JUNE 22, 1978
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Single hybrid houses 12-bit data-acquisition system 113

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Few plaudits for communications bill, 84
The proposed revision of the Federal Communications Act is reaping decidedly downbeat reactions from industry and Government telecommunications executives. One oft-raised criticism: the bill is not sweeping enough, ignoring or slighting some vital areas.

Single hybrid acquires 12-bit data, 113
A 12-bit data-acquisition system offers the convenience and cost savings of a single integrated-circuit-compatible package, together with the high performance and reliability of a hybrid circuit. It acquires data at 50 kilohertz or faster from many sources.

Scopes sharpening accuracy, 138
Digital readouts and crystal references enable delayed-sweep oscilloscopes to take the uncertainty out of measuring nanosecond intervals. This is part 2 in a continuing series on time and frequency measurement.

And in the next issue . . .
32-bit minicomputer architecture . . . a C-MOS erasable read-only memory . . . semiconductors and thermal design.
For a show that is growing in size and attendance, there comes a time when success itself is a problem. That seems to be the case for the National Computer Conference, which earlier this month had a record number of exhibitors and registrants. What with the delays in getting into the parking lot, the long lines registering, and the difficulty in having a bite to eat, the show had all too evidently strained the facilities available to serve it.

Probably the toughest test came for the exhibitors assigned to the “West Hall” at the Anaheim, Calif., convention center. This extra show space was actually a parking garage converted to hold the overflow.

As computer editor Tony Durniak put it, “The garage was a severe environmental test chamber for the computers, but though the hardware seemed to survive, the sales engineers manning the booths wilted in the heat and humidity.”

To make the garage usable, it was necessary to put up temporary walls, lay down carpeting, hang light fixtures, and install air-conditioning units—the latter as much to keep the equipment happy as soothe the attenders. But even with air conditioning, the booths got rather warm.

As a result of this year’s problems, the show’s chief sponsor, the American Federation of Information Processing Societies, is planning to ease the strain for next year’s show, which will be in New York City. According to Larry Curran, Boston bureau manager, who put together a wrap-up story in Anaheim on the exhibitors (p. 88), the federation is welcoming suggestions in its struggle to keep everyone happy.

“One of the complaints is the show-business hoopla in the exhibit floor,” he points out. “For example, booths limited in space to a maximum of 2,400 square feet have been growing vertically to see which name sign can outdraw the other. One exhibitor tried upmanship by hiring airplanes trailing commercial messages to circle the convention center.”

Another exhibitor came prepared to put up a two-story booth but had to shrink. Assigned to the garage area, the company had to chop off the top half of its display in order to fit under the 8-foot ceiling.

How’s business? Booming along, according to the roundup of key companies contacted in our midyear sampling. All across the land there are signs of better-than-expected sales, despite the problems of inflation and economic uncertainty (p. 81).

Perhaps the most encouraging word from the veterans of past roller-coaster sales rides is that the electronics industries are generally better able to handle the eventual downturn expected next year than in previous market cycles. Overcapacity promised by double ordering and inventory imbalances may be a thing of the past—or at least much reduced. Apparently neither buyers nor sellers want to go through the costly trauma of empty orders.

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Readers' comments

Language difficulties
To the Editor: The basic contention of Langer and Dugan ("Say it in a high-level language with 64-k read-only memories," April 13, p.119) that "the availability to microcomputers of high-level programming languages... will not be mitigated by the availability of larger ROMs is simply not true. Their implication that with ILL Basic and Nibl now available in ROM, APL, Fortran, Pascal, or Cobol will be next is equally spurious.

From the beginning, Basic has been available with inexpensive non-disk-based microcomputers because of its single-pass, entirely self-contained nature. Fortran requires not only a compiler, but also a linker or link-editor, as well as execution-time support. Though some of these can be put in ROM, how do the authors propose saving and documenting the large amount of high-level source code written by the user? The answer is that users will require an expensive disk-based system for program development. Simply having a compiler in ROM will only save having to load it into random-access memory from disk.

Consider how much greater the problem is in moving from Fortran to APL, Pascal, or Cobol. These languages have dynamically definable data structures, recursive sub-routine calls, and other bizarre features. To put the compilers, libraries, and run-time monitors all into ROM should take several full processor address spaces. That certainly will not leave much room for the user source and object codes, or for the remainder of the development system.

I can only assume that the authors, working as they do for a major semiconductor manufacturer, have attempted to make a case for the new ROMs their employer will shortly release. There will be uses for the 64-K and the future 256-K ROMs, but they will not "affect the ways in which computer software is implemented [and] stored." High-level languages will be used because of the availability, not of large ROMs, but of high-level language compilers or interpreters.

L. Edward Reich
Arlington, Va.

The authors reply: Some of the exceptions Mr. Reich takes to our article seem to be due to a miscommunication of our point about the widened availability of high-level languages encouraged by the advent of cheap, large ROMs. The user we have in mind does not have a "large amount of high-level source code" to process. Indeed, the equipment for handling such a load has been considered a prerequisite for the use of high-level language tools. Now, by means of ROM, and of course other technology, these tools can be made available to people using desktop computers with very limited or no external peripheral capabilities.

Further, Mr. Reich is right that APL will not be next after Nibl, because it preceeded Nibl by several years, though not, alas, under the auspices of National Semiconductor. The IBM 5100 desktop computer uses a proprietary ROM to store its APL. The system could, and probably will, serve as a model for a whole class of systems.

As for the relevance of the ROM in Cobol systems, since publication of the article we have received letters from two different manufacturers of such terminal-based systems saying that the crucial parts of their systems are ideal for large ROMs.

In the case of Pascal, Mr. Reich might consult "ROM-based Implementation of UCSD Pascal and Its Applications in Math Education" by the University of California at San Diego's Institute for Information Systems (May 15, 1978). The author of this note has stated privately that "64-K ROMS seem to offer a neat way to make a sophisticated software system available to... users with S-100-based hardware."

Mr. Reich feels that we have attempted to make a case for some new parts our employer is about to release, and that is true; but we have attempted it by suggesting that concepts embodied in such parts are common, not just for National, but for anybody who has the imagination to grasp their potential.

Electronics / June 22, 1978
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Circle 7 on reader service card
News update

- An automated wire-routing and soldering technique, using conventional printed-circuit boards and dating from the early 1970s, is finally available for use in production runs. Up to now, no wiring service has existed for the technique, which was developed as Infobond by the Inforex Inc. division of that name in Burlington, Mass., and as Tiers (through insulation electronic reflow system) by the Weltek division of Wells Electronics Inc. in South Bend, Ind.—though Weltek was supplying automatic machines.

However, a year-old company in Waltham, Mass., called Bondex Inc., has designed and built six multi-headed, fully automatic machines to perform the job, which consists basically of heat-removable electronic soldering. [Electronics, May 25, p. 134]. Bondex also has developed special boards and the manual tools needed to make prototype boards with the technique. Although the company now does wiring of production quantities, it is considering leasing its machines, says James Steranko, founder of Bondex. Steranko helped develop Infobond while with Inforex.

Jerry Lyman

- The U.S. Navy continues to go all ahead, full, in its effort to equip all of its vessels and aircraft with standard, militarized computers and peripherals. And the Qantex division of North Atlantic Industries Inc., for one, could not be happier. The Plainview, N.Y., firm has just received an order in excess of $1.4 million for 93 of its AN/USH-26 Cartridge Magnetic Tape Units [Electronics, Dec. 23, 1976, p. 54].

The new order is, according to Qantex president Joel Kramer, the service’s “largest single release” and brings the division’s USH-26 backlog, under its requirements contract with the Navy, to $3.8 million. The tape unit has received interim approval by the Navy; full approval is expected by late summer, and with that Kramer expects a lot more orders. “Right now,” he adds, “there are lots of uses, as in tactical situations, that can’t be ordered for until full approval.”

Bruce LeBoss

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**Electronics** / June 22, 1978
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Motorola UB CMOS

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Electronics / June 22, 1978
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Growing up in good times and bum times

Here we go again. Business, we are told by the people who are doing it, is great (see p. 18). Bookings, backlogs—all the indicators point upward. But wait. Isn't it time for those who have lived the recent history of the electronics industries to glance over their shoulders, start to think about economic cycles, and remind themselves that everything that goes up inevitably comes down again—especially growth curves? One semiconductor executive even admits that he would welcome the rain that follows the sunshine. "We're in a masochistic state of mind, looking for a sign of it," he says. "In fact, we're getting nervous and we'd love to get it over with." His anxiety is that of one who has ridden his share of downturns that were economic killers.

That anxiety is being fed by Government economists talking about reduced growth in the second half and uncertainty about what lurks in 1979—while some private forecasters say there might be a recession next year. Then there is inflation to worry about, not to mention foreign competition, the devaluation of the dollar, and its resulting weakness in the world money markets. All this adds up to a repeat of the old boom and bust cycle—or does it?

Consider some of the indications amid the signs of prosperity that this time around the makers of semiconductors, computers, television sets, instruments, components, and the like are waltzing to a different tune. Remember 1974 and the glutted inventories of those who purchased electronic equipment? In 1978, there is no inventory buildup discernible to electronics managers. And what about double and triple ordering? So much of the last upsurge turned to paper because of that quaint custom. Then there were lead times that stretched so far one could fairly hear them twanging as though about to snap. Not this time—delivery schedules and backlogs appear to be sane, reasonable, and manageable. Finally, there were lists of companies hell-bent on expansion, only to find themselves with square footage and no business to fill it with. Now, semiconductor makers are just beginning to talk cautiously about adding capacity.

What all this seems to add up to is maturity—that blessed state defined as full development. In other words, electronics people have pulled up their socks and prepared themselves for prosperity. No more the gleeful flight to the heights only to be followed by the sickening plunge to the depths; it appears that careful planning and mature consideration have replaced the bandwagon instinct that made young entrepreneurs rich even as it aged them overnight.

Which is not to say that next month or next quarter might not bring with it a change in the climate and an end to the good times. But it does mean that the change won't be so abrupt as it has been in the past. Thanks to the spread of electronics across a broad applications base, the electronics industries appear finally to be able to handle some sales falloff gracefully and with maturity. In short, the electronics industries have grown up. If that is truly the case, it has been a long time coming.
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Meetings

Fiber Optic Con West, Fiber Optic Communication and Information Society (Boston), San Jose Convention Center, San Jose, Calif., July 19–20.


Wescon/78 Show and Convention, Electronic Conventions Inc. (El Segundo, Calif.), Los Angeles Convention Center, Los Angeles, Sept. 12–14.

Sixth Computer-Aided Design and Computer-Aided Manufacturing Conference and Exhibition (CAD/CAM VI), Society of Manufacturing Engineers (Detroit), Hyatt House, Los Angeles, Sept. 19–21.


ISHM '78, International Society for Hybrid Microelectronics (Montgomery, Ala.), Radisson Hotel, Minneapolis, Sept. 25–27.

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Circle 31 on reader service card
Look for significant new linear products to emerge from Texas Instruments in the third and fourth quarters as the semiconductor giant cashes in on its diverse process technologies. Of the 39 devices planned, TI will mix technologies in plasma-display-driver ICs with noise-immune diffused MOS inputs, low-power C-MOS inside, and bipolar outputs with high breakdown voltage characteristics. This bIDFET (bipolar diffused complementary-MOS field-effect transistor) process will make plasma displays competitive with cathode-ray-tube displays as soon as the price for the 32-bit ICs drops to 14¢ per bit, according to TI.

Among other technology explorations, the firm is heavily engaged in an ambitious program to replace the majority, if not all, of the mechanical sensing devices on autos with silicon elements. Under contract with one of the Big Three automobile manufacturers, the Electronic Devices division initially will offer temperature sensors replacing nickel-wire devices and offering response times on the order of 1 to 5 seconds. The company has also developed surface-acoustic-wave devices for UHF TV tuners, enabling the Federal Communications Commission to broaden its frequency assignments for adjacent channels. The filter and resonator are available together with complete schematics and complementary discrete metalized semiconductor field-effect transistors as part of a tuner kit.

At the same time, all of TI’s digital technologies are hot. For example, due in the fall is a 256-K bubble-memory device. In a 22-pin package, the new device has a block-replicate structure and uses an asymmetrical-chevron cell arrangement rather than the older T-bar. Not to neglect semiconductor memories, samples will appear before year’s end of a 64-K erasable programmable read-only memory, a 64-K random-access memory with a single 5-V supply, and a 256-K charge-coupled memory. The future, TI envisions, will bring 2-µm line widths to very-large-scale technologies that promise both higher speed and lower power. First up is a Schottky version of integrated injection logic expected next year with gate delays in tens of nanoseconds. For the 1980s, TI is bullish on metalized semiconductor field-effect transistors, which will have better yields since they will eliminate the defect-sensitive oxide. The technology will feature propagation delays of a few nanoseconds while drawing but 10 µw per gate.

