width of the exposed line is thus wider near the substrate than at the surface, causing undercutting that facilitates liftoff.

Enhanced. Though the amount of undercutting is satisfactory for discrete transistors, it is insufficient for VLSI circuits. Matsushita has therefore developed a two-layer resist method that provides enhanced undercutting.

Two different resists are used for the two layers, with the bottom resist more sensitive than the top one. Because the electron beam scatters as it penetrates the resist, the higher sensitivity of the bottom layer causes greater undercutting (see bottom diagram). The sensitivities of the two layers must be close, though, to allow correct exposure of the two layers simultaneously.

Initials. For the top layer Matsushita uses polymethyl methacrylate (PMMA). For the bottom, it employs a version of Matsushita Positive Resist (MPR), a copolymer, that is formulated to be only slightly more sensitive than PMMA.

Electron-beam exposure is used only for defining the gate, which is positioned accurately to within ±0.2 μm. Gates are made using either aluminum or chromium-platinum-gold metalization; in either case, the metalization is 0.6 μm thick.

The resist used in making the super-high-frequency transistors is a single layer of PMMA 1 μm thick. For the ring oscillator transistors, the bottom layer is MPR 0.5 μm thick and the top is PMMA 0.5 μm thick.

IBM Corp., too, has been working on electron-beam exposure of a positive resist. It delivered a paper on a two-layer resist process at December's International Electron Devices Meeting in Washington, D. C. □

West Germany

Grundig launches projection TVs

Ahead of its European competitors by at least a year, West Germany's Grundig AG has readied a color projection TV system intended mainly for home use. It has thus ushered in a market that it expects will grow more quickly than the sluggish U. S. market (see "Projection TVs: a

Projection TVs: a brighter future

Thus far, color TV home projectors, imported from Japan or the U. S., have turned up only sporadically in Europe. But now that Grundig AG has started to produce such systems in quantity—and will sell them for up to $500 less than the imports—the market should rapidly take shape. For 1980, Grundig predicts Europe-wide sales of up to 30,000 units as other companies join the act and as imports drop in price.

The market rise, Grundig says, should be much faster than that in the U. S. There, forecasts say that a level of only 100,000 sold units will be reached in 1979, about five years after home projectors were introduced. The reason for the relatively slow start, Grundig believes, is the high initial price, about $6,000, for a high-quality projector. But since prices have fallen to between $3,000 and $4,000, sales in the U. S. are gaining momentum, with the market predicted to eventually stabilize at 200,000 to 300,000 units a year.

Besides the lower initial price, Grundig says two other factors should help the European market develop faster. One is a claimed more advanced technology. The other is the higher quality picture resulting from Europe's use of 625 TV lines, versus the 525 lines used by the U. S. and Japan.

Of the European market, Grundig says West Germany will initially claim a 55% to 60% share. That share should drop and stabilize at about 40% as sales in other European countries pick up.

Besides home use, the firm sees many commercial and institutional applications for home projectors—for instance, in school and other auditoriums; at conferences, seminars, symposia, and meetings; in hotel lobbies, restaurants, and bars; at exhibitions; and for advertising.

brighter future").

Having its debut at the current International Fair for Learning Aids in Düsseldorf, the Cinema 9000 will go to market in April and sell for about $3,800. It uses three projection tubes to produce, on a 96-by-125-centimeter screen, a color picture about six times larger than that of a 26-inch TV set.

Remotely controllable by infrared signals, the projector also accepts inputs from external video sources like video recorders, TV cameras and slide or film scanners. The system also offers digital tuning and channel selection and automatic station search.

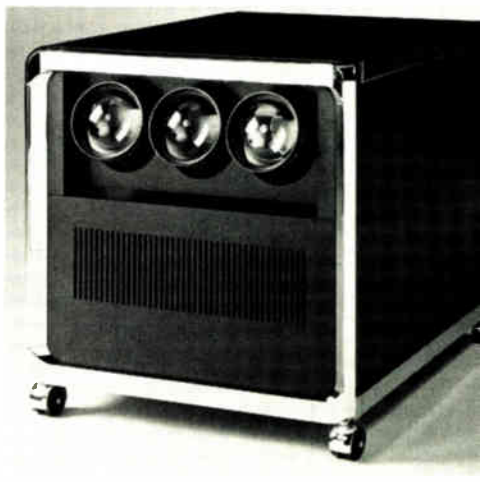
What should prove to be a strong selling point is the projected picture's great sharpness and brightness. It sports a maximum luminous intensity of about 140 candelas per square meter—equivalent to roughly 40 foot-lamberts. More tangibly, the picture is more than twice as bright as that in a movie theater, Grundig says. This means the Cinema 9000's picture is clearly visible even in daylight.

As Roland F. Klink, product manager for video and TV systems at the Nuremberg-based firm, explains it, the brightness is due to three factors: optimized optical systems, a special projection tube design, and the projection screen.

The screen, made exclusively for the company by a U. S. firm, is constructed of a plastic that is covered with a highly reflective aluminum foil and then with a thin washable plastic layer. Its concave shape results in a uniform light distribution across the surface, which produces an acceptable viewing angle of 45°, according to the company. The shape, in combination with the foil, also yields a picture 12 to 15 times brighter than that achieved with a diffuse light radiator, Klink says.

The optical systems, one each in the three projection tubes, consist of four high-precision plastic lenses whose surfaces are specially treated to increase the light transmission and thus further enhance the picture intensity. Called the TV-Proclar, the optical system comes from West Germany's Schneider Optische Werke and is also made exclusively for Grundig. The system has a focal

Picture this. Grundig believes its home projection TV (below, left) will initiate a fast-growing European market. The picture is 12 to 15 times brighter than that of U. S. and Japanese models, and the projector (below, right) can serve as a coffee table.



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length of 135 millimeters and an aperture setting of f:1.2.

Like the screen, the projection tubes are supplied by a U. S. company. The special phosphor materials they use considerably improve the light yield, contributing to the Cinema 9000's high luminous intensity. (For competitive reasons, Grundig will not reveal the names of the U. S. suppliers.)

Designed as a movable, glass-topped unit that can serve as a small coffee table (see photos), the projector houses a 14-watt high-fidelity sound section and the same video receiver that Grundig uses in its top-of-the-line color TV models. The three 6-inch-diameter projection tubes, for red, green, and blue, are arranged in a line and produce the picture by simple additive color mixing.

As a shield against X rays, the designers have resorted to a 2.5-mm-thick lead-glass plate mounted between the tubes and the optical system. They have thus kept the radiation to only 50 microroentgens per hour. □

France

Synchrotron lures researchers to X-ray lithography for IC fabrication

In much human endeavor, success depends on knowing where to draw the line. But in the semiconductor business these days, it's getting to be as much a matter of knowing how to draw lines. For as integrated-circuit designers pack more and more elements onto their chips, line widths have to get smaller and smaller; sooner or later they will be shaved down to less than a micrometer. And when that happens, the major French chip makers expect to have the necessary expertise.

Up and coming. Although conventional photolithography and electron-beam lithography will surely predominate over the next few years, there is a good chance that when submicrometer geometries become prevalent, X-ray lithography will become standard. Work in this area has been going on for nearly five years at the suburban Orsay campus of the University of Paris, and a half dozen companies and government research outfits are now running experiments there. They are working with ACO (for Anneau de Collisions d'Orsay), one of two electron storage rings at the Laboratoire d'Utilisation de Rayonnement Electromagnétique (LURE).

Although there are more powerful synchrotrons in the world, points out Yves Petroff, codirector of LURE, "at the moment, ACO is the most powerful ring available anywhere for this kind of work." The ring develops an energy of 540 megaelectronvolts and current intensities as high as 100 to 150 milliamperes. Furthermore, it will not be until the early 1980s, Petroff maintains, that higher-intensity storage rings now under construction in West Germany and the United States will become available for use.

The ACO spectrum extends from about 6 angstroms (X rays) to 10,000 Å (infrared) and peaks at about 16 Å, a soft X-ray region very suitable for lithography. Equally important, the beams extracted from the ring have very low dispersion—about the same as a laser. As a result, at 10 meters from the ring the window through which the beam emerges measures 7 centimeters wide by 2 cm high.

Keeping a distance. Because the beam diverges only slightly, masks can be anywhere from 10 micrometers or so up to 1 millimeter away from the wafer. The distance eliminates contact damage without creating geometric and penumbral distortion that are problems when the radiation originates from a point source [*Electronics*, Nov. 9, 1978, p. 99].

The outsiders now using ACO are IBM-France, Thomson-CSF, the French atomic energy commissariat's Laboratoire d'Electronique et de Technologie d'Informatique (LETI), Le Centre National d'Etudes des Télécommunications (CNET), Laboratoires d'Electronique et de Physique Appliquée (LEP) of the NV Philips Gloeilampenfabrieken group, and Engins Matra SA, which has joined forces with the U. S. firm National Semiconductor Corp. to produce metal-oxide-semiconductor ICs in France.

They share 18 hours a week—at some $300 an hour—on one of the six light lines that fan out from the storage ring. "Next year they will have a line all to themselves," Petroff says.

The outsiders are conducting experiments to see how mask materials and wafers stand up to X rays and what the optimum wavelengths might be for submicrometer lithography. Silicon nitride is a commonly used mask substrate and the resist is usually polymethyl methacrylate (PMMA). As for damage to wafers caused by exposure to X rays, Petroff reports that it has not been as much as was expected.

Minuses. Although he helped pioneer the concept in France, Petroff realizes that X-ray lithography has drawbacks. "We are too far in advance," he says. "Masking is just part of the problem." When line widths get down 3,000 Å (0.3 μm), he points out, the positioning system for the masks has to be accurate to within about 600 Å (0.06 μm).

Then there are the costs. A storage ring designed to expose wafers would cost some $15 million, about 10 times what an advanced electron-beam machine to produce the masks would sell for, "and you'd still need an electron-beam machine to produce the masks for X-ray exposure of wafers," he notes.

Still, a storage ring designed for X-ray lithography with a dozen or so working light lines may happen. Such a facility is one possibility being considered for the new laboratory that CNET is building at Grenoble as part of the national effort in very large-scale integration. □

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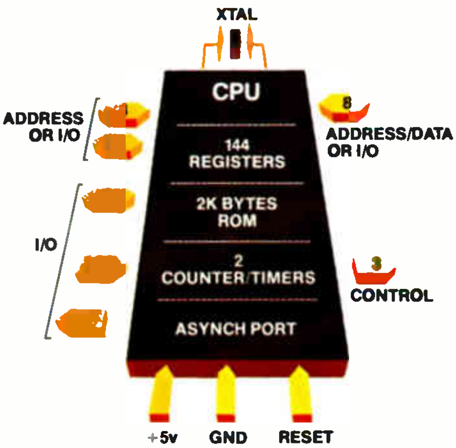

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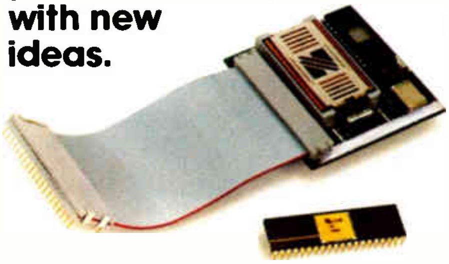

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Has bubble memory's day arrived?

Evidence is that major developments reported by Bell Labs and IBM at California conference will overcome obstacles

by Larry Waller, Los Angeles bureau manager

For magnetic-bubble memories, March 12 could well emerge as a pivotal date. On that day, at an otherwise routine technology conference at Indian Wells, Calif., two firms that are giants in advancing technology disclosed research projects that appear to have found the means of overcoming some nagging obstacles. And, perhaps most significantly, both techniques may be implemented by currently used manufacturing processes.

First up at the meeting—the Third International Conference on Magnetic Bubbles—was Bell Laboratories scientist Andrew H. Bobeck, credited with initial development of the bubble. He told how he and his team eliminated the conventional magnetic coils presently used to drive memory devices. Following the Bell paper, International Business Machines Corp. scientists described their experimental 15-K bubble device, whose so-called wall-encoded structure has four times the information-storage density of conventional devices. IBM also told of its other development, a contiguous-disk technique for building multimegabit bubble chips using conventional photolithographic methods [*Electronics*, March 1, 1979, p. 39].

The Bell technique, developed at Murray Hill, N. J., replaces magnetic coils with a "dual conductor" method that applies current through over-and-under conducting layers to move the bubbles. In addition to benefits of one-third smaller size and potential lower costs, it exceeds present speed limits of 400 kilohertz or so. "There's no limit, it can go to 20 megahertz," says Bobeck. On the other hand, coils face speed limitation for lack of response at higher frequencies, he says. Research to date has put the new configuration with 8-micrometer periods and 2-μm bubbles through its paces at 1 MHz. Bell has already fabricated experimental devices to demonstrate the technology and is now designing the first bona fide chips, in the 1-to-5-kilobit range. Furthermore, it expects to have a 256-K, 1-MHz coilless device in about a year.

Look, no coils. It works this way: instead of the usual coils on each side of the device package that set up a single magnetic field where bubbles move, Bell Labs substitutes two conductive layers, similar except for slightly overlapping oval apertures. The conductive layers rest atop the garnet material holding the bubbles. When a 350-milliampere current is applied alternately to the layers, these apertures also become individual magnetic fields that do not quite touch. It is the four-phase pulsing of the current through the layers that drives the bubbles forward in a loop pattern from one aperture—acting as a magnetic pole—to another. Thus bubbles move from a generator on one side of a chip to a detector on

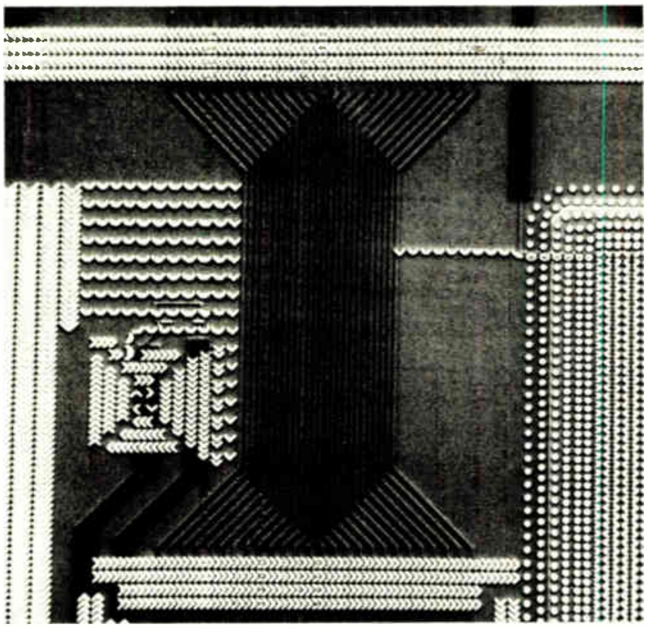
Putting it all together

Though each of the IBM and Bell Lab developments is highly significant in itself, the question to listeners at the conference, who included those in the forefront of bubble work, became: "Are they compatible, and can they be practically combined?" Answers IBM's Hsu, "I certainly think so." Bell's Bobeck concurs, saying, "I see no reason why they can't work together."

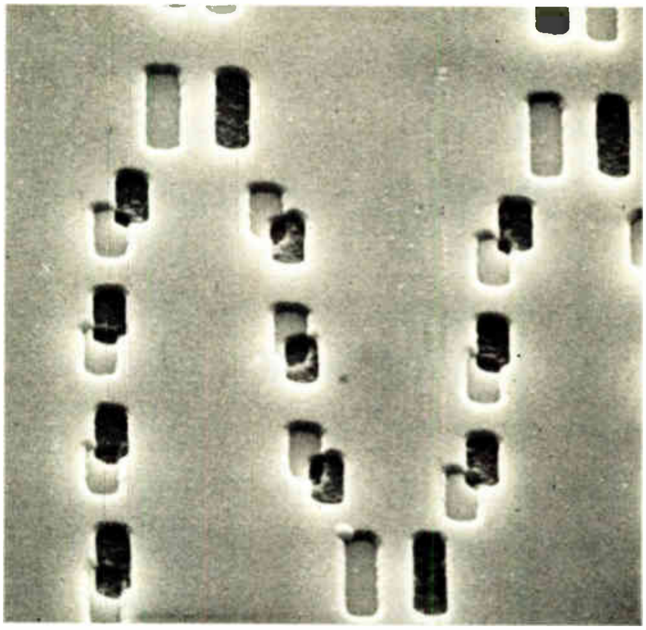
As both developers see their creations, in addition to density and speed advantages, compatibility with existing processing technology is a most important feature. Many of the techniques for manufacturing semiconductors that present bubble memories also use can be applied without change to the new magnetic devices.

The next step for the Bell and IBM innovations will become clear as their impact is felt throughout the industry. But Bell makes no bones about its rush to get coilless drive devices into operation where magnetic memories already store digitally recorded messages. The improved devices may also go into high-capacity digital switching systems, and in a variety of terminals, the company says. IBM, which so far has put no bubbles into commercial operation, is as usual keeping its plans close to its corporate vest.

For commercial bubble producers, Rockwell International's Microelectronic Device division in Anaheim, Calif., is quick to jump on the bandwagon. "It's a generational development," bubble business manager John L. Archer says of the two announcements. Rockwell has already done some work along these lines and will focus on getting them into its next generations of devices, he says. Texas Instruments vice president H. Dean Toombs indicates TI will work with the Bell approach to determine its commercial feasibility; the IBM technique is also interesting, he says, because of its "potential for higher density." TI's next-generation products will use present field-access structures, but the new technologies could be incorporated later, he adds.



IBM's technique. Scientists at the research lab in San Jose, Calif., have made an experimental 15,000-bit bubble device that uses two types of bubbles to gain fourfold increase in density over present devices. Chevron elements are half as tall and wide as usual.



Bell's bubble. This is a portion of an 8-micrometer dual-conductor shift register fabricated by Bell Labs. The darker apertures are in the first conductor and the lighter ones are in the second conductor. Technique was developed at Murray Hill, N.J.

the other, without all the previously needed coils and associated drive electronics.

"The bigger the aperture, the stronger the field, which looks like a bar magnet," observes Bobeck. The shape of the aperture produces and maintains the proper shape of the bubbles in the garnet layer beneath, solving a problem in earlier conductive approaches, he adds.

Though the results he reports derive from 8-μm-period devices with bubble diameters of about 2 μm, Bobeck says Bell can get to 4-μm periods with little difficulty. One big difference is that the "overlapping ovals are easier to fabricate than 16-μm chevron gaps," he adds.

Surprising many listeners was Bobeck's assertion that a 256-kilobit memory designed with the new drive will require just 350 mA, against some 600 mA needed by present devices from Rockwell International Corp. and Texas Instruments Inc. This works out to a milliampere-per-micrometer figure of 1.5, says Bobeck—well on the way to the ideal of 1 mA/μm. He also expects cost per bit to decline sharply because of density and elimination of coils that, he estimates, account at present for 10% to 20% of the total package expense.

IBM's Ta-lin Hsu, manager of the exploratory device group at the research lab in San Jose, Calif., says that the basis of the super-density development is "a method for encoding the domain walls of the bubble so that two different types of bubbles represent the 1 and 0 and can be distinguished from each other." This concept of distinguishable bubbles enables IBM to pack them more tightly into the same device, since conventional, magnetically similar bubbles require empty spaces to represent a 0 data location. "Such randomly located gaps in an array of bubles place a fundamental restriction on the achievable storage density," says Hsu. Also, they must be kept four to five bubble diameters apart.

How it's done. IBM's wall-encoded bubbles overcome this by inducing different internal magnetic structures, after the company's earlier experimental work on lattice arrays. Those arrays were controlled by current, rather than by conventional magnetic fields, and required many costly and complex fabrication steps. IBM is therefore dropping its lattice technique and concentrating on wall-encoding, says Laurence L. Rosier, manager of advanced storage technology at San Jose.

Wall-encoding, Hsu claims, makes possible the storing of 15-K bubbles at a density of 3.3 million per square centimeter or 22 million per square inch. It uses bubbles of 2.7 μm in diameter, but has a bubble period of only 5.6 μm because of essential differences with conventional designs.

Besides the two types of bubbles, the Permalloy chevron elements that the bubbles move between are half as tall and half as wide as conventional elements. "Thus, four times as many can fit into the same area," he says. Furthermore, in contrast to present bubbles that have to be separated by four to five diameters because they repel each other and would push into gaps in the array, the new IBM distinguishable bubbles may be packaged much more closely. The oppositely coded bubbles permit separations, from center to center, down to approximately two diameters. Chevron gaps are 1.4 μm.

The device is fabricated on a thin film of yttrium, samarium, calcium, and germanium, containing all the functions needed to read, write, and store data. Tests show the wall states of the bubbles are stable under all normal operating conditions, says Hsu. The only possible drawback of the quadrupled density is that access time is also increased by four. "So designers may want to partition the chip to compensate," he says. □

Consumer electronics

British, French in U. S. teletext race

Antiope backers seek to wipe out UK's head start in 'TV magazine' systems by winning CBS St. Louis shootout

by Arthur Erikson, Managing Editor, International

The British are a good two years out in front when it comes to teletext, one of the new batch of telecommunications services that eventually will transform home television sets into computer terminals of sorts. And unlike the hare that built up a commanding lead on the tortoise in their fabled match race, the British have not by any means pulled off the course for a nap. Yet the French, their main adversaries in this domain, hope to leapfrog to the forefront—by capturing the teletext race in the United States.

This month, the CBS/Broadcast Group of CBS Inc. is due to start side-by-side tests of the British and French teletext systems at its St. Louis station, KMOX-TV. The tests will run about a year and the results could be crucial to the decisions that the Federal Communications Commission will one day have to make about teletext. This service broadcasts digital signals on two lines during vertical blanking intervals (so as not to disturb regular programs), then decodes them at the receiver into so-called pages of alphanumeric information that televiewers can call up for display on their screens.

As the tests in St. Louis go on, both the British and French will be hustling to line up backers elsewhere around the world. The British pitch is succinctly put by Keith Jones of Thorn Consumer Electronics Ltd., who heads the teletext working party of the British Radio Equipment Manufacturers' Association (Brema). Say Jones, "We have a proven system with two years' operational experience, together with teletext decoders already in production. What's more, the British system was optimized for broadcasting and is very robust with rugged error-correction features." The ruggedness, the British claim, stems from using TV synchronization pulses to define data fields.

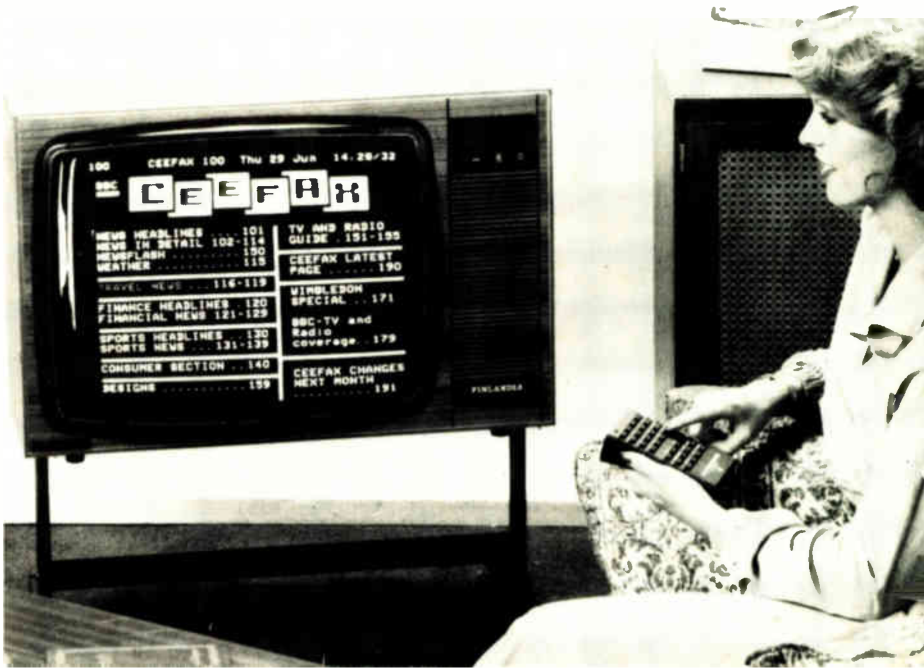
Those arguments have persuaded broadcasters in Sweden and in West Germany to give the UK system a try. The Swedish Broadcasting Corp. will start a $500,000 trial this spring; it will involve some 200 receivers and the pages will consist of subtitles for the deaf on regular programs.

German trial. Though still unsure who eventually will control the service in West Germany—the post office or the broadcasters—broadcasters will stage a big teletext trial during the West Berlin radio and television show in August. This will be followed starting in early 1980 with a tryout involving several thousand viewers in Dusseldorf.

The French counter that because their system came later, it has a more comprehensive design. "The UK system was conceived by television people. Antiope was conceived by computer people working with television people," says Jean Guillermin, president of Sofratev (Société Française d'Etudes et de Réalisations d'Equipments de Radiodiffusion et de Télévision), a company set up by the government-controlled broadcasting organization Télévision de France (TDF) to sell radio and TV technology abroad.

Antiope (L'Acquisition Numérique et Télévisualisation d'Images Organisées en Pages d'Ecriture) was worked out at a joint research center set up at Rennes by TDF and the Secretariat d'Etat aux Postes et Télécommunications (PTT), which

Getting the picture. British teletext system, shown here in its British Broadcasting Co. version, which is called Ceefax, uses television synch pulses to define its data fields.



has telephone services under its wing. The researchers made Antiope different in two significant ways from the predecessor British systems, called Ceefax by the British Broadcasting Corp. and Oracle by the Independent Broadcasting Authority [*Electronics*, Feb. 5, 1976, p. 68].

For one thing, the British system transmits a 40-character row of teletext during the 50 microseconds it takes to transmit one television line. The French system is asynchronous, with no row/line correspondence. For the second thing, Antiope has 16-bit coding for each alphanumeric element, compared with 8 bits for the British system. "We can work with smaller video bandwidths," Guillermin maintains, "and even adapt the frequency to avoid interference by multipath transmission."

For the U. S. trial, then, adapting Antiope to the National Television Standards Committee (NTSC) video bandwidth of 4.2 megahertz from the 5-MHz bandwidth common for Europe was fairly simple: the number of 40-character rows per page was cut back to 20 from 24 by reprogramming the control microprocessor. The UK hardware suppliers, in contrast, had to cut the character count per row to 32 and the number of rows to 20 as well.

Need for LSI. Like most people in the business, Brema's Jones is convinced that decoders based on large-scale integrated (LSI) custom chips are essential to open mass markets to teletext and to Viewdata, the service that ties TV sets to computer data banks through telephone lines. (The British post office, which pioneered Viewdata and now calls it Prestel, has an extensive trial under way. Public service is to start this year backed by $200 million for five years.) Texas Instruments, GEC Semiconductors Ltd., Mullard Ltd. of the Philips Gloeilampenfabrieken group, and Motorola Semiconductor all have decoder chip sets on the market; General Instrument Microelectronics Ltd. is weeks from announcing its set, and Motorola Semiconductor is farther down the pike. Their goal is chip kits that would make decoder-equipped TV sets cost something like $200 more than regular sets.

The R&D tab is high and going higher. For a Viewdata trial in Canada, GEC Semiconductors reworked the line and row counters on one chip of its teletext/Viewdata decoder to shift to a 32-character, 20-row format. GEC managed to do the rework in just four weeks, reports managing director Chris Turner. But since a 40-character row will probably become standard for both teletext and Viewdata, UK decoder makers are looking for other ways around the bandwidth limitation. Gerald Crowther, who heads up Viewdata and teletext development at the Mitcham laboratories of Mullard, says one possibility is to send the first 20 characters for a row on one line and the second 20 on the succeeding line. Mullard is working on this concept together with Signetics Corp., also in the Philips group.

Costs. The French, too, are sure that they will succeed only if they can hold the line on decoder costs. Says Guillermin, "We hope to set the added cost for a system board and controller for a TV set between 400 and 500 francs [roughly $95 to $115] by late 1981." To get the figure that low means custom chips, so Guillermin sees less sophisticated decoders costing about 2,500 francs (roughly $590) for the interim.

The UK semiconductor houses still have not had a substantial return from their heavy investment in decoder chips. That, not surprisingly, has made their French counterparts wary of developing decoders on their own. So the joint TDF/PTT research center in Rennes, the Centre Common d'Etudes de Télévision et de Télécommunications (CCETT), has set three semiconductor producers in France to work on chip sets.

The three companies doing the work are Efcis, jointly owned by Thomson-CSF and the French atomic energy agency; RTC-La Radiotechnique-Compélec, a components-producing unit of the Philips group; and Texas Instruments. Each of the three has its individual approach, but the system dictates a common sectioning for the decoder—an acquisition unit to extract the digital data from the broadcast (or telephone modem), a microcomputer to process the data and store the pages, and a display driver. ☐

Programmables excite pacer firms

Longer-life batteries and LSI circuits have led to pacemakers that last 10 years and cost up to $2,500

by Larry Marion, Chicago bureau

Large-scale integration and other state-of-the-art electronic technologies have spawned a whole new generation of cardiac pacemakers. The industry, which totals $300 million per year worldwide, turned to upgrading electronic circuitry after licking reliability and power-supply problems in the mid-1970s. Almost a score of new models have been introduced in this past year with a variety of programmable functions that allow doctors to tailor the devices to individual needs.

"There's been an explosion of programmable pacemakers and all the manufacturers are jumping on the bandwagon," says Richard Reis of the Federal Food and Drug Administration in Washington, D. C., the agency responsible for regulating the design, manufacture, and use of pacemakers and other medical devices.

Allowing for change. Part of the reason for making pacers programmable was the need to adjust to recent improvements in operating life. Longer-life lithium-oxide batteries have been substituted for mercury-zinc, and better hermetic sealing now prevents moisture from shorting out pacer circuits. Because the power lasts five years or more, the change in a patient's condition likely to occur in that time calls for pacer adjustability. Physicians want units with, for example, pulse-generating sequences that may be varied to coincide more closely with the changing needs of the patient.

Although programmable pacemakers were first developed a decade ago, early units were cumbersome, concedes George M. Heenan, senior vice president of Medtronic Inc., the Minneapolis-based giant in the industry. Also, the large number of discrete components and their big power drain led to a bulky package with a short lifespan, and doctors shunned them.

Physicians receptive. But the new pacers are very popular. Dr. W. Gerald Rainer, a Denver, Colo., cardiac surgeon, reports: "When I first looked at the programmable pacer, I thought 2% to 3% of my patients would need them. But now 60% of my new implants receive them." Some surgeons will put in a programmable pacer costing $200 to $300 more than a standard unit simply for its future value to a patient whose condition may change.

About 10 firms now market pacers that can be programmed for a variety of pulse rates and widths. Some also sense and respond automatically to heart malfunctions.

At the core of the new units, which cost $2,200 to $2,500, are complementary metal oxide semiconductors on a hybrid substrate. Medtronic, Cardiac Pacemakers Inc. of St. Paul, Minn., ARCO Medical Products Co. of Leechburg, Pa., and Intermedics Inc. of Freeport, Texas, all have reduced the number of separate components to about two dozen. This is less than half the number used in older fixed-pulse-rate devices and a tenth of the number in the earlier programmable units. Furthermore, reducing pulse parameters to the exact level needed by the patient has doubled estimated pacemaker lifetimes again—to 10 years or more, notes David J. Fischer, manager of pulse generator development and applications at Cardiac Pacemakers.

Although the models vary, they operate similarly. To reprogram the device after implantation, a physician would enter a new pulse rate or width using an external controller that transmits the new information to the pacer in digital form modulated on a radio-frequency carrier. A pickup coil or a reed switch inside the pacer receives the signal, and a logic or rectifier-capacitor circuit decodes the signal and changes the characteristics of the pacemaker's output pulse.

The new ARCO programmable pacemaker now undergoing clinical investigation features 8 pulse frequency choices, 8 pulse energy (amplitude and duration) choices,

Needler. Medtronic senior vice president George Heenan with needle used to program the first programmable pacemaker.

plus 12 sensitivity settings for responding to ventricular contractions (R-waves). The last parameter is only offered on the ARCO unit; combined with the other two pulse parameters it yields 448 meaningful programming possibilities. The pacers can be made to compensate for things like heart rate changes, impedance buildup at the heart-lead interface, and diminishing sensitivity to R-waves due to body–pacer impedance mismatches.