Attempting to humanize microcomputers, General Instrument Corp.’s Microelectronics group in Hicksville, N. Y., has developed a programmable sound generator that emits various familiar or exotic sounds for such uses as video and nonvideo games, music synthesis, and alarms for industrial and security controls. Called the AY-3-8910, the n-MOS device interfaces with most 8- and 16-bit microprocessors and has three independently programmed sound channels, an analog envelope generator, and two general-purpose 8-bit input/output ports. Housed in a 40-pin dual in-line package, the chip is available off-the-shelf at $3 in lots of 50,000. The firm also is developing a lower-cost version, which it calls the Gimini Cricket. Designated the AY-3-8912, it will come with but one 8-bit 1/0 port and be available in a 28-pin DIP at $2.50 for 50,000. A similar device from TI uses linear/integrated-injection-logic technology and comes in 16- and 28-pin packages.
Panel to send
software copyright
Ideas to Congress

In a report to be sent to the President and the Congress on July 31, the blue-ribbon presidential Committee on New Technical Uses will recommend that the language of copyright laws protecting computer programs and data bases be strengthened. The committee will also suggest that the coding, testing, and debugging required to develop a computer be protected by copyright, since those processes are part of a written work by an author. But, the committee adds, the concept behind the software—in this case, the algorithm—is a general concept and should remain in the public domain. The report will also attempt to define the act of copying software—long a thorny problem—as loading a program to run.

System permits
hook-up of phone
to ac outlet

A new company, Astech Inc. of Bedford, Mass., has developed a way to connect a phone extension to any ac outlet for $229. The patented technique, which the company describes only as reactive coupling, involves connecting the phone line to the power line. The system, called Phone Link, consists of two units. One connects the phone line to the power line; the other connects it to a wall outlet. Each has a receiver, transmitter, and decoder. The company says that its system adheres to Federal Communications Commission regulations that allow connection of customer equipment to the telephone network.

Fairchild quitting
small-Instrument
business

Fairchild Camera and Instrument Corp. is getting out of the business of making and selling small instruments in order to devote all its resources to large test systems. James Moreton, general manager of the Instrument and Control division, says the company is talking to other firms about the sale of product lines. Most of one line of digital panel meters has been sold to Dynamic Sciences Inc. of Van Nuys, Calif., and the IEEE-488 family of bus couplers and bus testers has been sold to Ics Electronics Corp. of San Jose, Calif.

SIA prepares
to take position
on Japanese trade

The Semiconductor Industry Association is culling Government data preparatory to issuing a policy statement this fall on Japanese trade. Although Fairchild Semiconductor, Mostek, and National Semiconductor have held rather hawkish views on Japanese electronic imports to the U. S., the 35-member SIA is expected to take a milder stance by looking at such things as equalization of duties between the two countries and improved tax measures. The latter might include lower capital-gains taxes and credits for research, development, and investment. Some believe that these measures would help the competitiveness of U. S. companies better than quotas or present antidumping and countervailing-duty laws, which take too long to be enforced to do any good.

Precision reference
provides 3 outputs

Single-voltage references are not uncommon, and neither are bipolar ones. But this month Analog Devices Inc. of Norwood, Mass., will introduce a multiple-voltage reference that is unusual. It provides three outputs simultaneously with a maximum deviation of 5 ppm over the full commercial range of 0° to 70°C. The pin programmable device, designated AD 584, has a total of seven possible outputs—+2.5 v, +5v, +7.5 v, +10 v, —5 v, —7.5 v, and —10 v.
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Single silicon chip synthesizes speech in $50 learning aid

There's now a chip that can talk to a child. It duplicates human speech electronically in a teaching aid called Speak & Spell, which was shown for the first time at the Consumer Electronics Show in Chicago earlier this month. Developer Texas Instruments Inc. plans to sell the aid for only $50. (The chip itself is not for sale.)

Working with a pair of 128-kilobit read-only memories and a special version of TI's TMS1000 8-bit microcomputer, the silicon chip can produce a total of 200 seconds of sounds for a vocabulary of over 200 words. However, it is capable of accessing a lot more memory—as much as 2.1 megabytes. Since the speech generator uses memory at a maximum rate of only 1,200 bits per second, it could be designed to speak for as long as 30 minutes.

Chip. The firm calls its metal-oxide-semiconductor chip the TMCO280. It is built with the metal-gate, depletion-load, p-channel technology used in TI's earliest calculators. The chip contains an entire digital signal processor, with timing and decoding circuits, a 10-stage digital filter, and a digital-to-analog converter. Everything fits on a 44,000-square-mil piece of silicon. Only with p-channel MOS did TI have the confidence that it could build such a large chip reliably.

Basically, the chip takes data randomly every 20 milliseconds from a ROM coded with representations of the sound waveform. Data is addressed in blocks: small ones for, say, a single spoken letter, larger ones for a phrase of several words. From the data, the chip synthesizes an analog waveform with adequate fidelity for intelligible speech.

The data taken from the ROM—anywhere from 4 to 49 bits in each 20-millisecond frame, depending on the complexity of the sound—will average less than 1,200 b/s. Still, this rate is sufficient to carry the 4-kilohertz bandwidth needed for speech. The secret is a data-compression technique called linear predictive coding.

The technique makes it possible to encode a complex speech waveform stored in ROM by equipment that analyzes components of a human voice.

**Talk is chip.** Elements in TI's synthesizer chip (tinted blocks) recreate speech from data placed in ROM by equipment that analyzes components of a human voice.
with very little data. "A speech signal has a lot of redundancy," explains Richard Wiggins, a staff scientist at TI's Central Research Laboratory in Dallas. "The data base that's needed to define it is actually very small."

Linear predictive coding defines speech by determining the characteristics of a time-varying digital filter that is directly related to the characteristics of the vocal tract determined by the lips, tongue, teeth, and so on. "LPC is widely used in narrow-bandwidth communications, but when we said we were going to put in on a chip, everyone thought we were crazy," Wiggins remarks.

The reasons for incredulity are well founded. Linear predictive coding gets its name from the way the coefficients characterizing the digital filter are predicted from a linear combination of previous coefficients. In the TMC0280 there are 10 such coefficients. Combining them means lots of multiplications and additions—number crunching that would be a chore even for a minicomputer.

Many tricks. Wiggins and Larry Brantingham, a senior staff member in component design at TI's Lubbock, Texas, Consumer Products division, had to use several tricks to do the fast math. Even the narrow 4-kHz bandwidth for speech requires 160,000 additions and an equal number of multiplications every second—about 6 microseconds for each operation. Minicomputers would have trouble executing the 10-by-14-bit multiplication in that time.

To get around the speed problem, Wiggins transformed the LPC algorithm into a lattice formulation to keep all coefficients less than unity so that fixed-point math could be used. Brantingham designed the number-crunching circuits with a pipelined approach so that several operations are carried out at once.

Modeling. Speech is first broken down into voiced and unvoiced sounds. Voiced sounds, like l, o, and m, have a definite pitch and include vowels and fricatives that can be represented by low-frequency, high-amplitude signals. Unvoiced sounds, like s, f, and sh, are mostly rushing air and are represented by low-amplitude, random high-frequency signals similar to white noise.

The characteristics of the vocal tract are imparted to the sounds by the LPC filter. In all, 12 parameters determine the sound created in any 20-ms period: the first is the energy or amplitude; the second is the unvoiced or voiced signal, which includes pitch information; and the other 10 are the filter coefficients. □

Communications

Line is busy for electronic telephones as competitors flock to show wares

Semiconductor makers, traditional telephone-equipment suppliers, new equipment makers: all are crowding into the electronic telephone market. Last week's Consumer Electronics Show in Chicago saw the introduction of new electronics-laden telephones from a number of firms, while others showed prototypes or discussed plans to enter the business.

The decade-old retail telephone market was pretty much on hold until Government action last fall struck down telephone company regulations that prevented most consumers from installing their own equipment. The resulting spate of new products is making many observers predict another consumer free-for-all, much as happened with digital watches and calculators.

Among the traditional phone suppliers, GTE Automatic Electric Inc.'s Consumer Products division in Northlake, Ill., took the wraps off a miniaturized phone that uses two custom integrated circuits, one to convert the push-button entry to regular dial pulsing and one to perform tone ringing.

The one-piece Flip-Phone is about 2 by 2 by 7 inches and weighs less than the handset alone of a conventional model. It will be available in some areas in October, with full distribution in 1979, at a suggested retail price of $49.95, says Tom Massey, division general manager.

GTE also showed a prototype based on the 1650 n-channel metal-oxide-semiconductor single-chip microcomputer from General Instrument Corp., Hicksville, N.Y. The unit "will probably be available in

Teaching aid launches TI's voice synthesizer

"Say it—COLOR: C—O—L—0—R," commands the voice in the box as the letters appear on a blue fluorescent display. Beneath the toylike orange-plastic exterior of a word-teaching device called Speak & Spell, Texas Instruments Inc. has hidden its speech-synthesizing chip that reproduces words uttered by a male voice.

The educational product, which will be available next month, joins others in TI's Learning Center Product group that include a silent spelling aid, a "first watch" time-telling aid, and beginners' calculators. Speak & Spell has a vocabulary of more than 200 words that it says randomly for the various exercises. The unit's push buttons select exercises, which include pronunciation, as above, spelling quizzes, and Hangman, a spelling game. Users also punch in letters for the spelling game using the keyboard.

The company records all the words in two 128-kilobyte read-only memories, which are low-performance p-channel MOS chips designed expressly for Speak & Spell. Although TI refused to comment on future products involving synthesized speech, a spokesman said the technique could be used "anywhere an alphanumeric display would go." Since the firm is researching all three areas of speech processing—speaker verification, word recognition, and of course, speech synthesis—it is probably closer than any other manufacturer to the home computer that will listen and speak.

World Radio History
AFIPS for controlling costs.”

Smith is not sure what those suggestions will be, but he feels that the NCC management should try to avoid high-labor-rate locales, if possible—“although that’s difficult to do because so few cities can accommodate a show this size.” He thinks costs might also be cut by eliminating the circus atmosphere at the NCC. The show-business influence was evident in Anaheim at a number of booths, ranging from puppet shows and animated figures to flashy models making product pitches.

Gimmicks needed. Other exhibitors, though, believe there must be some showmanship, especially if their booth is in a remote location. For example, Morris D. Dettman, director of advertising for Honeywell Information Systems, Waltham, Mass., says “you need a gimmick to attract the crowds, especially if you’re on the fourth floor of the Coliseum, as we’ll be next year.”

Also a possibility for the fourth floor next year—in the attic, as Dettman calls it—will be Digital Equipment Corp., if the Maynard, Mass., minicomputer giant exhibits. Because it had not been in the show for the three previous years, DEC wound up in the almost unbearably hot “West Hall”—a euphemism for a converted parking garage—at Anaheim. Booth locations are assigned according to a formula that allocates more points to an exhibitor for consecutive years in the show than for booth size.

“We were way down on the list, and so we got the fourth floor,” says Andrew C. Knowles III, DEC’s corporate vice president for marketing. “That’s a bad position, and if we end up there, we may not be in the show next year.”

Photovoltaics

Thin-film cadmium-sulfide solar cells have efficiencies boosted to 9.15%

Photovoltaic solar cells using cadmium-sulfide–copper-sulfide thin-film technology have demonstrated efficiencies of 9.15% in full sunlight, according to researchers at the University of Delaware’s Institute of Energy Conversion at Newark. Moreover, IEC director Allan M. Barnett believes that 10% efficiency—the Department of Energy's 1980 goal—will be demonstrated by the end of this year.

He also contends that the institute's researchers should be able to beat the DOE 1986 price goal of 30 cents a watt for a manufactured cell. He predicts the demonstration as early as 1982 of cells that could sell for 25 cents per watt.

Significant. The 9.15% efficiency was hailed by the DOE's Donald Feucht, chief of advanced materials research and development in the Solar Technology division, as a significant contribution toward making solar electric power competitive with other energy forms. Barnett spoke at the four-day 13th Photovoltaic Specialists Conference sponsored by the Institute of Electrical and Electronic Engineers in Washington, D.C., early this month.

Materials for single-crystal silicon cells now on the market cost about $150 per square meter, compared with the Delaware institute’s current $3 per square meter for thin-film cadmium-sulfide cells, Barnett says.

Barnett certainly caught the attention of some silicon-oriented solar-cell specialists at the conference. They had been discussing the potential of polycrystalline silicon and thin-film ribbon production techniques for increasing efficiencies and lowering photovoltaics costs before hearing his paper.

In an interview at the conference, Barnett moved to counter skepticism by some of the participants about his claims for reproducibility and price. He says he is in the midst of lining up five independent companies to participate in a $6 million continuous-process pilot plant using Federal research and development funds to demonstrate the feasibility of the 25¢/w goal by 1982. However, he declines to identify the companies involved until all are committed.