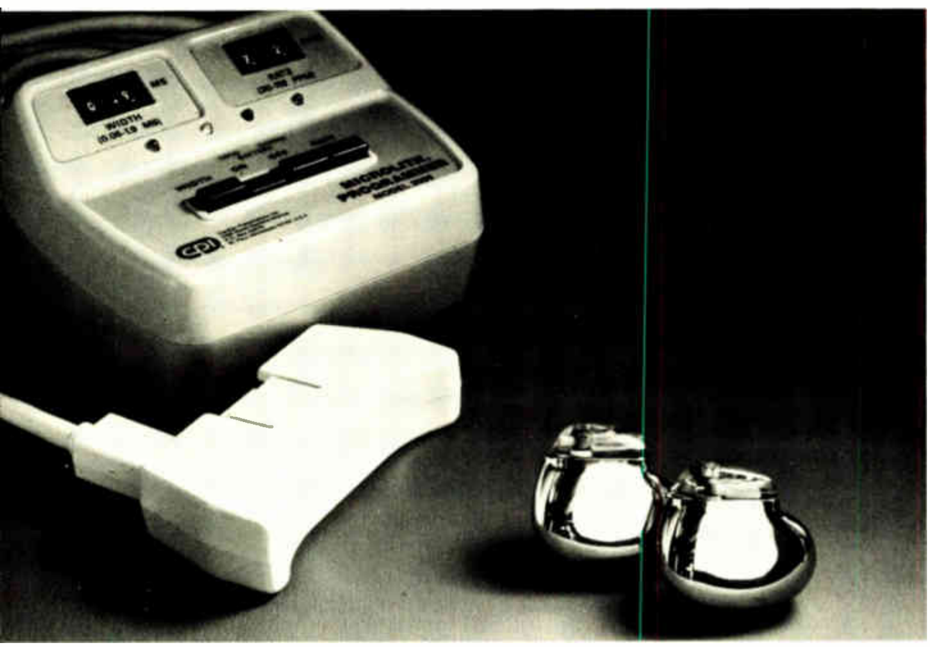
Chambers sequenced. The models being readied for introduction later this year are even more versatile. The FDA recently gave preliminary approval to Medtronic's Byrel model, which senses and paces both chambers of the heart in sequence. Heenan says the device will increase blood flow about 25%, "and will be the only one in the world with programmable rate and timing."

Again using a C-MOS logic circuit, many discrete transistors, and other digital components on a hybrid substrate, the Byrel "is basically two pacemakers with a timing and logic circuit between them," explains Whitney A. McFarlin, vice president for pacing products at Medtronic. The dual-chamber pacer is heavy and bulky by current standards. It weighs 135 grams and has 110 components, several times the number in standard one-chamber units. To reprogram the Byrel, the external controller transmits a 15-millisecond pulse on a 150-kilohertz carrier.

Multifunction. Though the Byrel was mainly a packaging challenge to Medtronic, its new Spectrax multifunction programmable unit is its most complex electronics package. Two custom ICs, one a C-MOS chip for logic, signal decoding, and memory, the other a linear IC for battery monitoring and heart-chamber sensing, enable physicians to reprogram five functions, explains Ted Adams, manager of product development. In addition to pulse width and rate variability, the Spectrax can be changed from pulse on demand to continuous pulse, and it can alter the timing of the pacer's sensing circuitry.

The fifth function adapts its output to a heart with a widely fluctuating natural pulse rate: if the heart slows below a preset rate, the pacer will automatically take over and gradually increase the heart rate until it reaches a safe clip. The Spectrax also has fewer parts—15—and weighs less—43 grams—than any other programmable or fixed-rate unit on the market, Adams says. Other manufacturers, including Intermedics, are clinically testing their versions of a multiprogrammable pacer like the Spectrax. □

Complete set. Small, shiny objects are pacemakers; the controller with which they are programmed is at left. Called the Microlith-P, the unit is from Cardiac Pacemakers Inc.



Companies

Offshore subcontractors boom

One independent operator, Interlek/Dynetics, links West Coast office with Manila plant to offer fast turnaround, high volume

by William F. Arnold, San Fancisco region bureau manager

Even though most big electronics companies are international enterprises, when business is booming as it is now they turn to another offshore production—that of independent subassemblers who contract to package a variety of high-volume parts, often on short notice.

Without these subcontractors, electronics industries would be even more production-limited than they now claim to be. In fact, the subcontractors are so much in demand that it's not unusual for one to package the same type of part, such as a dynamic random access memory, for competing semiconductor makers. Moreover, these plants assemble devices—including up-to-date memories, microprocessor parts, and tone generators—in a variety of packages from ceramic and Cerdip to plastic and from 8 to 40 leads. Nor are these subcontractors, which dot regions of Hong Kong, the Philippines, Singapore, South Korea, and Taiwan, necessarily small operations. Interlek/Dynetics Inc., for example, has a 100,000-square-foot plant in Manila cranking out close to 500,000 units a day, a figure it expects to double next year.

Taking a close look. Workers at Interlek's assembly plant in the Philippines inspect some of 500,000 devices made each day.

"I view these services as necessary for flexibility," declares the manufacturing vice president of a leading electronics company who prefers to remain anonymous. The subcontractors offer short turnaround and capital savings, he says. Agreeing, another electronics vice president also declares that, because the independents deliver high-quality parts, "we would use them in good times and bad."

The latter was referring specifically to Interlek/Dynetics, which he says provides "excellent" service—high yields, good delivery, and reasonable prices. "No one has the support they do," he says. What he means is that the company is unusual for an offshore independent in that it not only has a Manila plant employing 5,000 workers, but also a liasion office with 30 persons, including six engineers, in San Mateo, Calif., just north of Silicon Valley. Other offshore independents have salespersons who report to the factory, acting, however, more like a combination of freight forwarder and order taker, declares Jacob Ratinoff, who is president of Interlek, a California corporation, and chairman of the affiliated Dynetics, a Philippines corporation. "The U. S. side here keeps us in tune with the industry," he says.

Quick response. The aim is quick response because "moving fast is one of our advantages over everybody else," Ratinoff states. For fast action, the two far-flung operations are connected by five leased teletypewriter lines, two on a 24-hour basis, and an international facsimile link. To process and analyze communications, the San Mateo end has an NCR 8250 computer, six cathode-ray-tube terminals, and 20 million bytes of on-line memory, matched on the Philippines end by an equivalent NCR 8250 and two CRTs.

Every morning, Ratinoff says, he and his staff monitor 40 meters of teletypewriter copy from the Philippines plant containing yield, shipment, and inventory information on each of its products. When a problem occurs, Interlek tells the customer and the resulting solution goes back to the plant via teletypewriter, facsimile, or—if need be—by plane.

By "quick turnaround," Interlek means delivery of 500,000 assembled parts in six to eight weeks, Ratinoff explains. Ninety percent of Dynetics' three-shift production is in medium- and large-scale integrated circuits; the rest is split between watch modules and hybrids. Dynetics has packaged all the popular density random-access memory parts and expects soon to be assembling 64-K

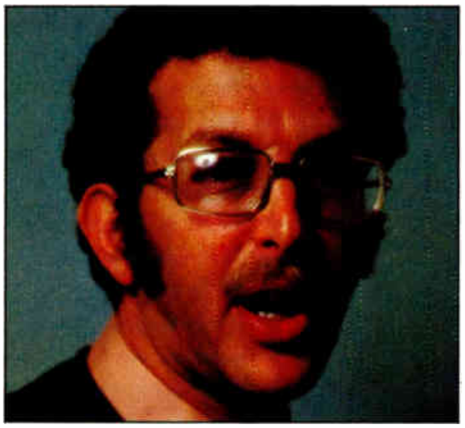
Quick reactions. Jacob Ratinoff, president of Interlek, says his firm's advantage is fast response to customers' requirements.

versions as well, among others. More than half of the top 50 U.S. electronics companies have used Interlek/Dynetics' services.

"Our goal is to run at the industry's speed," Ratinoff says. He may be exceeding it, because his operation has doubled in size each of the past few years to reach $30 million this year. Naturally, it expects to double again next year. To keep pace, he is spending a "few million dollars" on automated bonders, trimmers, markers, and the like, often acquiring them quickly by paying cash. "We're the most sophisticated subassembly operation in the world," he boasts.

That's a far cry from the picture in 1973 when Ratinoff, a successful insurance and real estate entrepreneur, co-founded Interlek/Dynetics. The boom was on then, he recalls, and the operation quickly expanded from 10,000 to 40,000 square feet—just in time to lose "a couple of million dollars in 90 days" on light-emitting-diode watches when the market bombed during the 1974–75 downturn. Ratinoff says he's seen profits since mid-1975.

The future. Although the track record is impressive, time will tell whether it will continue. Interlek staffers say that industry's attitude is changing and that "now people are penciling us into their long-range plans." But one electronics vice president is not so sure. "They could get caught in a real pinch when the economy goes down," he says. However, another points out that it's in the industry's own interest to keep Interlek/Dynetics in business. □



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Where other systems require scores of individually typed instructions, the Starplex System can do the same job at one stroke of a key.

Where other systems offer you blood, sweat, and repetition, the Starplex System offers HELP, PAUSE, EDIT, DEBUG, CONTINUE. To name a few of the unique functions on our keypad.

Where other systems leave you fumbling

	STARPLEX	INTEL	TEKTRONIX
SIMPLE KEYSTROKE CONTROLS	EDITOR SYSTEM UTILITIES	NONE	NONE
SYSTEM OPERATING MODES	FORMS OR COMMAND DRIVEN	COMMAND DRIVEN ONLY	COMMAND DRIVEN ONLY
CRT-ORIENTED EDITOR	YES	NO	NO
HIGH LEVEL LANGUAGES	2	2	NONE
ISE CAPABILITY	MULTI-PROCESSOR	SINGLE PROCESSOR	SINGLE PROCESSOR
PROM PROGRAMMER	INTEGRATED OPTION	SEPARATE	SEPARATE
PRINTER	STANDARD	OPTIONAL	OPTIONAL
TOTAL PRICE (Exclusive of PROM Programmer and ISE)	$13,800	$21,870	$21,230

through thick manuals looking for escape clauses, the Starplex System guides you through your work path with a series of menus, prompts, lights, and audible signals.

And while some systems can communicate only in assembly, ours is fluent in BASIC and FORTRAN. Languages which can be loaded — as usual — with one keystroke.

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do not hesitate to publish here a comparison chart which will show at a glance where things really stand.

The Starplex System is designed to be used with current and future National microprocessors, as well as BLC/SBC Series/80 microcomputers.

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All the software you'll need is included in the package. A powerful operating system, macro assemblers, editor, debugger, and other key software modules.

We also offer the In-System Emulator (ISE), an extremely valuable option for hardware development. It works through an easily understood command interface. ISE uses its own memory for memory mapping — a time-saving feature which also allows true real-time debugging.

Because Starplex ISE incorporates symbolic debugging, you can debug code in the same assembly mnemonics in which it was written. And it's the only system emulator capable of debugging two microprocessors simultaneously in a multi-processor system.

By any standard of comparison, the Starplex Development System represents a colossal leap-frog over the field in every category, save one: Price. And so, while others ask in excess of $20,000 for the privilege of unnecessary toil, our price is just $13,800. On the theory that not only is less more, but more should cost less.

We would jump at the chance to tell you the whole story in detail. Write or call me for a complete brochure on the Starplex Development System. Address your request to Mark Levi, General Manager, Microcomputer Systems, National Semiconductor Corporation, Drawer 34, 2900 Semiconductor Drive, Santa Clara, California 95051. Or dial these toll-free numbers: 800-538-1866; 800-672-1811 in California.

In Europe, write National Semiconductor GmbH, Industriestrasse 10, 8080 Fuerstenfeldbruck, West Germany."

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Transmitting data by satellite calls for special signal handling

Long distances, limited carrier power, mixed kinds of noise, affect choice of multiplexing, modulation, and coding techniques

by Harvey T. Hindin, *Communications & Microwave Editor*

☐ When all the highly publicized satellite systems for digital data handling finally go into full operation, they will be able to handle just about any kind of signal that comes their way—digitized voice, facsimile, and television, as well as data. They will be brilliant proof of the validity of signal processing theory developed carefully over the years and difficult for the nonspecialist to understand in detail.

However, more and more nonspecialists will become involved with the technology, either as users, who need to make intelligent buying decisions, or peripherally, as suppliers of related communications, satellite, and satellite-link equipment. For their purposes, the principles of digital signal processing can be set forth simply. They concern multiplexing, modulation, and coding, their interrelationships, and subsequent effects on bit rate, bandwidth, and signal-to-noise ratio.

The suppliers of the new data handling systems are listed in "Who's who in satellite communications" on page 92, the many services available in the table on page 94. When the high-speed options become available, the already flourishing market in data communications is expected to grow still faster. The demand will boom as

Who's who in satellite communications

American Satellite Corp., Germantown, Md.
- is only carrier without its own satellite
- leases transponders from Western Union and RCA
- specializes in data services from low speed to 56 kb/s

American Telephone & Telegraph Co., New York, N. Y.
- cannot legally own satellites at present, but decision will be reviewed by FCC in July 1979
- uses Comstar satellites courtesy of Comsat
- has proposed Advanced Communications Service for data transmission (might use Comstar replacement)
- will compete with IBM's Satellite Broadcasting System and Xerox's XTEN if ACS is allowed
- provides various data services now through telephone connections

Communications Satellite Corp., Washington, D. C.
- handles international U. S. communications by satellite
- provides voice and data services
- owns Comstar and Marisat systems

Comsat General Corp. (subsidiary of Communications Satellite Corp.), Washington, D. C.
- provides AT&T and GTE with FDM Comstar satellites
- provides international maritime service with Marisat
- owns 42.5% of Satellite Business Systems (service due in 1980)

Intelsat Corp.,Washington, D. C.
- operates international communications satellites
- handles traffic between countries globally
- is known as a carrier's carrier

RCA American Communications Inc., Piscataway, N. J.
- provides broadcast, Government, and commercial services on two TDM Satcom satellites, with a third to be added later
- offers voice, data, and TV services—mostly cable TV
- supplies Canada's Telesat with Anik B satellites

Satellite Business Systems, McLean, Va.
- will start its service for high-capacity users in 1980
- owned by IBM Corp., Comsat General Corp., and Aetna Insurance Corp.
- will directly compete with AT&T's ACS and Xerox's XTEN service
- will handle voice, data, and television in a TDM approach at 14/12 GHz

Telesat Canada, Ottawa, Canada
- is a joint Canadian government-industry venture
- operates 4 Anik satellites at 6/4 GHz
- handles voice, television, and data
- will offer 14/12-GHz digital data service

Western Union Telegraph Co., Upper Saddle River, N. J.
- flies two Westar satellites providing voice, television, and data channels
- will launch a Tracking and Data-Relay Satellite System (TDRSS) in cooperation with the National Space and Aeronautics Administration for voice and data
- will use four satellites for TDRSS having 6/4-GHz and 14/12-GHz capability with TDM

Xerox Corp., Stamford, Conn.
- has proposed XTEN service that will compete with ACS and with SBS
- will use local microwave links to earth stations
- will lease transponder space
- will provide data services of all kinds

soon as people see just what can be done economically, explains Philip N. Whittaker, president of Satellite Broadcasting Systems, exclaiming parenthetically, "Who needed the car before it was invented?"

At the heart of all of the digital data services is the question of packaging the data, so that it can be transmitted efficiently. Proper packaging requires the choice of a multiplexing scheme before any other consideration.

Data multiplexing

The efficiency of a satellite-based communications system—that is, the measure of how much data can be transmitted, how accurately, and for how long—depends to a large extent on the multiplexing technique chosen. No practical design is possible until there is a method for combining multiple users into one bigger channel.

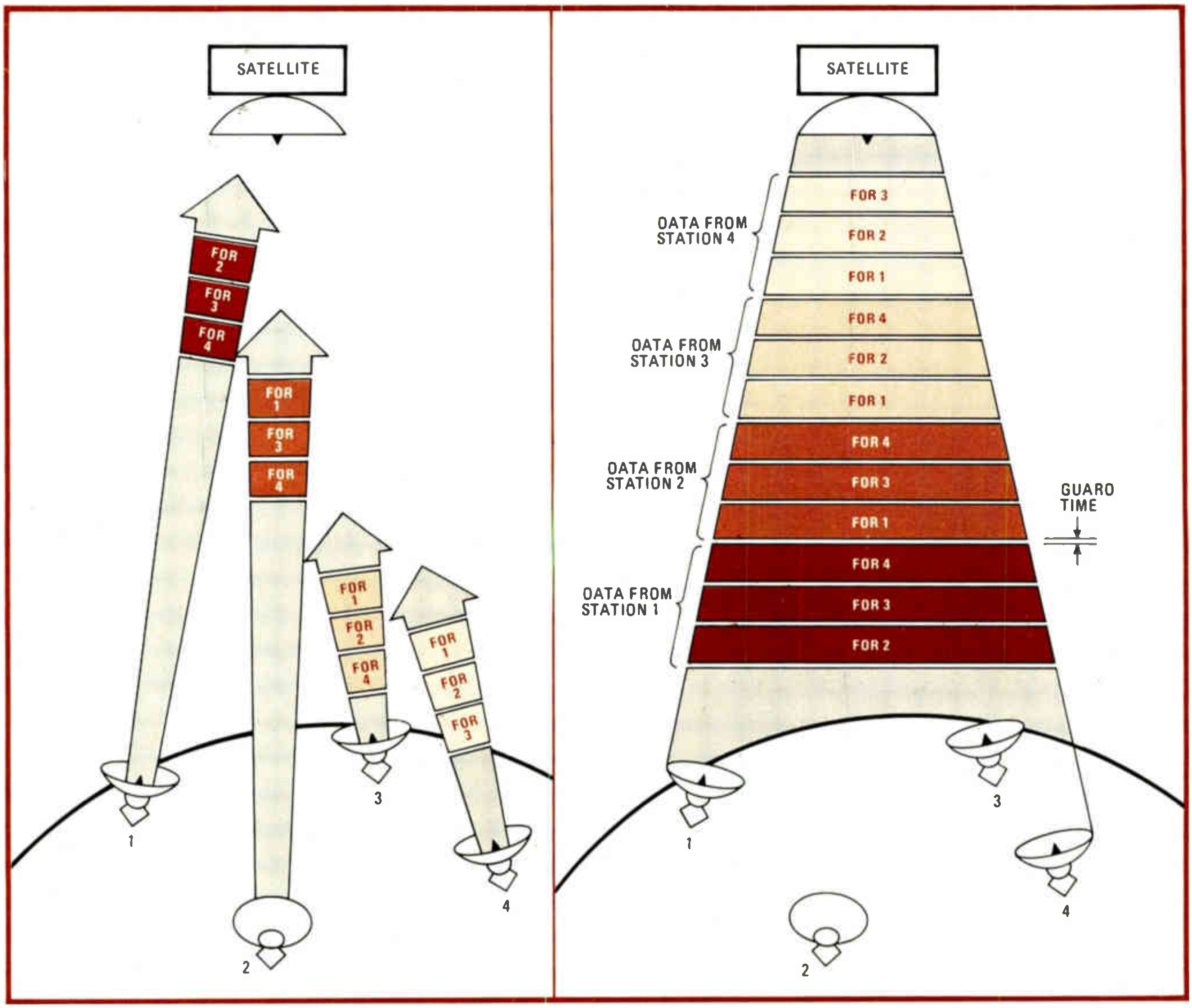
The two possibilities are frequency-division multiplexing (FDM) and time-division multiplexing (TDM) (Fig. 1). For future digital systems, TDM is a natural choice. For one thing, it makes more efficient use than FDM of the channel bandwidth that determines channel capacity. Requiring only a single carrier, TDM can allot the entire available bandwidth to a single channel, whereas FDM shares the bandwidth among several parallel channels and for this reason has to waste some of it on preventing interference between adjacent channels.

The case for TDM is further strengthened by the availability of digital large-scale integrated circuits. These make it economical to build dedicated data terminals, as Eugene R. Cacciamani, vice president (technical) of American Satellite Corp., is quick to point out. "Our whole satellite system is going digital," he says.

There is a third advantage. "Voice, data, facsimile, and television signals may be efficiently combined for transmission using TDM after changing the analog signals to digital form," says Burton I. Edelson, assistant vice president and director of Comsat Laboratories in Clarksburg, Md. TDM is also particularly suitable for the latest satellite data-transmission technique, packet switching (see "Pick a packet," p. 95).

In a typical TDM system, many earth stations link up with the same satellite transponder, which is used exclusively by a single specified carrier during a specified time slot. At any one time the transponder output amplifier may therefore be operated at saturation or in a nonlinear mode with the most power output it can deliver. Since there are no adjacent frequency channels, there are no intermodulation or crosstalk problems.

Though TDM is efficient in terms of bandwidth, the price paid for this efficiency is synchronization problems.



1. Time-division multiplexing. The signal from an earth station is a set of bursts of digital data with coded addresses to particular receiving stations. Each burst has a synchronized time slot, so that interference is not a problem. Each receiver reads only properly addressed bursts.

Every pulse must be well synchronized by clock signals so the information of data bursts will come and go when they are supposed to and not interfere with each other. Real-time computing systems using large-scale integrated circuits can do this—but at a price that increases rapidly as data rate increases.

Desirable though TDM is for digital communications, it will take many years to affect the rather substantial present investment in FDM satellite and ground equipment. American Telegraph and Telephone Co. and RCA American Communications, for instance, will still "pay the bills," as one wag at Bell Telephone Laboratories puts it, by transmitting voice and television information via satellite by fm/FDM.

Indeed, many in the U. S. feel that digital TV transmission is a long way off. "For TV transmission," says Bernard Mirowsky, manager of advanced technology for RCA American Communications, "the cost plus the technology of fm/FDM is up to the job." It also appears that analog techniques provide a certain subjective picture quality that broadcasters appreciate. However, digital TV will ultimately be accepted, he feels.

If TDM has failed to evolve fast in the U. S.—the first theoretical discussions were some 20 years ago—the same is not true of Canada. For example, it converted Telesat's FDM message service to TDM over two and one-half years ago. As is typical in such conversions, the TDM terminal equipment was designed to integrate smoothly into the fm/FDM, intermediate-frequency, radio-frequency, and baseband equipment.

Modulation

The older FDM system had a capacity of 240 duplex voice circuits. The digital setup has the equivalent of 400 such circuits, providing a 61-megabit-per-second signal with quaternary phase-shift-keying modulation. The knowledge gained from it will be extremely useful in Telesat's 91-Mb/s digital system for the forthcoming Anik C satellite.

The outputs of most data-generating machines are baseband signals made up of direct-current components that cannot be transmitted through a satellite link. These

PROPOSED NEW SATELLITE DATA SERVICES	
Direct television broadcast	TV broadcasts directly from satellite to roof-mounted antennas
Video conferencing	Multiple locations connected on demand with television signals
Videophone	Individual telephones equipped with video screens
High-speed computer links	Wideband computer-to-computer links permitting rapid exchange of large volumes of data
High-speed facsimile	Transmission of documents or pictures at nearly instantaneous speed
Mobile marine aeronautical	Communications with individual vehicles, ships, aircraft,by satellite
Telemail	Transmission of mail by facsimile between post offices
Telemedicine	Consultations or transfer of records and data on individual patients
Telereference	Central reference service accessible by telecommunications
Electronic shopping	Viewing and selection of merchandise by TV (with automated billing)
Interactive tele-education	Classes on TV, with students able to talk with instructor

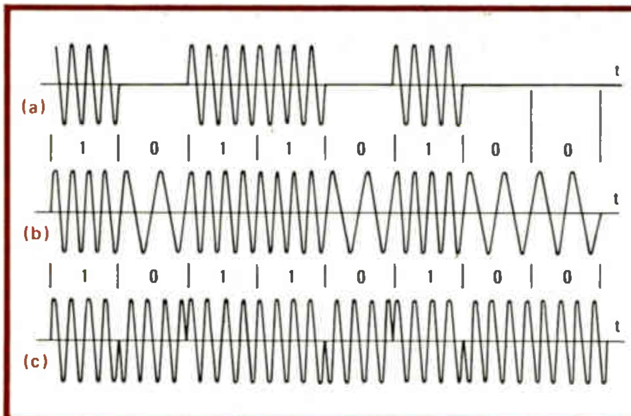
SOURCE: THW

signals must be impressed on a frequency—microwave, in this case—that can pass through the system.

For binary signals, the simplest thing to do is switch the carrier amplitude between two or more values—usually on or off. The resultant amplitude-shift-keyed (ASK) modulated wave then consists of radio-frequency pulses representing binary 1s and spaces representing binary 0s (Fig. 2a). Alternatively the frequency (Fig. 2b) or the phase (Fig. 2c) can be shifted.

Frequency-shift keying (FSK), another simple procedure, is also sometimes used to send digital signals over a TDM system. In this system, a carrier signal is made to alternate between two discrete frequency values. But most common is some form of phase-shift keying.

In a binary PSK system, every shift from a 1 to a 0 or vice versa in the baseband data signal causes a 180° phase shift in the phase of the carrier it was modulating (Fig. 2c). With quaternary (four-phase) modulation, a phase shift of 0°, 90°, 180°, or 270° is applied to the phase



2. Baseband. A series of pulses representing 1s and 0s can modulate a carrier frequency by turning it on or off (a) or shifting its frequency from one value to another (b). It may also cause the signal's phase to shift 180° at every change from 1 to 0 or 0 to 1 (c).

of the carrier. Here each shift represents 2 bits from the sequence to be transmitted. Pairs of binary digits combine four ways (00, 01, 10, or 11), each of which is assigned a corresponding phase value. The transmitted carrier merely shifts phase for each pair of bits, or dibit, in the sequence of message bits.

No limit

There is theoretically no limit to the bit-grouping procedure. Tribit sequences in a message may be similarly set up to phase-modulate a carrier with eight different phase shifts in a 360° range.

According to Wilbur Pritchard, president of Satellite Systems Engineering Corp. in Bethesda, Md., the TDM signal assembly technique may be combined with almost any particular modulation to optimize the transmission qualities of a given system. So, "the user may have a choice of TDMA with binary or quaternary phase-shift keying and so on." For the newest services, like the one proposed by Satellite Broadcasting System for the large industrial users with dedicated earth stations, the trend appears to be toward TDMA/QPSK because it makes efficient use of bandwidth and power and can readily be digitally implemented.

If the bandwidth is the limitation—the commonest satellite occurrence—a binary or quaternary-phase-shift keying scheme is preferable. Such a system can fully utilize the capabilities of an all-digital design since it offers the best tradeoffs between channel capacity, power and equipment complexity.

Perhaps even more than available bandwidth, received carrier power, and cost, error-rate performance is what determines the most appropriate modulation method for a particular digital application, since a high error rate shrinks effective channel capacity. When the satellite data service companies considered all these factors, they mostly selected PSK over either ASK or FSK, in large part because of the low error rate achievable with this form of modulation.

Yet for certain applications, those in which its simplicity and hence inexpensiveness counts, FSK is not to be ignored. For instance, for Comsat Laboratories in Clarksburg, Md., it makes good economic sense on a series of environmental data-collection platforms—essentially antennas linked to a bunch of sensors and transducers—that it is using to transmit unsynchronized bursts of FSK-modulated rf carriers to a data-collection receiving terminal.

Error rate is lower for PSK than for other modulation schemes because for receivers limited mainly by thermal noise—the best possible actual situation—the theoretical lower limit on digital error rate for any modulation scheme depends on how hard it is for that noise to cause one signal to appear to look like another.

This error rate lower limit occurs when there are two signals and they are diametric opposites of each other in phase. This is the case with binary PSK and could not be so with a pair of frequencies in FSK, where the signals are at best orthogonal.

Nevertheless to save on bandwidth, quaternary PSK is often used in preference to BPSK, with an adjustment that makes its error rate equal to that of BPSK. With

Pick a packet

Digital data transmission by satellite packet switching is a natural for the time-division multiplexing approach since it is based on low-duty-cycle bursts of information

Though not yet available commercially through satellites, packet switching is a form of digital communications that is well suited to the unique nature—high data rates put out at random times—of certain computer communications. Simply put, a packet is a collection of data bits—of variable length up to thousands of bits—plus addressing and control information to allow the routing of data through a given network.

All that must be done to put packets in a TDM satellite, says senior scientist Richard Binder of Bolt Beranek & Newman Inc. of Cambridge, Mass., is to attach "packet header information to each burst. This adds a small extra overhead to that already required for frame and phase acquisition but permits switching functions to be readily established. Each station must only monitor the downlink traffic for the proper header to reliably determine which traffic to accept."

Binder and his colleagues Irwin M. Jacobs, president, and Estil V. Hoversten, vice president of development, Linkabit Corp. in San Diego, Calif., all agree that "the technology has significant promise for providing for a variety of data services and it will be be used for at least some applications in the 1980s."

Because of the flexibility of system packet switching, the military originally conceived of it as a method to insure survivability of their data transmissions. Moreover, data encryption is readily achievable.

Some packet experiments have already been performed, with others in the offing. The Atlantic Packet Satellite Program organized by Bolt Beranek & Newman and Linkabit is typical. It used the facilities of Intelsat 4 to hook up earth stations in West Virginia, Sweden, England, and Maryland with Arpanet, the U. S. Defense Advanced Reserch Project Agency's computer-controlled data network. In this experiment, a computer control at each earth station switched the satellite channels. A 38-kilohertz channel on Intelsat was used for the link.

The program lasted four years and while much data concerning operational problems was obtained, perhaps the most interesting from a practical point of view was the final experiment. This experiment made use of 32-kilobit modulations and demodulation for burst acquisition and processing of both binary and quaternary phase-shift-keyed-modulated signals. Of great interest also for the ultimate cost-effective communications link of the future was the fact that the Maryland site was unmanned and linked into the system only through the satellite.

Many questions must be answered before data transmission by packet switching through satellites becomes a reality. Not the least of these is the cost problem. The Atlantic experiment has shown that the concept is feasible but the cost of interfacing and processing—especially at high data rates—is still an unknown quantity.

As a result of the work done to date, a wideband link experiment will be carried out. With this system, a domestic satellite communications carrier will provide a digital packet link at up to a 3-megabit-per-second rate.

QPSK, 2 bits of information are conveyed in a pulse that would carry only 1 bit of information with BPSK. But for equal bit rates, and equal received carrier power, the QPSK signals are twice as long as BPSK signals and contain twice the energy. This increased signal energy exactly compensates for the performance loss due to using 90° rather than 180° signals.

The relative performance of different phase-modulation schemes is characterized by what are known as "signal space" diagrams that show the carrier phase of the signals (Fig. 3).

The diagrams are drawn for a fixed ratio of E_b/N_o where E_b (watts per bit per second) represents average signal energy per received bit and N_o (watts per hertz) is noise power spectral density. Because of this normalization, the signal vectors, considered to be voltages, are larger by virtue of the multiple information bits and greater amount of energy they contain per waveform.

Each PSK modulation implies a carrier bandwidth expansion factor, B_E. The higher the number of signal levels, the smaller is B_E but the greater the vulnerability to noise. The actual bandwidth required is equal to the transmission rate in bits per second divided by the bandwidth expansion factor. In rare cases eight-phase PSK may be dictated by bandwidth considerations, despite its high error rate and the difficulty and expense involved in implementing it.

A variation of QPSK, dubbed OKQPSK for offset-keyed quadrature phase-shift keying, may further reduce bit error rate. It is available, for example, as a switch-selectable option on the 120-Mb/s modulator-demodulator built by Spar Technology Ltd. of Quebec, Canada, and sold to providers of satellite digital service.

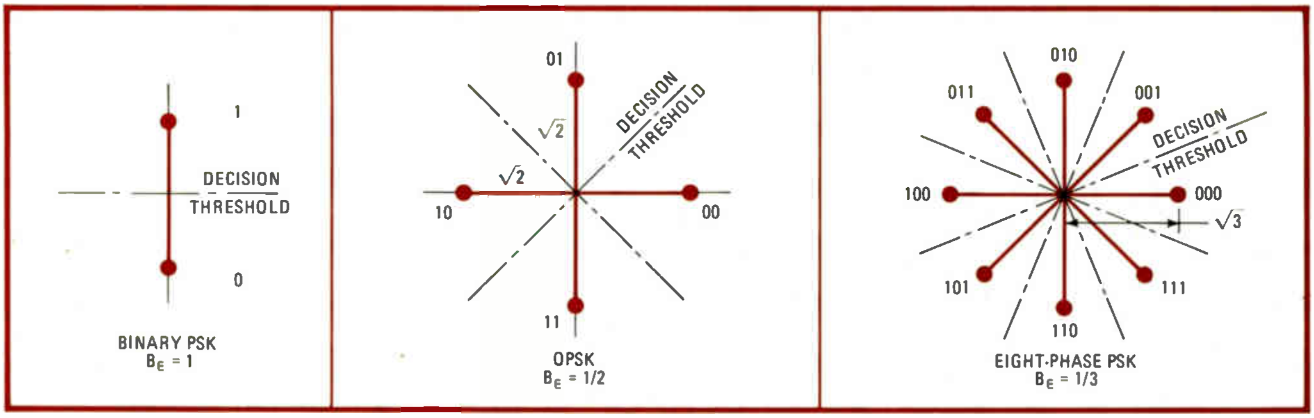
In contrast, the modem being built by Fujitsu Ltd. and Harris Corp., Cleveland, Ohio, for Satellite Broadcasting System's TDM system will be straight—not offset—QPSK, says SBS's assistant director of engineering, William G. Schmidt. SBS concluded on the basis of several studies that the improvements due to OKQPSK were not cost-effective. The SBS modulators were designed—probably for the first time—to conform to a computer simulation of the path from earth station up to satellite and back down to earth station rather than an arbitrary set of fixed specifications, Schmidt says. This will certainly lower their error rate, he notes.

Another typical QPSK modulator is Comsat Labs' 1.544-Mb/s device. This modulator is intended for use in an upcoming international computer-to-computer data link by satellite (Fig. 4).

Controlling error

Errors can be detected and eliminated if bits bearing information are interleaved at intervals with additional bits providing information about the data bits. When these redundant, or parity, bits are analyzed (decoded), it can be determined whether or not an error is present in the information bits. Then a request can be made for retransmission of the faulty portion of the message.

A variety of such forward error correction (FEC) codes exist for distributing various percentages of redundant



3. Signal space. These schematic diagrams represent the relative amplitudes and phases of PSK-modulated signals. The decision threshold lines are boundaries for which a decision must be made by the receiver to determine which particular signal has been received.

bits through the data bit stream. The problem here is the penalty paid in bit overhead. A ¾-rate FEC code, like the one used on Telesat's present 61-Mb/s system, adds 1 redundant bit to every 3 information bits. Similarly, ⅞-rate FEC, like the one to be used by Western Union in its Advanced Westar, according to John Pope, assistant vice president, engineering department, limits the system to 87.75% of its theoretical maximum throughput. Which FEC rate is chosen depends on cost and other system tradeoffs in a complicated manner.

Codes that correct errors as fully as possible must take the nature of the errors into account. For example, errors occurring on the link from earth station to satellite tend to be Gaussian or white noise, whereas those on a terrestrial connection tend to be of the burst kind.

The best procedure in many cases is continuous transmission with FEC combined with a procedure called automatic repeat request. ARQ takes care of the burst type of errors and FEC is best for distributed errors. With these two techniques, the data is transmitted continuously as if there were no possibility of error. But when a large block of data is determined from FEC to be substantially in error, the ARQ interrupts the transmitter and tells it to retransmit that block.

The go-back-n approach is one ARQ technique. Here, when an ARQ is received, the transmitter storage buffer backs up and retransmits all the information starting from the offending block. The alternative is selective-repeat ARQ, in which only the offending block from some time back is retransmitted.

What's taking so long?

That phrase, "some time back," bears examination. A satellite in geostationary orbit is about 36,000 kilometers above the earth's surface. At the speed of light, at which data is transmitted, this altitude causes a time delay of about 250 milliseconds in a one-way connection from earth station to satellite to earth station. For a voice circuit, this creates delay or echo problems that can be treated with echo suppressors or cancellers. But for data transmission, certain echo conditions can severely degrade the efficiency of a data communications protocol like IBM's Bisync [*Electronics*, June 8, 1978, p. 105], which is used by almost every data machine.

This is due, in part, to the fact that such protocols were developed when only terrestrial delays—on the order of 35 milliseconds for a coast-to-coast link—were a matter of concern.

For example, Bisync employs a stop-and-wait technique of error control that automatically requests retransmission when an error is detected.

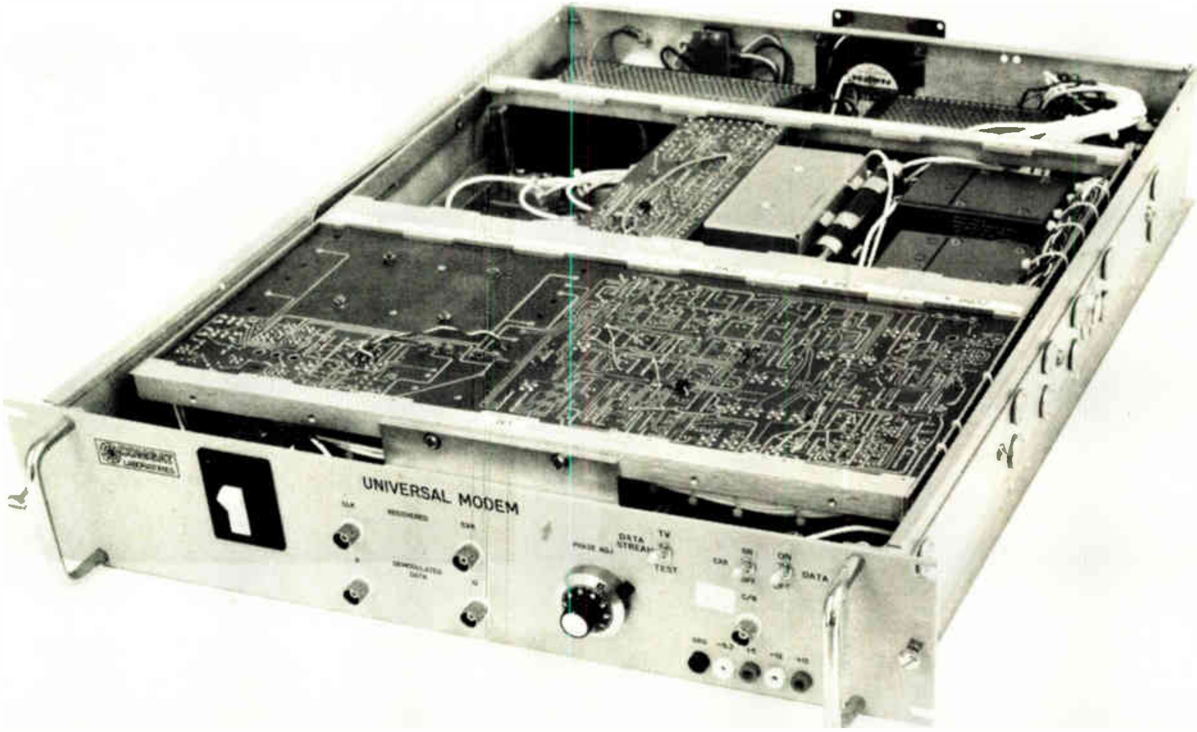
Consider, then, that it may take between half and three quarters of a second for a block of data to travel from earth station to satellite to another earth station, have an error detected, and send back a request to repeat data. Depending on the bit error rate of the system, the amount of retransmission and the time taken may be so drastic as to severely limit the system throughput.

In satellite systems, therefore, ARQ-like functions are performed by satellite delay-compensation units, pieces of hardware that are used when maximum system throughput is necessary and will see more use as data rates and number of satellite users increase. Meanwhile, a more cost-effective solution lies in applying software rather than buying hardware. For example, newer data-transmission protocols such as the Synchronous Data Link Control [*Electronics*, Sept. 14, 1978, p. 175] have been proposed as a Bisync replacement because they are character- rather than bit-oriented and can more readily accommodate satellite delay problems. These protocols are not yet in general use in systems.

A delay compensation unit is simple in principle to construct although its actual implementation in any given situation depends on data and error rates, data block size, and throughput (Fig. 5). It is basically a data-stream controller. When all is well, no ARQ is received and transmission goes on as usual. When either a go-back-n or selective-repeat ARQ is received, the controller turns off the data source. An output is then sent to the satellite from a data buffer acting as a storage unit. This accomplished, the controller turns over control to the data source once again.

The American Satellite Corp. claims that its satellite delay compensation unit, depending on the type of data, doubles or triples a system's throughput. The various forms of the devices can operate up to 56 kb/s.

For the moment, though, not everyone is concerned with delay, and, for many customers, data rates are low enough for it not to be a problem. For example, RCA says that only two or three of its data customers at present



4. Computer to computer. More experiments soon to be performed by Comsat Labs will test computer-to-computer talk at their native channel-to-channel rates. Modulator-demodulators such as the one shown will be necessary at 1.544-megabit-per-second data rates.

worry about delay affecting their throughput.

All methods of coding and decoding data streams are binary in nature. This is due to limited theoretical understanding of nonbinary codes and the difficulty and expense of building digital but nonbinary coding machines. Though, in certain cases, nonbinary coding offers more efficiency, present and foreseeable systems will remain binary. This is so since in a binary code, once it is determined that a bit of information is incorrect, the correct information is known since there are only two possibilities. In a multilevel system, this is not the case.

In any particular system, considerations of data rate, allowable error rate, efficiency, and expense help to determine which coding-decoding scheme is used. Coding may be as crude as a simple look-up table such as is used in parts of the data-encryption standard developed by National Bureau of Standards for encryption of data [*Electronics*, Feb. 15, 1979, p. 81], or coding may follow a specific algorithm.

Parity checking

A typical algorithm is the parity check code. In this code, the encoder accepts a block of k information bits from the data machine and calculates a set of n sums of combinations of these bits and possibly other past information bits. The resultant block of n excess bits, dubbed parity bits, is appended to the k information bits. The code efficiency may be defined as k/n and the higher this number is, the better, in terms of system throughput.

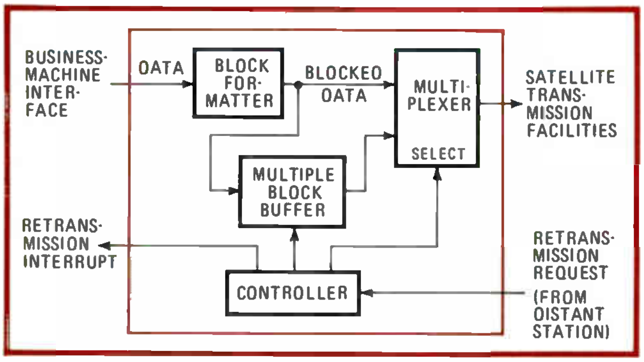
If the parity bits are used to check only the k information bits preceding them in a given block (assuming that information bits are transmitted first, and then parity bits), the code is known as a block code. If the parity bits also check information bits which appear in preceding blocks, the code is dubbed a convolutional code. This latter code is commonly used along with a particularly efficient decoding scheme dubbed the Viterbi algorithm.

Coding and decoding the bit stream in these ways is "a good means of increasing communications efficiency where signal-to-noise ratio is limited," as it is by the limited power of a satellite, points out Anthony S. Acampora, a member of Bell Laboratories' technical staff in Holmdel, N. J. "Power savings of several decibels are readily achievable using simple encoders and decoders," he adds.

To a great extent, these two major classes of codes have the same theoretical capabilities. But the implementation methods for each differ considerably. One may have advantages over another in a given application in terms of equipment cost alone. Thus most satellite coding is convolutional because this is more readily implemented than block codes.

Since all of the block codes or convolutional codes in use in satellite data transmission circuits have a great deal of mathematical structure, they are amenable to to complete analysis using matrixes and number theory. The results tend to be exotic and code comparison is a subject for specialists.

Much study on this subject has been done by John S. Snyder, a member of Comsat Laboratories' technical staff for the TDM Intelsat V satellites. Says Snyder: "Our preferred approach is burst encoding, in which the data sequence in a given time frame, or burst, is encoded as a whole." What's more, he applies FEC universally to all system data bursts. Snyder, however, feels that block coding will become easier in the future with develop-



5. Hold on now. When the receiver decides noise has caused too many mistakes, it may request repetition of one or many blocks of data. The storage buffer reacts to this signal until retransmission is complete. The data machine then takes over again.

ments in large-scale integrated-circuit technology.

Special codes have also been developed which are particularly suitable for correcting random errors or bursts of errors or combinations of the two. The performance of these codes is near theoretical optimum.

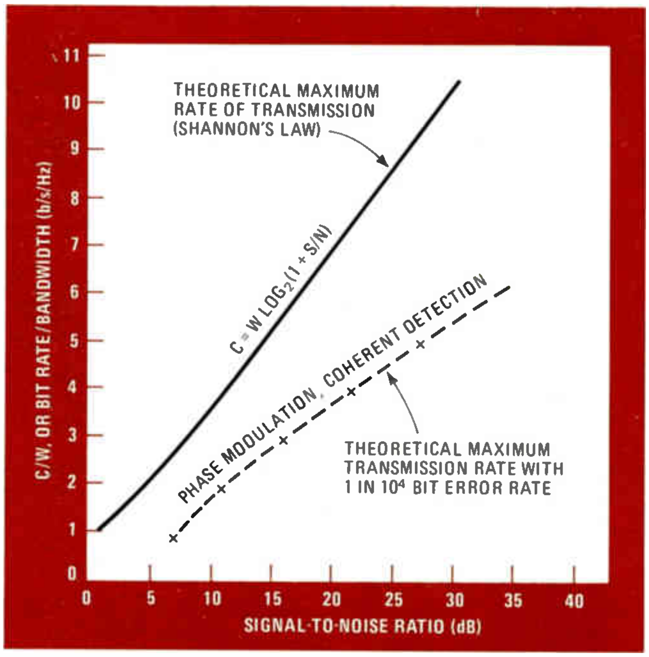
There still is room for equipment makers to improve coding hardware. With the anticipated greater use of packet switching, codes that can deal with correction for losses in synchronization will have to be developed to a greater extent than they now are.

And, perhaps most important of all, from the viewpoint of military and sensitive commercial data, coding for data encryption is on the way. Typical is the equipment provided by American Satellite Corp. Its data encryption device handles serial data on synchronous links and encrypts and decrypts it using the National Bureau of Standards' data encryption standard (DES) algorithm. Among other techniques, RCA and SBS will also offer data encoding. Says John Boning, RCA's vice president, "It's a real market for both commercial and military applications."

Is there a limit?

"The burst transmissions proposed for the Advanced Westar system will operate at up to a 250-Mb/s rate" says Philip Schneider, vice president, satellite systems and services, at Western Union, which is putting up the bird. Western will operate four such satellites in the Tracking and Data Relay Satellite System in cooperation with the National Aeronautics and Space Administration. Two will be for use exclusively by NASA, one exclusively for commercial service, and one will be shared. Not only will TDM be available, but both common rf bands at 6/4 gigahertz and 14/12 GHz will be used with some switching done aboard the satellites instead of at the ground station. Now 250 Mb/s is an exceptionally high rate compared to the 56-kb/s systems considered high now (most systems work is still lower) and leads to the question: is there a bit rate limit for digital modulation?

It turns out that such a limit exists (Fig. 6) and the systems that have been used or proposed do not even come close. The limit is directly calculable, given some assumptions about the operating characteristics of the systems in question. And, though engineers may use all



6. Limits. The various forms of PSK modulation now popular for satellite data communication have far to go before they approach the theoretical channel capacity of a system limited by thermal noise. The limit is set by Shannon's law.

their design ingenuity, any claim to exceed this upper bound (known as the Shannon limit) should be looked upon in the same way as a perpetual motion machine.

Early work in this area was done at Bell Labs by Henry Nyquist, who studied the capacity of a noiseless communications channel—an idealized but useful limiting case. He found that if a number of different voltages or symbols are transmitted, the channel capacity (C in bits per second) is $C = 2W\log_2 L$, where W is the channel bandwidth in hertz and L is the number of distinguishable signal levels.

While this is indeed a finite channel capacity, it is unrealistic, as it does not consider that real channels are noisy. It took another Bell Labs scientist, Claude Shannon, to find a limit for channel capacity under noise some 20 years later in 1948.

Shannon found that with noise present, while the channel capacity is still proportional to the available bandwith, it is not proportional to the base 2 logarithm of the number of signaling levels, but is proportional to the base 2 logarithm of the channel signal-to-noise ratio increased by a factor of one. Or, expressed as an equation $C = W\log_2(1+S/N)$.

There is no way to exceed this rate for the set of parameters and assumptions made. One of these assumptions—that of the nature of the noise—is critical. Shannon assumed that the noise was truly random or "white noise" with equal probability of appearing at any frequency. Shannon's noise assumption was the theoretical minimum he could count on. Even if all external noise and sources of interference were to be removed from the satellite system—and this is an impossible task—the fundamental motion of the atoms in the physical system would still produce white noise. In an actual system, total noise is higher. □

Megabit bubble modules move in on mass storage

Memory boards containing four 256-K bubble chips each form replacement for semiconductor or disk media

by William C. Mavity, *Rockwell International Electronic Devices division, Anaheim, Calif.*

☐ Putting new life into the old saying that good things come in small packages is the RBM256 bubble memory, which stores over 256 kilobits of information on a 1-square-centimeter chip. Designed after extensive consultations with system designers, it will slip into place in applications where semiconductor memory and such storage media as disks are now the standard devices.

The architecture and features of this bubble device help make it an attractive alternative. So do two new boards that together make up a bubble subsystem with more than 1 megabit of storage: a linear module with four of the chips and associated operating circuitry and a programmable control module that governs a number of the linear modules.

The new chip provides all the recognized benefits of bubble-domain technology: small size, low power, nonvolatility, nondestructive readout, and moderate access time. Such memories also boast high reliability due to the complete absence of moving parts, storage density higher than any other type of serial memory, and low cost per bit due to both the high storage density and batch production processing.

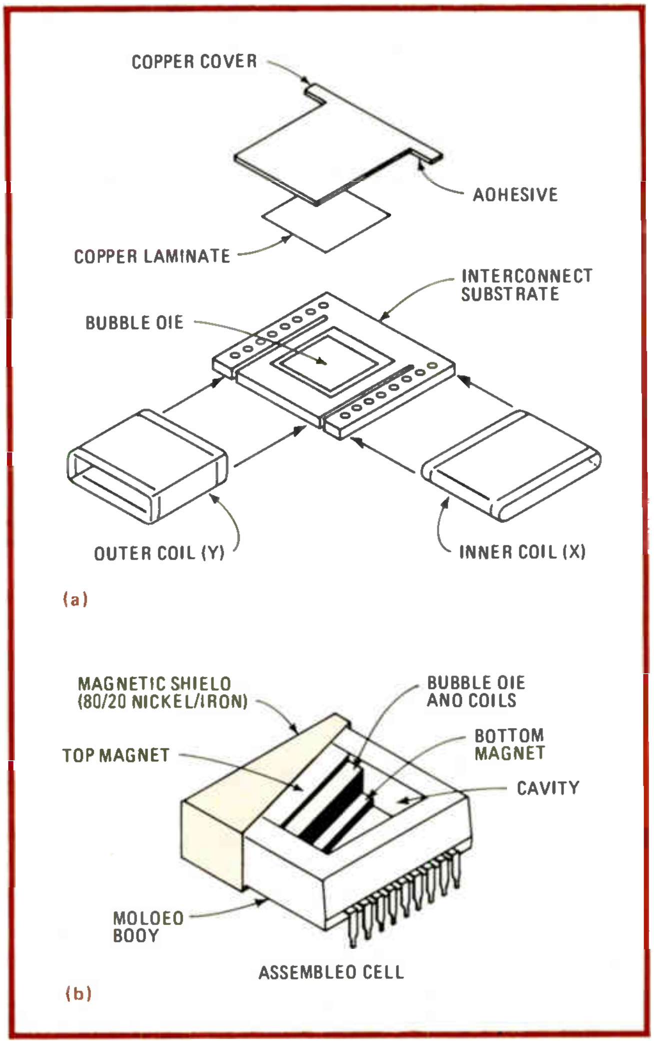
The structure

The RBM256 fits into an 18-pin dual in-line package, 1.2 inches on a side (Fig. 1). Two permanent magnets, one above and one below the cavity containing the chip, provide the magnetic bias field. Between the permanent magnets are two orthogonal coils, X and Y, driven 90° out of phase, with X leading Y to provide a clockwise rotating magnetic field in the plane of the bubble device. This 150-kilohertz magnetic drive field causes the movement of the bubbles one bit position for each 360° of rotation. The coils may be driven continuously or in an intermittent stop-start mode with no data loss.

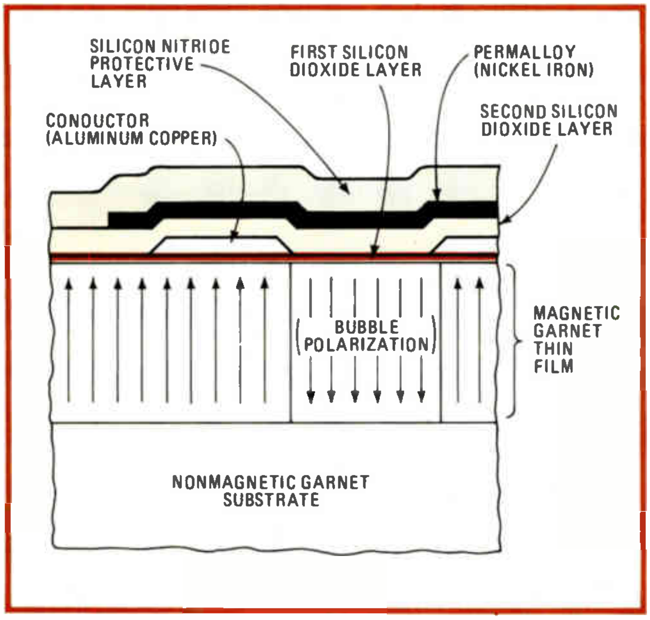
Within the coils is a copper plate that acts as an electrostatic shield for the sense line. It also is an equipotential surface, forcing the magnetic lines of flux to remain parallel to the chip; that is, it insures a uniform magnetic field over the surface. Below the plate, within a cavity, is a substrate holding the chip. The cavity is filled with epoxy when the device and its copper-laminated cover are in place.

Only two precise masks are needed to fabricate the chip (Fig. 2), as opposed to several for silicon memory devices. First come two depositions onto the magnetic film: a thin layer of silicon dioxide to prevent stress on the surface of the thin garnet film, then a layer of aluminum-copper alloy. The first masking step defines conducting paths and loops in the Al-Cu for bubble switching and generation.

Next, a second precise thickness of silicon dioxide is



1. Go-between. The 256-K bubble chip is mounted on an interconnect substrate, covered with a copper plate, and enveloped by two coils of wire. This assembly is then molded into an 18-pin package. The magnets on either side of the chip and coils provide the bias.



2. Two do. The bubbles reside in a thin film of magnetic garnet, which rests on a nonmagnetic substrate. Only two precise masks are needed for the other layers; the first defines paths and loops in the aluminum copper and the second makes chevrons out of Permalloy.

deposited, insulating and spacing a following layer of Permalloy from the garnet surface. The second masking step, on the Permalloy, forms the chevron pattern of tracks defining locations for the bubble propagation and detection. Permalloy is 80% nickel and 20% iron and is easily magnetized and demagnetized. Ion milling defines sharp Permalloy edges.

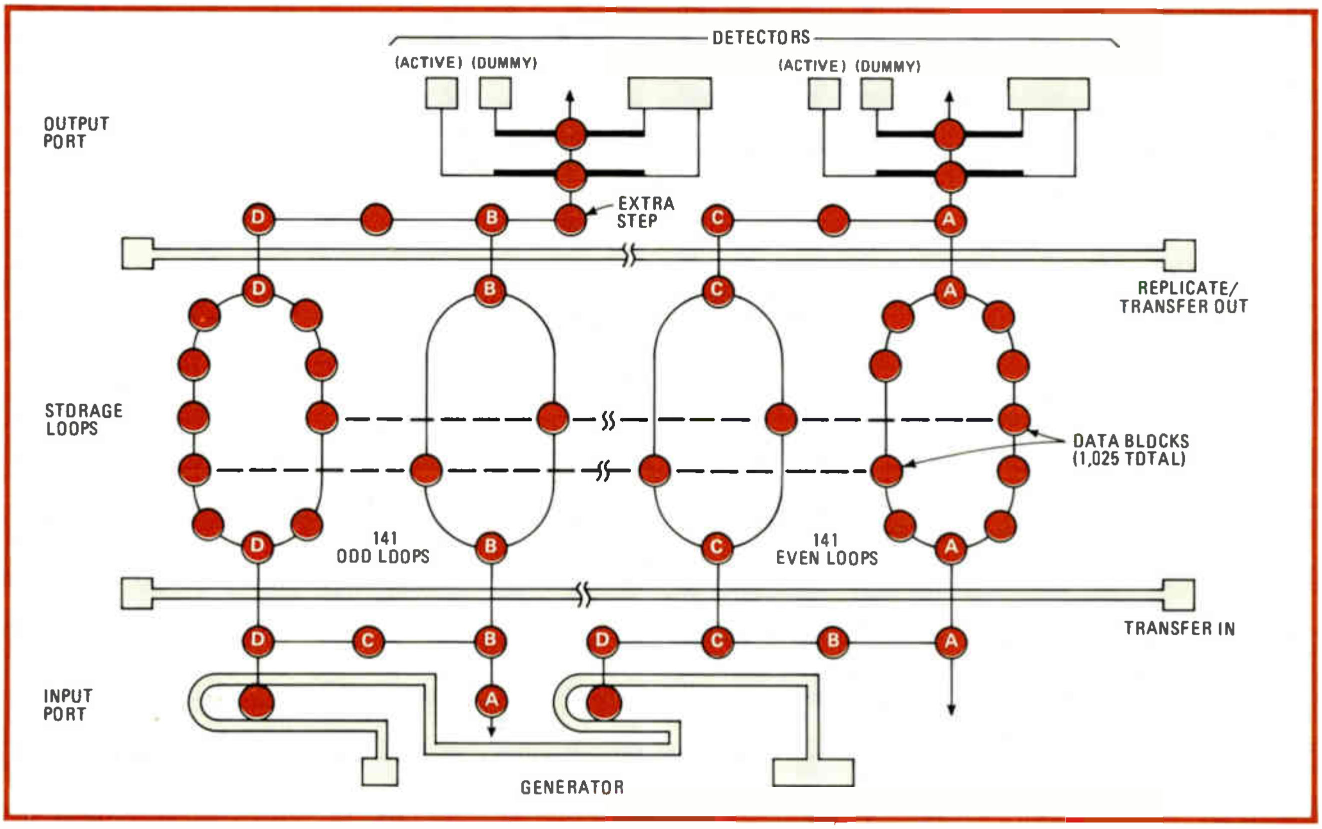
The chevron pattern incorporates only one gap per cell rather than the two required in older H- and T-bar patterns. Not only are there fewer gaps to fabricate, but they can be made larger, thus lowering the tolerance levels and increasing yield. The distance between the chevron centers is 14 micrometers, or about 4.5 times the 3.2-μm diameter of the bubbles generated on the die. The garnet thin film is approximately 3 μm thick.

The architecture

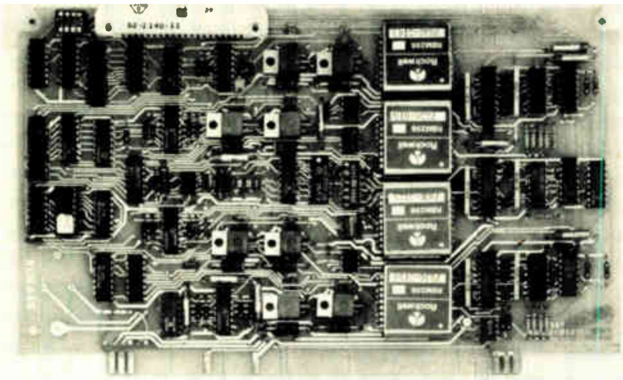
The RBM256 patterns form a block-replicate architecture that provides complete block accesses just as do floppy disks and magnetic tapes. The chip has three distinct parts (Fig. 3): the bubbles are generated at the input port, stored in the loops, and read out and erased at the output port. A bubble's presence indicates a 1, its absence a 0.

A data block comprises the same relative bit positions in all of the storage loops, with the bits feeding into and out of the loop alternately to the right and left side of the chip (even-numbered bits to the right, odd to the left). In the RBM256, there are 1,025 bit positions per loop, which means 1,025 blocks per device. In most applications, the 1,025th block is not used because this value is one greater than a power of two.

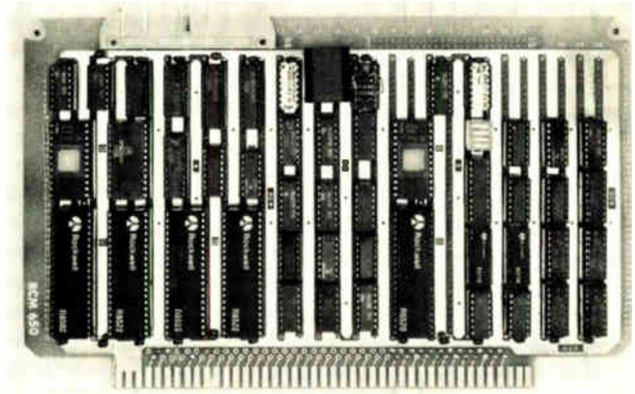
The device contains 282 loops, with 260 of them guaranteed to meet specifications. The 22 unused loops are identified when the part is shipped. The user stores the good-/bad-loop data in an independent program-



3. Block-replicate. The chip has an input port where the bubbles are generated, loops where they are stored and an output port where they are turned into electrical impulses. There are 282 loops, each with 1,025 bit positions, so there are 1,025 blocks per device.



4. A million plus. The RLM658 linear module provides over a million bits of storage. The sense amplifier, coil drivers, and generator and logic circuits for four 256-K bubble modules are all on the board, as is a PROM that maps the positions of the defective loops.

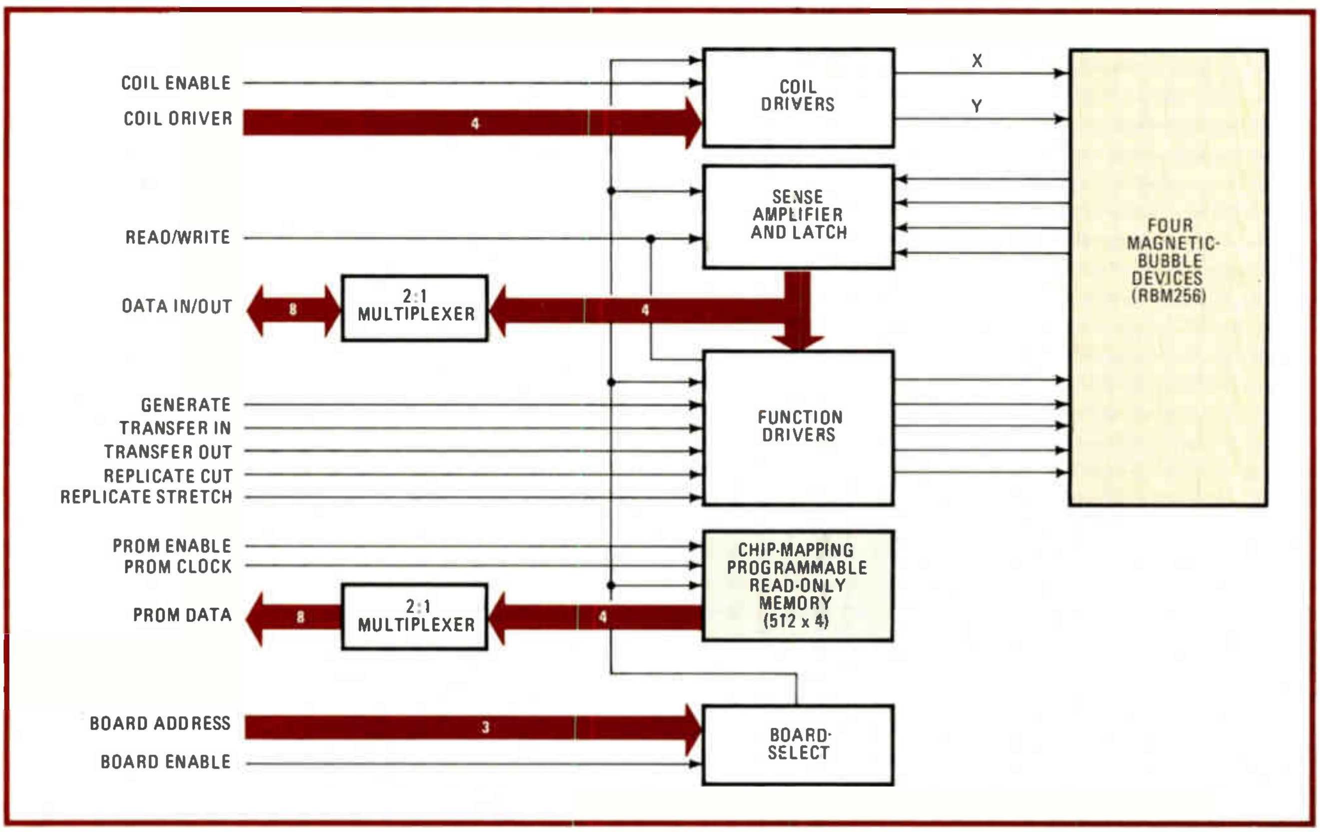


5. Controller. The RCM650 control module provides the interface between one or more linear modules and the system bus. It can handle up to 16 of the RLM658 linear modules, thus providing from 128 kilobytes to 2 megabytes of memory.

mable read-only memory. When a number of devices are put on a circuit board, which will be the typical use, a common mapping PROM can accommodate as many as 16 bubble memory devices. If the loop data is stored in the bubble device itself, an electrical or logical failure can destroy that information, requiring factory service.