One is ready. Only one company is ready to sign, he says. Industry sources believe that company is Shell Oil Co.'s ses Inc., also of Newark and a specialist in CdS cells. Barnett says he expects to disclose all participants by the summer’s end, begin operations a year later, and scale up cell production to an annual capacity of 100 kilowatts at the end of 1981 or early 1982.

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design improvements in the 7.8% efficient cell reported by the institute 21 months earlier, he explains. Process technology was not involved. “We found [energy] losses in some screwy places,” he says. One example occurred with the relocation of a cell grid that had been blocking sunlight entry. “That sent the current up, but then the fill factor went down into a shunt loss that was unpredictable.”

Arkansas getting largest solar unit

The sun shines bright on Blytheville, Ark., and when the doors of its Mississippi County Community College open for the fall 1979 semester, it will own the world’s largest photovoltaic installation. The 360,000-watt setup heats and supplies hot water, as well as electric power.

Funded by the U.S. Department of Energy and the county itself, the photovoltaic system alone will cost about $15 million. It is all part of a Federal program intended to demonstrate the feasibility of photovoltaic power as an alternative to conventional ways of heating and providing electricity.

Daniel P. Ahearne, president of Team Inc., which is putting the system together, says the school “should be able to generate 93% of its total power requirements, with luck.” Ahearne’s Springfield, Va.–based systems consultant group is responsible for design and installation. He detailed the system’s promises and problems during a panel discussion at the IEEE’s 13th Photovoltaic Specialists Conference in Washington, D. C.

Receivers. To reach its 360-kilowatt peak output in full sun, the system will employ 600 solar photovoltaic receivers mounted in optical concentrators with a 20× concentration, Ahearne says. The receiver assembly also tracks the sun across the skies.

Prototype collectors have been developed by Honeywell Inc., with each receiver containing 100 rectangular, glass-faced silicon cells, each measuring 1.75 by 2 inches. Solarex Corp., Rockville, Md., which developed the cells, says they can achieve a 14% efficiency. The resultant $6- to-$7-per-watt cost of the concentrator-receiver units will be lower than any photovoltaic system installed to date, Solarex says.

The sun’s heat, focused at each receiver, is carried off by a water-based cooling system to the school’s heating and hot-water systems. The photovoltaic cells themselves are kept at 55°C.

Charges. The array will also charge a 2,400-kw battery bank for use at night and during overcast weather. Excess power will be fed to the Arkansas-Missouri Power Co. for credit, Ahearne says. Should the battery bank run low, power can be drawn from the utility at off-peak hours when lower rates prevail.

“Illusion is the name of the game,” he says, in describing how the system was designed. “If rigid hardware standards existed today, the Department of Energy could not have afforded to fund the program. The equipment prices would have been out of sight.”

Packaging & production

Silicon furnace gets multiple charges

Unintentionally, the quartz crucible in which single-crystal silicon is grown by the common Czochralski method turns out to be a throwaway item. This is because the crucible cracks as it cools from its 1,400°C-plus operating temperature each time a crystal has been pulled. At anywhere from $190 to $240 each, it is an expensive object to throw away, accounting as it does for more than half the total material costs of crystal growing, according to Robert G. Wolfson, manager of advanced materials at the Lexington (Mass.) Vacuum division of Varian Associates.

The firm, a manufacturer of crystal-pulling furnaces and other production gear for the semiconductor industry, thinks it has a way to prevent cracking. Its idea is simple: don’t let the crucible cool down.

Auto charging. To eliminate cooling, Varian is developing a furnace with an automatic charging mechanism that drops raw silicon pellets into a small amount of melted silicon that is allowed to remain in the crucible after a completed ingot is removed. There is nothing really fancy about the charger—it consists basically of a hopper for storing the pellets and a vibratory feeder that moves the silicon to the crucible. Wolfson calls it “an extrapolation of well-established techniques.”

Varian’s new furnace will be able to be repeatedly recharged, producing up to 100 kilograms of ingots before the crucible must be replaced. In contrast, conventional Czochralski furnaces produce an ingot weighing 20 to 25 kg. The company is under contract to the Department of
CONTROLLED AVALANCHE RECTIFIER DIODES

The BYW54 to 56 and the 1N5060 to 5062 are two new families of controlled avalanche rectifier diodes. Both families feature good thermal fatigue properties due to glass encapsulation which not only provides good thermal stability but also low leakage.

Although both families can be successfully used in either professional or consumer applications, the BYW54/55/56 have peak working reverse voltages $V_{RWM}$ of 600/600/1000 V respectively. The 1N5060/5061/5062 have values of $V_{RWM}$ of 400/600/800 V respectively. Both families are designed for an average forward current of 2.0 A maximum and a non-repetitive peak forward current of 50 A maximum.

The new devices are made in the SOD-57 outline which measures only 3.81 mm diameter maximum.

NEW RANGE OF INFRARED DETECTORS

The RPY66/89 range of infrared detectors are specifically designed for applications where a rugged low-cost sensor is required. Typical applications include intruder alarms, fire alarms, door opening and light switching sensors, radiometers, gas analysis, machine tool and guard controls, low-cost spectrometers, and speed indicators.

The new detectors employ a ceramic material known as lead lanthanum zirconium titanate which utilises the pyroelectric effect to produce an electrical output due to a change in temperature. This material was developed in our Research Laboratories and its properties are optimised for infrared applications.

Each device is mounted in a TO-5 type can with an infrared window and incorporates a low noise impedance changing device to simplify the electronic circuit interface. There is a choice of element size, either 2 x 2 mm, or 2 x 1 mm. The window may be either a silicon one which has a substantially constant transmission for incident wavelengths from 1 µm to beyond 15 µm, or a "daylight filter" version which has a long wavelength pass filter allowing transmission of radiation from 6.5 µm to greater than 14 µm.

The device can be considered as an n-channel FET with its gate connected through a capacitance in parallel with a high impedance to the case. Source and drain are accessible through the remaining connections.

MINIATURE PUSH-BUTTON SWITCHES FOR INSTRUMENTATION

We have extended our range of thumbwheel switches to include a new series of miniature push-button switches. Designed the F-series, these switches are available as 10-position numerical, 10-position coding and decoding, and 16-position coding switches. The coding versions are 1-2-4-8 binary output, 1-2-4-8 complementary only output, and 1-2-4-8 binary and complementary. These may be supplied with or without diodes.

The new switches are front mounting, using plastic end-pieces fitted with springs. They have a black polycarbonate housing and use glass and paper epoxy printed circuit boards. The 10-position switches feature 5 x 3 mm characters, and the 16-position switches have 3 x 1.9 mm characters. The front panel area of each switch measures only 24 x 7.62 mm. The switches are intended for block mounting, and incorporate snap-on switch housings. The push-buttons which are marked "+" and "-" give a clearly defined movement when they are operated; the engagement of the switch in its new position can be easily felt when the buttons are depressed.

Contact resistance at 10 mA, 50 mV, is less than 100 mΩ; insulation between circuits is at least 10 MΩ. The switches are designed for a maximum working voltage of 100 V and a maximum load of 0.5 A; both a.c. and d.c. Life time is greater than 10⁶ operations, and their operating temperature is −25 to +70 °C.

BANDSWITCH DIODE WITH OPTIMIZED PROPERTIES

The VHF bandswitch diodes BA482/483 for VHF TV tuners feature low parasitic capacitance. These bandswitch diodes are electrically equivalent to the type BA182, combining both low diode capacitance with low forward resistance. The new devices are produced in a hard glass SOD-58 (DO-34) whiskerless outline using advanced technology to optimize their electrical properties.

The BA482 is designed for use in tuned circuits. At a reverse voltage of 3 V and frequencies from 1 to 100 MHz, the diode capacitance is 1.2 pF maximum; series resistance at 200 MHz and 3 mA forward current is 0.7 Ω maximum. For the BA483, which is intended for use in coupling loops, the maximum diode capacitance is 1.0 pF and the maximum series resistance is 1.2 Ω. The maximum continuous reverse voltage for both types is 35 V.

The new bandswitch diodes are designed for 0.2 inch pitch (5.08 mm) mounting.

POWER TRANSISTORS FOR HF/VHF TRANSMITTERS

Three new power transistors for h.f./v.h.f. transmitters are intended for class-AB or class-B service in high power applications. These n-p-n transistors are resistance stabilized and guaranteed to withstand severe load mismatch conditions. Designated BLW76/77/78, the new devices are supplied in a 7/8" flange envelope with a ceramic cap (SOT-121 variants) and delivered in matched hFE groups.

The BLW76 is designed to deliver 60 W peak envelope power at $V_{CE}$ = 28 V, and the BLW77 will deliver 130 W P.E.P., both specified in class-AB up to 28 MHz. The intermodulation distortion is better than −30 dB. The BLW78 is designed for CW (class-0) applications up to 150 MHz to deliver 100 W; the gain is greater than 6 dB and the efficiency is better than 70%.
Energy under the low-cost silicon solar array project administered by the Jet Propulsion Laboratory in Pasadena, Calif.

The furnace will be ready next March. To demonstrate feasibility in the interim, Wolfson's engineers have modified a Varian model 2850 crystal-growing furnace to accept an external recharging mechanism.

Wolfson says the assembly has so far been used in three runs, recharging the furnace up to three times during each run without any problems. Soon, the furnace will produce "high-quality, dislocation-free, single-crystal silicon suitable for semiconductors or solar cells," he says.

Longer ingots. The largest ingots in the modified furnace will be 4 inches in diameter and about 36 in. long, but the new furnace will deliver ingots up to 72 in. long. Wolfson emphasizes that although the division can grow larger-diameter ingots, the DOE contract calls for 4 in. "because that's about the largest the solar-cell firms can handle in diffusion furnaces and other equipment."

The recharging mechanism is loaded with polycrystalline silicon pellets through the access port to the storage hopper. The access port is then closed, a vacuum is drawn in the recharging enclosure, which is isolated from the growing chamber, and the enclosure is back-filled with argon to the same pressure (10 to 15 torr) as the furnace's growing chamber (see drawing). It is this isolation that allows the crucible to remain at its high operating temperatures.

When the ingot being pulled is completed and raised into the cooling chamber above the crucible, the isolation lock between the growing chamber and the recharging mechanism is opened. A feed tube directs pellets singly or in clusters from the vibrating feed tray into the lower feed tube. A tantalum lip on the lower tube extends over the lip of the crucible, directing the pellets into the melt.

Trade

Commerce giving U. S. electronics firms a new kind of assist with dealings in Japan

U. S. electronic firms who feel official barriers have unfairly blocked them from selling in Japan may now be able to get some real help from the Department of Commerce.

"If you can identify the [Japanese] government's hand in a case, we can go after it," Paul T. O'Day told a Computer and Communications Industry Association meeting earlier this month in Anaheim, Calif. The CCIA gathering was held in conjunction with the National Computer Conference.

O'Day, a deputy director for industry and trade at the Department of Commerce, is eager for cases involving electronics companies. "We are interested in developing solid cases in your area of whatever [the Japanese] do domestically to keep out your products," he told the CCIA members, most of whom were unaware that the Commerce program was in existence.

The program is run by a group called the Facilitation Trade Committee. Formed late last year, it grew out of the negotiations between Administration trade representative Robert Strauss and high-level Japanese trade officials, and its job is to review specific grievances brought by American companies. If it judges them warranted, it takes them up with Japan's all-powerful Ministry of International Trade and Industry.

It already has been successful in nearly 25 nontechnological cases.

The makeup of the committee varies, reflecting the kinds of cases brought to its attention. For example, when cases involving the electronics industries are filed, a dozen or so specialists from the Science and Electronics Directorate of the Commerce Department will be called in, according to O'Day. The permanent head of the committee is Frank Well, assistant secretary for industry and trade.

Examples of unfair restrictions abound, and CCIA members gave a number of them to O'Day. A common one: a Japanese customer cancels an order or refuses to honor a contract for equipment, citing some vague policy change as the reason. Also named are troubles in upgrading or changing an established product. One member said his company tried to add an internal peripheral board, but MlTI arbitrarily reclassified the equipment, calling for higher tariffs and causing insurmountable delay in selling.

In another kind of problem mentioned at the CCIA meeting, a Japanese firm agrees to buy a quantity of electronic products but actually takes delivery of only a few before refusing the rest, even breaking a signed contract. Then, months later, a copy of the product, often improved, starts turning up, perhaps in the Common Market, manufactured by the Japanese firm. "It happens too often to be coincidence," says a computer firm president; "MITI has to be involved in it."

Facts wanted. Terming himself "the window onto the program," O'Day asks electronics companies to come forward with complaints, not just "word-of-mouth horror stories that often are myths, but hard facts that can be documented." His experience so far has shown that often MlTI "is not aware of them but corrects them when informed," he says.