In a typical application, 256 of the 260 good loops contain binary data and four are used for housekeeping. With 1,025 blocks of 260 bits per block, there are 266,500 usable bits to accommodate many applications such as the replacement of fixed-head disks and other binary storage media. When eight RBM256 devices are used in parallel, the extra 32 bits in the 2,080-bit block can embrace a 16-bit block-address header and a 16-bit suffix for a cyclic redundancy-check character.

At the chip's output port, the loops are tangent to a series of replicate/transfer-out switches (Fig. 3). Either replication or transferral is performed on an entire block at a time. During replication, each bubble in the block is stretched and cut, forming two identical bubbles. One of the two sets continues around the loops; the other goes to one of two read tracks. The 282 data sites have the 22 invalid sites scattered among them. All of the 282 sites are read, and control circuitry finally compacts the data



6. Linear blocks. Four-bit-wide data from the bubble memories is routed to four of the linear module's eight data lines through a multiplexer. The other lines serve for module enable, coil enable to begin data movement, read or write, and the defective loop information.

stream back into a valid 260-bit series.

Two independent data detectors alternate in operation during the read process. Each is composed of two magnetoresistive elements. Active and dummy detectors connected in bridge configurations give maximum noise cancellation for a high signal-to-noise ratio.

Since all 282 bits in a loop transfer out simultaneously, some means must be provided for interlacing them into a serial data stream. As shown at the top of Fig. 3, the extra bubble sites (called spacers) between the transfer-out sites plus the extra step just before the active detector for odd-numbered bits do this interlacing.

At the next cycle of the rotating field, the bubble labeled A will reach an active detector; B will be in the extra-step site; and C and D will have moved into spacer sites. At the next cycle, A will move into its dummy detector and B into its active detector; while C will be poised to move into its active detector, and D will have moved into the position B has in the figure.

For erasure, a data block is simply transferred to the read tracks, rather than replicated at the output port. However, it is possible to read the block before erasure.

At the opposite edge of the chip, bubble generation takes place. The controller circuitry uses the same PROM mask to assure that the data goes to valid loops. A pair of generators, connected in series, produces odd and even blocks of data, and a set of simple transfer-in switches then transfers the block into the loops at one instant—odd bits on the left, even bits on the right.

At 150 KHz, the RBM256 takes less than 4 milliseconds on the average for access to the first bit of a block. It consumes about 1 watt of power when operating. Its temperature range is $-10°C$ to $+65°C$; if operated at 100 KHz, the range is $-10°C$ to $+70°C$. Nonvolatile storage during shutdown is maintained from $-50°C$ to $+100°C$.

Linear module

Of course, it takes more than a good storage site to make up a working memory. The RLM685 linear module (Fig. 4) and the RCM650 controller board (Fig. 5) provide the remaining extras. The linear module contains four RBM256s, forming a 1-million-plus bit memory board, organized as 256 kilobits by 4 bits.

The electronics necessary to operate the devices—the sense amplifier, coil drivers, generator, etc.—are all on the module (Fig. 6). Also resident is the PROM containing the mapping of the unused loops for each of the four devices. The user provides the power supply.

Four-bit-wide data from the four RBM256s are routed to four of eight data interface lines, in accordance with a switch setting. Other interface lines serve for module select or enable, coil enable to begin data movement, read or write, and defective loop information from the PROM. Each of these controls is designed to be functionally independent.

The module interface uses transistor-transistor-logic voltage levels, with the low level being active for the bidirectional data buses and operational signals. When dc power is applied, the memory is ready to accept commands. All functional elements are protected; no command is recognized without the presence of the module-select terms and its board-enable signal.

Coil-driver circuitry controlled by four timing signals drives the bubble devices in parallel. The sensing electronics consists of resistors (to complete the detection bridges), a preamplifier, sense amp, and latch. Data on the output lines is valid until the next cycle, provided the module remains enabled and the system remains in the read mode.

Circuit operation

The transfer-in, and transfer-out/replicate circuits all operate in parallel, but the four generator circuits are driven individually. Thus the generators may be activated every bit time to create a block of data, but the other signals may not be activated more often than once every 282 bit times, as they are required only once per block. Passing current pulses through the respective loops on the surface of the bubble chip accomplishes all these functions. Since the loop is designed for low-duty-cycle current pulses, the functions are ac-coupled to protect against burnout from incorrect input signals.

The addressed block is first positioned at the transfer-out switch and activation of the transfer line empties it onto the read track, clearing the memory location. For a write or read operation, the external controller refers to the PROM for loop-redundancy information to use as a data mask.

It also is possible to read data nondestructively. First, the replicate signal is activated when the block location corresponding to the desired address is at the transfer-out switch. Then the control circuitry brings the read/write signal high and directs the stretching and cutting of each bubble in the addressed block.

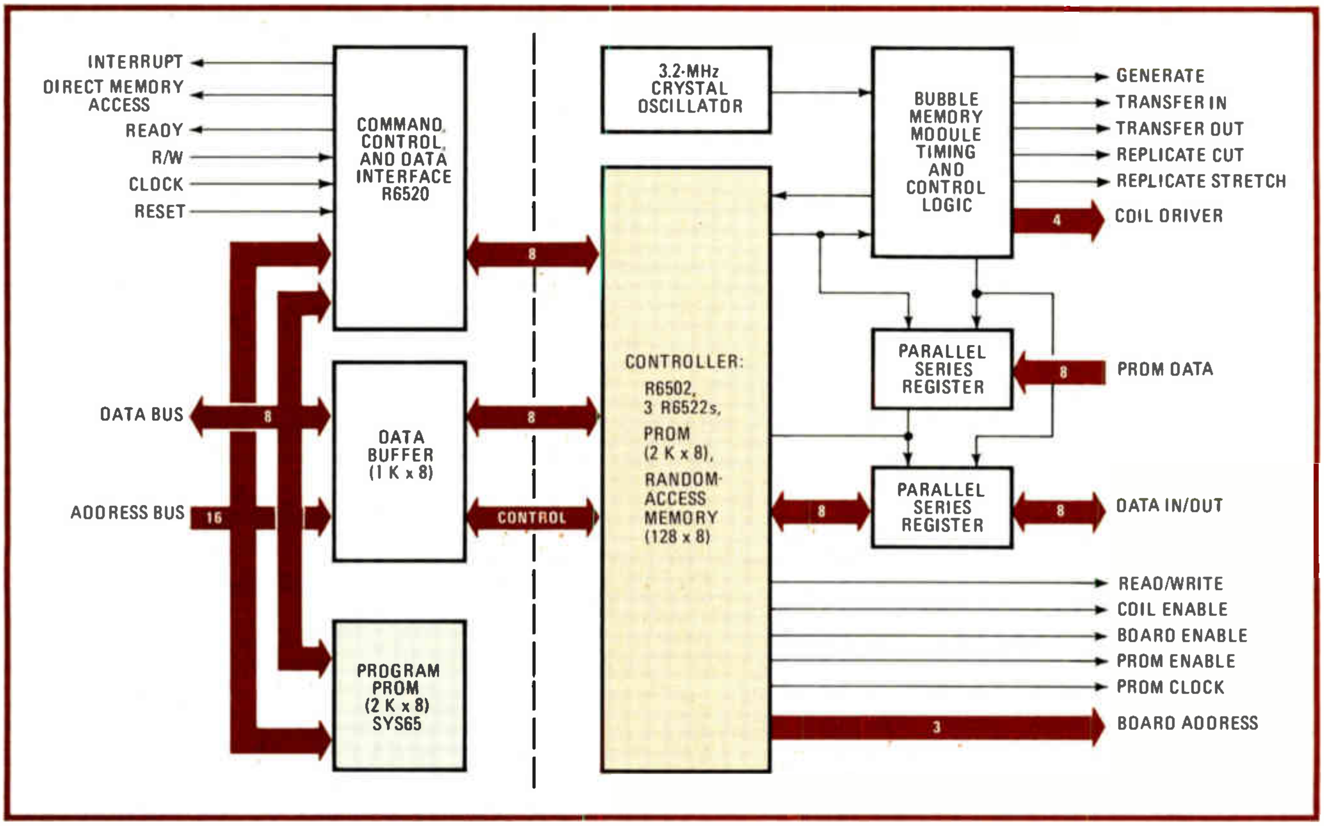
When used with an appropriate controller, the RLM658 is hardware- and software-compatible with Rockwell's System 65 software development system for the 6500 family of microprocessors. It can also be used with many 6800 microcomputer development systems.

From 1 to 16 RLM658 modules in a system environment provide from 128 kilobytes to 2 megabytes of storage. However, implementing such a bubble memory subsystem requires controller circuitry. The RCM650 programmable control module complements such an arrangement of RLM658s. It is also software-compatible with the 6502 microprocessor and the System 65 and 6800 development systems.

A typical development system consists of one RCM650, two RLM658s, and a System 65. This 256-kilobyte system is a good example of how a controller operates in conjunction with storage modules based on RBM256 bubble-memory devices.

A controller board

There are two fundamental types of circuitry on the RCM650. On the left of the dashed line in Fig. 7 is the System 65 interface, including the required address-decoding, timing, and direct-memory-access logic. The PROM on the left of the line contains software programs for a System 65. On the right of the dashed line are circuits required to operate the linear modules, including all the control signals, redundancy logic, and board addressing needed to drive as many as 16 RLM658s.



7. Smart. On the left of the dashed line is the interface for the development system, in this case a System 65. On the right are the circuits to operate the linear modules. The heart of this RCM650 control module is a 6502 microprocessor and three 6522 versatile interface adapters.

On initial power-up, the RCM650 controller goes into a reset mode and each memory section (a single RLM658 or a pair of them) is polled for its present address. The 128-byte random-access memory on the controller module stores this address. This power-on sequence also determines how many modules are present and how many bubble devices are active on each module. Block-length modifications are automatic. During operation of a memory section, a counter in the controller tracks the loop positions. With the current address of the memory modules always known, the number of cycles required to the next desired address can be calculated, and the bubbles move that many steps to provide access to any block of data.

A separate 1-kilobyte RAM on the controller serves as a data buffer. The System 65 may not execute programs from this RAM while the controller is executing a command, but it can enter this space for data when operating a program elsewhere in the host's memory.

The R6502 central processing unit and three R6522 versatile interface adapters (VIAs), to the right of the dashed line in Fig. 7, are the heart of the control module. The module is instructed by a program stored in a 2-kilobyte PROM and by the contents of several registers, set up by the host processor and kept in the 128-byte RAM. Through automatic handshaking with one of the R6522s, the controller communicates commands and control data to the R6520 parallel interface adapter. The PIA acts as an input/output interfacing device under control of the System 65.

For storage and reference involving a linear module, an invisible DMA transfers the data to the on-board 1-kilobyte buffer RAM. (That is, the DMA does not interfere with the System 65 operation.) The controller accesses an R6520 port during these DMA operations, which allows the port to act as a bus buffer. It also lets the port act as a latch between the controller and the module's internal data bus.

In the System 65, both read and write commands to the bubble memory are identical during setup and operation; they differ only in the direction of data flow. The user specifies the buffer RAM's starting address, block address, and number of blocks to be accessed. A set of subroutines called bubble-memory I/O drivers, written for the System 65 and resident in the on-board system PROM, organize these blocks into files with names that are stored in a directory along with the associated block addresses. This directory is in a specific location on a bubble memory chip.

These subroutines perform four major functions: open file, read byte, write byte, and close file. More complex file management routines can be derived from these four basic functions, such as initialize directory, compress data, delete file, rename file, list file, etc. The System 65 assembler, editor, and loader can use these routines for source-program and object-code manipulations.

In short, the user can employ the controller and linear modules to access information stored in the bubbles for any standard memory applications. Also, the System 65 includes six vacant slots for adding more memory and I/O modules. With an auxiliary card cage, the bubble memory can be expanded to 2 megabytes. □

Rate multiplier controls noninteger frequency divider

by Michael F. Black
Texas Instruments Inc., Dallas, Texas

Frequency dividers capable of dividing by integer and noninteger values can be built inexpensively from very few parts now that synchronous binary rate multipliers are available on single chips. To increase the resolution of the noninteger value, the rate multipliers are simply cascaded.

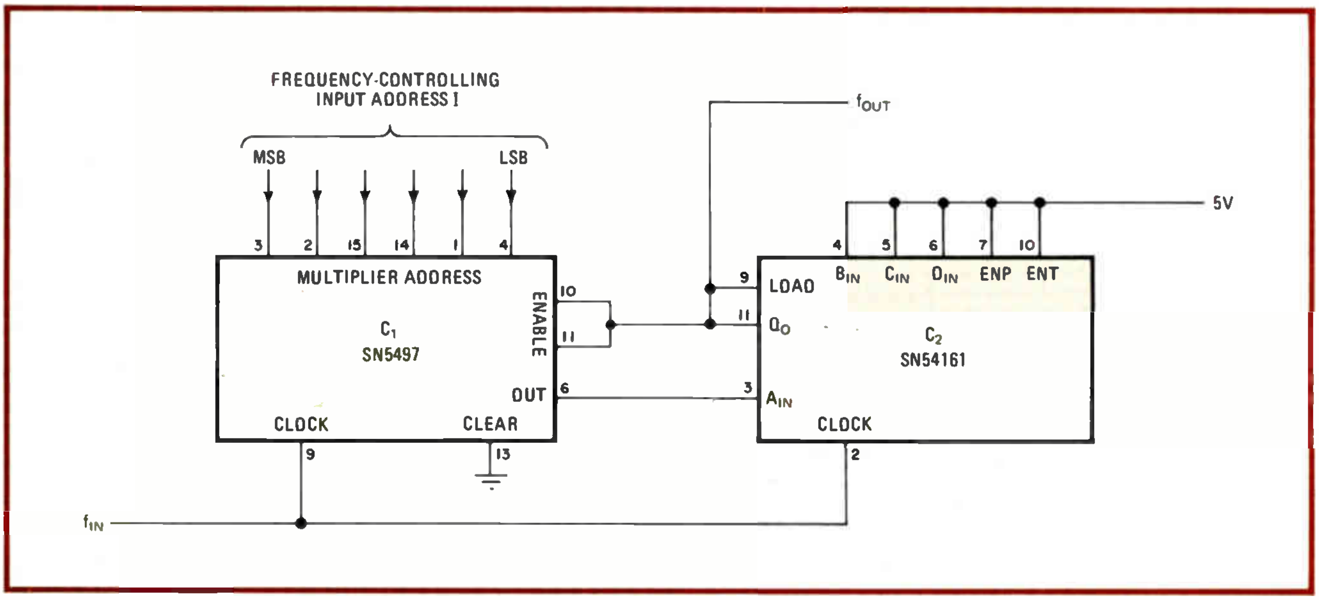
The ratio at which division is performed is set in an indirect manner by the 5497 rate multiplier. This number lies between two values preset in the 54161 synchronous counter, n and n − 1. The circuit divides the input frequency by a ratio directly proportional to the time the counter spends in the n mode versus the time it spends in the n − 1 mode.

The number of input pulses rate multiplier C_1 passes to synchronous counter C_2 is proportional to input address I. In this instance the counter is preloaded at either 14 or 15 by inputs A_{in} through D_{in}. C_1's output (pin 6) is connected to the counter's input A_{in}. Address I consequently controls the percentage of time the counter spends at divide values n = 2 and n = 3.

The rate multiplier's pulse-train output frequency is $f = f_{in}(I/M)$, where M is the size of the rate multiplier (in this case $2^6 = 64$). This particular circuit configuration results in $f_{out} = M(f_{in})/(nM - I)$. The actual divide ratio is $n' = n - (I/M)$.

The value of M determines the size of the available frequency step. The circuit as shown has been used to set f_{out} from 4 to 6 megahertz in steps of about 30 kilohertz; adding one more six-line rate multiplier would bring the step size down to about 400 hertz. Frequency steps in hundredths of a hertz can be easily obtained by cascading more multipliers.

This divider circuit will generate the exact number of clock pulses per second desired, but there will be some phase jitter, with $\Delta\phi = 360/n$. □



Continuous division. Synchronous frequency counter uses rate multiplier in two-chip circuit to program circuit's divide ratio at any value. Output frequency is proportional to the time spent between two preset divide values, n and n − 1. Multipliers can be cascaded for step-size resolution all the way down to hundredths of a hertz. The amount of phase jitter at the output, in degrees, equals 360/n.

Standby crystal time base backs up line-powered clock

by William D. Kraengel, Jr.
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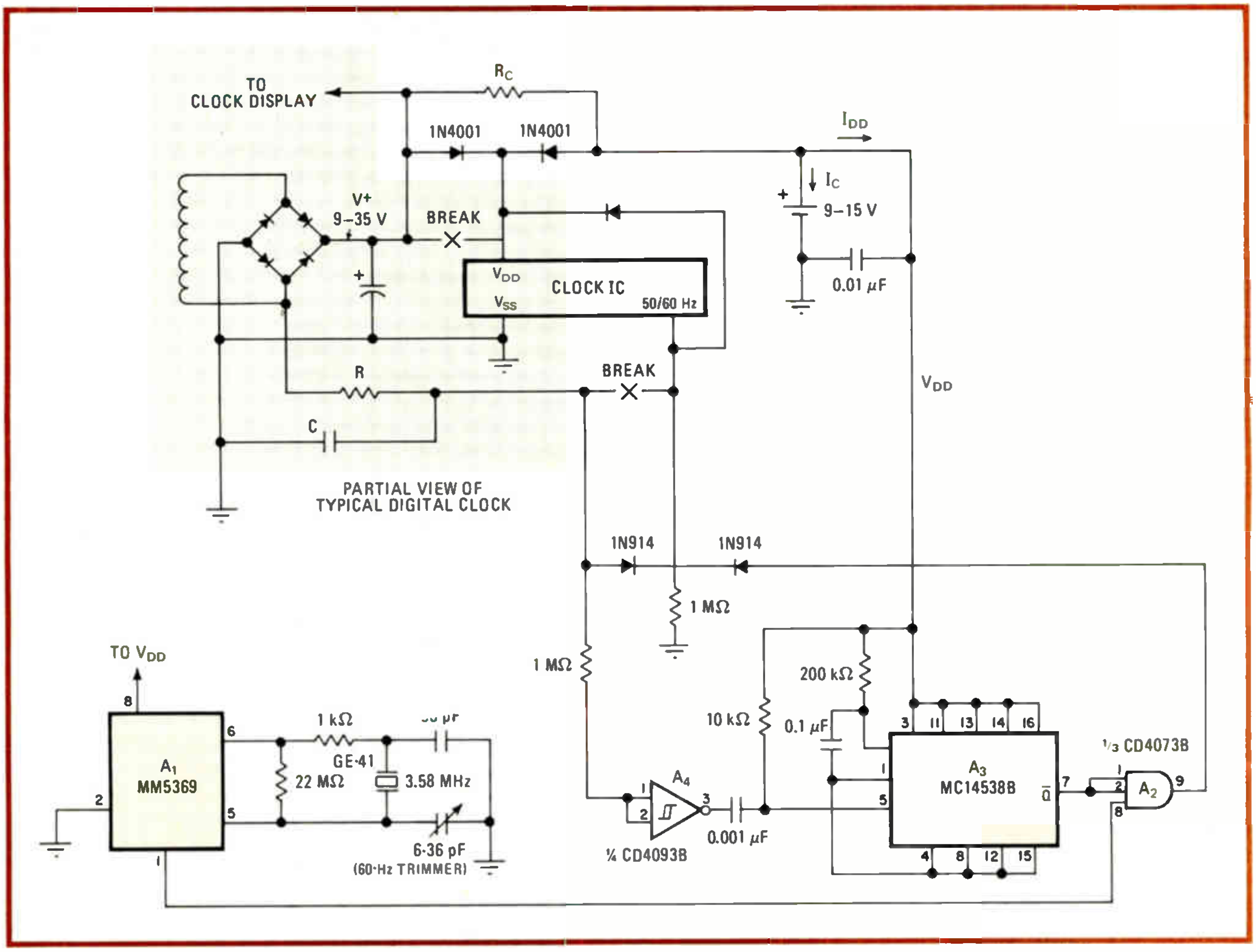
This battery-powered, crystal-controlled time base provides accurate and glitch-free performance when it takes over as the 60-hertz frequency standard that drives a digital clock during a power outage. The cost of the unit is about $7.

More long-interval timing circuits would probably use the ac power line as a time base because of its long-term average-frequency accuracy (1 part in 10^7), were it not



Standby standard. Battery-powered, crystal-controlled time base, having sufficient accuracy for most short-term applications, takes over clock-driving duties of digital chronometer in event of ac power loss. Unit uses 3.58-MHz oscillator, which is divided down to 60 hertz.

for the transients and blackouts that occur frequently. This back-up time base takes over smoothly in such instances and has sufficient accuracy over a period of several hours to satisfy all but the most demanding applications.

The standby time base uses a low-cost crystal oscillating at 3.58 megahertz, which is generally the frequency required for the color-burst circuits in standard television receivers. The frequency produced by the crystal's programmable oscillator-divider chip, A_1, is 60 hertz. This signal is fed to one input of an AND gate, A_2, which is activated if line power is lost.

During normal operation, the battery is trickle-charged (I_c) by the clock's supply through R_c, at a rate of 0.01 C, where C is the capacity of the battery in ampere-hours. R_c is equal to $(V^+ - V_{bat})/(I_c + I_{DD})$, where I_{DD} = 2.5 milliamperes. The digital clock must be modified slightly, as shown, in order to lengthen the charge life of the battery. Thus the digital clock's display will be blanked while the battery is the power source.

Meanwhile, one-shot A_3, configured as a missing-pulse detector, is triggered by Schmitt trigger A_4 at the beginning of each cycle of the ac input.

The one-shot's pulse width is 20 milliseconds, slightly longer than the period of the 60-Hz line input. Thus, A_3 is continually retriggered, and so A_2 is disabled.

With a loss of line power, the battery takes over the supply chores. A_3 times out, and then A_2 is enabled, so that the 60-Hz signal derived by the crystal circuit drives the digital clock's timing chip. The maximum length of time between the power outage and the first clock pulse from the standby unit is 8.3 milliseconds.

Almost the reverse action occurs when the ac line power is restored. When the filter capacitor in the clock's power supply recharges enough for the line pulses to rise above the set threshold of the Schmitt trigger, the one-shot is triggered, and the AND gate is disabled. As the voltage across the filter capacitor rises further, the power source duties revert back to the digital clock's power supply. □

Controller halts playback when taped voice pauses

by N. Bhaskara Rao
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Few typists can transcribe a dictated message or speech without stopping the tape recorder from time to time. The illustrated circuit stops the recorder automatically at the end of a sentence or other pause. Its programmable halt time is proportional to the length of the preceding playback segment.

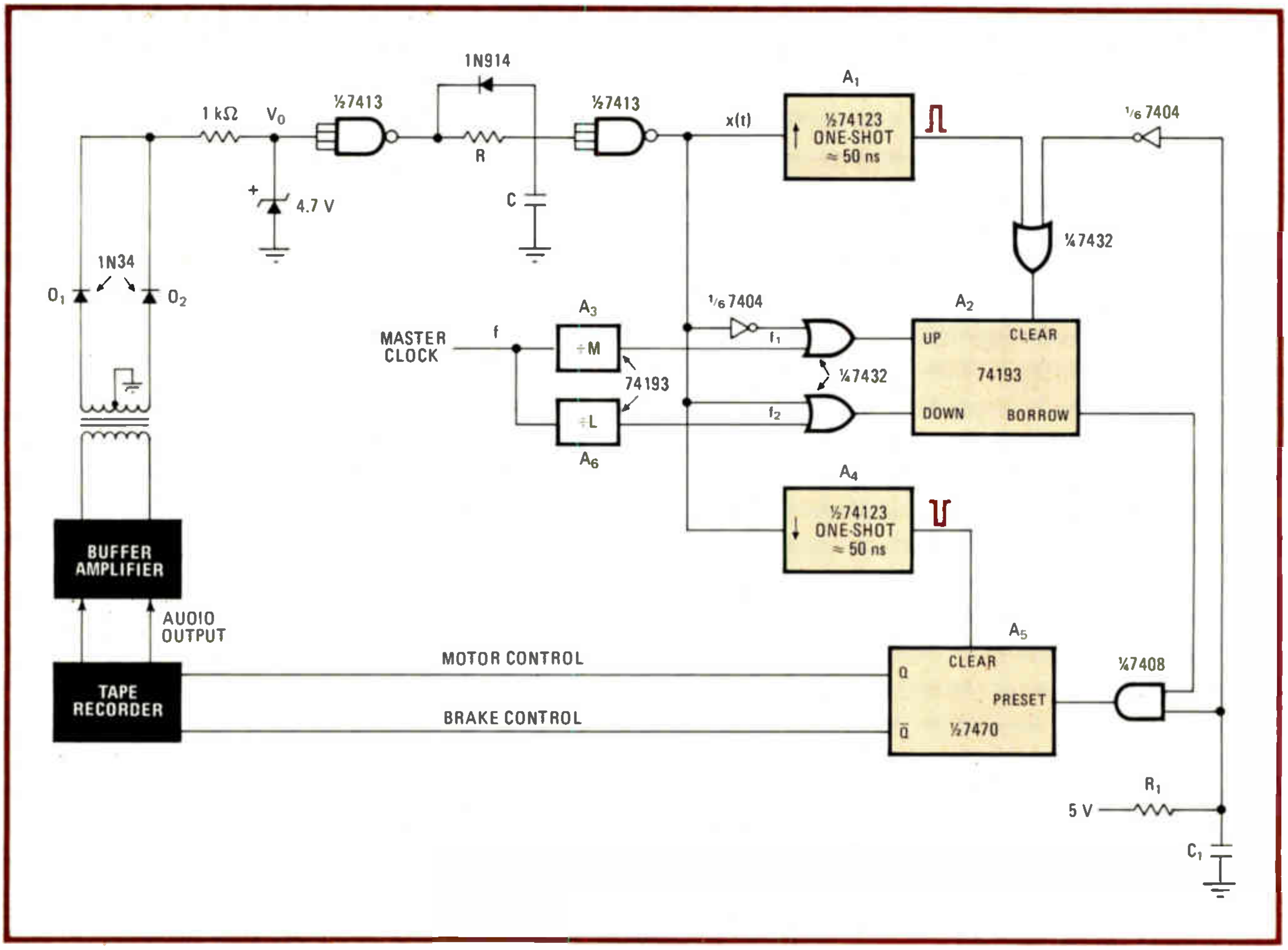
The circuit is preset on power up by R_1 and C_1. Audio signals from the output of the tape recorder may then be fed into a buffer amplifier having a low output impedance, so that a dc voltage proportional to the audio input is produced by the full-wave rectifier, D_1 and D_2.

The 7413 Schmitt triggers and an RC network define the time delay, T. The voltage at x(t), which is initially set high by the audio signal, goes low when V_o is low for a period greater than T, so that any pause in the audio signal triggers the recorder-halting circuit. The delay time selected may be varied for the particular application by adjusting one or both elements of the RC network.

As one-shot A_1 is triggered by x(t), A_2 is cleared and starts to count up. If the time during which x(t) is high is T_{on}, then the output of A_2 at the end of that period is given by $N = f_1 T_{on}$, where f_1 is derived from divider A_3 and the master clock frequency, f.

As x(t) goes low at the end of a phrase, one-shot A_4 is triggered, flip-flop A_5 clears, and the recorder's motor is braked to a halt. At the same time, A_2 starts to count down at a rate, f_2, which is determined by divider A_6 and the master clock. As A_2 goes through zero after a time equal to $T_{off} = T_{on}(L/M)$, where L and M are the divider ratios, it generates a borrow pulse that sets A_5 and restarts the recorder's motor. The audio output from the recorder then sets x(t) high, and the cycle repeats.

Because the actual interface between A_5 and the tape machine varies widely with the recorder used, the wiring details of this portion of the circuit are not shown. Other parts of the circuit may be easily modified to suit the application. For instance, the 74193 ratio counters each provide divisor ratios to 15, but they may be replaced by dividers that provide any value of L and M. □



Pausing for write time. Unit brakes tape recorder's drive after each sentence of taped message to provide transcription secretary with time to write information. Circuit uses up-down counter to derive a halt time proportional to the length of the preceding playback period.

What to look for in logic timing analyzers

More channels, assorted speeds, display options, novel triggering schemes ensure there's an instrument for every digital timing problem

by Martin Marshall, *Marshall Enterprises, San Francisco, Calif.*

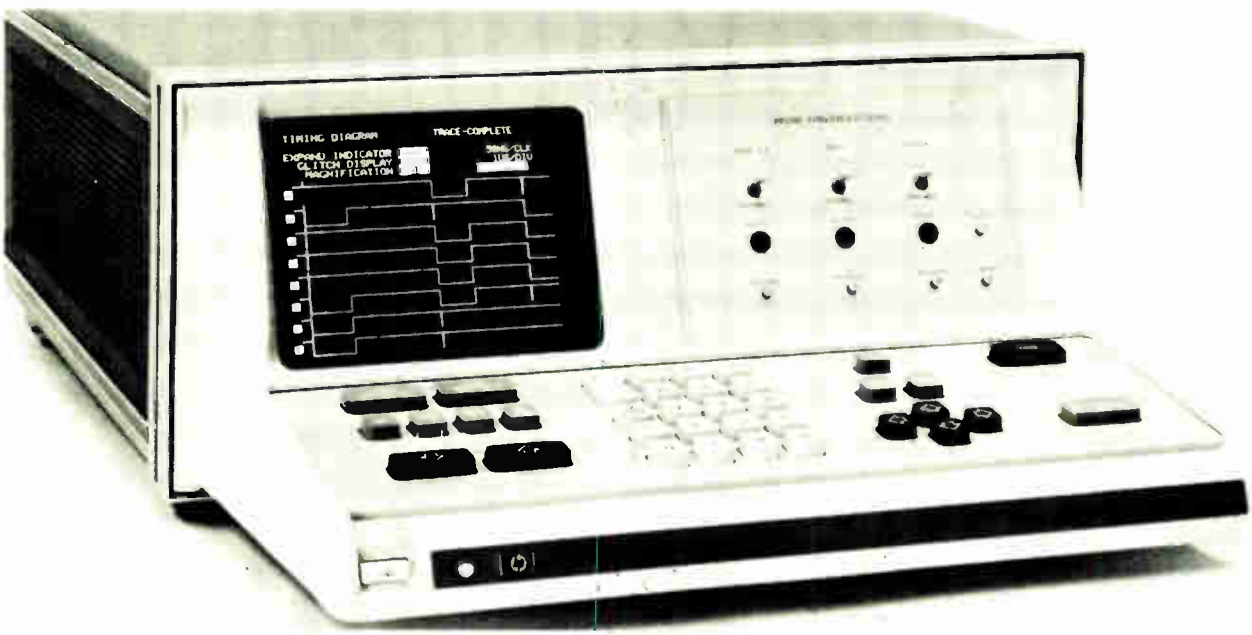
☐ Logic timing analyzers have learned a lot of new tricks in the six short years of their existence. From the start their high-speed asynchronous clocking marked them as the instruments of choice for solving hardware-related problems like short-duration glitches, skewed signal arrival, and intermittent timing failures. Software troubles are usually taken on with logic state analyzers that synchronize their clocking with the clock of the system being tested and thus are 5 to 10 times slower. But sometimes problems that appear to be software-generated are in fact hardware-related and require the more detailed analysis possible with the faster asynchronous instrument.

Small time windows

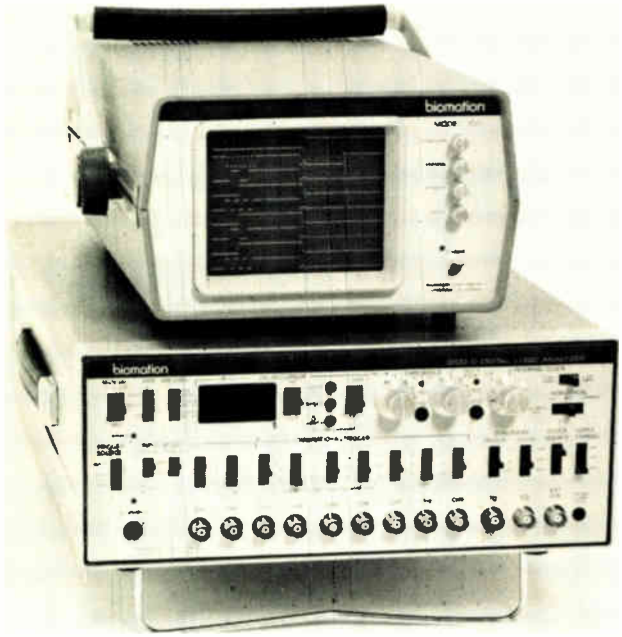
Most currently available logic timing analyzers are capable of both synchronous and faster asynchronous operation. In either mode, the analyzer monitors digital signals on address, data, or control lines, confirming proper word construction on a bit-by-bit basis.