Reacting to O'Day's remarks, CCIA members reflected skepticism and frustration from years of problems in trying to do business in Japan. One member scoffs at "being reduced to being detectives to put together a case." Another calls it "nitpicking a case-by-case defensive posture." Still others fear retribution by MlTI against firms that complain.

But all such objections can be overcome, O'Day holds. CCIA president A. G. W. (Jack) Biddle sees it as "an opportunity that should not be missed." Discussions among CCIA members might also uncover common experiences that could be
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Add-on makers face loss of a choice

The $500 million market for IBM-mainframe add-on memories is extremely price-sensitive, forcing independent competitors to balance profit margins against the cost of being compatible. As they take aim at the newest IBM processors, the System/370 models 3031, 3032, and 3033, they may no longer be able to choose between static and dynamic random-access memories: the 3033 is so fast that the more expensive static chips may be necessary. The use of such chips could force them to lose some of their price advantage compared with IBM's $110,000-per-megabyte memories.

The required refresh cycle makes the dynamic-RAM add-on slower than a unit using static chips. But even though IBM has used static RAMs in all of its semiconductor memories, some add-on makers have chosen cheaper dynamic parts and compensated for the difference in speed by the design of their interface with the central processing unit.

New dynamics. As the last of the add-on makers introduced their IBM-303X-compatible wares at the National Computer Conference, the score became two favoring dynamic RAMs and three choosing static parts. But those using dynamic chips admit that they may have to go static in order to attach to the speedy top-of-the-line 3033 processor.

Intersil Inc., Cupertino, Calif., does no direct marketing, but its add-on box surfaced at the NCC under the label of Memorex Inc., Santa Clara, Calif. Both firms say the add-on box uses 8-K dynamic RAMs and can hold 10 megabytes of memory at $74,000 per megabyte.

They note, however, that the unit currently attaches only to the 3031 and 3032 processors. Intersil marketing vice president Richard Andrieni says the firm is starting tests with the faster 3030 computer and hopes the dynamic RAM will also work with it.

National Semiconductor Corp.'s Computer Products Group, also in Santa Clara, hopes to use the company's own 5290 16-K dynamic RAM in its newly introduced 833X family of add-ons [Electronics, June 8, p. 36], according to group general manager Dave Martin. Although National is sure it will work with the 3031 and 3032 computers, Martin concedes that the firm has still not decided if the dynamic part will be used in the 3033-compatible memories, or if National will secure static chips from an outside vendor.

4-K statics. Previously announcing units were Intel Corp.'s Memory Systems division, Sunnyvale, Calif.; Cambridge Memories Inc., Bedford, Mass.; and Electronic Memories & Magnetics Corp. of Hawthorne, Calif., each of which say they are using in-house 4-K static RAMs for products that attach to the entire IBM 303X family.

Intersil's Andrieni thinks it is not yet clear whether the fastest dynamic RAMs now available can be used to achieve the required 3033 memory speeds. "The breakoff appears to be somewhere at about a 100-to-120-nanosecond dynamic RAM," he says.

But National's Martin says there is no risk involved for his company. They already have a 4-K static design "to fall back on," he reports.

Navigation

GAO's Navstar plans are not very popular

A plan proposed to Congress to make a military satellite navigation system still being developed the core of the nation's radio-navigation network by 1985 is drawing sharp criticism from Federal agencies. The proposal for joint military and civilian use was submitted late last month by Congress's investigative
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Motorola 16K RAM Prices

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<th>Type</th>
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News briefs

New top-of-the-line unit from Harris Computer Systems
Harris Corp.'s Computer Systems division, Fort Lauderdale, Fla., has introduced its top-of-the-line series 500 computer system, expanding its capability to directly address memory from a previous limit of 726 kilobytes to 3 megabytes. Instead of Harris' usual 24-bit architecture, the new unit uses a 48-bit bus structure. It also uses the Vulcan virtual-memory operating system. The model S550, which can support up to 48 interactive terminal users is priced at $255,000, and the $570, for as many as 64 interactive terminals, is $376,000. Shipments will start early in 1979.

Honeywell, GE to combine international computer operations
General Electric Co. of Fairfield, Conn., and Honeywell Information Systems of Waltham, Mass., have agreed in principle to merge the worldwide operations of GE’s Information Services Business division with Honeywell’s time-sharing marketing operations in the United Kingdom, Europe, and Australia. GE would own 84% of the proposed new company, Honeywell 16%.

Fluke to expand custom-IC manufacturing facility
The John Fluke Manufacturing Co. of Mountlake Terrace, Wash., is expanding its custom integrated-circuit laboratory from an 8,000-square-foot research-and-development department to a 25,000-ft² in-house manufacturing facility. The lab has been producing custom ICs for Fluke’s precision and standard instrumentation line for the past six months. The laboratory’s capabilities include thin- and thick-film hybrid manufacturing, with programmable automatic laser trimming to be added shortly. The expansion is expected to increase the present 20,000-device/year output tenfold.

Fairchild looking to expand automatic test line
Negotiations are nearing completion for the purchase of Testline Instruments Inc., Titusville, Fla., by Fairchild Camera and Instrument Co. The acquisition by the Mountain View, Calif., company would broaden its coverage of automatic test equipment, now limited to semiconductor and memory testing. Testline’s AFIT 4000 and 3000A are large- and medium-sized production board testers; the AFIT 1500 and 1000, portable board testers.

TI to supply gear for 1980 Winter Olympics
Texas Instruments Inc.’s Data Systems division announced at the National Computer Conference that it had been selected as a supplier for the 1980 Winter Olympics to be held in Lake Placid, N.Y. It will supply model 990 minicomputer systems, plus several 700 series silent terminals and peripherals, for hotel reservations. Also announced were an 8-bit data-bus version of the TMS9900 microprocessor; a 16-bit microcomputer-on-a-chip with a resident erasable programmable read-only memory, the TMS9940; and a development system for the 9940, the $2,750 990/40DS. It also added Pascal, a high-level language, to its 9900 family.

Arm, the General Accounting Office. It calculates that $277 million could be saved over eight years by relying on the new $3.13 billion triservice Navstar/Global Positioning System and by phasing out seven systems regarded as overlapping. But agencies now using the systems proposed for phase-out object. The Department of Transportation, responsible for navigation policy planning, leads the opposition, with vigorous support from its Federal Aviation Administration and the Coast Guard. Other criticism comes from the White House Office of Management and Budget and the Defense Department.

All concur in effect that GAO has oversimplified complex issues and advanced an overly optimistic timetable for reliance on a not-yet-proven satellite system that would lead to scrapping billions of dollars in existing user hardware and training. They point out that Navstar, to have
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See Power Supply Section 4000, and Transformer Section 5600, Vol. 2, of your EEM catalog; or Power Supply Section 4500, and Transformer Section 0400, Vol. 2, of your GOLD BOOK for complete information on Abbott products.
24 satellites in three planar orbits of eight satellites each [Electronics, Oct. 16, 1975, p. 39], will not be fully operational before 1985 and has not yet been proven feasible.

**Tests beginning.** The Air Force is only now beginning tests at its Yuma, Ariz., range using the first two Rockwell International Corp. satellites in orbit. The Pentagon says a decision to deploy Navstar/GPS will not be made before February.

DOT charges it "would come very close to dereliction of duty" to make plans around a system several years away from operation and to forego "necessary and cost-beneficial improvements to currently proven and needed systems." Another irritating aspect of GAO’s plan is its recommendation that the President name a single navigation systems czar.

According to the plan, the government would phase out the FAA- and military-funded very-high-frequency omnidirectional ranging (VOR) systems, tactical air navigation (Tacan) systems, and Vortac (a combination of the two), as well as the Coast Guard’s Loran-C and its more accurate Air Force counterpart, Loran-D, plus the navigation component of the Army and Marine Corps developmental position-location reporting system. The Navy’s long-established Transit satellite system could also be dropped, as could the military’s nondirectional beacons.

"The total investment in VOR-DME [distance-measuring equipment] is of the order of $2 billion," retorts the Transportation Department "This cannot be scrapped overnight." Supporting the DOT is the Pentagon, which notes that "more recognition should be given to the need for backup systems."

**Helping out.** Along with Navstar, the GAO proposes use of three systems already available: self-contained inertial and doppler radar systems and civilian nondirectional beacons, plus the Coast Guard’s eight proposed Omega low-frequency transmitters.

The military believes it would need up to 25,000 air, ground, and seaborne receivers of varying complexity for Navstar. These would determine position on the ground and in the air by picking up accurately timed ultrahigh-frequency signals from two or more satellites. Location could be determined with accuracies between 30 and 300 feet.

As for civilian use, the Federal Aviation Administration doubts that a cheap enough receiver could be developed in time—GAO talks about a $2,500 receiver based on a 100,000-unit market. It calls this assumption "a fundamental weakness of the report." The Coast Guard also calls the receiver development unrealistic, adding that it would be unable to locate positions accurately enough in coastal waters.

## Canada

### Business group seeks aid for technology

Trying to help high-technology companies in Canada do business, an association of Canadian companies is out to swing more weight in government councils. Late last month, the Canadian Advanced Technology Association, or CATA, presented a multifaceted plan to major departments of Canada’s executive branch, including the ministries of Industry, Trade and Commerce, Communications, and Defense.

The group, founded in late 1977, seeks adoption of:
- Research and development tax credits.
- A federal and provincial government “Buy Canadian” program.
- An end to discrimination by governmental agencies against small companies.
- Assistance in solving the capitalization problems of small companies.
- Modification of the federal sales-tax structure so that goods are not taxed at the manufacturing but at the purchasing level.

**Doing well.** CATA members—companies with more than 51% of their common stock held by Canadian citizens—are doing well, and sales overall have increased tenfold in the last five years. But the group
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TI thinks their PEP plan is aces high...and it is. Signetics SUPR II has Level A and Level B back-to-back. National Semiconductor presents B+ and A+ and there's no joker in that. Fairchild's Matrix VI enters the high stakes game as a formidable competitor. But Reliability, Inc., has five of a kind, ace high, and that's tough to beat.

But let's get away from the poker table and talk electronics for a moment. You know Reliability, Inc. has built a reputation as America's largest independent burn-in facility in the past ten years. We offer all the techniques of PEP, SUPR II, B+ and A+, or Matrix VI. We'll give you temperature cycle, bake, burn-in, continuity test or electrical test, to mention a few specifics. And with our new branches opening in Mountain View, California and Singapore, we're more capable than ever.

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Circle 55 on reader service card
Softened labor bill could pass late in Congress

Watch for some form of S. 2467, the Labor Law Reform Act, to emerge from the Senate later in this session despite the filibuster efforts led by Sen. Orrin Hatch (R., Utah). That's the judgment of senior Senate staff members who note that the bill—one that has electronics companies, large and small, fearful that passage would wipe out safeguards against union entry to organize their plants—will be softened by amendments to protect industry interests. One key amendment would eliminate union access to plants during working hours to woo workers and limit access to areas like cafeterias during lunch and parking lots between shifts. What troubles senators like Hatch, however, is that a strong prolabor version is already through the more liberal House, and any weakening on the Senate side could tip the scales toward labor in a House-Senate conference seeking to reach a compromise on the two versions.

Motorola gets $370,000 from DOE for photovoltaics

June busted out with a $460,000 Department of Energy system design award for a 500-kw photovoltaic concentrator system. It will be split 80–20 by Motorola's Government Electronics division in Scottsdale, Ariz., and the Arizona Public Service Co., an electric utility. Following completion and acceptance of the nine-month design study, the companies stand to get an estimated $6 million to $8 million contract about June 1979 to build the demonstration system at the Phoenix Sky Harbor International Airport. First, however, the department would have to approve the second phase as one of the 9 projects to be selected from among 17 first-phase competitors. The department's project manager is Edward Burgess of Sandia Laboratories at Albuquerque, N. M.

TI seen ready for entry into photovoltaics

Energy insiders say Texas Instruments Inc. is preparing for the plunge into photovoltaics before the year is out, getting into the systems end of the solar-cell business as well as photovoltaic cell manufacturing. Longstanding signs of the Dallas company's interest include its quiet acceptance of Department of Energy research-and-development money totaling about $3 million over the last two years and an in-house proprietary systems project. They were supported by two TI papers at the IEEE's 13th Photovoltaic Specialists Conference in Washington, D. C., earlier this month. Their titles: "Optimized Solar Module Design," in a session on low-cost production, reflecting the company's interests in tandem-junction silicon cells; and "A 1982 Low-Cost Photovoltaic Module Factory Study" during session dealing with low-cost R&D for large-scale production.