An example of the need for a timing analyzer's inherent speed advantage appears upon examining the status activity of an 8080-type microprocessor. Though the microprocessor itself operates at only 2 megahertz the status information multiplexed onto its eight data channels is available only within a 50-nanosecond time window occurring between system clock cycles. Not only must the 8 status bits arrive within that 50-ns window, but two sync lines must change state as well. To examine the skew of these signals properly, the 50-ns interval should be broken down into five 10-ns samples. This is possible only if the analyzer is running at a 100-MHz sampling rate. A state analyzer running synchronously at 2 MHz cannot perform this kind of analysis, as the skew of the signals would not be magnified sufficiently.

Examining the timing relationships of a microprocessor to its peripheral chips, or of timing within non-microprocessor-based systems, brings up further examples. Even a slower microprocessor such as the 1-MHz 6800 chip features input/output data hold times in the 10-ns range. Faster, newer chips like Nippon Electric's high-speed version of the Advanced Micro Devices AMD 2900 can be added to the list of examples. Such a bipolar chip, with its 60-ns instruction cycle time,



1. Grabbing the glitch. In addition to data, the timing analyzer displays fast transients or glitches that can affect the system's operation. The glitch detection circuit stretches the duration to one sampling interval. Glitches can be seen above at the center and right side of the CRT.



2. Separate CRT. Logic analyzers often require an oscilloscope or a separate CRT for timing display. The 100-MHz Biomation 9100 D offers eight data channels, a sync channel, and choice of clock or trigger qualifier channels. It has a word depth of 1,024 words.

demands the high speed of the timing analyzer.

Another advantage timing analyzers have over most state analyzers is their ability to detect glitches. These infrequent transients are too short for detection at synchronous sampling times, but they affect system operation nonetheless. Special latching circuitry detects glitches as short as 5 ns in duration and stretches the transients to one sample interval for recording by the analyzer. Figure 1 shows several waveforms containing glitches captured and displayed using this circuitry.

Evolution of the timing analyzer

Since the beginning, manufacturers have searched for the best combination of triggering, memory size, speed, display, and data reduction to fit the user's needs. The number of channels of data the instrument can record is also of prime concern (see Table 1).

The earliest units monitored 8-channel buses, but users needed more diagnostic capabilities and channels. The trigger qualifier, a separate channel whose history is not recorded in memory but whose state becomes an added trigger criterion, was introduced. Biomation Division of Gould Inc., Santa Clara, Calif., offered a 9-channel analyzer which recorded the history of an 8-channel bus plus a sync line, with its model 920D and model 9100D (see Fig. 2). User demand for 16-channel bus analysis resulted in 16-channel timing analyzers such as the Biomation 1650; the LA501 and 7D01 from Tektronix Inc., Beaverton, Ore.; model 740 from Moxon Inc., Irvine, Calif.; the 50D16 from BP Instruments Inc., Cupertino, Calif.; and model 1850 from E-H International Inc., Oakland, Calif.

The latest increase in channel population is due to the synthesis of timing and state analysis in the Biomation K100D and the 1615A from Hewlett-Packard Co., Colorado Springs (Colo.) division. The reason for the combination of instruments is that timing analysis need only be done on a single bus, whereas state analysis may usefully include more than one bus. The HP 1615A offers 8 channels for timing analysis and assigns 16 channels to state analysis; this allows monitoring of a 16-bit address bus plus an 8-bit data bus.

The K100D's 16 channels can perform timing and/or state analysis; with an optional adapter, the unit can be configured as a 32-channel data domain instrument. This permits the monitoring of a 16-bit address bus and a 16-bit data bus, or an address bus, an 8-bit data bus, and various control lines within the system.

How fast is fast enough?

Manufacturers have differed on how fast a timing analyzer should be, with some even presenting the user with a choice of speeds in different products. The first timing analyzers operated at 10 MHz, but none manufactured since then are slower than 20 MHz. Today's units run at 20, 50, 100, or even 200 MHz—which is the proper selection? The answer, of course, depends upon the speed of the equipment that the user wishes to analyze. The user must determine the minimum time interval to be resolved in the system. Often skew factors in the hardware logic of the system, rather than the clock rate presented on the bus, determine this figure.

If that minimum interval is 50 ns, then a 20-MHz analyzer such as the HP 1615A, Biomation 920D, or Moxon 740 (Fig. 3) is the answer. If it is 20 ns, then one of the 50-MHz analyzers such as the Biomation 1650, E-H 1850, or E-H 1320 can be considered. At 10 ns there is the 100-MHz Biomation K100D and Biomation 9100D; and at 5 ns, or 200 MHz, the Biomation 8200. The Tektronix plug-in timing analyzer, model 7D01, is chameleon-like with respect to speed. It is configurable for 20 MHz on 16 channels, 50 MHz on 8 channels, or 100 MHz on 4 channels.

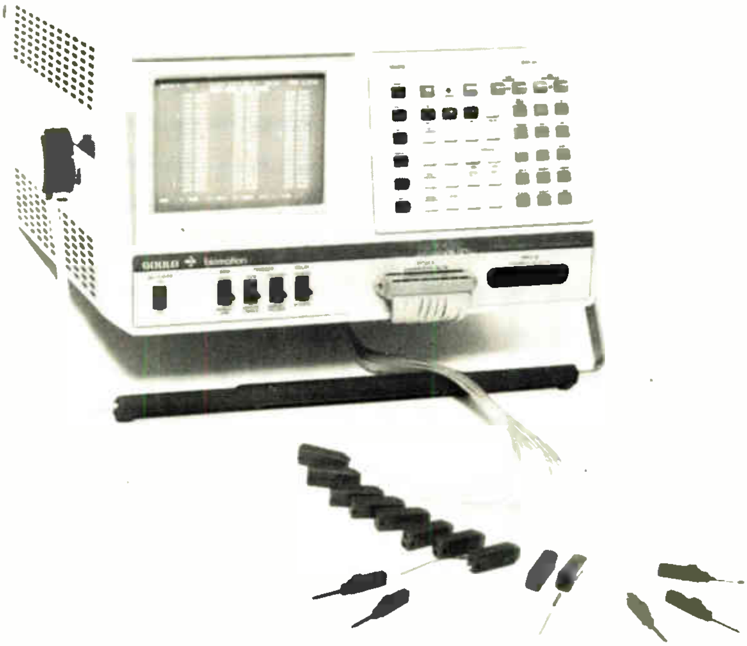
Probes are sometimes a forgotten component of logic analysis, even though they are the part of the analyzer that interacts directly with the system under test. Each probe affects the signals it is monitoring and limits the speed of the analyzer, depending upon the probe's input capacitance and impedance.

The faster timing analyzers have probes in the megohm impedance range and capacitances of 5 to 15 picofarads. Tektronix, Biomation, and E-H all specify impedances higher than 1 megohm, but E-H specifies its impedance at the analyzer's BNC input connectors, whereas Tektronix and the Biomation K100D have their impedances specified at the probe tip.

Probe arrangement

Manufacturers also differ on whether to arrange the probes individually or in groups. Hewlett-Packard arranges its probes in eight-channel pods, with short leads emanating from the pods; Tektronix attaches somewhat longer leads to the same type of pod arrangement. Biomation and E-H have individual probes beginning at the front panel of the analyzer, claiming that this allows easier connection of physically divergent parts of the system at the same time. Tektronix and Biomation

3. Analyzers evolve. This Moxon 740 timing analyzer can monitor up to 16 channels of data at a 20-MHz sampling rate. The elimination of numerous front-panel switches and addition of a CRT were two evolutionary changes in logic analyzer design.



4. Hybrid probes. Each Biomation K100D probe has a hybrid circuit providing a high-impedance input for high-speed signal monitoring. The K100D performs state as well as timing analysis and features an extensive array of triggering and display capabilities.

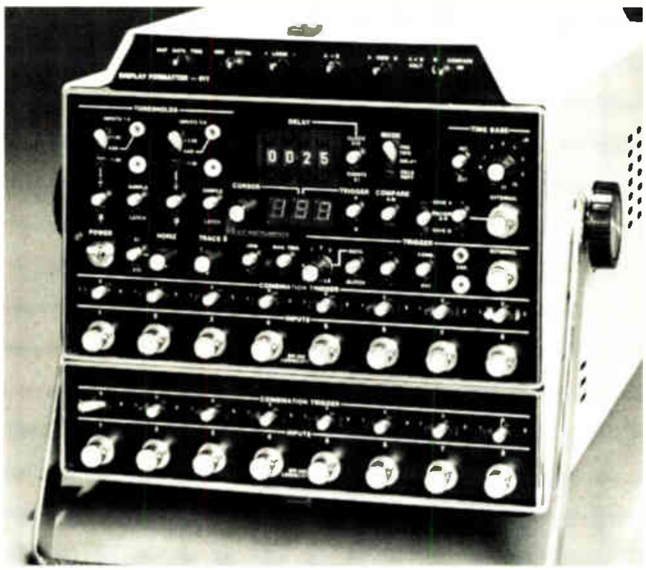
K100D analyzers reduce the degradation of high-speed signals by using hybrid circuits close to the point of probing. Tektronix places the hybrid circuitry in the probe pod; the K100D puts one in the tip of each individual probe (Fig. 4).

Triggering is the key

Although speed is a major factor in excluding some timing analyzers, final selection requires evaluating the analyzer's ability to trigger, its ease of use, and its ability to reduce the captured data into an intelligible display. The first of these criteria, triggering, has become an art form nearly as sophisticated as the programming techniques it unravels.

The earliest and simplest triggering criterion is the parallel word trigger. All of the analyzers have it. If the analyzer is connected to a 16-bit address bus and the selected trigger word comes along, the analyzer stops recording and its memory stores pretrigger information up to its capacity.

Clock delay was the next feature added. With it, the user can examine the program in blocks, using the same trigger word. Examining sequential blocks of program is made possible by increasing the clock delay on successive analyzer recordings (Fig. 5).



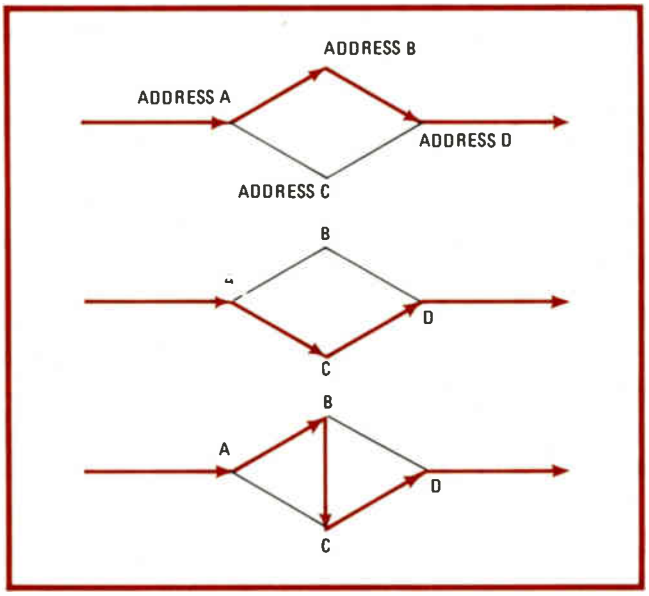
5. Trigger tactics. The BP Instruments model 50D16 16-channel timing analyzer's triggering capabilities include parallel word, clock delay, and events delay. The last two permit examination of a sequential program block or subroutines by increasing trigger delay.

However, programs invariably contain subroutine loops and even nested loops, and potential trigger words occur many times on successive passes. To allow the analyzer to pick apart these loops, a pass counter was added to the triggering section. The pass counter delays recording into memory by counting trigger word occurrences, rather than clock cycles, to allow triggering on the nth pass through a subroutine. Nearly all the latest timing analyzers have this feature.

Only two, however, can make use of on-board sequential word triggering. These are the Biomation K100D and the HP 1615A. Sequential word triggering is a very useful technique for selecting a unique program path out of a seemingly ambiguous set of paths. The analyzer will trigger on word B, but only when it is preceded by word A. In hardware terms, word A arms the analyzer and word B (or the nth occurrence of word B) triggers it.

In software terms, one can picture a program path through a subroutine beginning with word A and ending with word D. Between A and D, there are three distinct paths by way of words B and C. These are ABD, ACD, and ABCD (Fig. 6). The three paths can be distinguished by triggering on sequences of words BD, AC, and BC, respectively.

In a typical application, words A, B, C, and D are



6. Separating address flow paths. Sequential triggering can be used to sort out program paths that are otherwise indistinguishable to the logic analyzer. In practice, sequential triggering can be used to define key I/O maneuvers such as a particular subroutine.

16-bit addresses in a microcomputer program. When triggered, the analyzer's memory will store a listing of the program's address flow. The K100D can take the extra step of qualifying the analyzer's trigger on sequential 18-bit words, allowing one to include control line signals in the trigger as well as a 16-bit address bus.

HP's model 1615A performs sequential triggering somewhat differently. Its 8-channel timing bus can arm its 16-channel state analysis bus, or vice versa. Triggering on successive 16-bit address words is not included on the model 1615A.

Intermittent failures are the most troublesome because they occur infrequently and do not show up during normal repetitive measurements. To combat intermittent logic problems, a number of analyzers include a trigger-on-noncomparison mode.

The mode works like this. The unit captures a normal block of data from a suspected portion of the program, using trigger criteria X, Y, and Z, and transfers it into a second reference memory inside the analyzer. Next, using the noncomparison mode, the analyzer will first wait for data that meets criteria XYZ. When that data arrives, it will compare the captured data with the normal data in its reference memory. If the data is different, the instrument triggers. If not, it re-arms itself and waits for criteria XYZ to recur.

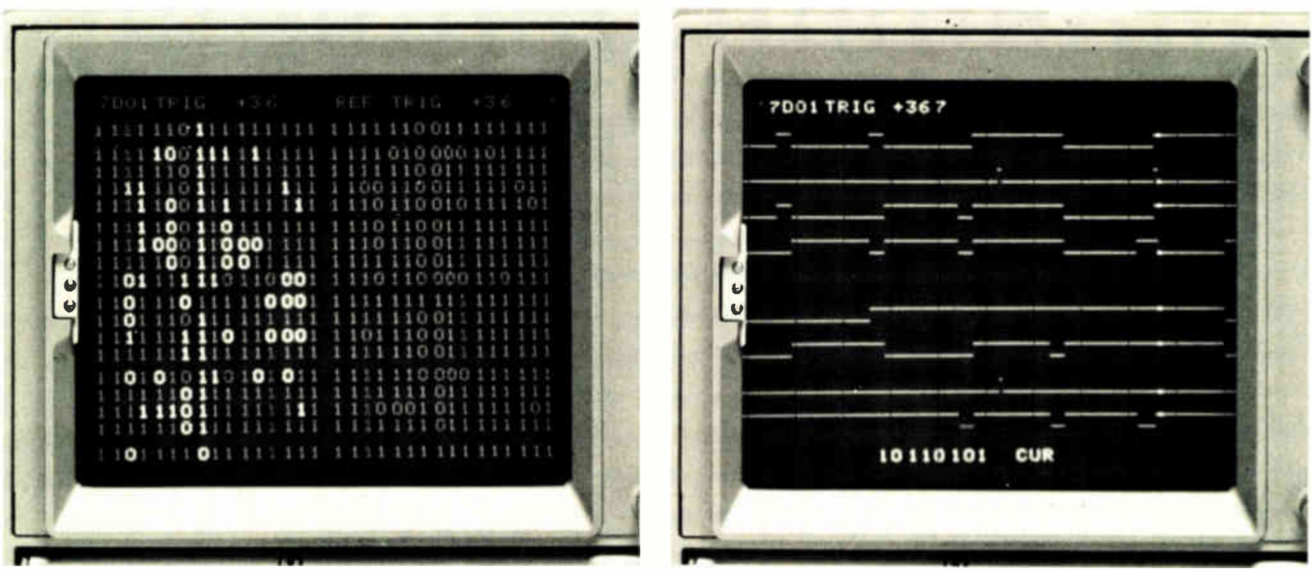
Reducing the captured data

Biomation's K100D adds a useful twist to this process. It can define both the channel width and the word depth of the memory used for comparison. For example, suppose an unusual combination of data in subroutine A is suspected of causing a jump to an incorrect address. If the data in subroutine A is always changing, then it is possible to limit the comparison to just the 16 address channels, even though the analyzer is simultaneously recording the data bus.

Next, given that subroutine A is 103 addresses long, the comparison can be limited to just those 103 words in the reference memory. This is most useful in the likely case that subroutine A is accessed from any of a number of different places and exits into other subroutines. In other analyzers, the length of the comparison memory is fixed, but the number of channels compared can still be limited very simply by pulling the probes off the unwanted channels.

Trigger on disappearance

Another convenient triggering feature shared by the E-H 1850 and Biomation K100D is the ability to trigger on either the appearance or disappearance of the trigger word. This is helpful in triggering on the end of a message using the system's message-valid signals. For example, it may be that three control lines must go high in order that a peripheral device receive a message on a



7. Displaying the data. Tektronix' 7D01 logic analyzer features data domain (left) and timing diagram (right) display formats. It offers a vertical line, or cursor—the bit makeup of the data word it intersects is displayed at bottom (right). Trigger word position reads out at top.

LOGIC TIMING ANALYZERS COMPARED

Manufacturer and model	Maximum speed (MHz)	Channels	Memory depth (words)	Triggering: 1st appearance or disappearance	Triggering: Clock delay	Triggering: Event delay	Triggering: Parallel word	Triggering: Sequential word	Triggering: No. clock qualifiers	Triggering: No. trigger qualifiers	Reference memory	Digital holdoff (samples/time)	Built-in CRT	Display format
Biomation K100D	100	16[a,b]	1,024	yes	yes	yes	yes	yes	2	2	yes	14 samples	yes	T, A, B, O, H, S
Biomation 920	20	9	256	no	yes	yes	yes	no	1	1	no	none	no	T
Biomation 1650/116	50	16	512	yes	yes	no	yes	no	1	2	yes	none	no	T, O, H, M
Biomation 9100D	100	9	1,024	yes	yes	yes	yes	no	1	1	no	none	no	T
Biomation 8200	200	8	2,048	yes	no	no	yes	no	no	no	no	none	yes	T
B P Instruments 20D	20	8	256	no	yes	no	yes	no	no	no	no	none	no	T
B P Instruments 50D16	50	16	510[c]	yes	yes	yes	yes	no	no	5	yes	3 samples	no	T, B, O, H, M
E-H International 1850	50	18	512	yes	yes	yes	yes	no	1[g]	3[g]	yes	4 samples	no	T, B, O, H, M
Hewlett-Packard 1615A	20	8[a]	256	yes	yes	yes	yes	yes	6	no	no	15 ns to 2 μs	yes	[f] T, B, O, H
Moxon 740	20	16	64	no	yes	yes	yes	no	1	no	no	none	yes	T, B, O, H
Moxon 745	20	16	1,024	no	yes	yes	yes	no	1	no	no	none	yes	T, B, O, H
Tektronix 7D01F/7704	100	4	1,016	no	yes[d]	yes[d]	yes	no	1	2	yes	10 ns to 300 ns	yes	[e] T, B, O, H, S, M
	50	8	508	no	yes[d]	yes[d]	yes	no	1	2	yes		yes	
	20	16	254	no	yes[d]	yes[d]	yes	no	1	2	yes		yes	

Notes:
[a] 16-state channels included
[b] 32-state channel option
[c] 2,046-word memory option
[d] Delay feature option
[e] ASCII character option
[f] Glitch only included
[g] With optional probe pod

T = timing
B = binary
O = octal
H = hexadecimal
M = mapping
S = search
A = ASCII

separate 8-bit data bus. To find the end of the message, the unit can be triggered when the three control lines go from 1-1-1 to any other state. The easiest way to do this is to set the analyzer to trigger on the first disappearance of the trigger word 1-1-1.

Glitch filtering

The timing analyzer's equivalent to the oscilliscope's trigger holdoff feature is called digital filtering, glitch filtering, or digital trigger holdoff. It simply requires that the trigger word remain valid for more than one sampling interval. It is especially useful when examining three-state buses or systems that are insensitive to very short glitches. In these cases one may be sampling at five times system clock speed and yet not want to generate a false trigger on a glitch that is only a fifth of a system clock interval in duration.

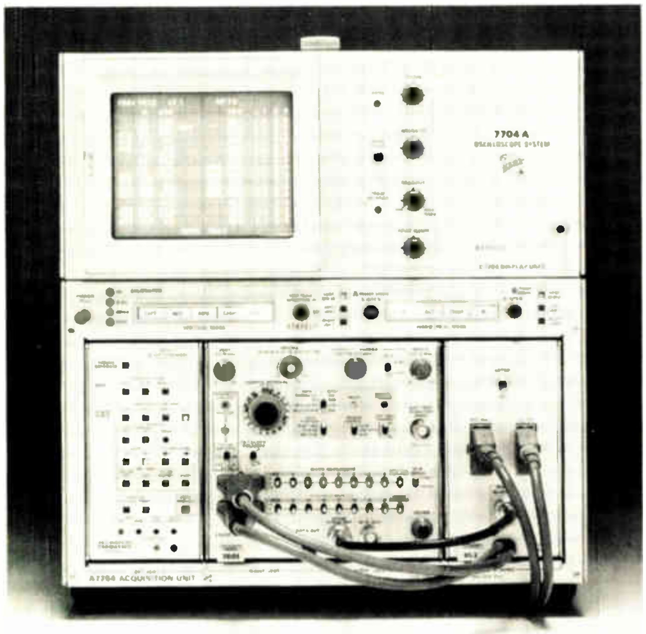
E-H's model 1850 will digitally filter a trigger word for up to 4 samples, whereas Biomation's model K100D will filter for up to 14 samples. HP's 1615A filters a trigger from 15 ns to as long as 2 microseconds; Tektronix' model 7D01 will filter from 10 to 300 ns.

Interpreting the analyzer's data often depends on the display method chosen. This means the captured data must be reduced into more convenient forms.

The first timing analyzers offered only a timing diagram display. However, manufacturers soon realized that their timing analyzers would also be used for state analysis, so they included data domain display formats such as binary, octal, and hexadecimal representations of the data (Fig. 7, left). Most timing analyzers currently available have these display modes, along with other auxiliary display features.

Cursor calculations

One of the most useful of these is the cursor. This is a vertical line superimposed on the CRT that not only helps align the raw data vertically, but is also helpful in calculations. For example, the position of the cursor in the analyzer's memory is read out digitally on the CRT (Fig. 7, right), as is the position of the trigger word. To find the time difference between two points, the cursor



8. ASCII format. The optional ASCII character display converts 7-bit ASCII information into letters, numbers, and symbols for direct interpretation of program statements. This feature is helpful in debugging software-generated problems.

position readings are subtracted after placing the cursor successively over the two points.

Biomation's model K100D has two cursors and reads out their difference in position and time directly. The two cursors are also used to define the word depth of the comparison memory for the trigger-on-noncomparison (or the comparison) mode.

Horizontal magnification in the timing diagram mode has become another standard feature. The magnification factor is displayed digitally on the CRT on the Tektronix and Hewlett-Packard models. It registers automatically on the time line transversing the middle of the Biomation K100D's CRT screen.

The time line is a row of dots showing sample intervals, with intensified dots every five markers and digital readout of the location of the first, last, and center sample displayed. Expansion factor readout is also given. Previous Biomation analyzers and the E-H model 1850, also have a horizontal expansion feature, but the magnification factor is not read out on the CRT.

ASCII display mode

An optional feature worth considering is an ASCII character display offered by both the Tektronix 7D01 and Biomation's K100D. This mode displays 7-bit ASCII information directly as ASCII characters on the CRT. The Tektronix unit uses a separate plug-in ASCII module in place of the normal formatter (Fig. 8). The K100D houses ASCII circuitry inside its mainframe.

These two analyzers also provide a search mode for scanning the analyzer's memory for a user-specified word. This feature is useful when observing the number of passes through a given subroutine, for checking access to portions of a program, and for finding unnecessarily long loops. The word can be keyed in on the K100D; the 7D01 selects it from among those words in the analyzer's reference memory.

The number of occurrences of the searched-for word is read out digitally on the K100D's CRT, and an asterisk is placed next to each such word in a data domain listing of the data. Repeatedly pushing the 7D01's search button and counting the number of button pushes on one sweep through the memory gives the number of occurrences of the searched-for word.

Strictly speaking, a logic analyzer's usefulness lies in its data acquisition and data display features. But as the analyzer's sophistication increases, so does the possibility of error in control settings. To combat this, HP, Biomation, and Moxon have gone to keyboard control of the instruments' functions, with the result that the front panel of the logic analyzers look more like computer terminals than oscilloscopes or minicomputers.

Keyboard entry complements the use of a microprocessor inside the analyzer to perform self-checking as well as calculation and display functions. On older timing analyzers, the user's memory of trigger and control settings was mechanical, indicated by the position of the switches on the front panel. Keyboard-controlled models display the settings on the CRT either in menu format, as in the HP 1615A, or in a status display mode, as in the Biomation K100D.

The microprocessor inside both units performs the housekeeping chore of making sure the key connections are operating at each startup. The Biomation K100D's microprocessor performs the additional function of controlling an error light on the instrument's front panel. It goes on whenever the operator makes a mistake in entering control settings.

Future timing analysis

From probes to display output, the logic timing analyzer has come a long way since 1973. Further improvements will probably be in the area of finding smarter ways to reduce the captured data. Perhaps data-reduction schemes such as Hewlett-Packard's signature analysis techniques [*Electronics*, March 1, 1977, p. 89] may be implemented.

Another possibility is the addition of an RS-232 interface capability so that the analyzer can be used for remote analysis. This could permit a centrally located diagnostic center to perform and interpret tests using a telephone modem. Such a center could take advantage of computer-aided diagnosis and a factory service team to locate problems remotely. The on-site technician would only be needed to position the probes.

Timing analyzers may also eventually use on-board programmable read-only memories to store previous trigger settings and comparison data tables. This would allow a measurement to be repeated by a single press of a button, avoiding the resetting of every function on a complex analyzer.

The complexity of logic timing analyzers must expand along with the complexity of the digital designs they are intended to debug. And since highly skilled personnel remain in short supply, future analyzers are bound to use microprocessors to do more and therefore ask less of their operators. □

A new breed of linear ICs runs at 1-volt levels

Clever circuit design turns standard bipolar processing into a micropower technology

by Robert J. Widlar, *Puerta Vallarta, Jalisco, Mexico*

□ Sophisticated linear circuits such as operational amplifiers, comparators, and voltage references can be made to run at micropower levels supplied by a single power cell. This has implications beyond portable instruments, medically implanted devices, and remote telemetry. Entirely new areas of applications are opened where the IC need not operate from system power supplies, but from residual voltages within the system.

It turns out that precision linear integrated circuits can be made to operate with a total supply voltage of 1 volt, even over a −55°C to 125°C temperature range. What's more, minimum biases of 0.8 V should be acceptable over limited temperatures. This does not require special processing. It can be accomplished with standard bipolar devices that use new methods of circuit design and IC layout. And the techniques described here are in no way restricted to low-voltage operation. In fact, they can be used to improve the performance of devices operating from higher voltages.

The purpose of this article is to acquaint both users and designers of ICs with what can be done at low voltages and to show that its engineering base is sound—sound enough to give some assurance that low-voltage devices can be produced in high volume with yields that are reasonable.

These designs are not theoretical analyses. They are based on an IC in volume production at National Semiconductor Corp., the LM 10.* This is a high-performance op amp and voltage regulator completely specified for operation down to 1.2 V. Limited operation down to 1.0 V is possible.

Although linear circuitry can be made to work at voltages little greater than the base-emitter voltage (V_{BE}) of the transistors used, the first thing to set straight is that no processing trick is likely to produce silicon transistors with a drastically reduced V_{BE}.

What determines V_{BE}

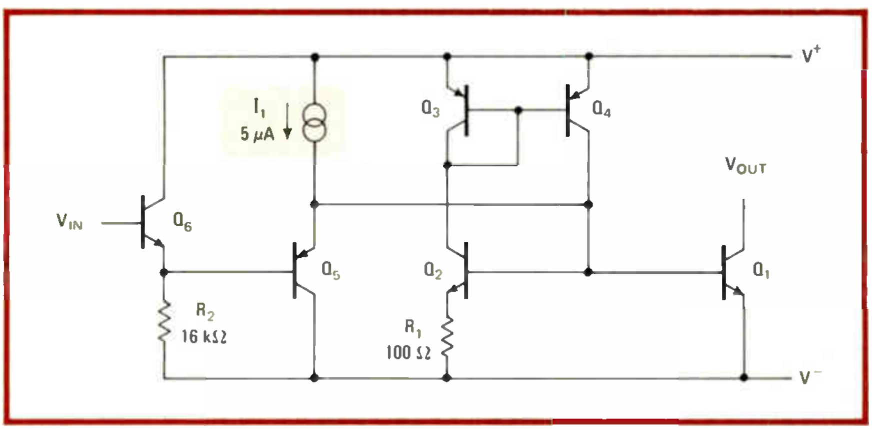
Area, gain, and current determine V_{BE} as shown by the empirical relationship of the following equation, which expresses V_{BE} in terms of readily available engineering data:

$$V_{BE_0} = \frac{kT_0}{q} \ln \frac{I_C}{J_{SB} h_{fe} A_j} \qquad (1)$$

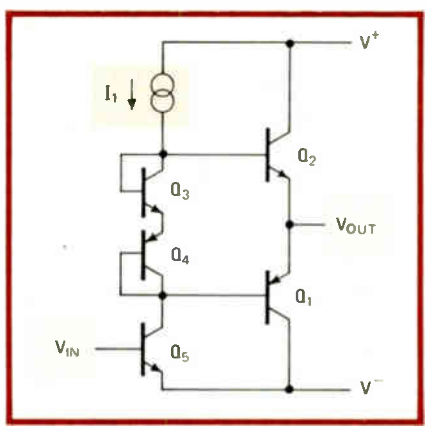
where

k = Boltzmann's constant
T_0 = absolute temperature
q = the charge of an electron (kT/q = 25.8 mV at a temperature of 27°C)
I_c = collector current
A_j = the junction area
h_{fe} = peak ac current gain
J_{SB} = a factor depending on transistor structure.

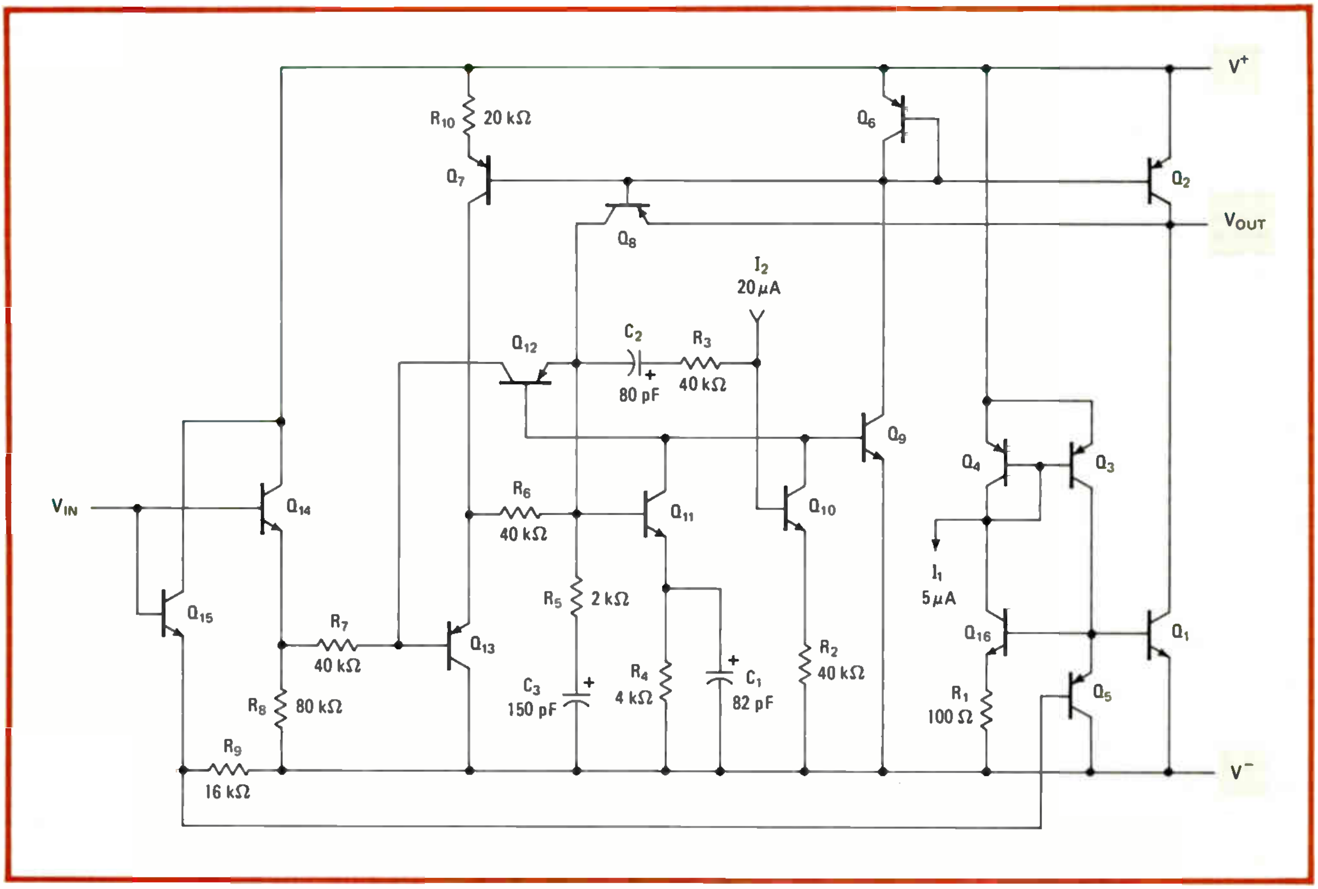
*All substantial rights for the ideas presented have been sold to National Semiconductor Corp., Santa Clara, Calif.



1. Low-voltage Darlington equivalent. Circuit performs the same function as a Darlington device, except that its output can go into hard saturation while being biased from 800 mV. The standby current for the 20-mA output is 10 μA, ideal for proper biases.



2. Class-B amplifier. The output stage of this circuit requires 1.2 V just to turn on, 2.4 V for operating at half the supply.



3. Ideal solution. This circuit provides answer to the output stage problem: a class-B amplifier that saturates to supply rails and operates from 0.8 V. The lower of the two signal paths, Q_{15} through Q_1, is the Darlington equivalent diagrammed in Fig. 1.

The double-diffused npn transistors used in high-performance linear ICs almost always have negligible electron-hole recombination in the base region, as required by the equation. For $T_0 = 300$ K, they give $J_{SB} = 4.4 \times 10^{-13}$ ampere per square centimeter, or 2.8×10^{-18} ampere per square mil. Deviations of 10 millivolts from the predicted V_{BE} would be considered unusual.

Thus an npn transistor with a 1-mil-square emitter and current gain of 200 exhibits a V_{BE} of 550 mV at 1 microampere. Changing any one of the terms of Eq. 1 by a factor of 10 alters this V_{BE} by 60 mV.*

Equation 1 also applies to vertical and lateral pnp transistors with $J_{SB} = 7 \times 10^{-13}$ A/cm². However, good processing is required for base recombination to be negligible (h_{fe} in the order of 100). Further, determining effective junction area is a three-dimensional problem that is especially onerous when it has to be solved for lateral transistors.

Significant reductions in V_{BE} would require a material like germanium with a lower bandgap voltage. It is doubtful that ICs will be made with low bandgap materials in the foreseeable future because they have a limited (65–80°C) maximum temperature and the processing is not compatible with existing techniques.

To obtain operating voltages in the vicinity of 1 V, many standard design methods that have been applied for years simply cannot be used. The Darlington connection is one of these. It is not practical to stack up two V_{BE}s and have the sum approach 1 V under worst-case conditions. Let this be a guiding rule for low-voltage design.

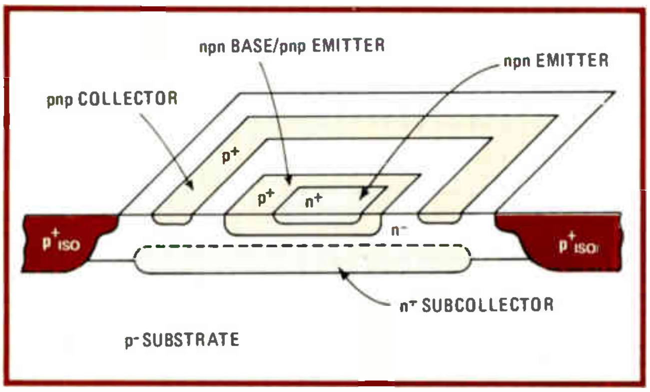
*It might be argued that J_{SB} can be made a factor of 10 larger, but the h_{fe} for a given collector-emitter punch-through voltage would be lowered as much and the V_{BE} would stay the same for all practical purposes.

A Darlington equivalent

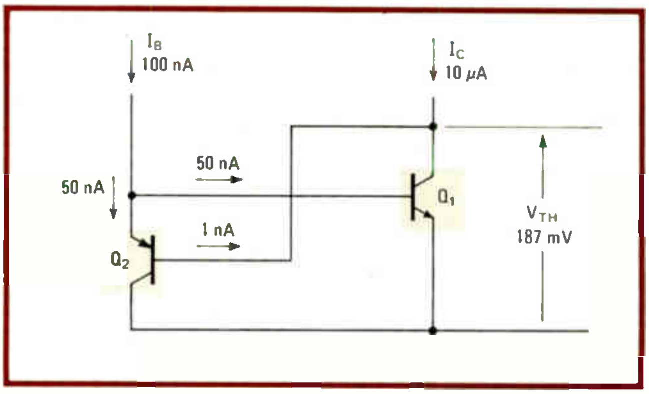
Figure 1 shows a circuit that performs the same function as a Darlington, except that the output can go into hard saturation and can be biased from 800 mV. A boost circuit is used (transistors Q_2, Q_3, and Q_4) to increase the current available to the base of the output transistor as a function of load current. This is required to eliminate biasing difficulties and reduce standby current when the circuit must deliver large peak currents. The standby current for the 20-mA output is 10 μA. Since the emitter current of Q_5 increases with the current through Q_1, the transconductance of the circuit is higher than that of a single transistor. Resistor R_1 limits boost as maximum output is approached, so that the base current of Q_5 does not produce an excessive voltage drop across R_2.

Considerable experience with such boost circuits has shown that they do not unfavorably alter the frequency response of the inverter, at least with frequencies below a few megahertz.

Proper operation requires that the voltage drop across R_2 be about 100 mV. This is arranged by making Q_1 and I_1 no larger than necessary, then making Q_5 large



4. Combined structure. The collector of the lateral pnp transistor (Q_{12} in Fig. 3) recovers excess current from the npn device (Q_{11} in Fig. 3). On occasion, this configuration can be implemented to operate the npn device linearly in saturation.



5. Saturation threshold. This equivalent circuit is helpful in analyzing the saturation characteristics of npn transistors in linear ICs. Depending on current gain, the pnp can run at 1/200 of the current of the npn, enabling the saturation threshold to reach 187 mV.

enough to get the required V_{BE} differential. Tolerances are no great problem. Equation 1 shows that the V_{BE} of an npn transistor will vary ±20 mv for an h_{fe} between 100 and 400. The tolerance of V_{BE} in a pnp transistor depends on epitaxial layer thickness and resistivity. A variation in excess of ±10 mv indicates the process is running out of control.

Push-pull outputs

The output stage presents one of the more interesting problems in low-voltage linear design. The conventional circuit in Fig. 2 is of little value because it requires 1.2 V just to turn on and 2.4 V to get an unloaded output swing equal to half the supply voltage.

A class-A output could be used to get a full swing signal. But the quiescent current would then have to be at least equal to the peak load current. This would result in a great deal of wasted power, even if the operating current could be tailored to individual applications.

The circuit shown in Fig. 3 provides a nearly ideal solution to the output stage problem. It operates from less than 1 V, has a quiescent current of some 50 μA, can swing to the supply rails, and will deliver a ±20-milliampere output current. It is also an excellent example of the kind of problems encountered in low-voltage design.

It can be seen that there are two distinct signal paths. The lower one, Q_{15} through to Q_1, is the Darlington equivalent described earlier. The upper one, driving the pnp output transistor, is much more complicated. Three common-emitter stages are used to get the required level shift and phase relationships.

At first glance, it would seem that this complicated signal path would be impossible to frequency-compensate as a feedback amplifier, especially when included with other gain stages. However, R_4, the R_2–Q_{10} shunt, and Q_6 are used to lower gain, and overall feedback is provided through Q_7. This controls response and reduces gain to about that of the lower signal path.

In positive saturation, a separate feedback path is established through Q_8, so that excessive base drive is not fed to the output transistor.

At high temperatures, Q_{11} is required to operate in saturation. Its collector-emitter voltage is the emitter-base voltage of Q_9 minus the voltage drop across R_4. Under no-load conditions, the current through Q_9 is 1 to 2 μA, so that its V_{BE} is low. As a result, the collector-emitter voltage of Q_{11} will become forward-biased, increasing base current. The resulting voltage drop across R_6 can drastically reduce gain. This is especially noticeable with light loading on the pnp side.

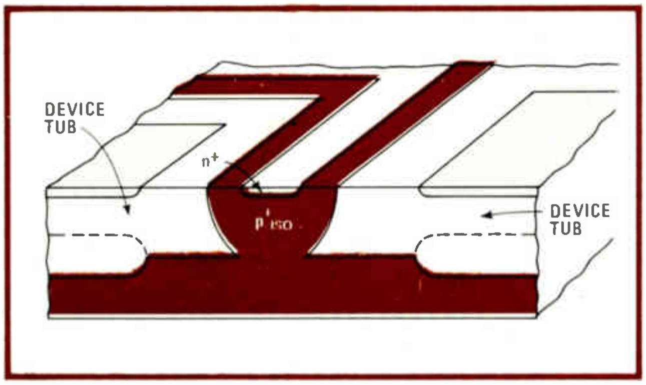
This problem can be solved using the structure in Fig. 4, which is a combined npn (Q_{11}) and pnp (Q_{12}). When Q_{11} goes into saturation, its collector-base junction is forward-biased and the base acts as a lateral pnp emitter, increasing base current. This excess current is picked up by the pnp collector and routed through R_7, producing an equal and opposite voltage drop, so that the net change at the emitter of Q_{14} is negligible.

A limitation

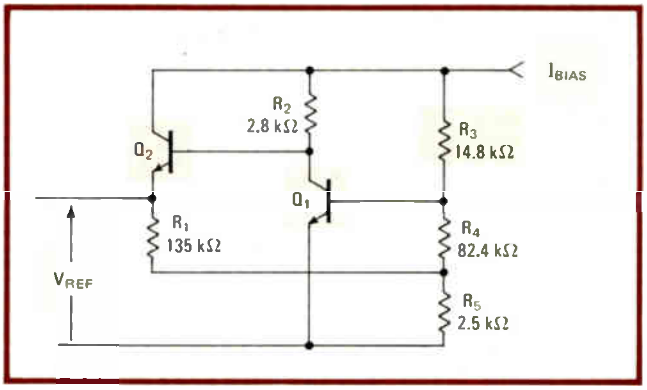
This suggests a fundamental limitation of low-voltage micropower circuits. As operating currents are reduced, V_{BE} goes down, but the voltage at which saturation starts (V_{TH}) does not. With increasing temperature V_{BE} goes down, while V_{TH} goes up. Thus, lower currents will reduce the maximum operating temperature. The technique described above will permit operation into saturation, but it is useful only in certain applications.

The V_{BE} of the npn transistor can be determined from the method described earlier. Because the calculation of effective junction area for the lateral pnp is quite complex, it is probably best determined by measurement. Typically, the npn V_{BE} at h_{fe} = 200 might be 50 mv higher than that of the pnp with equal currents. If a drop in net current gain to 100 is considered the threshold of saturation, the pnp will be running at 200 times less current than the npn (see Fig. 5). This produces a further difference of 137 mv in V_{BE}, so the saturation threshold becomes 187 mv at 25°C. Variations in this for a given process can be computed from a knowledge of the allowed npn h_{fe} values. Lower threshold can be obtained by designing the pnp for high V_{BE}—that is, with a wide base; but not much help can be expected from changes in geometrical factors, unless the structure is very wrong in the first place.

Discrete transistors normally have an offset voltage of 100 to 200 mv, even in hard saturation. This is not



6. Isolation-wall capacitor. One electrode in the structure consists of the p+ isolation diffusion, connected to V−, while the other electrode is an n+ emitter diffusion, made in an area that is otherwise unused. Thus the capacitors do not require additional die area.



7. Voltage reference. The reference provides an output of 200 mV and operates with bias voltages below 800 mV, making it possible to use the rechargeable nickel-cadmium cell as a power source. The drift is 0.002%/°C versus 0.004%/°C for standard references.

necessarily true for IC devices. The reason for this can be seen with the aid of Fig. 5. As base drive is increased above the value shown, the pnp absorbs the current, and its V_{BE} goes up. This requires lower collector-emitter voltage on the npn. This will continue to $V_{CE} < 1$ mV as long as the current gain of the pnp is high enough not to cause excessive npn collector current. The low lateral pnp current gain is what gives gold-doped ICs a high npn saturation offset.

Isolation-wall capacitors

For frequency compensation, the complex signal paths in Fig. 3 require over 300 picofarads of capacitance. This can be emitter-isolation capacitance, which yields about 1 pF/mil², instead of the 0.1 pF/mil² of metal-oxide-semiconductor capacitors. In addition, 75% of this capacitance is diffused into the isolation wall itself. The structure is shown in Fig. 6. Since this region is normally dead space, the capacitors do not increase die area. As an example, the LM108 on a 58-by-59-mil die has over 1,000 pF of isolation-wall capacitance available. The negative electrode of this capacitor is, of necessity, connected to the V^- terminal. Breakdown voltage is around 5 V, and the capacitance is voltage-sensitive. In practice, it requires some diligence to arrange a circuit so that this type of capacitance can be used rather than one that increases die area. It would seem that such effort is well spent.

Standard bandgap references can easily be designed to operate from a 1.3-V supply. This is unnecessarily high and undesirable in that it excludes the rechargeable nickel-cadmium cell as a power source. The circuit in Fig. 7 was designed to get around this. It provides a 200-mV output voltage while operating with supply voltages down to 800 mV.

The 800-mV reference

Circuit operation is most easily understood if R_2 and R_5 are shorted out for the moment. This done, it can be seen that the reference voltage is equal to the voltage drop across R_3 plus the emitter-base voltage differential between Q_1 and Q_2. The former component is proportional to the emitter-base voltage of Q_1 and has a negative temperature coefficient. The latter has a positive temperature coefficient. First-order temperature compensation can be obtained by adding these voltages in the proper proportions.

The collector current of Q_1 is essentially the bias current (I_{bias}) less the current through the R_3-R_4-R_5 divider. If the bias current does not change with temperature and the divider current varies as emitter-base voltage, the collector current of Q_1 can be made proportional to absolute temperature. This done, the value of R_2 can be chosen so that the reference output does not change for small changes in bias current over a wide temperature range.

Drift-curvature correction is obtained by holding the collector current of Q_2 constant while that of Q_1 varies with temperature. This causes the ΔV_{BE} component to have a nonlinear term like V_{BE}, but with opposite sign:

$$\Delta V_{BE} = \frac{kT}{q} \ln \frac{J_{01} T}{J_{02} T_0}$$

$$= \frac{kT}{q} \ln \frac{J_{01}}{J_{02}} + \frac{kT}{q} \ln \frac{T}{T_0}$$

Excessive correction is actually obtained, but this can be fixed by returning R_1 to the proper tap on R_4–R_5. The result is a typical 0.002%/°C drift rather than the best-case 0.004%/°C for the standard bandgap reference.

FETs considered

Some thought has been given to using field-effect transistors for low-voltage linears because of their success in digital ICs. It is true that FETs can be made to operate more or less independently of the bandgap restriction of bipolars. But, as a practical matter, their threshold voltage (V_P) has a tolerance at least as great as the V_{BE} of bipolar devices. In a production environment, some devices might have a lower operating voltage than bipolar, while others might not.

Another drawback of FETs is that the transconductance, even at moderate current densities, is much less than that of bipolars. This means that a 10:1 change in drain current can easily require a change in gate-source voltage as great as the V_{BE} of a bipolars.

There are numerous other problems with all-FET circuits as far as low-voltage operation is concerned. But

The bandgap reference

The bandgap reference compensates for the second-order nonlinearities in the emitter-base voltage and for temperature drifts inherent in the resistance paths. It is well known that the emitter-base voltage of a bipolar transistor has a fairly linear negative temperature coefficient. The emitter-base voltage differential between two transistors operating at different current densities has a positive temperature coefficient. If these two voltages are combined in the proper proportion, a temperature-stable voltage equal to the bandgap voltage of the semiconductor material will result (V_{g_0} = 1.205 V for silicon). This is illustrated with the simplified circuit.

Analytically, the emitter-base voltage differential is:

$$\Delta V_{BE} = \frac{kT}{q}\ln\frac{J_1}{J_2}$$

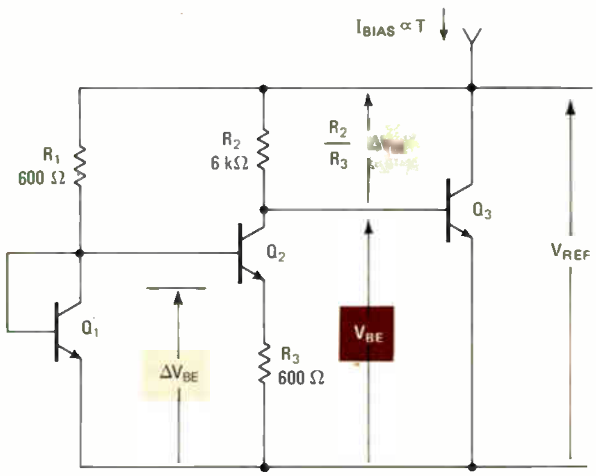
where J_1 and J_2 are the current densities in Q_1 and Q_2. The V_{BE} as a function of temperature is given by:

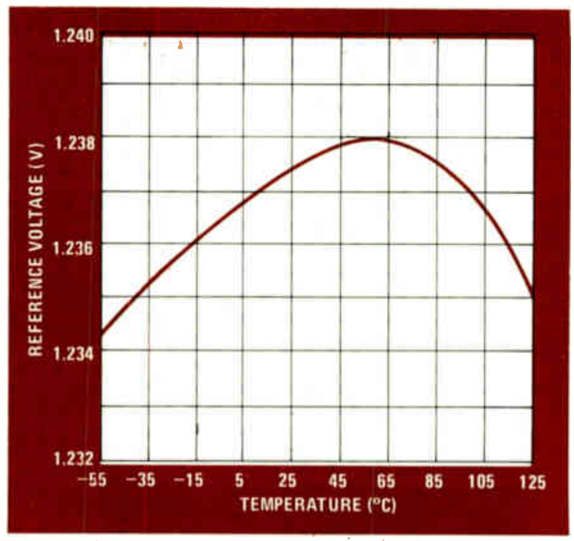
$$V_{BE} = V_{g_0}\left(1-\frac{T}{T_0}\right)+\frac{T}{T_0}V_{BE_0}+\frac{kT}{q}\left[(n-4)\ln\frac{T}{T_0}+\ln\frac{I_c}{I_{c_0}}\right]$$

where V_{BE_0} (Eq. 1 on p. 115) is V_{BE}'s value at T_0 and I_{c_0}, and n is related to base minority-carrier mobility.

The logarithmic terms in the V_{BE} equation require that the reference be raised above the bandgap voltage for minimum drift. They also introduce a nonlinearity that limits the best-case temperature stability to about 0.004%/°C, as shown in the plot. Some correction for this curvature can be made by splitting R_1 (see figure) and connecting a diode across one part.

Precise measurements have indicated V_{g_0} = 1.185 V and n ≅ 1 for double-diffused npn transistors. This contrasts with V_{g_0} = 1.205 V and n = 2 for lateral and vertical pnp transistors. The upshot of these differences suggests bandgap narrowing because of disorder in the crystal lattice due to heavy base doping.





this does not mean that FETs need be excluded. If properly biased, they may well complement bipolar devices in such slots as op-amp input stages. However, there is an uncertain future for all-FET circuits particularly when standard bipolar technology can so readily be shown to be a successful competitor.

Processing

As mentioned earlier, standard linear processing developed in 1968 for such devices as the LM101A and LM111 will suffice for the designs discussed here. Current gains of 200 for npn transistors, 150 for lateral pnps, are typical.

Minimum breakdown voltages should be 45 V, except as altered by localized defects. Therefore, these techniques are not restricted to low voltages, although there would certainly be a market for those devices with low breakdown voltage.

The circuit complexity apparently required for low-voltage design involves the use of many high-value resistors, especially when micropower operation is involved. This requirement can be satisfied by ion-implanted resistors, as long as the required sheet resistance is less than 4 kilohms per square. Above this value, there seems to be a practical problem of control.

Implantation is not a new technology, but it does have its quirks. For one, implanted resistors are necessarily quite shallow, resulting in a small radius of curvature where the junction intersects the surface. This reduces breakdown voltage and increases sensitivity to spurious surface phenomena. Recognizing this, however, it is not difficult to arrange the design and chip layout so that these resistors see only a small fraction of the total supply voltage.

In conclusion

The foregoing indicates that low-voltage circuits can be more complicated than conventional IC designs. Applying these techniques to discrete designs would be absurd. But this is not so for ICs. The LM10, for example, has about the same die size as an IC voltage regulator. Manufacturing yield, to date, is also about equal. Ultimately, cost should be lower since the more expensive power package is not required. □

Digital voltmeter has audible output

by William S. Wagner
Northern Kentucky University, Highland Heights, Ky.

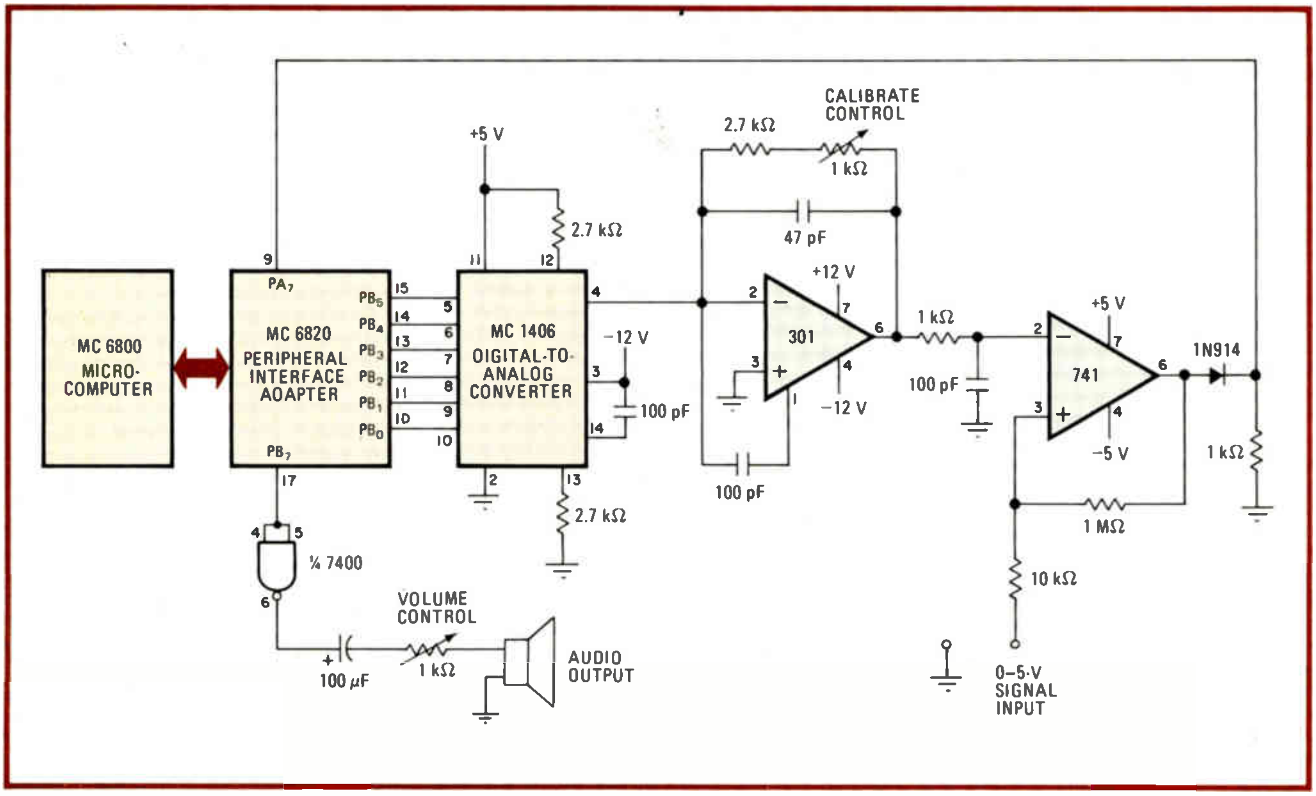
Using a program written for the 6800 microprocessor, and an appropriate interface, this system converts a 0-to-5-volt dc signal into an equivalent sequence of audio tones. Thus, the system will be particularly useful to visually handicapped technicians who troubleshoot logic circuits, as well as in applications where it is not practical to read the voltage from a standard voltmeter's display face.

The voltage to be measured is converted to a series of tones of short duration (dits) to represent quantities extending from 1 to 9. The quantity 0 is represented by a single tone (dah) of relatively long duration. A decimal point is represented by a pause. Thus, for example, 2.5 V yields an equivalent audio output of dit-dit, pause, dit-dit-dit-dit-dit. An 0.3-V signal yields dah, pause, dit-dit-dit. And a 4.0-V signal generates dit-dit-dit-dit, pause, dah. The resolution of the measurement is about 0.1 V.

As implied in the figure, the 6-bit MC 1406 digital-to-analog converter is used in a feedback loop with the 741 operational amplifier for tone generation. The dc input signal is compared to the voltage at the inverting port of the 741. If there is a voltage difference, the digital input to the MC 1406 is adjusted, under program control, until the voltage difference is minimized. The binary word at the output of the MC 6820 peripheral-interface adapter then represents the dc voltage, and is converted to an audio output by the remainder of the program. The frequency and length of the individual tone, the time interval between digits, and the rate at which the dc input signal is sampled are all controlled by the software.

The program requires 250 bytes of memory. The first four instructions initialize the program. The instructions contained between addresses 000C and 00021 comprise the digital-voltmeter part of the routine. Steps 0012 through 0016 set a built-in delay in order to allow the analog portion of the interface sufficient time to update. The instructions commencing at 0018 cause the program to jump to the audio portion of the program (addresses 0023 through 00A0) when the aforementioned match of input and d-a voltages occurs.

In the analog part, the dc voltage is converted to a final 6-bit binary-coded word and stored in an accumulator. Each bit is checked to see whether it is a 0 or an



Potential cure. Microprocessor-based system transforms logic-range voltages into coded series of audio tones for technicians who are unable to observe standard voltmeters. The resolution of the measurements, limited by interface's d-a converter, is 0.1 volt.

6800 PROGRAM FOR AUDIO VOLTMETER

Address	Mnemonic	Address	Mnemonic	Address	Mnemonic
0000	LDX 0004	005C	BNE F7	010C	BNE FD
0003	STX 8000	005E	PULA	010E	DEX
0006	LDX FF04	005F	PSHA	010F	BEQ 03
0009	STX 8002	0060	ANDA F0	0111	COMB
000C	LDB FF	0062	BEQ 3F	0112	BRA F0
000E	CLRA	0064	PULA	0114	LDX 1FFF
000F	STAB 8002	0065	ASLA	0117	DEX
0012	LDX 0055	0066	PSHA	0118	BNE FD
0015	DEX	0067	BCS 11	011A	PULA
0016	BNE FD	0069	PULA	011B	DECA
0018	TST 8000	006A	ASLA	011C	BNE E2
001B	BPL 06	006B	PSHA	011E	RTS
001D	DECB	006C	BCS 13	0120	LDX 03FF
001E	ADDA 01	006E	PULA	0123	ORAB 7F
0020	DAA	006F	ASLA	0125	STAB 8002
0021	BRA EC	0070	PSHA	0128	LDAA 25
0023	LDS 00B0	0071	BCS 15	012A	DECA
0026	PSHA	0073	PULA	012B	BNE FD
0027	ANDA 70	0074	ASLA	012D	DEX
0029	BGT 03	0075	PSHA	012E	BEQ 03
002B	JMP 0120	0076	BCS 17	0130	COMB
002E	PULA	0078	BRA 1A	0131	BRA F0
002F	ASLA	007A	LDA 08	0133	PULA
0030	ASLA	007C	JSR 0100	0134	ASLA
0031	PSHA	007F	BRA E8	0135	ASLA
0032	BCS 0C	0081	LDA 04	0136	ASLA
0034	PULA	0083	JSR 0100	0137	ASLA
0035	ASLA	0086	BRA E6	0138	PSHA
0036	PSHA	0088	LDA 02	0139	JMP 0053
0037	BCS 0E	008A	JSR 0100	0140	LDX 03FF
0039	PULA	008D	BRA E4	0143	ORAB 7F
003A	ASLA	008F	LDA 01	0145	STAB 8002
003B	PSHA	0091	JSR 0100	0148	LDAA 25
003C	BCS 10	0094	LDAA 02	014A	DECA
003E	BRA 13	0096	LDX FFFF	014B	BNE FD
0040	LDA 04	0099	DEX	014D	DEX
0042	JSR 0100	009A	BNE FD	014E	BEQ 03
0045	BRA ED	009C	DECA	0150	COMB
0047	LDA 02	009D	BNE F7	0151	BRA F0
0049	JSR 0100	009F	PULA	0153	PULA
004C	BRA EB	00A0	JMP 000C	0154	ASLA
004E	LDA 01	00A3	JMP 0140	0155	ASLA
0050	JSR 0100	0100	PSHA	0156	ASLA
0053	LDAA 01	0101	LDX 00FF	0157	ASLA
0055	LDX FFFF	0104	ORAB 7F	0158	PSHA
0058	DEX	0106	STA 8002	0159	JMP 0094
0059	BNE FD	0109	LDAA 25		
005B	DECA	010B	DECA		

integer from 1 to 9, so that it can be determined if short or long tones are to be produced by the dit and dah subroutines, respectively. The instructions commencing at 0053 sets a time interval between the processing of the first and second integers of the measured voltage, and the instructions starting at 0094 set the time interval between readings, or samples.

The actual short-tone subroutine extends from addresses 0100 to 011E. The instructions specified from 0101 to 010F determines the length and frequency of the short tones. Addresses 0114 through 0118 set the time interval between dits.

There are two subroutines for the generation of long tones. One is called (address 0120) when the first integer of the voltage measured is 0. The second is called (0140) where the second integer is 0. Both contain instructions for setting the length and frequency of the long tone. □

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.

Calculator notes

TI-59 converts s coefficients into two-port net parameters

by G. Papaioannou
Physics Laboratory, University of Athens, Greece

The two-port scattering (s) coefficients that are so important in characterizing the small-signal behavior of microwave circuits are easily translated into their popular y, z, g, and h parameter counterparts with this TI-59 program. The program also performs the reverse conversions—that is, from the y, z, g and h parameters to the s coefficients.

Using the s parameters is advantageous at high frequencies for two reasons. First, the parameters of a two-port network are more appropriately related to the measurement of the incident and reflected waves of a device having a specified input and output impedance than to the measurement of admittances and impedances. Second, it is difficult to determine the y, z, g, and h parameters at high frequencies, because finding the set of four values required to characterize each parameter involves the absolute short-circuiting and open-circuiting of either the input or output port—conditions difficult to achieve in the microwave region. Still, engineers often desire to know the conventional parameters at high frequencies, and vice versa, and this program has been developed to aid them on those numerous occasions.

Given the known parameters A_{ij} of a two-port, four-terminal circuit, where i and j may equal 1 or 2, corresponding to the two input leads and two output leads of the device under test, the program solves the complex (real and imaginary term) matrix for the desired M parameter:

$$M_{11} = c[(2/D)(1+aA_{22})-1]$$
$$M_{12} = c(2/D)A_{12}$$
$$M_{21} = cde(2/D)A_{21}$$
$$M_{22} = bd[(2/D)(1+aeA_{11})-1]$$

where constant a through constant e vary with the type of conversion being performed (see table), and where $D = (1+aeA_{11})(1+aA_{22})-eA_{12}A_{21}$. This set of equations in A is valid for the y, z, g, and h parameters if they are normalized to Z_0, the output impedance of the circuit whose characteristics are represented by the s parameters. The normalizing of the conventional parameters must take place before the conversion to the s parameters is carried out. The required normalization formulas are shown in the table (right).