New EFT rules permit terminal sharing by S&Ls

Final regulations governing electronic funds transfer transactions by Federally chartered savings and loan associations have been approved. They permit associations to share automated teller machines on their premises with other financial institutions, says the Federal Home Loan Bank Board. But American Bankers Association president A. A. Milligan is not altogether happy with an electronic-banking consumer-protection bill (H. R. 12775) proposed by the House Banking Committee. "Generally, the measure represents a substantial improvement over previous proposals," Milligan says, but he notes that the bill's proposed minimum pricing of EFT services is still unrealistically high.
Van Deerlin’s impractical principle

Despite 20 months of hearings, studies, and analyses, the long-awaited rewrite of the 1934 Communications Act just introduced on Capitol Hill is widely regarded as a shallow piece of work. That, at least, is the opinion of most industry and Government specialists after a first reading. Numbered H. R. 13015 and called The Communications Act of 1978, it is the product of the House subcommittee on communications chaired by California Democrat Lionel Van Deerlin. First hearings are expected next month.

The Van Deerlin bill is strong on good intentions but weak on their implementation. It would substitute marketplace competition wherever possible for Federal regulation of telecommunications and broadcasting. The role of the Federal Communications Commission would be sharply reduced, confined largely to technology and its impact on spectrum usage. Sound good? Wait a minute.

Oligopoly for monopoly

Competition in telecommunications would be achieved by opening the market completely, except that no one with a monopoly service like American Telephone & Telegraph Co. would be allowed to manufacture equipment. But if AT&T spun off Western Electric Co. and its $8 billion in annual sales, it could enter any markets it chose—from data-processing services to cable-television distribution, with the latter completely deregulated. One widely respected early advocate of competition sums it up this way: “The bill pays lip service to competition but does not come to grips with the issues. The end-user equipment market would become competitive, it’s true, but it would be controlled quickly by an oligopoly of Western Electric, IBM, and a few others, possibly foreign companies. Meanwhile, AT&T could wreak havoc in markets like cable television and computer services. They already have the lines in place.”

Similar criticisms are heard on the broadcasting side, where H. R. 13015 would phase out periodic license renewals in favor of market competition. Licenses would be issued for an indefinite period subject to revocation for violations of law. The bill would reduce the number of licenses for radio and TV stations that could be held by any single organization but—in its haste to get the Government out of the regulatory business—it seeks to avert opposition from existing licensees by exempting them from any cutbacks unless they voluntarily disposed of a holding. Broadcasters were surprised to hear that former FCC Commissioner Nicholas John-

son, who once reveled in the role of the wild-eyed radical, rejects the approach. A free market, Johnson says, “would be preferable to the present system of regulated monopolies. But I’m afraid Van Deerlin has proposed instead to put us at the mercy of unregulated monopolies.”

Several critics concur with the communications-equipment-makers’ lobbyist who says, “The legislation reads like a college paper in sophomore economics on ‘If I could change the world, here’s how I would do it.’” Another attributes Machiavellian motives to the authors: “If I thought they were smart enough, I’d say they deliberately left it so full of holes that all of us [in industry] can respond, get our part amended, and come away saying we won something. But that is not the way to write good legislation.”

Goodness is in the eye of the beholder, of course, and the Van Deerlin subcommittee staff headed by chief counsel Harry Shooshan seems satisfied with the product of its labor. Staff members reject the notion that they have dodged the whole international area by noting that making treaties is a prerogative of the President subject only to later congressional consent. The fact that the needs of the developing land-mobile communications market with its enormous potential are nowhere addressed is countered by the observation that it is not yet a big enough issue for inclusion in a bill that is already more than 200 pages long.

Amendments to come

The faint praise that can be heard for H. R. 13015 is damning. More often than not, it labels Van Deerlin’s bill “a good beginning” and not much more. The bill’s advocacy of a free marketplace is good; so is its corollary that the Federal government should cease overregulating the market. What is bad about the bill is that, after years of close regulation, the withdrawal would come so swiftly that the resultant vacuum would likely stifle as many innovators as the existing structure has repressed.

The giants of the telecommunications industry view deregulation as a challenge; most growing companies see it as a threat. Each group will move in its own way to fill that vacuum by getting H. R. 13015 amended in ways that will advance its own interests. Legislation that passes into law is certainly the product of compromise. But the Van Deerlin bill is so vulnerable to amendment that, if it passes, the resultant law may be unrecognizable by its authors.

Ray Connolly
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*Modified Formulation Technology

In addition, dimensionally-precise molded construction makes Type 292C Capacitors ideally suited for automatic insertion. As you can see, they're readily available taped and reeled for use with high-speed assembly equipment. Other options include a choice of body formulations to meet characteristics Z5U (general application), X7R (semi-stable), and COG (NPO).


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Siemens is familiar with all these criteria from its own experience as a manufacturer of film circuits for, say, carrier frequency and radio link, telephone and data systems. They prove their worth day in, day out, all over the world, some of them in severe climatic conditions – thanks not least to the consequent use of passivated semiconductors in the Siemens hybrid components.

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Siemens components for film circuits

Circle 60 on reader service card
Chips bring self-tuning controller to the hardware stage: page 67

A new thick-film resistive material (magnified 10,300 times) promises to combine high performance with lower costs: page 70
SwitchMax. A new series of RCA transistors designed and built for high performance in off-line power supplies, converters, and pulse-width-modulated regulators. SwitchMax transistors are hot-temperature tested. To give you new predictability under operating conditions. New efficiency in heat sink design.

**Performance that starts with design.** These RCA n-p-n transistors have a multiple-epitaxial, double-diffused structure, fine emitter geometry, and a trimetal system. Which make SwitchMax transistors rugged. And give them excellent high-current and fast switching characteristics, with improved second breakdown.

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RCA Power experience is working for you.
Expansion plans in the solid-state field for the British giant General Electric Co. Ltd. appear to center around joint European ventures with U.S. semiconductor makers. An impeccable source says its discussions are with companies like Intel and Fairchild Semiconductor that have no English or Continental production base. On another tack, GEC, an Intel distributor, is working with the U.S. firm to obtain Ministry of Defense type approval for shipping certain Intel products in wafers. When required by the ministry, GEC could perform diffusion in the UK. The firm also is talking to other U.S. semiconductor makers facing difficulties with tighter ministry procurement procedures for ICs.

Plasma color displays are reaching toward the size of cathode-ray-tube TV receivers, with a 16-inch diagonal unit up and running in the Technical Research Laboratories of NHK, Japan’s public-service broadcast system. Peak white brightness is still a fairly dim 7 ft-L, but it is the same as in a display of only a quarter the area that was shown last year. NHK engineers maintain the brightness by driving the top and bottom halves of the display independently, which permits twice as long an application of the drive to each line. Another NHK group had developed a flat display that uses ultraviolet generated in positive columns to excite phosphors. Almost 10 inches diagonally, it has a brightness of about 11 ft-L, but it may not be amenable to sizing upwards because it is difficult to make.

The Hirst Research Laboratories of General Electric Co. Ltd. is readying a new charge-coupled-device TV camera incorporating charge overflow circuitry that handles overloads of 1,000 times saturation without picture blooming. Chips with 300-line resolution and others with antiblooming circuitry have been demonstrated separately, and the lab is putting the two techniques together in a 9-by-11-mm chip yielding a 72,000 element array—300 lines each with 240 image points. GEC says that its three-phase, three-level buried-channel, polysilicon, frame-transfer CCD technology can be stretched to match the 448- and 512-line systems from U.S. companies by going to high-resolution electron-beam mask making.

Barring a last-minute change of mind, postal authorities in Greece are planning to award a contract worth as much as $100 million to East Germany to expand the country’s telephone network. If the order is placed, it will be over the heads of at least three native communications producers managed by or affiliated with Siemens AG, Philips, and Standard Elektrik Lorenz AG, an ITT subsidiary, The contract for installation of about 250,000 new subscriber lines is likely to be followed up with orders for exchange equipment. The East Germans’ offer is up to 50% lower in price, and includes some kind of a barter deal.

Coming up: an electroluminescent display less than 2 in. thick with a diagonal equivalent to that of a 7-in. cathode-ray tube. Sharp Corp. is offering samples of the display for about $1,360 and plans to begin quantity sales next year. The unit has 12 rows of 40 characters, displayed as a seven-by-nine-dot matrix. Brightness is in excess of 15 ft-L, and power consumption is less than 7 w. At the recent Chicago Consumer Electron-
ics Show, Sharp displayed a black-and-white TV set with an EL display. Area of the picture is 120 by 90 mm, compared with 144 by 74 mm for the character display. The firm says the TV display has a peak white brightness of 25 ft-L and a 30-step gray scale with a contrast ratio exceeding 50 to 1. It expects to start selling a portable TV with a similar display within two years.

Sales curves flatten for French telephone makers

French producers of telephone and telegraph equipment saw their sales curves flatten last year and don’t expect any improvement this year. Reporting its 1977 results in early June, the industry trade association SITT (Syndicat des Industries Téléphoniques et Télégraphiques) noted that the $2.139 billion revenues were up just over 16%, well under the nearly 25% annual gains registered in the mid 1970s. The growth should slow even more this year: export orders are down; and the government-owned telephone network has earmarked only a slight increase for hardware investments. However, these investments are at a high level, since the plan is to expand the network to 20 million primary lines by 1982.

VCR camera to cost $760 in Japan

Technical improvements plus production economies are responsible for the sharply reduced price tag that Victor Co. of Japan is putting on its new color TV camera for video cassette recorders, now on its way to Japanese and American consumers. Victor says its roughly $760 camera features a new form of color-stripe filter integrated into the faceplate and new circuits to separate the chrome and luminance signal components in its output. Helping to lower manufacturing costs is the firm’s move of the production line to its TV plant to take advantage of economies of scale. The $760 version is the cheapest of three models and features a fixed lens with a 25-mm focal length. In the U. S., Magnavox showed the Victor camera at the Chicago consumer show under its own label. It plans to price them starting at $895.

Addenda

Cooperation across the English Channel may spread to computers. The French and British governments are commissioning a study on collaboration in computer development and manufacture. . . . Engineers at Japan’s NHK public broadcasting system have devised a 60-in.-diagonal color TV. The picture is as bright as on the basic 30-in. tube, because a parabolic mirror reflects it within a fairly narrow viewing angle. . . . Motorola has hit a slot-machine jackpot for the 6800 microprocessor with two British makers of the equipment: Barcrest Ltd. specializes in electronic slot machines, while Bell Fruit Ltd., the largest British maker of the machines, expects to go solid-state within a year. . . . CII-Honeywell Bull will take a majority holding in R2E (Réalizations Etudes Electroniques), the company that pioneered distributed data processing in France. The $6 million firm is likely to be a good customer for CII-HB peripherals, while the big computer maker is likely to become a volume customer for R2E’s microprocessor-based Micral computers, as they are smaller than anything CII-HB now offers. . . . The VHS camp of video cassette recorder has won a significant new follower: Britain’s Thorn Consumer Electronics Ltd. is starting to sell three-hour VCRS made by Victor Co. of Japan, originator of the Video-Home-System technology.
New AM/FM signal generator for long - medium - shortwave

1978 will see SSB introduced on a wide scale for international maritime and aeronautical radio, meaning high demands on the purity and stability of the signals used in testing the equipment — and making the SMLH the ideal signal source for producers of and workshops servicing marine and aero radio sets, HF direction finders, antennas and amplifiers.

The SMLH covering 10 kHz to 40 MHz is a precision generator offering optimal price/performance, high spectral purity and frequency stability plus excellent modulation characteristics. Expandable to a power signal generator and power sweeper, its output ranges from 0.05 mV through 10 V.

The SMLH is economical and easy to operate — use it for all measurements on active and passive components, sub-assemblies and whole units. With its negligible AM distortion it's just right for measuring receivers. The low frequency drift — typically 25 Hz/5 min after one-hour warmup — and linear frequency response (±0.2 dB) enable measurements on highly selective filters and receivers working on narrow channel spacings. A 6-digit counter shows the output frequency with maximum resolution of 1 Hz. Its high output voltage makes the SMLH an obvious choice for multisignal measurements and for checking very high intermodulation margins. IM is 50 dB down in multitone AM.

Options (simply add on without any trimming):
- crystal oscillator for higher counter accuracy (2 x 10^-6/year), 2-W amplifier for boosting the output power, sweep oscillator covering 100 kHz through 40 MHz, overload protection.

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- Pore- and pipe-free watch cases are centrifugally cast in induction furnaces, whereby close dimensional tolerances and sharpness of contours must be observed.
- Quartz crystal oscillators are single-crystalline natural or synthetic pieces of quartz to which a very thin coating of metal is applied under high vacuum.
- Discrete components such as resistors, capacitors, diodes and transistors are also vapour-coated in vacuum.
- Functional coatings for “integrated” components are applied in vacuum etching processes. The various discrete and integrated components are connected by a thin-layer network that is vapour deposited.
- Single-crystalline materials for semiconductor applications which are subject to stringent purity and quality requirements are made possible by vacuum process engineering.
- Integrated circuits that contain thousands of transistors, diodes, resistors and capacitors within a few square millimeters also consist of single-crystalline material, in this case, silicon.
- Solar cells that replace conventional batteries consist of single-crystalline silicon, vapour-deposited metal contact coatings, masking and passivation coatings and optical coatings.
- LEDs and LCDs for the digital displays have vapour-deposited contact coatings, conductor paths, reflection-reducing optical coatings and cathode-sputtered mask coatings.

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Oxford laboratory develops hardware for self-tuning controller

Prototype uses SBC 80/10 to monitor response of system to a control input; from this, it adjusts the transfer function.

Self-optimizing computerized process control is taking the step from theory into hardware in a microprocessor-based developmental system from the department of engineering science at Oxford University. The system features a program that continually adjusts its transfer function so that it exactly models the process. For example, it compensates for runaway thermal instabilities.

By contrast, conventional analog controllers assume an unchanging transfer function. An operator must compensate for runaway thermal instabilities.

Demonstration. To introduce the self-tuning controller to potential users, David Clarke and his development team have put together a demonstration unit called Sesame, for self-tuning evaluation system and microcomputer equipment. It is based on the Intel SBC 80/10 single-board computer.

As a developmental system, it comes well equipped: 16 kilobytes of fast static random-access memory from Intel; a twin-drive floppy disk from Icom Inc.; an analog interface board from Analog Devices Inc. onto which is packed a 16-channel multiplexed 12-bit analog-to-digital converter, two 12-bit d-a converters, and a real-time clock system; a keyboard; and a display.

Clarke says a complete self-tuning controller could be constructed from an 8080 processor with associated clock, 2.5 kilobits of read-only memory, 500 bits of RAM, and a-d and d-a converters, together with an operator console. For consumer applications, he believes that a dedicated microprocessor eventually could be designed to optimize itself automatically for every installation.

Sesame can be taken to any plant, connected to existing process-control channels, and put on line rapidly. For equally fast on-line program modification, the Oxford group developed an interpreter based on the 2-k Tiny BASIC. When tailored to the group’s applications, by the addition of floating-point routines, interrupt handler, and disk interface, the interpreter fits into 5 kilobits of read-only memory.

Two roles. Clarke predicts that his self-tuning controller will be used in industrial and commercial roles. In industry, it is a natural for controlling processes that are nonlinear and time-varying and processes in which the control parameters are unknown.

It is also ideal for process systems with long time constants. The Lund Institute of Technology in Sweden has already applied conventional digital computers with self-tuning programs to thickness control in paper mills and load control in ore-crunching plants.

In office and consumer applications further downstream, Clarke sees one-chip microcomputers with self-tuning programs controlling such functions as central heating systems. Present-day on-off controllers hunt around the set point and are grossly inefficient, he says.

These controllers could be replaced by present-day industrial analog controllers, which can give far better tracking. But they require that the coefficient of the proportional, integral, and differential terms must be set by skilled technicians. Moreover, they take no account of changes in such parameters as the external temperature.

However, a self-tuning controller will adjust to such parameters as long-term changes in the outside temperature, and it also can adjust to differences between installations. It works by applying a control input to the system being controlled, then comparing the actual system response to that predicted (see diagram). From this, the parameter estimator works out the coefficients of an algorithm describing the new behavior. These coefficients feed into the controller, which computes the required input to achieve a target output. Thus the control parameters are constantly updated to adjust for any external disturbances.

Following successful analog and digital simulations, Sesame is pro-
Compact dielectric ceramic resonator simplifies microwave-frequency control

When is a solid cylinder lighter than air? When it is a ceramic dielectric resonator used in place of the cavities that stabilize the frequency in microwave oscillators.

Such resonators, developed by engineers at the Nippon Electric Co., have reached the takeoff point for incorporation into systems. Now they are hard at work on a series of experimental transistor microwave oscillators. Their ceramic material permits a more compact configuration than their cavity counterparts, so they are lighter. Also, they can be coupled easily to striplines.

Features. An important bonus for circuits using the new dielectric resonator is that it is the only frequency-determining element in the oscillator. Thus the same microwave integrated circuit can be used with a series of resonators to cover a frequency band. Furthermore, the load power is coupled through the resonator, eliminating the possibility that energy at any other frequency can be coupled to the load.

An added advantage is the ability to combine outputs of several microwave ICs for higher power output without any adjustments. NEC engineers have combined the power output from four stepped-electrode-transistor oscillators through a single dielectric resonator for an output of 263 milliwatts at 6 gigahertz.

The low-loss ceramic NED-39, developed in NEC's central research laboratory in Kawasaki for resonator use, is predominantly a mixture of barium and titanium oxides with a few tenths of a percent of other oxides. It has a dielectric constant of 39 ± 0.5. Since the linear dimensions of the resonator are inversely proportional to the square root of the dielectric constant, the ceramic component is much smaller than a comparable cavity, where the dielectric constant for the air within it is essentially unity.

Thus a resonator for a 7-GHz bandwidth measures only 7.5 millimeters in diameter and 3 mm high. The metal cylinder surrounding a typical 7-GHz cavity is 70 mm in both diameter and height.

The high dielectric constant of NED-39 provides a discontinuity at the cylinder surfaces that in effect confines the electrical field within the resonator. NEC engineers say performance is excellent, with an unloaded Q at 7 GHz on the order of 7,000.

However, the magnetic field extends outside the resonator, permitting coupling to a nearby 50-ohm stripline. A movable metal disk at one end of the cylinder can vary frequency by about 1% without degrading performance. Also, a varactor connected to the stripline can control or modulate the frequency.

Another feature of NED-39 is the way in which the temperature coefficients of the dielectric constant and thermal expansion offset each other's effects on resonant frequency. The resulting temperature coefficient of frequency can be controlled between 0 and 50 parts per million per degree centigrade. But an unstabilized oscillator has a small negative temperature coefficient, so adding the resonator can result in a design with a coefficient on the order of 1 or 2 ppm/°C.

For extra frequency stability, the NEC lab has fabricated a temperature-stabilized resonator that gives an oscillator a stability of ±10 ppm over a 70°C range. For the highest possible stability, phase lock to a quartz crystal improves it to ±3 ppm over the same temperature range.

Two types. With the basic resonators, NEC has developed many types of oscillators. The central research lab has developed one type, shown in the figure, that uses metalized semiconductor field-effect transistors. Operating in the 6-to-12-GHz bands, these oscillators have higher efficiencies than those made with Gunn diodes.
New recorder family: precision priced right

For XY and YT plots there's now the recorder ZSK 2 in five different models so you can choose exactly the right one for your application, and at the right price.

ZSK 2 works on the principle of a self-balancing potentiometer. This gives minimal non-linearity (0.1%) and guarantees good reproducibility (0.05%). The high writing speed of >110 cm/s on both axes combined with fast acceleration produces superior dynamic characteristics. Deflection factors calibrated between 10 µV/cm and 11 V/cm, electronic limiting of the writing area for DIN A3 and A4 plus governable zero offset make operation easier, whilst inputs for remote control and ratio recording mean greater variety of use.

The models differ in their inputs:

- **Universal model 02**
  - Sensitivity 10 µV/cm; floating input amplifiers with guard; timebase generator.
- **Standard model 04**
  - Sensitivity 5 mV/cm; differential amplifiers for both inputs.
- **Lab model with timebase 06**
  - Sensitivity 100 µV/cm; floating input amplifiers; timebase generator; offset-voltage source.
- **Lab model 08**
  - Sensitivity 100 µV/cm; floating input amplifiers.
- **System model 10**
  - Sensitivity 100 mV/cm; direct inputs Z∞ 20 kΩ.

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ZSK 2 recorder family

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diodes and lower noise levels than those made with Impatt diodes.

The microwave and satellite communications division has developed a type using bipolar SETS [Electronics, Jan. 22, 1976, p. 63 or 6E]. They operate in the 6- and 7-GHz bands at extremely low noise levels. However, 7 GHz is about the limit for efficient operation of these transistors, so the division uses MESFETS for higher frequencies.

An oscillator developed by the lab for operation in the 7-GHz band uses NEC's NE464R GaAs MESFET, which has a gate width of 1.5 micrometers. Output is 100 milliwatts, with an efficiency of 15%, and frequency stability over a range of $-10^\circ$ to $50^\circ$C is only 1.8 ppm/$^\circ$C. Fm noise is reduced more than 30 decibels over nonstabilized oscillators.

**West Germany**

**Thick-film resistor material reconciles good performance with lower cost**

Thick-film resistor technology, long a standoff between the high-priced cermet and low-performance organic techniques, is effecting a major reconciliation between economy and performance. Behind this move is a West German components producer, Preh-Werke, with a radically different technique dubbed polypyron.

“Our new method is a low-cost alternative to the expensive cermet technique, yet it matches most of the latter's technical parameters,” says its inventor, Wolf-Erhard Steigerwald, senior vice president. Compared with organic resistors, polypyron devices have better dielectric strength and better noise, temperature, and moisture behavior. As potentiometers, they exhibit superior contact resistance characteristics.

Just how much better the performance is cannot yet be pinned down because the technique is still being refined by the Bad Neustadt firm and measurements are not yet complete. “But preliminary results show that the improvement is substantial,” Steigerwald says. Temperature coefficients can range from $\pm 200$ ppm/$^\circ$C to $\pm 600$ ppm/$^\circ$C, almost as good as for cermet resistors, he says.

**Process.** The polypyron resistors use a resistive paste in which nonconducting, refractory, inorganic particles from 1 to 5 micrometers in diameter are dispersed in an organic binder. To form a conducting layer, these particles are coated with complex liquid or plastic pyropolymers formed by subjecting gaseous hydrocarbons first to dehydrogenation in a pyrolytic environment and then to condensation.

A major advantage is the ease with which the conductivity of the pyropolymers may be altered during manufacture so that specific resistor values can be obtained. Changing the layer’s thickness, crystal structure, expansion coefficient, or doping, or varying the particles’ material combination, crystal structure, or surface area are all possibilities. Combinations of these schemes can produce a conductivity range of 10 ohms per square to 1 megohm/sq.

Steigerwald and his development team also have come up with new materials for the binder and the substrate onto which the paste is screen-printed. Essentially they are noninflammable organic substances.

Moreover, the hardening process is new to thick-film engineering. It involves heating resistive particles in the binder by microwave radiation, a technique that insures uniform and simultaneous hardening throughout the resistor’s volume. Also, microwave hardening can be selectively applied so that even small areas can be heat-treated without affecting the surrounding substrate.

**Savings.** What makes polypyron a low-cost technique compared with the cermet approach “is the use of less expensive materials,” Steigerwald points out. “Moreover, the microwave hardening process takes a very short time and can be highly automated.”

Also, the Preh technique lends itself to a high degree of reproducibility in making resistors with uniform, close-tolerance resistivity values. The technique uses resistor materials with conducting particles having a maximum possible concentration in the binder, and the resistivity values are determined primarily by the properties of the conducting particles.

The technique lends itself to producing discrete resistors, resistor networks, resistors for hybrid cir-
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circuits, and resistive elements for potentiometers. Moreover, "polypyrone unlocks areas of application that have thus far been closed to thin-film technology for reasons of costs," Steigerwald declares. The first products, he confides, will have their debut at Munich's big Electronics show in November.

France

6800s ease task of sonar operator

Time was when a subchaser's success depended largely on the skills of its sonar operators. But now it is as much a matter of how cleverly a sonar maker can process the echoes digitally with microprocessors, although a well-trained ear still is essential for some situations.

"An operator simply can't exploit all the information this sonar develops," says Stéphane Zyromski, speaking of the Beluga sonar under development by his group at Thomson-CSF's submarine-equipment division at Cagnes-sur-Mer on the French Riviera. So to sift out what is significant among the echoes, Beluga analyzes them with three microcomputers built around Motorola M6800 microprocessors.

Beluga continues the Thomson tradition of naming sonars after fish and was designed for warships of 1,500 tons or more. It sends out sound waves at a fairly low frequency, either 6.75 or 7.80 kilohertz, and high sound levels, up to 135 decibels (the reference level is 1 microbar/meter). The combination makes for a maximum range of 40,000 yards.

In effect, the sonar divides the sea around the ship into thousands of cells, each about 1.5 m thick, along the range of each 7.5° pencil beam. To cover the range out to the 20,000 yards realistic for naval operations, the sonar has to process some 500,000 cells. No human operator could analyze that much information, hence Beluga's signal extractor and its three microcomputers.

The cylindrical transducer head is made of 48 identical arrays of piezoelectric transducers. For active surveillance, the arrays may be powered simultaneously or selectively. The 6800's memories can store up to 50 tracks, and as many as 12 of the most interesting can be passed on to the plan-position display for operator evaluation.