In order to check the program, consider the conversion of the z parameters to the s parameters, where $Z_{11} = 100\Omega+j50\Omega$, $Z_{12} = 200+j50$, $Z_{21} = 200+j0$, and $Z_{22} = 400+j400$ at $Z_0 = 50$ ohms. Keying in the required information as instructed, keeping in mind to divide all Z_{ij} by Z_0 before entering, yields $s_{11} = 0.391+j0.558$, $s_{12} = 0.096-j0.266$, $s_{21} = 0.028-j0.273$ and $s_{22} = 0.911+j0.198$. □

CONVERSION OPERATORS AND PARAMETER NORMALIZERS

Transformation	Constant a	b	c	d	e	Z_n	Y_n	G_n	H_n
$s \to y$	1	1	−1	1	1	$z_{11} = Z_{11}/Z_0$	$y_{11} = Y_{11}Z_0$	$g_{11} = G_{11}Z_0$	$h_{11} = H_{11}/Z_0$
$s \to z$	−1	1	1	1	1				
$s \to g$	−1	1	−1	−1	−1	$z_{12} = Z_{12}/Z_0$	$y_{12} = Y_{12}Z_0$	$g_{12} = G_{12}$	$h_{12} = H_{12}$
$s \to h$	1	1	1	1	−1				
$y \to s$	1	1	−1	1	1	$z_{21} = Z_{21}/Z_0$	$y_{21} = Y_{21}Z_0$	$g_{21} = G_{21}$	$h_{21} = H_{21}$
$z \to s$	1	−1	1	1	1				
$g \to s$	−1	1	−1	1	−1	$z_{22} = Z_{22}/Z_0$	$y_{22} = Y_{22}Z_0$	$g_{22} = G_{22}/Z_0$	$h_{22} = H_{22}Z_0$
$h \to s$	1	−1	1	−1	1				

TI-59 PROGRAM FOR TWO-PORT PARAMETER CONVERSION

000	LBL	053	x⇄t	106	2	159	RCL	212	RCL	265	A′
001	A′	054	STO	107	=	160	17	213	16	266	LBL
002	R/S	055	10	108	STO	161	=	214	×	267	B′
003	×	056	R/S	109	03	162	R/S	215	RCL	268	SBR
004	RCL	057	STO	110	x⇄t	163	RCL	216	18	269	E
005	00	058	11	111	×	163	13	217	=	270	EXC
006	÷	059	STO	112	2	165	STO	218	R/S	271	16
007	RCL	060	01	113	=	166	01	219	x⇄t	272	EXC
008	19	061	R/S	114	STO	167	RCL	220	×	273	17
009	+	062	STO	115	04	168	14	221	RCL	274	GTO
010	1	063	12	116	RCL	169	STO	222	16	275	A′
011	=	064	STO	117	07	170	02	223	×	276	LBL
012	STO	065	02	118	STO	171	PGM	224	RCL	277	C′
013	05	066	R/S	119	01	172	04	225	18	278	SBR
014	STO	067	STO	120	RCL	173	C	226	=	279	E
015	01	068	13	121	08	174	×	227	R/S	280	STO
016	R/S	069	STO	122	STO	175	RCL	228	LBL	281	00
017	×	070	03	123	02	176	17	229	A	282	STO
018	RCL	071	R/S	124	PGM	177	×	230	SBR	283	19
019	00	072	STO	125	04	178	RCL	231	E	284	GTO
020	÷	073	14	126	C	179	18	232	GTO	285	A′
021	RCL	074	STO	127	−	180	×	233	A′	286	LBL
022	19	075	04	128	1	181	RCL	234	LBL	287	D′
023	=	076	PGM	129	=	182	19	235	B	288	SBR
024	STO	077	04	130	×	183	=	236	SBR	289	E
025	06	078	C	131	RCL	184	R/S	237	E	290	STO
026	STO	079	÷	132	16	185	x⇄t	238	EXC	291	16
027	02	080	RCL	133	=	186	÷	239	00	292	EXC
028	R/S	081	19	134	R/S	187	RCL	240	EXC	293	18
029	×	082	=	135	x⇄t	188	17	241	17	294	STO
030	RCL	083	INV	136	×	189	×	242	GTO	295	17
031	00	084	SUM	137	RCL	190	RCL	243	A′	296	GTO
032	+	085	09	138	16	191	18	244	LBL	297	A′
033	1	086	x⇄t	139	=	192	×	245	C	298	LBL
034	=	087	÷	140	R/S	193	RCL	246	SBR	299	E
035	STO	088	RCL	141	RCL	194	19	247	E	300	1
036	07	089	19	142	11	195	=	248	STO	301	STO
037	STO	090	=	143	STO	196	R/S	249	00	302	00
038	03	091	INV	144	01	197	RCL	250	STO	303	STO
039	R/S	092	SUM	145	RCL	198	05	251	18	304	16
040	×	093	10	146	12	199	STO	252	STO	305	STO
041	RCL	094	RCL	147	STO	200	01	253	19	306	18
042	00	095	09	148	02	201	RCL	254	GTO	307	STO
043	=	096	STO	149	PGM	202	06	255	A′	308	19
044	STO	097	01	150	04	203	STO	256	LBL	309	+/−
045	08	098	RCL	151	C	204	02	257	D	310	STO
046	STO	099	10	152	×	205	PGM	258	SBR	311	17
047	04	100	STO	153	RCL	206	04	259	E	312	INV SBR
048	PGM	101	02	154	17	207	C	260	EXC		
049	04	102	PGM	155	=	208	−	261	19		
050	C	103	05	156	R/S	209	1	262	EXC		
051	STO	104	E	157	x⇄t	210	=	263	17		
052	09	105	+	158	×	211	+	264	GTO		

Registers	
R_0	a
R_{16}	b
R_{17}	c
R_{18}	d
R_{19}	e

Labels	
A	s ⇄ y
B	s → z
C	s → g
D	s → h
E	a-e coefficient subroutine
A′	main program
B′	z → s
C′	g → s
D′	h → s

Instructions

- Key in program
- Select the conversion desired and press the corresponding label key

  A program subroutine will set the appropriate values for constants a–e (see accompanying table). Note that one key serves for the s → y and y → s transformations; constants a-e are identical.
- Enter real and imaginary components of known parameters

  ($A_{11\,R}$), R/S, ($A_{11\,I}$), R/S, ($A_{22\,R}$), R/S, ($A_{22\,I}$), R/S, ($A_{12\,R}$), R/S, ($A_{12\,I}$), R/S, ($A_{21\,R}$), R/S, ($A_{21\,I}$), R/S

  Parameters z, y, g, and h must be normalized before they are entered (see accompanying table)
- Real part of M_{11} will be calculated and displayed.

  Press R/S to recover $M_{11\,I}$. The remaining parameter components will be displayed in the order M_{12}, M_{21}, M_{22} each time R/S is pressed.

Engineer's newsletter

Getting started in custom ICs

"No experience necessary," says educational projects manager Bob Simpson of Interdesign Inc.'s integrated-circuit design course. He claims **the course will allow engineers outside the semiconductor industry to design their own custom ICs and set them up for specific applications.** The company spent more than a year and a half preparing the material, which consists of text, 10 self-contained audio-visual lectures, and three technology kits (C-MOS, bipolar, and one on linear and n-MOS devices). At $975, it's not something the individual engineer will buy but it's a good deal for company purchase or lease at $100 per week. Contact Bob at 1255 Reamwood Ave., Sunnyvale, Calif. 94087, or call him at (408) 734-8666.

Test jig simplifies amplifier testing

Testing amplifiers for compliance with the data sheet is hard enough without having to put together a base plate for the heat sink, banana jacks for the power supply connections, pin sockets for connection to the amplifier's pins, and other bothersome trivia. TRW RF Semiconductors is **offering a $39 test fixture dubbed "The Demonstrator" to save you the trouble.** The kit, which includes a sample wide-band high-power hybrid amplifier, fits the TRW 28XX series and the Motorola MHW series, according to TRW applications engineer Don Feeny. Call him about the kit at (213) 679-4561 or write TRW RF Semiconductors, 14520 Aviation Blvd., Lawndale, Calif. 90260.

Get hot on printed-circuit soldering

With high-density packaging finding its way into nearly every electronic system, it's important to keep up with the latest techniques for soldering printed circuits and microminiature assemblies. One way would be to attend the Illinois Institute of Technology's **14th Annual Soldering Technology Seminar held April 30 through May 2** at the McCormick Inn in Chicago. The three-day seminar, conducted by Howard Manko, author of "Solders and Soldering," will cost $335. His subjects will include the physics of wetting, the chemistry of fluxes, electrical and mechanical design, printed-circuit troubleshooting, inspection, and quality, and special considerations for soldering hybrids. For registration and hotel information call (312) 567-3300 or write the program chairman, Soldering Technology Seminar, Department of Electrical Engineering, Illinois Institute of Technology, Chicago, Ill. 60616.

Finding the right ion implantation angle

In ion implantation, an ion beam is directed at a wafer of single crystal silicon to produce controlled deposits of dopants. High-yield semiconductor or IC production demands precise calculation of implantation "channeling"—the phenomenon by which ions are steered through the crystal by collisions with its atoms. The angle at which the ion beam strikes the substrate strongly influences ion channeling.

Information about the relation between ion beam angle and the atomic number and energy of the ions has only been available for older implantation types. But now a National Bureau of Standards publication sponsored by the Defense Advanced Projects Research Agency **can bring you up to date with current laboratory practice.** Send $2.50 for "Angular Sensitivity of Controlled Implanted Doping Profiles" (number SD-003-003-01997-6) to the Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20402. Add 65 cents for delivery abroad.

Harvey J. Hindin

Tektronix expands graphics system line

New units in 4050 family use bipolar bit-slice microprocessor to increase speed up to 30 times over 6800-based 4051

by Robert Brownstein, San Francisco regional bureau

Aiming to offer greater resolution for an ever-widening applications base while simultaneously topping the competition, Tektronix is expanding its single, desktop graphics computing system into a line of three. It is adding models 4052 and 4054 to its popular four-year-old model 4051.

In a market for desktop computers that is growing fast—(about 40% per year according to Venture Development Corp.'s 1978 estimate)—Tektronix sees the three products satisfying a broad range of user requirements from low-cost graphic systems to high-end systems. Their particular strengths are for applications geared to research, engineering design, and management reporting, according to Howard Mikesell, general manager of the information display division of the company.

The 4051, which was introduced in November 1975, uses a 6800 microprocessor, imposing certain restrictions on the new system because the designers had software compatibility among the three systems as an important design goal. On the other hand, they also wanted to increase system speed in the new units.

"What really slows down systems like the 4051 are floating-point numerics and transcendental functions, which are prominent in line transformations," explains Gary P. Laroff, product marketing manager. The 6800, with its fixed instruction set, is not the most efficient tool for computing these functions. Therefore Tek chose to redesign the entire system using a fast 16-bit bipolar bit-slice processor that emulates the instruction set of the 6800. Their design employs four 4-bit 2901s.

Unlike the metal-oxide-semiconductor 6800, the new processor has its transcendental functions and floating-point instructions in its microcode. The result, in some cases, is that programs can run up to 30 times faster on the 4052 than on the 4051, according to Laroff. Needless to say, the new systems also beat the tar out of competitive systems built around MOS microprocessors.

Having taken care of the speed problem, the designers next shifted their attention to the resolution arena. Whereas the $9,800 4052 looks exactly like the $5,995 4051 (both have 11-inch screens) and is easily mistaken for its lower performance relative, the $16,500 4054 with its 19-inch screen and cursor thumbwheels is immediately distinctive. The large screen makes a difference in resolution, too. "There are about 300,000 resolvable points in a typical desktop raster-scan graphics system compared to 13 million for the 4054," Laroff points out.

What's more, the larger screen accommodates up to 133 lines of text, which means a user can preview whole pages of computer printout on the screen—a first in desktop systems. Instead of a dot-matrix char-

Fratenal twins. Although the units are nearly identical externally, the processor in the 4052 is totally redesigned, replacing the 4051's 6800 with a bit-slice emulation. As a result, the former is much faster than the latter yet retains software compatibility.

acter generator like that used in the two smaller systems, the 4054 features a vector character generator. The quality of the characters is better and more fonts are available.

Both the 4051 and 4052 have constant-time vector generators; it takes the same time to draw a short vector as it does to draw a long one. In contrast, the 4054 has a constant-rate generator. Its ability to draw short vectors faster adds up to a significant overall improvement in drawing speeds, according to Laroff.

Like the 4051, the new systems come equipped to interface with other accessories such as X-Y plotters or printers via the IEEE-488 general-purpose interface bus, but they do it three times faster. A user can buy an optional serial interface and here, too, the communications rate is given a boost: the 2,400-bit/second maximum rate of the 4051 is now pushed up to maximum of 9,600 b/s in the option for both new units.

System memory capacity is enlarged from the standard 8 kilobytes of read/write memory in the 4051 to 32 kilobytes in both the 4052 and 4054. Both may be expanded to 56 kilobytes with add-in options, according to Laroff. Read-only memory packs for binary loading and matrix commands that are optional for the 4051 are included in the firmware in the new systems.

All three systems will run the full selection of Plot 50 software, including Tek's new modeling and reporting software, which allows users to work in English-like statements, store data in matrix format, and construct a model for problems like budget analysis, key performance indicators, and profit planning. Reports with graphics to spotlight data trends are then quickly constructed by running the model as a program.

Both the 4052 and 4054 are available for lease as well as for sale. The prices given on the previous page apply to small quantities. In addition, the usual large-quantity discount and original-equipment-manufacturer terms apply.

Tektronix Inc., P. O. Box 500, Beaverton, Ore. 97005 [338]

Chip handles I/O channel

Monolithic device implements common mainframe technique for Intel's 8086 and other high-performance microprocessors

by William F. Arnold, San Francisco regional bureau manager

The input/output channel so popular in boosting the systems performance of large mainframe computers has been adopted by Intel Corp. for its 16-bit 8086 and other high-performance microprocessors. To be available in sample quantities during the second quarter, the 8089 input/output processor, or IOP, as it is called, is the first I/O controller of its kind for microprocessors to be designed on a single chip.

Eight-bit microprocessor systems commonly employ direct-memory-access controllers to swap data between system memory and high-speed peripherals. But these controllers typically cannot handle the throughput, power, and control functions of the newer 16-bit processors, says Intel product manager Bruce McCormick. Even tying a separate microprocessor to the DMA controller does not help the situation much either, he adds.

No interruptions. Intel designed the 8089-device as a bus-compatible peripheral controller dedicated to input/output handling that works in real time and in parallel with the 8086 without interrupting it, McCormick says.

"Suppose the host CPU requires I/O. It 'wakes up' the 8089, which picks up the I/O program it's going to need from memory. Then, under control of that program, it sets up the peripherals, does the direct memory access, data conversion, and comparison, and then lets the host CPU know it's finished," he explains.

One 8089 can control, for example, a floppy disk and keyboard, as well as a cathode-ray-tube's display memory and refreshing. Managing a CRT can take 20% of a processor's time—time the 8086 can now devote to other, more important tasks, he points out.

The single-chip 8089, made with Intel's advanced metal-oxide-semiconductor process, HMOS, "is addressing a need in a way it's never been addressed before in microcomputers," McCormick declares.

The Santa Clara, Calif., company has high hopes for the chip in applications involving things like industrial control, text editing, word processing, and communications control. To complement the 8086's multiprocessing orientation, "you can group IOPs together in modules of two for almost any number of I/O channels you want," he says.

Speed. To make sure that the 8089 is fast enough as a DMA controller, Intel designed it with two fast speeds, a 5-MHz version with a DMA transfer rate of 1.25 megabytes per second, and due later, an 8-MHz part with a 2-megabyte/s rate. For larger systems, where the 8086 and 8089 would share the system bus, Intel has developed a bipolar 8289 bus-arbitration unit to act as a traffic cop. In this configuration, the 8089 would have a program of up to 64 kilobytes, accessible through its own local bus. In some smaller systems, it would use the 8086's 1 megabyte of system memory and thus share the same bus.

The 8089, an approximately 240-mil-square die in a 40-pin package, can interface with either 8- or 16-bit units on either its local bus or the system bus. Included also is a powerful instruction set that includes bit-manipulation instructions.

Intel Corp., 3065 Bowers Ave., Santa Clara, Calif. 95051 [339]

When you're searching for component solutions . . .

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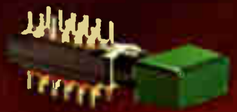

PBS-Series horizontal mounting

The secret to widening your choice of pushbutton switches is the unusual flexibility of Centralab's modular pushbutton switch systems. You'll find lighted and non-lighted switches for pc board or front panel mounting; single station or ganged assemblies with 10 to 25mm spacings; 2-4-6 or 8 pole designs for push-push, push-pull, momentary or interlocking operation with lockout optional; silver or gold contacts; epoxy sealed terminals; and a variety of switch housing materials. An outstanding choice of other options include buttons, colors, lenses, filters and legends.

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Circle 128 on reader service card

Computers & peripherals

Printer churns out up to 150 c/s

Using a 9-by-18-dot matrix, unit quickly produces letter-quality printouts

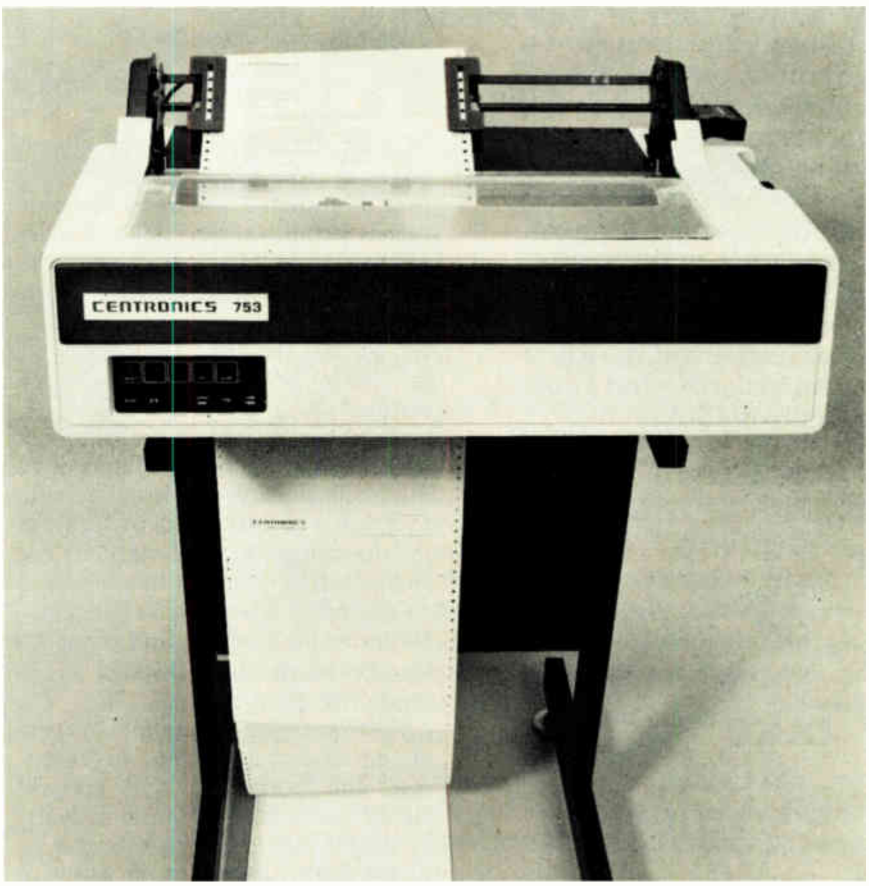
Throughput rates on word processors aren't what they could be, to say the least. Text generation is done in a snap, but waiting for the printout can seem like an eternity. Centronics Data Computer Corp., however, promises to change that situation with a dot-matrix printer that can knock out 130 to 150 characters per second while producing nearly letter-quality copy.

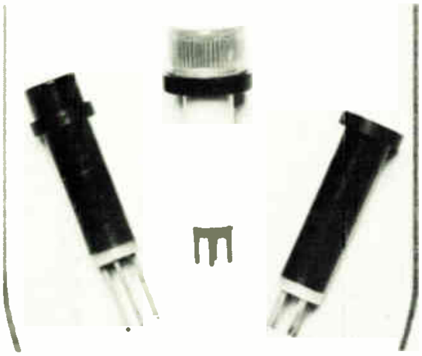
"Letter-quality printing is what a lot of people want from a word-processing system," notes Richard J. Buba, product marketing manager, "and we're supplying the end user with it at five times the speed and about half the cost of current daisy-wheel printers."

The microprocessor-based model 753 uses a nine-pin printing head to produce a software-controlled dot matrix that is 9 dots high and up to 18 dots wide. Since each letter is printed in this format, the dots are so close together that they seem to overlap, practically eliminating the white space between them, which is so obvious with other printers.

The 753 offers a choice of uniform or proportional spacing. Right-margin justification is also available. With proportional spacing, the printer adjusts the horizontal space allocated to each letter depending upon the letter's width, just like the print on this page. With uniform spacing, the space occupied by each letter is constant, as with a standard typewriter.

Other product features include: a 96-member ASCII character set, 132-column printing, bidirectional





lenses are of the fresnel type and have either regular or low-profile front-panel projections. At 20 mA, they have a minimum average lifetime of 10 years.

In quantities of 100 or more, standard LEDs are priced at $2.93 apiece. Delivery takes three to five weeks.

Data Display Products, 303 North Oak St., Inglewood, Calif. 90301. Phone (213) 677-6166 [346]

IREDs offer up to 60 mW in any of four packages

The HLP20-60 series is composed of infrared-light-emitting diodes (IREDs) housed in any of the four packages shown. Models of the gallium-aluminum-arsenide units, which have hemispherical emitting surfaces, can provide up to 60 mW of output power, and any wavelength between 715 and 950 nm can be ordered.

The IREDs have a power efficiency of over 18%, rise and fall times of less than 12 ns, and bandwidths to 40 MHz. Delivery is from stock to eight weeks. Details on other advantages of GaAlAs IREDs over GaAs units are covered in the HLP series application manual.

Hitachi America Ltd., 707 West Algonquin Rd., Arlington Heights, Ill. 60005 [345]

Packaging & production

Versatile inspector sells for $22,900

Z80-based analog IC tester performs like costlier units, is easily programmed

GenRad has been strong in incoming testing since the early 1970s. Now the company may have scored a major price-performance breakthrough with the introduction of its model 1731, a microprocessor-based analog integrated-circuit tester that sells for $22,900. About twice the price of a typical benchtop tester, the 1731 compares in accuracy, flexibility, and breadth of capability with large testers costing four to six times more, according to the company.

With a Z80 microprocessor running the tests and a 6502 controlling the cartridge tape system, the 1731 offers:

- Software that permits fast, comprehensive testing of 3,000 to 5,000 different analog devices (ranging from operational amplifiers, voltage comparators, regulators, and voltage followers to current-mirror op amps). Up to 20 tests per device can be made in from one-half to three seconds.
- Prompting that enables unskilled personnel to make exact quantitative tests in addition to simpler evaluations.
- Data logging, through IEEE-488 and teletypewriter ports, and statistical analysis by external computer.
- Self-test and diagnosis to minimize downtime and modular construction to speed repair.
- Test fixtures, at one-sixth the cost of other available units, that can be wired for the user in 15 minutes to one hour.
- A proprietary slew-rate test method that makes measurements of 1,000 V/μs possible.
- Current-sensing protection of fragile metal-oxide-semiconductor input devices.
- Provision for automatic device handling.
- Growth potential for testing other analog devices.

Comparing the 1731 with units priced in the hundred-thousand-dollar range, William Kabele, project manager of the Electronic Instrument division, reasons that while the overall throughput may not be as great, one half to three seconds per device is more than adequate for incoming tests. "You can buy a lot of 1731's for what one of the larger systems cost," he adds.

Easy operation. With a calculator-like keyboard, users step from one program section to another during initial set-up. For example, following a GenRad-supplied program sheet and watching the display, a user presses the device-select key and keys in identifying data from the program sheet for the unit to be tested. He then selects his sorting requirements and keys the test conditions: up to eight different sets of supply voltages, loads, and source impedances.

Using another menu, the user selects specification or performance limits for up to 20 device characteristics—from offset voltage to power supply rejection ratio. Again, this data is taken from a supplied program sheet or, as with test conditions, is tailored to suit the application. Once this information is keyed in by, for example, a supervisor, testing is a simple matter of inserting a device, pushing a button, and removing the unit—a process that can be totally automated with the addition of handling equipment.

Users have a choice of a simple pass-fail display or of a thorough, quantitative display of device performance showing which parameters failed to match specification. Negative alphanumerics highlight out-of-spec values.

The 1731 also includes self-testing at power-up. A small program in read-only memory checks to see that the basic architecture is sound, then loads the operating program from the unit's magnetic tape. After the program is loaded, internal testing proceeds throughout the system.

If there is a flaw, the display says so; the operator can insert a diagnostic tape and specialized socket adapter and test further. Faults can be isolated down to the individual IC if necessary, but board-level isolation is usually sufficient since GenRad will swap a good board for a bad board in one to two days. Delivery

time for the entire system is approximately 12 weeks.

GenRad Inc., 300 Baker Ave., Concord, Mass. 01742. Phone (617) 369-8770 [391]

Analyzer measures photo-mask line widths

Designed for automatic, highly accurate measurements of line widths on integrated-circuit photo-masks, the MPA-2A Micro-Pattern Analyzer measures line widths from 0.5 to 199 μm. It is accurate to within ±0.1 μm, and repeatable to within ±0.05 μm. Mask sizes cover the range from 2.5 by 2.5 in. to 6 by 6 in. and may be checked using a magnification of 800×.

The instrument automatically scans the image of the mask produced by the system's objective lens with a mirror slit in the image plane. A linear encoder detects the line edge and the movement of the slit in units of 0.03 μm.

Measurements, which are presented on a 5-digit display, are automatically recorded by the printer. The price of the instrument is approximately $60,000; delivery takes 30 days.

Nikon Inc., Instrument Division, 623 Stewart Ave., Garden City, N. Y. 11530. Phone (516) 222-0200 [395]

Tester classifies LEDs by brightness and color

With light-emitting-diode displays being increasingly used in high-volume applications, a need is developing for an instrument that not only can measure an LED's brightness but can also recognize its color. The microprocessor-based 4000 tester can do both in less than 2 seconds.

With its color-recognition option the tester can distinguish between green, amber, orange, and infrared, as well as make spectrophotometric measurements. A classification signal can sort displays into 16 different brightness categories. The 4000 tests any LED readout of up to 10

digits, each digit with up to 40 segments.

The instrument can perform incoming inspection tests, production tests, and production selection. It can be programmed to perform tests in any order and may be reprogrammed when necessary.

The standard model 4000 includes a cathode-ray-tube terminal, a photodetector, a microprocessor-controlled high-speed test system, and one preprogrammed programmable read-only memory. Additional PROMs can be supplied; a printer and a PROM programmer are also available as options.

The 4000 sells for $38,500 and has a delivery time of 60 days. The color option sells for $10,000.

E-H International Inc., 515 Eleventh St., Oakland, Calif. 94607 [394]

Wafer preparation system is microprocessor-controlled

Designed to ease the processing of semiconductor wafers, the Autofab system can be configured with wafer scrubbing, coating, baking, and developing subassemblies. The system provides direct access to all wafer processing steps through its microprocessor-based control unit. Commands, readouts, and warnings are displayed in simple English, making operator training time as little as 30 minutes, according to the company. A built-in audiovisual alarm system indicates error conditions without erasing the existing display. If power fails, a battery backup system retains stored data for up to 24 hours. The system sells for from $40,000 to $120,000.

Computervision Corp., Cobilt Division, 2727 Augustine Dr., Santa Clara, Calif. 95051 [396]

Microcomputers & systems

Z8000 gets development unit

Especially designed for 16-bit microprocessor, unit supports 8-bit processors too

When the Z8000 hits the streets later this year, it will not be the only 16-bit kid on the block. In order to become king of the hill, it will need a microprocessor development system able to rally support from the 8-bit processor gang. The question, then, is: with which of the 8-bit processors should such a system ally itself?

At next month's Paris component show, Advanced Micro Computers plans to unveil its answer in the form of the AmSYS 8/8, a development system designed for the Z8000 that supports the 8080 and 8085, as well as the Z80. AMC's American parent, Advanced Micro Devices, will be a second source for Zilog's Z8000 and has for some time been producing its version of Intel's 8080A (the Am9080A) and the 8085.

"The reason the Z80 is in the group is that some people will grow from the Z80 to the Z8000, so it is essential to include it in the system," states John Drakeford, marketing manager for AMC. He also notes that since "it gives people a warm feeling to keep their 8080 routines," an 8080A-to-Z8000 translator is included in the software package.

The present system is built around an Am9080A because, under the terms of its agreement with Zilog, AMD cannot yet make its own Z8000, Drakeford explains. But AMC plans two option boards that will employ the 40-pin version of the Z8000 and plug directly into the 8/8's multimaster bus (Multibus). Due out this summer is an evaluation/prototyping board that should cost under $1,000. A second module, the 96/4116, is being readied for fall delivery. This will include 16,384 16-bit words of memory, two read-only memory sockets, and three 8-bit input/output ports. With the 4116, estimated to cost $1,400, the 8/8 will be able to go by a new name: the AmSYS 8/16.

Besides the Am9080A central processor, the standard 8/8 includes 32 kilobytes of random-access memory (expandable to 64 kilobytes), 512 kilobytes of disk storage, one RS-232 serial port, six 8-bit parallel ports, macro-assemblers for the Z8000 and 8080 in addition to the translator, plus such items as a linking loader, editor, and debugger.

Designed as a desktop system, the 50-lb unit is priced at $7,450. Options include macroassemblers for the Z80 and 8085, an additional printed-circuit board for expanding read-only memory and erasable programmable ROM, a cathode-ray-tube terminal, and line printers of various speeds.

Advanced Micro Computers, 3340 Scott Blvd., Santa Clara, Calif. 95051. Phone (408) 988-7777 [371]

High-speed microcomputer aims for place in mini world

Continuing the trend toward abolishing the traditional distinctions between microcomputer and minicomputer markets [*Electronics*, March 15, 1979, p. 88], the Mk-16 is a high-speed 16-bit machine that offers memory-to-memory instruction speed rivaling that of high-end minis. In step with software trends too, it executes UCSD Pascal p-code.

The Mk-16 is available in two versions: one that employs high-speed bipolar circuitry and another that uses a single-chip processor built with complementary-metal-oxide-semiconductor-on-sapphire technology for low power. Both versions employ a writable dynamic control store, which lets users modify instructions during running time; this follows the microprogramming philosophy of bit-slice architectures. Over 20 address modes are provided and up to 16 megabytes can be addressed under the Mk-16's Megabus memory-management system.

Any of the system's 14 16-bit accumulators can serve as a stack pointer. The system handles byte and 16-bit word instructions and also has an instruction set for 32-bit math, so that it can emulate various microprocessors. Two 16-bit numbers multiply to a 32-bit product in just 9.6 μs or, with the high-speed option, 2.8 μs.

The Mk-16 is being offered as a

LAMBDA LAS 3905, 8 AMP, 80 WATT MONOLITHIC POSITIVE VOLTAGE REGULATORS

Description

8 amp positive regulator

The LAS-3900 series voltage regulators are monolithic integrated circuits designed for use in applications requiring a well regulated positive output voltage. Outstanding features include full power usage up to 8.0 amperes of load variation, internal current limiting, thermal shutdown, and safe area protection on the chip, providing protection of the series pass Darlington, under most operating conditions. In addition, a sense terminal is provided for elimination of voltage drop problems at high currents. Hermetically sealed copper TO-3 packages are utilized for high reliability and low thermal resistance when used with an appropriate heat sink. A low-noise temperature-stable diode reference is the key design factor insuring excellent temperature regulation of the LAS-3900 series. This coupled to a very low output impedance insures superior performance and load regulation.

The LAS-8900 series of four terminal regulators is available in a fixed output voltage tolerance of ±5% with a nominal output voltage of +5 volts.