Essentially, the extractor performs three analyses to pull out the necessary cells for the operator. It checks the signal-to-noise ratio, which is high for cells where there is a submarine or other substantial underwater object. It also examines the echoes for spatial coherence: underwater objects have distinctive sonar signatures, formed by the echoes that come back from adjacent beams, and they can be compared with stored signatures to sort them and distinguish them from background noise like bottom return. Finally, it checks echoes for coherence in time; that is, positions are compared from sweep to sweep.

For all its features, Beluga has an excellent price/performance ratio, Zyromski maintains. The basic version of the transducer head in its dome, a rack carrying the transmitter-receiver hardware, a rack for the digital signal-processing equipment, and an operator's console sells for about $2 million. Zyromski presented the gear to the world's navies during the early-June naval technology exposition in Rotterdam.

Is an automatic conductor next?

True to form, West Germany's Federal Railways continues to go all out for electronic gear, not only to enhance safety of train operations, but also to offset rising labor costs. One of the latest labor-saving systems in the Bundesbahn's lineup is this microprocessor-controlled automatic ticket-vendor now undergoing a test at the Kassel railroad station.

The heart of the AEG-Telefunken vendor is a registering and control unit using an Intel 8080 microprocessor with a directly addressable memory capacity of 64 kilobytes. Among the many jobs the unit handles are: controlling the operation of subsystems like the coin checker, printer, and the change-return apparatus; advancing the date and time-of-day with due regard to leap years and daylight-saving/normal-time switchovers stored in the memory; and processing the data on train fares prevailing at different times during the week.

Further, the control unit triggers an alarm when someone tampers with the vendor. It also helps perform fault diagnoses and sends messages on the operational status to a central station, such as reporting that the paper supply needs to be replenished. It even ensures that a ticket purchase in progress is completed should the system's power supply suddenly fail.

The vendor's needle printer produces tickets with the appropriate date, time of day, and fare, as well as the destination that the user has picked by pushing buttons on a 28-key panel. The print speed is about 140 characters per second. The panel is expandable to 64 keys if the vendor is to be used to sell tickets to destinations in a larger geographical area.
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Technological progress is a process of evolution. The familiar light-spray lamp, for example, uses minute-diameter flexible glass fibres to transmit light along a curved path. This same principle has evolved into a science that will have a significant impact on 20th century communications technology.

Philips optoelectronics engineers have developed this 'light fantastic' sufficiently to install the fibre optics transmission system.

Using 0.1 mm diameter fibres - each with a capacity of 1920 telephone channels - the system is also suitable for transmitting data, telegraph, video telephone and television signals. Once the problem of short-haul transmission have been resolved, it stands to reason that much greater distances will be covered. For, quite apart from its enormous economic and technical advantages over traditional copper-cable transmission systems, fibre optics is a
A logical answer to the future demands of global communications.

Optical transmission is one example of how Philips are translating advanced technology into practical innovation. Here are some more.

**Stored Program Control**, or SPC, presents the logical integration of advanced computer techniques with sophisticated communication electronics. This leads to drastic improvements in telephone, telegraphy and data communications.

**IRAS - Infra-Red Astronomical Satellite** - due to be launched into a 900 kilometre polar orbit in 1981, is the first scientific satellite designed to make a detailed inventory of infra-red sources in space. The on-board computer, which will process about 500 million bits of measured data per day, will be supplied by us along with other electronic systems.

**Solar energy** is used to re-charge the storage battery aboard each of the forty survey buoys currently performing a marine study in the Indian Ocean. Continuously monitored data is automatically transmitted from each buoy every hundred minutes via the Nimbus-Six satellite. The study is being carried out by the Commonwealth Scientific and Industrial Research Organisation (CSIRO). Philips supplied the solar collector panels.

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*Ripple and stability figures in constant voltage mode. Stability given for ±10% line variations.
New products international

Data-acquisition system lets users build to suit their needs and wallets

by Kevin Smith, London bureau manager

Built around a DEC LSI-11 card computer, system can handle up to 4,096 channels.

The freedom to mix and match transducers and peripherals in an integrated system is what every user of data-acquisition systems would like. Usually, though, it costs too much. But now Solartron-Schlumberger has put a Digital Equipment Corp. LSI-11 card computer instead of a full-blown minicomputer in its new 3550 plug-in module data-acquisition system. To tie the modules together into an operational system, they have come up with a new software language called Basac IV.

Like many of its competitors, the Farnborough, Hants., company till now has built its big acquisition systems around general-purpose computers like the DEC-11/04 and 11/34. But to cut costs and allow the user to tailor a hardware system to his needs from plug-in modules, it has turned to microprocessor technology. The LSI-11 was a natural choice because of the transferability and quantity of its existing software, says J.W. Williams, Solartron-Schlumberger’s marketing manager. The card processor is central to its operation, processing digitized measurements and status signals, storing and formatting data, and outputting it either to floppy-disk or to disk cartridges.

The 3550 mainframe incorporates up to 14 module cards, each a self-contained printed-circuit board that plugs into a 65-track mother board. The unit can control up to 4,096 channels via the company’s 3502B slave scanner unit and 3501B master measuring unit. It is designed to work with a wide range of the company’s already existing peripherals and transducers for measuring voltage, current, resistance, temperature, and strain. “We are aiming to produce a complete data-acquisition system in which all the components have been thoroughly tried, tested, and proved,” says Williams.

The 3550 processor has a priority-structured interrupt input/output system organized to give highest priority to the modules electrically nearest to the processor. The watchdog printed-circuit board that monitors alarm sensors thus gets maximum priority while the 28-K memory module has the lowest. The system operates asynchronously so that I/O devices run as fast as possible. Optional plug-in boards include an IEEE-488 interface bus and a storage bus for floppy-disk and disk cartridge.

A 500-W power supply is rated for the full plug-in board capacity and incorporates a power-down mode so that when the power line is low, the system switches over to standby operation but does not cause a system crash; the memory module is kept alive by a dc ground. A complete external power loss switches the memory to on-board battery power for up to 30 minutes. Restart is automatic.

Working from the Basic high-level language, Solartron has developed the Basac IV conversational high-level software system for use in a real-time measurement and data-acquisition environment. Typically, it is organized with a foreground-background capability so that the system can scan measurement channels while the processor is busy carrying out other computational tasks. The real-time executive routine is already proved on logging applications and handles all peripheral operations, program management, and time control.

The new 3550 is designed for use with the 3510 measurement system introduced just over a year ago. This unit incorporates a fast reed-relay scanner teamed with a variable-integration-time analog-to-digital converter, thus allowing the user to trade resolution for speed as re-
quired. The 3510 is based on the company’s patented pulse-width conversion technique originally developed for the Maestro series of digital voltmeters. A feature of the technique is its improved noise rejection, needed to maximize benefit from the 3510’s sensitivity at the longer integration times.

The 3510’s highest resolution of five digits at an integration time of 100 ms offers 100-nv sensitivity at the 10-mv level. Since strain and temperature measurements entail detecting input changes of no more than a few microvolts, the ability to recognize a change of 100 nV is an advantage. At all other scanning speeds except the fastest, the 3510 has a 1-μV sensitivity.

Also novel is the reed-relay scanner, constructed on a double-sided printed-circuit board having the reed switches on one face and their energizing coils on the other. The reeds are thus electrostatically and thermally screened from the coils, minimizing the possibility of errors due to spurious emfs. Also to improve switching performance, the reed is pulled in by a current pulse dropping to a far lower holding level, thus increasing switching speed and reducing power consumption. The net result is a 200-channel-per-second system.

Solartron-Schlumberger Ltd., Farnborough, Hampshire England GU14 7PW [441]

An integrated-circuit tester, designated model 1010, will dynamically inspect a 14- or 16-pin TTL device in 1 second. A four-digit LED display gives the results. Punjab Digital Industrial Systems Ltd., C-30, Industrial Focal Point, Phase II, S.A.S. Nagar (Mohali) -160051, Punjab, India [443]

Available with a four- or six-digit readout, the Orbit 74T electronic interval timers have 1-MHz crystal-derived time bases. Timing increments can be selected from 10 μs to 10^6 s. Orbit Controls Ltd., Lansdown Industrial Estate, Gloucester Road, Cheltenham, Glos. GL51 BPL, England [444]

Suitable for mounting in installations and equipment, a 220-V ac surge protector has current ratings of up to 10 A. Depending on the steepness of the waveform of the voltage surge, sparkover voltage is between 800 and 1,500 V. Cerberus AG, CH-8708, Männedorf, West Germany [445]

A battery-operated digital multimeter, Multi 2000, resolves 2,000 counts and will measure dc and ac voltage, dc and ac current, and resistance. It measures 160 by 110 by 50 mm. A.O.I.P. Dépt. Mesures, 83-85, Bd Vincent-Auriol, 75013 Paris, France [448]
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A personal computer, the Pasona-1, designed for use by researchers, engineers, and students, has 16 kilobytes of RAM and 2 kilobytes of ROM. It can be programmed in Basic or assembly languages. Kokusai Data Machinesystems Inc. 3-33-21 Takaido Higashi, Suginami-ku Tokyo 168, Japan [465]

Digital capacitance meter NS 535 is designed to test capacitors in quantity and to gather inspection data. It has a range of 1 pF to 999.9 nF. Digital limit comparators can be added. Anglo-Japan Electronics Corp., Maruzen Bldg., 2-3-10 Nihonbash, Chuo-ku, Tokyo 103, Japan [466]
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Motorola MC6800 earns listing on QPL.

It's the QPL-listed microprocessor with a fully-compatible hi-rel component family. The MC6800 recently earned JAN approval for listing in the QPL, Part II. Concurrently, DESC completed certification of Motorola's Austin, Texas factory for all its MOS integrated circuits. QPL listing for additional M6800 Family components is being pursued at this time.

Now the MC6800 can be used for defense systems with greater confidence than ever, and with less delay and red tape.

M6800 Family hi-rel series expanding to 38.

M6800 Family hi-rel series components numbered 28 at the end of the first quarter, '78, with additions through the third quarter raising the projected total to 38. A hi-rel version of the MC3870 single-chip microcomputer also is due for availability in the third quarter. All M6800 hi-rel series parts are processed to MIL-Standard-883.

MIL-processed M6800 Family parts include the MC6802-6846 two-chip system, a variety of I/O functions, programmable timer, data link controller, MODEM, IEEE 488 bus interface, and plenty of memories: 1K and 4K Static RAMs, 4K and 16K Dynamic RAMs, EPROM, and 1K, 8K, 16K, and 32K ROMs.

Our MOS high-reliability story is explained in a brochure covering wafer fabrication, assembly, testing, reliability, and how to order our hi-rel MOS products. For your copy, please circle the reader service number or write to Motorola Semiconductor Group, P.O. Box 20912, Phoenix, AZ 85036.

Motorola Hi-Rel Microcomputer Components

<table>
<thead>
<tr>
<th>Part Number</th>
<th>Function</th>
<th>Status</th>
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<td>MC6800BQCS*</td>
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<tr>
<td>MC6800CQCS*</td>
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<tr>
<td>MC6846BQCS</td>
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</tr>
<tr>
<td>MC6802CQCS</td>
<td>Microprocessor with RAM and Clock</td>
<td>Available</td>
</tr>
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</tr>
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*The military equivalent part numbers for the MC6800 are JM38510/40001BQG and JM38510/40001CQG.

Motorola Semiconductor Group
Probing the news
Analysis of technology and business developments

Electronics executives are smiling

Agreement that business exceeds forecasts for most sectors goes with the big question: when the next slump will come

The three little words they're singing these days in the electronics industries are "business is booming." With 1978 conditions described as good to great, caveats voiced by some of the more cautious executives are muffled by the refrain from those who see nothing but market strength ahead.

Of course, nowhere is it written that conditions cannot turn down and take those optimistic forecasters with them. Inflation, assaults on the dollar, lack of a coherent national energy policy—all or any of these and other factors could have a stultifying effect on growth, sales, and profits. Still, as the hard-eyed analysts on Wall Street point out (see "Analysts see health," p. 82), never before have the electronics industries been so well prepared to ride out a recession.

Better. In the semiconductor industry, where friendly differences of opinion are the rule, there is agreement that business so far this year has been better than most had expected. The Semiconductor Industry Association, for example, had predicted a 10%/12% growth rate; manufacturers now expect a figure closer to 15%.

One company that forecast a 15% growth rate right from the start was Texas Instruments Inc. Breaking that down further, James L. Fischer, senior vice president for U.S. and Asian semiconductor operations, sees a growth of 7% for discrete-device sales and 22% for integrated circuits. "The strongest sector is computers," he says, "but we see strength across the board—in the distribution, consumer, and industrial sectors as well." Business in the military segment is steady, he adds.