ABSOLUTE MAXIMUM RATINGS

PARAMETER	SYMBOL	MINIMUM	MAXIMUM	UNITS
Input Voltage	V_{IN}	0	25 (1)	VOLTS
Input/Output Differential	$V_{IN}-V_{OUT}$	0	20 (1)	VOLTS
Power Dissipation @T_C≤94°C	P_D		80 (1) (2) (3)	WATTS
Thermal Resistance Junction To Case	θ_{JC}		0.7	°C/WATT
Operating Junction Temperature Range	T_J	-55	150	°C
Storage Temperature Range	T_{STG}	-65	150	°C
Lead Temperature (Soldering, 60 Seconds Time Limit)	T_{LEAD}		300	°C

(1) The maximum input voltage of the LAS-3900 Series is limited by the maximum input-output differential, maximum power dissipation, or the maximum current limit safe operating area, whichever is less.

(2) For operation above 94°C T_{CASE}, derate @1.42 watt/°C.

(3) In case of a short circuit, the second breakdown protection designed in this regulator may require the removal of the input voltage to re-start the regulator.

Regulator Performance Specifications

Input voltage test condtions are as follows: V_1 = Vo + 3 Volts, V_2 = Vo + 10 Volts, V_3 = Vo + 150 volts, or the maximum input whichever is less.

PARAMETER	SYMBOL	TEST CONDITIONS V_{IN}	I_o	T_J	MIN	MAX	UNITS
Input Voltage	V_{IN}		10MA		Vo+2.6	25(5)	Volts
Output Voltage	V_O	V1 to V2	10MA to 8.0 Amp	25°C	0.95[Vo](1)	1.05[Vo]	Volts
Input-Output	$V_{IN}-V_O$		8.0 Amp	0°C to +125°C	2.6		Volts
Differential	$V_{IN}-V_O$		0.5 Amp	0°C to +125°C		20	Volts
Output Current	I_O	V1		25°C	0	8.0	Amps
Line Regulation(2)	$REG_{(LINE)}$	V1 to V3	5A	25°C		2.0	%V_O
Load Regulation(2)	$REG_{(LOAD)}$	V1	10MA to 8.0 Amp	25°C		0.6	%V_O
Quiescent Current	I_Q	V1	Output/Open	25°C		20	MA
Quiescent Current Line	$I_{Q(LINE)}$	V1 to V2	10MA	25°C		5	MA
Quiescent Current Load	$I_{Q(LOAD)}$	V1	10MA to 8.0 Amp	25°C		5	MA
Current Limit	I_{LIM}	Vo+5V		25°C		14	Amps
Short Circuit Current	I_S	Vo+5V		25°C		14	Amps
Temperature Coefficient	T_C	V1	0.1 Amp	0°C to +125°C		0.03	%Vo/°C
Output Noise Voltage	V_N	V1	0.1 Amp	0°C to +125°C		10(3)	uVrms/V
Ripple Attenuation	R_A	V1	2.0 Amp	0°C to +125°C	60(4)		dB

(1) Nominal output voltages are specified under ordering information.

(2) Instantaneous regulation, average chip temperature changes must be accounted for separately.

(3) BW=10Hz – 100 Hz.

(4) Ripple attenuation is specified for a 1 VRMS, 120 Hz input ripple. Ripple attenuation is a minimum of 60 dB at a 5 volt output.

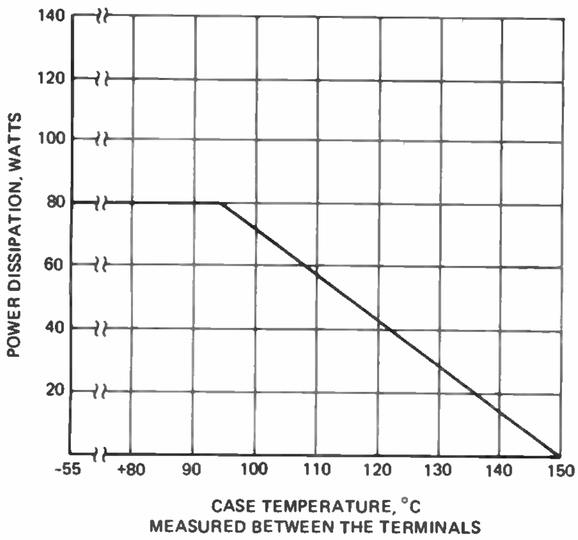
(5) The maximum input voltage of the LAS-3900 series is limited by maximum input-output differential voltage, maximum power dissipation, or the current limit-SOA, whichever is less.

Price List

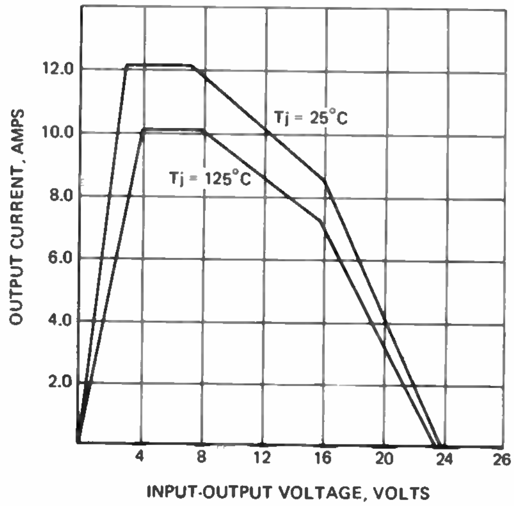
NOMINAL Vo VOLTS	DEVICE PART NO.	QTY 1-24	QTY 25-49	QTY 50-99	QTY 100-249	QTY 250-499	QTY 500-999	QTY 1000-2499	QTY 2500-4999
5	LAS-3905	$ 18.00	$ 16.50	$ 15.75	$ 14.75	$ 13.00	$ 11.90	$ 10.65	$ 10.00

CONTACT THE FACTORY FOR HIGHER QUANTITY PRICES. DEVICE CONFIGURATIONS, SPECIFICATIONS, AND PRICES SUBJECT TO CHANGE WITHOUT NOTICE

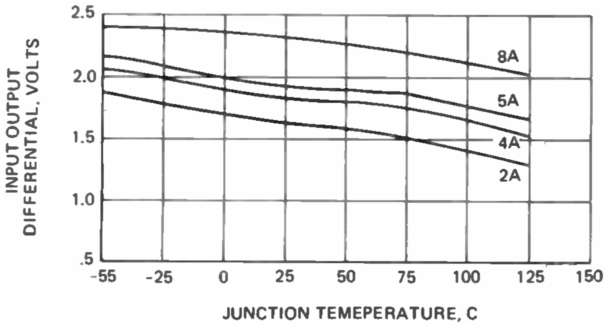
Operational Data



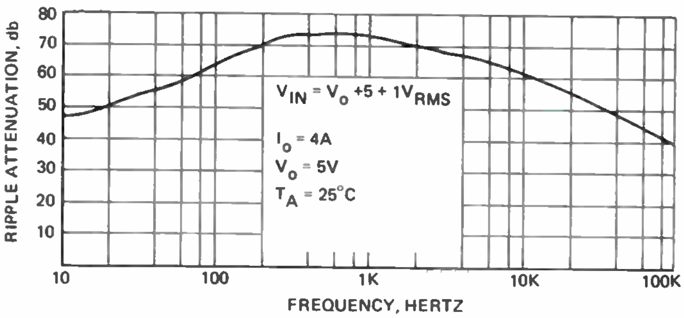
POWER DERATING



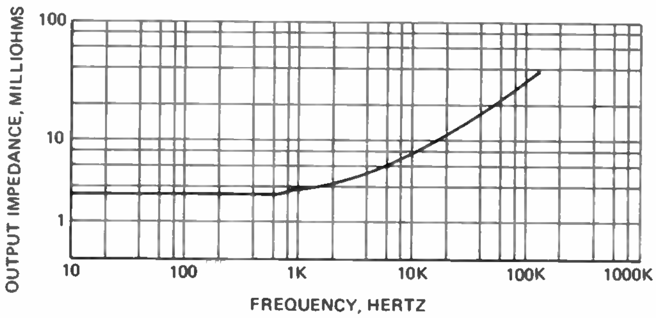
TYPICAL CURRENT LIMIT
VS INPUT OUTPUT
VOLTAGE DIFFERENTIAL



TYPICAL INPUT-OUTPUT
DIFFERENTIAL VOLTAGE vs
JUNCTION TEMPERATURE

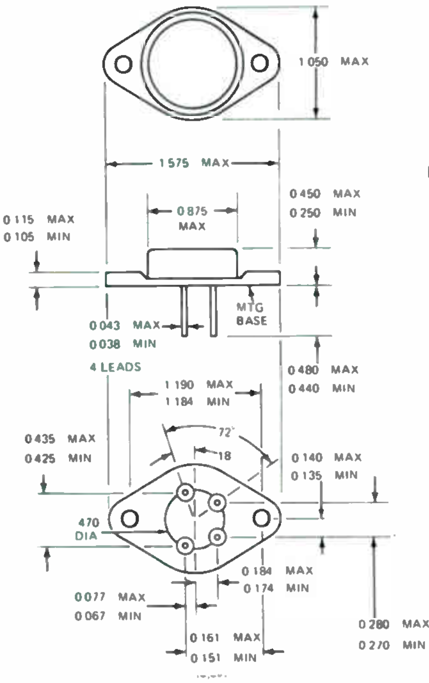


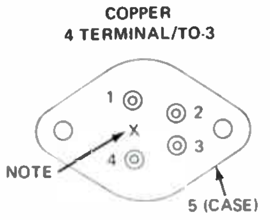
TYPICAL RIPPLE ATTENUATION
vs FREQUENCY



TYPICAL OUTPUT IMPEDANCE
vs FREQUENCY

Outline Drawing

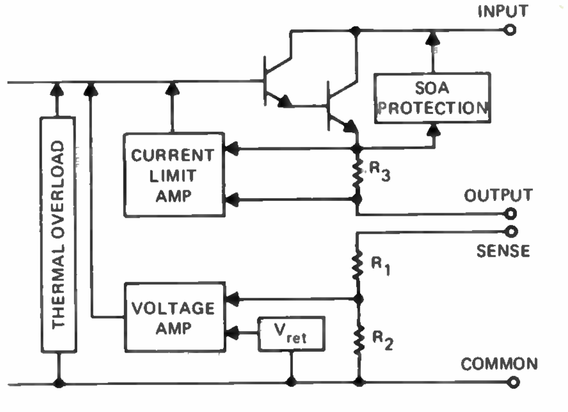




NOTE (X) = Case temperature measured at this point.

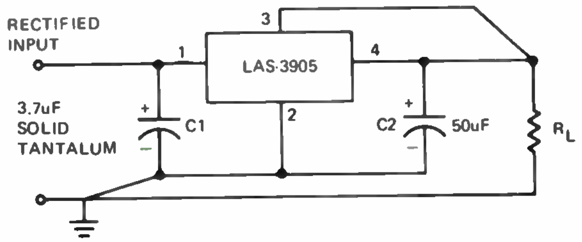
PIN	FUNCTION
1	INPUT
2	COMMON (ELEC)
3	SENSE
4	OUTPUT
5	COMMON

Functional Block Diagram

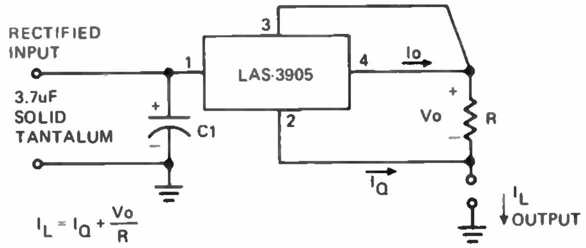


LAS-3905

Typical Applications



PIN 2 IS CONNECTED TO CASE.
C 1 TO BE PLACED AS CLOSE TO THE DEVICE AS POSSIBLE
FILTER CAPACITOR = 2000uF/AMP
8 AMP POSITIVE REGULATOR CIRCUIT



PIN 2 IS CONNECTED TO CASE.
C1 TO BE PLACED AS CLOSE TO THE DEVICE AS POSSIBLE.
FILTER CAPACITOR = 2000uF/AMP
FIXED CURRENT REGULATOR

Lambda staffed sales and service offices

ATLANTIC REGION
Melville, New York 11747
515 Broad Hollow Road
Tel 516-694-4200
TWX 510-224-6484

SOUTH-WESTERN REGION
Corpus Christi, Texas 78410
121 International Drive
Tel 512-883-6251

FAR-WESTERN REGION
Cerritos, Ca 90701
12607 Hidden Creek Way Suite J
Tel 213 926 0941
TWX 910-346-7649

NORTH-EASTERN REGION
Lexington, Massachusetts 02173
2 Militia Drive
Tel 617-861-8585
TWX 710-326-7558

MID-WESTERN REGION
Arlington Heights, Ill. 60005
2420 East Oakton St, Unit Q
Tel 312-593-2550
TWX 910-222-2856

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Sunnyvale, Ca 94086
599 N Mathilda Ave
Tel 408-738-2514
TWX 910-339-9243

POWER SEMICONDUCTORS DESIGNED, DEVELOPED AND MANUFACTURED BY

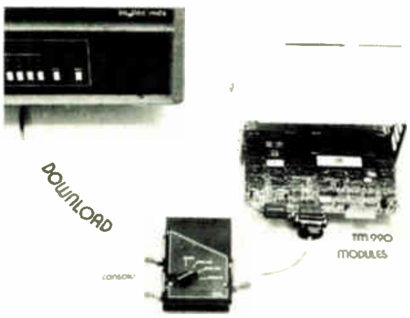
LAMBDA ELECTRONICS
DIVISION of Veeco INSTRUMENTS INC

Pascal development system (PDS-1) that includes video display terminal and 56 kilobytes of memory, as well as floppy disk, monitor, and p-code software. So configured, the Mk-16 sells for $12,500.

Mikros Systems Corp., 845 Central Ave., Albany, N. Y. 12206. Phone Mike Marvin at (518) 489-2561 [373]

Adapter links Itellec MDS with 9900-based modules

Used in conjunction with Pivot 9900 software [*Electronics*, Nov. 9, 1978, p. 187], the Pivot MDS adapter unit lets 9900 code developed on the widely used Intellec 800 microprocessor development system be downloaded into a 990 module. The adapter also permits transfer of the module's memory to disk files and operation of its monitor from the



MDS console, as well as normal MDS operation.

With the adapter, users can set breakpoints, examine memory, monitor input and output, and execute code from the console. It is priced at $260 with cables.

Processor Innovations Corp., 118 Oakland St., Red Bank, N. J. 07701. Phone Ken Wilson at (201) 842-8110 [374]

Utilities enhance OEM Basic and Fortran usage

Two software utility packages—one for Intel Corp.'s Basic-80, the other for its Fortran-80—allow original-equipment manufacturers to apply these high-level languages more directly to their single-board computer systems. Both are available as libraries of routines, stored on diskette, and run on the Intellec development system under the RMX/80 real-time multitasking executive.

The iSBC 802 Basic-80 Interpreter Package allows Basic-80 to be executed directly by the iSBC 80 family of single-board computers. It is supplied in two forms: relocatable and predefined. The former is compatible with a wide range of hardware, whereas the latter is specifically tailored for the iSBC 80/30, 32 kilobytes of RAM, and the iSBC 204 floppy-disk controller.

The iSBC 801 Fortran-80 Run-Time Package permits existing Fortran-80 programs to be executed on iSBC 80 systems without modification. It also offers formatted input/output and compatibility with the iSBC-310 high-speed math unit.

The iSBC 802 Basic-80 package costs $4,995, and the iSBC 801 Fortran-80 package is $1,000. Both these prices include resale licenses.

Intel Corp., 3065 Bowers Ave., Santa Clara, Calif. 95051 [372]

EXORciser-compatible drives store up to 2 megabytes

The EXORdisk III is designed for EXORciser, EXORterm, and Micromodule systems and consists of two double-sided, single-density floppy-disk drives in a tabletop cabinet with power, a controller board, and a cable to interconnect the two. The system's megabyte storage capacity can be expanded to 2 megabytes by adding a separate dual-drive unit.

Supplied with the system on one diskette is the disk-operating software, MDOS 3.0, enabling data transfers between single- and double-sided floppy disks. A complete 1-megabyte system costs $4,800 and can be expanded to 2 megabytes for an additional $4,200. A controller board with interconnecting cable may be purchased for $1,200.

Motorola Microsystems Group, P. O. Box 20912, Phoenix, Ariz. 85036. Phone (602) 962-2156 [375]

Data acquisition

D-a converter uses diffused resistors

12-bit monolithic device is differentially linear to ±½ LSB without trimming

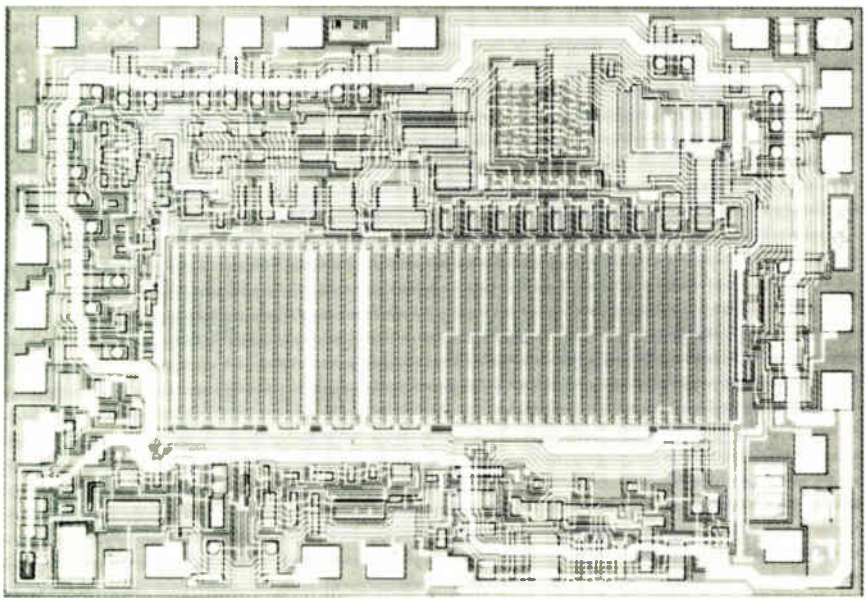
Traditionally, digital-to-analog converters have employed precision thin-film resistors that in most designs have required trimming, either by laser or zener diodes. Advanced Micro Devices has taken a new route with the monolithic 12-bit Am6012 by implementing a design with diffused resistors that do not need trimming. The resulting device provides true differential linearity to within ±½ least significant bit.

Monotonicity is achieved by a combination of the classical R-2R and 2^nR resistor ladder techniques in what is called a segmented 9-bit d-a converter. With the three most significant bits, a segment decoder divides the full output range into eight major segments. The 9-bitter further divides a selected segment into 512 parts. Summing all selected pieces generates the full output.

Diffusing the resistors in a single crystal assures better long-term stability and tracking, as well as high moisture resistance. The differential nonlinearity is guaranteed to be within ±0.12% of full scale over the range from −55° to +125°C. Furthermore, full-scale current output is specified at 4 mA, so that designers can use smaller load resistors and minimize RC delay. Typically, the unit settles to within ±½ LSB in 250 ns under load conditions.

The Am6012's price depends on temperature and package grades, ranging from $9.95 to $49.95 in 100s.

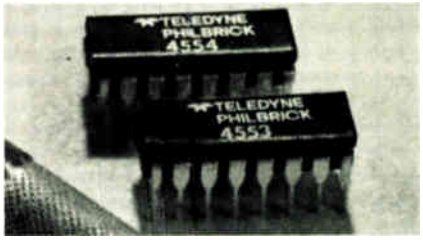
Advanced Micro Devices Inc., 901 Thompson Pl., Sunnyvale, Calif. 94086. Phone (408) 732-2400 [381]



C-MOS multiplexers work over wider temperature range

Data-acquisition systems can now be built to endure wide temperature variations using complementary-metal-oxide-semiconductor devices that operate over the range from −55° to +125°C. This specification applies to -01 versions of the differential four-channel 4553 and the single-ended eight-channel 4554, which are plug-compatible with the popular MPC4D and the MPC8S, respectively.

The units, compatible with transistor-transistor logic as well as C-MOS, switch channels in break-



before-make fashion on receipt of an enable signal and a logic word (2 bits wide for the 4553 and 3 bits for the 4554). They accept maximum inputs of ±15 V, have a maximum input leakage current of ±50 nA, and typically settle to within 0.01% of full-scale range for a change of 20 V between channels in 5 μs. Typical power dissipation is 7.5 mW.

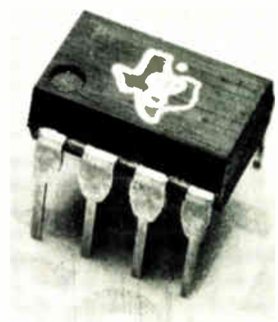
Units that operate over the −55°-to-+125°C range are priced at $27.48 in single quantities; the 0°-to-75°C versions sell for a relatively low $13.30. All models are available from stock.

Teledyne Philbrick, Allied Drive at Rte. 128, Dedham, Mass. 02026. Phone Ted Serafin at (617) 329-1600 [383]

I²L a-d converter resolves 7 bits for only 65¢

Designed for use with 4-bit microcomputers, the TL507C is an analog-to-digital converter that resolves 7 bits at a cost of only 65¢ in 100s. The integrated-injection-logic device uses a single-slope conversion technique to create an output pulse proportional in duration to the level of the analog input.

The converter consists of a 7-bit synchronous counter, a binary-weighted ladder network, a summing



amplifier, two comparators, a buffer amplifier, an internal regulator, and the required logic. Conversion takes approximately 1 ms and, with a 5-V supply, typically consumes only 25 mW. The TL507C will work from an unregulated 8- to 18-V or a regulated 3.5- to 6-V source over the temperature range from 0° to 70°C.

Texas Instruments Inc., Inquiry Answering Service, P. O. Box 225012, M/S 308 (Attn: TL507C) Dallas, Texas 75265. Phone Mary Perkins at (214) 238-5908 [384]

16-bit d-a converter settles in 10 μs

Engineers who need a fast-settling, low-cost digital-to-analog converter that accepts 16-bit binary or 4-digit binary-coded-decimal inputs can turn to the DAC71. The converter settles to within 0.003% of full-scale range in just 10 μs, typically.

The six models provide a choice of input codes (unipolar, bipolar, or binary-coded decimal) and voltage

or current outputs. Output voltage ranges can be 0 to 10 V or ±10 V, and output current ranges of ±1 mA or 0 to −2 mA are available. In addition to being linear to within ±0.003% of full-scale range at 25°C, the DAC71 has a gain temperature coefficient of ±15 ppm/°C.

Housed in a 24-pin ceramic package measuring 1⅜ by ¾ by ¼ in., the DAC71 is priced from $39 apiece in lots of 100 or more. Delivery is from stock to four weeks.

Burr-Brown, P. O. Box 11400, Tuscon, Ariz. 85734. Phone Herman Loopeker at (602) 746-1111 [385]

Circle 145 on reader service card

Power supplies

Lab supply sells for $275

Unit has a 5-V output and two 0-to-25-V supplies that can track or work alone

To work on breadboard designs, project engineer Prim Fernandez used to stack three single-output power supplies on his bench. But he found the stack cumbersome and difficult to control and, after looking around, decided that existing triple-output supplies were too expensive. So he persuaded his bosses at the B&K Precision division of Dynascan Corp. to branch out and produce an inexpensive three-output laboratory supply. The model 1650, now available at distributors at a cost of $275, is the result.

The 1650 has a fixed 5-V dc output that can deliver 5 A, plus a pair of completely isolated 0-to-25V dc outputs that can pump 0.5 A apiece. A front-panel switch allows the variable supplies to operate independently or in a tracking mode. When working in the latter mode, the variable outputs will track within 1% over the range from 2 to 22 V. Since they are completely isolated, the supplies may be connected to provide the bipolar outputs commonly needed by analog circuitry.

Regulation for the 5-V output is within 0.4% for a 20-V line change and 3% for a full load change. The variable supplies are regulated to within 0.2% for 20-V line changes and to within 0.1% for load variations from 0 to 0.5 A. Output ripple and noise is specified at less than 5 mV rms for the 25-V outputs and 10 mV rms for the 5-V.

Overvoltage protection for the 5-V supply is triggered at 7 V. In case of current surges, the supply output folds back to 2.5 A. The unit is guaranteed not to latch at the foldback current. The variable outputs also have current-limiting circuitry.

According to the company, the design of the isolated tracking outputs is unique, and it has applied for a patent on the concept. The circuit is built around a GE model H11A5 optoisolator that "is used in a pulse mode, not linearly," Fernandez explains. "It's like an analog-to-digital converter."

To keep costs down, the U.S.-made 1650 has a single analog meter with a switch that allows it to measure all six output voltages and currents. Meter accuracy is within 5% of full scale. To cut costs further, input filtering for the internal power supply is provided by a resistor in series with the rectifiers; more commonly a capacitor would be used. Possibly the most significant cost-cutting move is that the front-panel controls have been directly connected to the component-carrying printed-circuit board.

The 1650 also carries a one-year guarantee.

B&K Precision, Dynascan Corp., 6460 W. Cortland St., Chicago, Ill. 60635 [401]

Single-output supplies pack greater power in same space

Consisting of single-output linear supplies, the R series can provide 25% more power than competitive units the same size, according to the company. Purchasers can select from among 42 models with outputs ranging from 5 to 24 V and 1.5 to 33.7 A. Maximum power available is 315 W. These supplies have line and load regulation of 0.1% of output and ripple and noise specifications of 1.5 mV rms. Prices for single units begin at $37.

Deltron Inc., Wissahickon Avenue, North Wales, Pa. 19454. Phone (215) 699-9261 [404]

High-voltage power supply reacts to remote commands

A modular high-voltage supply, the remotely programmable model 230 is intended as a power source for sensitive applications like photomultiplier excitation. It is less than one-third the size of comparable rack-mountable power supplies.

The 230's output, which can be varied from 0 to 2,000 V dc and from 0 to 4 mA, can be specified as either positive or negative. An auxiliary output of 1 V per kV of main supply permits remote monitoring. The 230 sells for $300.

Pacific Precision Instruments, 1040C Shary Ct., Concord, Calif. 94518 [405]

Products newsletter

IBM offers quantity discounts on its Series/1

Since it was first announced in November 1976, the Series/1 minicomputer from IBM Corp.'s General Systems division lacked one thing every other minicomputer company offered—quantity discounts. **Now the Atlanta-based division is offering discounts on all Series/1 processors and Series/1 peripherals with 4900 model numbers, and even Series/1 licensed software.** Customers buying from 50 to 99 of any one item get 5% off the list price, whereas those purchasing between 100 and 149 units get a 10% reduction. The maximum 15% discount is applied to purchases of more than 150 items. IBM notes, however, that the units all must be installed within an 18-month period.

Ailtech digitizes spectrum analyzer

Look for Ailtech, the Ronkonkoma, N. Y., division of Cutler-Hammer Inc., to come out with an updated version of its model 727 rf spectrum analyzer. The new instrument, which will be designated the 757, **will feature a digitized display section offering such functions as a hold button to freeze the display for leisurely study, a mode in which the difference between the input spectrum and a stored spectrum is displayed, and on-screen readout of six key parameters.** The 757 will cover the frequency range from 1 MHz to 22 GHz and will sell for $19,975.

Data General cuts memory cost, adds software

Data General Corp. is cutting memory prices and adding software as part of its continuing effort to broaden the minicomputer marketplace. The Westboro, Mass., firm is expanding the Eclipse C/150 and C/250 computers to accommodate 1 and 2 megabytes of read/write memory, respectively. At the same time, **the company has slashed the price of its 300-to-600-ns MOS/ERCC memory to $28,000 per megabyte—a 53% cut.**

With cheaper, larger main memory available, designers are adding Data General's AOS (advanced operating system) to the Eclipse C/150. **Further adding to the usefulness of DG's machines are four new software packages: INFOS QUERY, the AOS text entry and editing system, Virtual Cobol, and RDOS X.25.** Highly interactive INFOS QUERY allows nonprogrammers to cull data from existing data bases and have it processed to reflect, say, sales trends. AOS text entry and editing includes word processing functions as well as data-base management. Virtual Cobol separates programs into the part in use, which goes into the main memory, and the remainder, which goes into mass storage. RDOS X.25 software provides access to packet-switched communications networks for pay-by-the-bit data transmission.

Graphics units write over 20,000 vectors

Employing a new technique called adaptive timing, Megatek Corp. of San Diego, Calif., is producing modular, stroke (vector-refresh) systems capable of writing more than 20,000 short vectors on a 4,096-by-4,096-element monitor with 30-Hz refresh. The Whizzard 5000 and 7000 families, whose members range from Data General–compatible boards to stand-alone systems, **employ a 32-bit architecture built from 2900-family bit-slice chips;** one model, the 5014, emulates Tektronix' 4014 storage-tube terminal and, like the others, provides high-quality moving graphics. Prices for the 5000 series start down at $6,400 for the graphic processor and vector generator boards.

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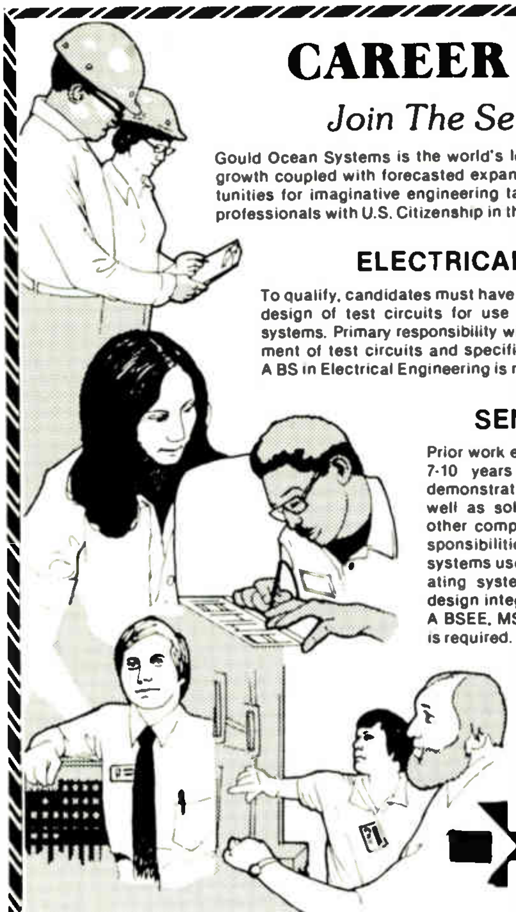

Gould Ocean Systems is the world's leading pioneer in the field of oceanic technology, and is continually striving to stay #1. Significant growth coupled with forecasted expansion and a solid commitment to new product development has created exciting professional opportunities for imaginative engineering talent with Gould's fast-moving Ocean Systems Division. Immediate openings are now available for professionals with U.S. Citizenship in the following areas:

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To qualify, candidates must have at least 5 years experience in the design of test circuits for use in complex digital and analogy systems. Primary responsibility will involve the design and development of test circuits and specifications for performance testing. A BS in Electrical Engineering is required.

SENIOR ENGINEER

Prior work experience should include at least 7-10 years of power control engineering demonstrating strong leadership abilities as well as solid experience in Fortran IV and other computer aided analysis. Areas of responsibilities will include analyzing power systems used for undersea propulsion, generating system requirements and overseeing design integration and evaluation processes. A BSEE, MS or PhD in Electrical Engineering is required.

ELECTRICAL ENGINEER

For consideration, candidate must have experience in either hardware design or test program development, plus a background in automatic test equipment. Primary responsibilities will involve the analysis and synthesis of circuits for prototype development, the development of software and hardware test programs, as well as the generation of engineering documentation. A BS in Electrical Engineering is required.

ELECTRICAL ENGINEER

For consideration, candidates must have 0-3 years electronic experience in either hardware design or test program development, plus a solid background in automatic test equipment. Primary responsibilities will involve the analysis and synthesis of circuits for prototype development and the development of software and hardware test programs, as well as providing liaison with other departments to expedite realization of hardware and software products. A BS in Electrical Engineering is required.

If you're up to the large scale challenges and the exhilarating growth pace that have established Gould as an integrated technology company . . .you'll be rewarded with an exceptional salary, a full benefits package and highly-visible advancement opportunities. Submit letter or resume in confidence with earnings history and salary requirements to:

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- **Computer Programming**
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- **System Design**
- **Airborne Instrumentation**
- **Installation Design — Electrical & Mechanical**
- **Electronic Circuit Design**
- **Micro-Processor Technology**

Please send your resume in confidence to:

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- ★ **Real-Time Software Development**
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- ★ **Communications/Digital Switching Systems**
- ★ **Control Systems Design**
- ★ **Micro/Mini Computer Applications**

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PROJECT ENGINEERS
SENIOR ENGINEERS
(Analog, Video)

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SENIOR ENGINEERS
(Digital Design)

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Electronics

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ENGINEER, ELECTRONIC

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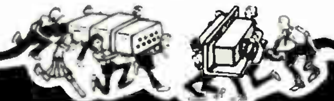

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