In Silicon Valley, after toting up the increased bookings and looking in vain for signs of a downturn, most semiconductor makers have increased their expansion appropriations. "We had already planned to increase our facilities, but now we're working the high side of our projections," says James C. Harwood, president of Signetics Corp.

Fairchild Semiconductor is increasing its capital equipment expenditure by 35%. National Semiconductor is just making expansion plans now, not because of caution but because its fiscal year does not end until May 31. And Intel's president, Gordon E. Moore, says the biggest obstacle to expansion is not necessarily any of the economic imponderables, but finding enough qualified personnel.

Some hard lessons about inventory and double ordering were learned in the 1974 recession, and the industry seems to be profiting from them. "We're trying to keep a balanced capacity so that there is no need for someone to order 40 weeks in advance," says National's E. Floyd Kvamme, senior vice president and general manager of the Semiconductor Products division. George D. Wells, senior vice president at Fairchild, notes, "Like us, the customer learns. Most say, 'The last thing we will ever do is double-order again.'"

Back east, the view is as bright as it is in the Golden State. Bernard V. Vonderschmitt, vice president and general manager of RCA Corp.'s Solid State division, sees a healthy inventory situation and no great rush to double-order. However, he expects the economy to weaken going
into 1979, possibly making 1978 a replica of 1977, with slower growth in the second half.

For General Instrument Corp.’s Microelectronics division, the second half is eagerly anticipated by Andy R. Sass, director of product planning, for its expected July-August influx of orders from the consumer marketplace. For GI, the year to date has been particularly good for industrial products, with shipments of semiconductors exceeding last year’s first half by 30%.

Amid all the bullishness, Motorola Inc.’s Semiconductor Group is taking a cautious stance. “We’ve had a great start in 1978,” says Pasquale Pistorio, director of world marketing, “but it wouldn’t be wise if we were to relax our cautious attitude and control of expansion. There is need to be vigilant.” John Welty, vice president and general manager, adds, “Over the past few years, the industry has experienced a bookings pause at the beginning of the third quarter. In 1976, the ‘pause’ extended through the second half of the year; in 1977, it ran from August through October.” So he, too, expects markets to soften in the second half.

Prosperity. For computer makers, the vista is perhaps described best by Donald M. Fuller, chairman and president of Microdata Corp. His outlook is perhaps described best by Donald M. Fuller, chairman and president of Microdata Corp. The only problems he sees range of 30% to 35% compounded growth projection for what he expects markets to soften in the second half. “Business has been pleasantly strong in all aspects of the industry, from components on up through systems,” says Hans C. Severiens, vice president at Merrill Lynch, Pierce, Fenner and Smith Inc. “It is hard to find an industry segment that is weak. All of them are going into the second half of 1978 with record backlogs.” Thus, it looks to him as though the industry will be in a healthy situation for the third and fourth quarters.

Despite this bright picture, Severiens sees slower growth rates in incoming orders as the summer starts. But “with the head of steam the industry has built, it would surprise me if the summer correction will be as severe as it was last year,” he adds. Similarly, he sees the national economy going into a slowdown in 1979, but the electronics industries “won’t be hurt very much by it. In that next recession, instrument and computer companies will continue to grow and semiconductor firms, although they may not be up, won’t suffer as they did in 1974 because their inventory situation is under control.” Hence, while 1979 will not be up as much as this year, Severiens forecasts, “it will be an up year, nonetheless.”

Less bullish for this year’s second half and for 1979 is Sal F. Accardo, vice president at Kidder, Peabody and Co., who sees the increase in semiconductor demand approaching 20% for 1978’s first half but leveling off at 15% for the full year. “I see a possible slowdown in the second half led by consumers who may stop buying because of inflation fears and aggravated by capacity build-up at both the user and manufacturer levels,” he says. Similar views are held by Kent A. Logan, vice president at Goldman Sachs and Co., who envisions the rate of acceleration in semiconductor orders turning down and, eventually, flattening. This is due to what he predicts will be “a slowing down of final equipment sales and involv-

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**Analysts see health**

The electronics marketplace appears healthier than ever, according to Wall Street analysts. Not only are incoming orders robust, backlogs at record levels, and inventories quite clean, with a minimum of double ordering, but the industry’s ability to weather a downturn or a recession is perhaps at an all-time high.

"Business has been pleasantly strong in all aspects of the industry, from components on up through systems," says Hans C. Severiens, vice president at Merrill Lynch, Pierce, Fenner and Smith Inc. "It is hard to find an industry segment that is weak. All of them are going into the second half of 1978 with record backlogs." Thus, it looks to him as though the industry will be in a healthy situation for the third and fourth quarters.

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tary accumulation of inventory” in the third and fourth quarters of 1978. Unlike last year, he says, when the second half slowdown was more seasonal than cyclical, the reverse will be true this year. Logan expects that the slowdown will carry into the first half of 1979 but, he notes, “will be nowhere near as bad as in 1974.” Accardo concurs. “Were a recession to develop, the industry may hold up better than in past recessions.”

Accardo sees several key semiconductor markets, such as the telecommunications and defense industries, holding up well. “There may be a nice incremental demand next year from Detroit,” he says, because of mandated fuel-economy and emission standards. These and other factors “indicate that the semiconductor industry may not perform as badly as has been its pattern in past recessions.”

The test and measurement instruments industry may fare even better. As was the case in 1977, the instruments market is growing faster than that for semiconductors. “Orders are up 15% to 20% thus far and for the full year may rival last year’s growth of 20% to 25%,” says Accardo. What’s more, if there should be a recession, “demand for instruments should hold up better than that for semiconductors.”

Logan of Goldman Sachs sees it differently. While capital spending is picking up across the board, he believes the instruments industry “may have a rougher time in late 1979” than the semiconductor sector. Capital spending will be fairly strong through early 1979, he says, suggesting that the slowdown in instrument orders will lag behind that in semiconductor orders, probably not occurring until the second quarter of 1979.

Managers of many electronics firms were quite cautious as recently as mid-1977 with respect to what they anticipated the demand to be for their products and “kept the lid on capital and discretionary spending,” he notes. “Now backlogs are at record levels and incoming orders are quite strong. Thus, they are starting to step up capital spending and raising discretionary spending, perhaps, just at the wrong moment.”

Logan concludes. Bruce LeBoss
Communications bill finds few friends

Proposed reorganization of phone and broadcasting markets criticized by Government and industry telecommunications chiefs

by Ray Connolly, Washington bureau manager

Superficial, sophomoric, and confusing.

These and similar derogations are being used by most industry and Government telecommunications executives in private conversations to describe new congressional legislation designed to deregulate and open America's telephone and broadcasting markets to competition and a free flow of technology. The two ranking members of the House subcommittee on communications, Rep. Lionel Van Deerlin (D., Calif.), chairman, and Rep. Lou Frey Jr., the panel's minority leader, introduced early this month the legislation containing 217 pages of sweeping changes (see "The big shakeup of 1978," p. 85).

Comments for attribution were guarded for the most part as interested parties sought to study the bill's implications before hearings begin next month. The Electronic Industries Association's John Sodolski, Communications and Industrial division vice president, believes the bill's sponsors are optimistic in their 1980 enactment goal because of the comprehensive nature of the legislation and its vulnerability to amendment.

"There are a number of developing areas like land-mobile communications as well as citizens' band radio that are not referenced directly at all," he points out, "and these need clarification to eliminate confusion." There is "a potential defect, too," Sodolski says, "in that it doesn't address the complex issues of internationalization" as global communications rapidly expand. In the international area, the Van Deerlin bill calls only for a task force to coordinate international facilities planning.

American Telephone & Telegraph Co.'s vice chairman William Ellinghaus proved most outspoken in an initial survey of 12 affected organizations, favoring some segments of the bill and opposing others.

Predictably, its proposal to free AT&T from the restraints of the 1956 antitrust consent decree limiting it to telephone services is welcomed by Ellinghaus. It would permit AT&T to form subsidiaries to enter the computer services market by linking its advanced Electronic Switching Systems to push-button telephones, and would also allow telephone companies to offer television programs to subscribers in competition with cable TV companies and broadcasters.

Hits hardware ban. On the other hand, AT&T opposes the provision that would bar monopoly carriers from making telecommunications hardware. That would require AT&T to divest Western Electric Co. three years from enactment of the law. The abolition of such vertical integration, Ellinghaus contends, "would slow technological innovation, increase the cost of facilities, and lead eventually to higher rates for service."

While General Telephone & Electronics Corp., the largest domestic competitor of AT&T, took much the same stance, other prospective large competitors were more cautious. For example, ITT Corp. and Communications Satellite Corp. say they are still studying the bill and probably will not comment publicly before hearings start. Satellite Business Systems Inc., the potential communications giant owned by IBM, Aetna Life & Casualty, and Comsat General Corp., says only that it "supports the legislation's suggestion of expanding the availability of competitive telecommunications services and a less stringently regulated environment." Even the pro-competition Ad Hoc Committee for Competitive Telecommunications, made up of small communications companies, speaks cautiously of the bill as an "excellent beginning" with "a very positive intent."

Independent equipment makers of the North American Telephone Association modify their high praise of the legislation's pro-competition "spirit" by calling for checks to protect smaller competitors from being overwhelmed by AT&T's entry

Backer. Rep. Van Deerlin of California heads House communications subcommittee and is sponsoring reorganization measure.
The big shakeup of 1978

Key provisions of H. R. 13015, the Communications Act of 1978, include:

- **Regulation:** replace the seven-member Federal Communications Commission with a five-member Communications Regulatory Commission whose presidential appointments would be limited to single terms of 10 years instead of the FCC's renewable seven years. CRC's 25% smaller staff would result from a new policy to substitute "full and fair" telecommunications marketplace competition for regulation. Common carriers would be free to compete for any service through subsidiaries but could not make equipment if they maintained a monopoly service. The CRC would retain powers over equipment quality control. More important, it would exercise Federal control over intrastate telecommunications, like telephones, that use radio frequencies in direct distribution of service to consumers.

- **Policy:** create a National Telecommunications Agency as a separate, executive policy-making body, with spectrum-allocation powers, to replace the National Telecommunications and Information Administration just beginning operations in the Commerce Department.

- **Broadcasting:** retain only technical rules for radio and TV broadcasters, eliminating the three-year license-renewal requirement immediately for radio and over 10 years for television. Both would be replaced with open-ended licenses subject only to legal challenges. New or revoked licenses would be awarded by random selection—much like a lottery—rather than by commission determination of the best-qualified candidate after hearings. License ownership would be limited to five radio and five TV stations, including at most three TV in the top 50 markets. This would affect only new licensees.

- **Fees:** administrative costs of the new CRC and NTA would be paid by fees—estimated at $400 million after 10 years—paid by licensees based on the "scarcity value" of the spectrum used and license processing costs, with fees—estimated at $400 million after 10 years—from licensees based on license would pay a high fee, less for a uhf or small vhf market station, with only nominal fees charged for multiuser channels like citizens' band. The money would also finance public TV through a new nine-member Public Telecommunications Programming Endowment replacing the Corporation for Public Broadcasting; it would also support rural telecommunications facilities loans, plus minority-group broadcast interests through a 30-year, low-interest loan account.

into any market if the 1956 antitrust constraints were removed.

Similar fears were expressed by individual independent equipment makers, who believe AT&T, using its affiliates, will undertake a massive lobbying effort to amend vague sections of the bill in its favor. That is how they read the observation by AT&T's Ellingshaus that "the Congress is a more appropriate forum for resolution of this issue than are the courts."

**FCC stance.** At the Federal Communications Commission, sources say chairman Charles Ferris is unhappy with many aspects of the bill. For starters, there is the provision that would permit totally uncontrolled equipment competition by independent Western Electric Co. and other giants, like IBM, certain to enter the market. Ferris says only that the agency has "started to take a 'zero-based' look at our own regulations and will develop our view on the rewrite bill based on that."

Politically, there are signs that the Van Deerlin bill is in trouble already. Apart from Rep. Frey, who admits he has reservations about some aspects of the legislation, none of other 12 subcommittee members was asked to cosponsor the bill. Moreover, House Speaker "Tip" O'Neill is reportedly unenthusiastic about the sweeping scope of the legislation.

Other signs being read as significant are the silence of the White House and of Sen. Ernest Hollings (D., S. C.), chairman of the Senate's Communications subcommittee and Van Deerlin's counterpart in the upper chamber. Hollings, staffers report, is "taking a let's-wait-and-see approach" to the legislation until the air clears, and has no plans to introduce a matching proposal in the Senate.

Electronics / June 22, 1978
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The emulation fever that has hit the IBM computer market in the last month appears to be spreading. This time the target is Data General Corp.'s Nova minicomputers.

Although they are not the first to do so, Ampex Corp. of El Segundo, Calif., Lear Siegler Inc. of Anaheim, Calif., and SCI Systems Inc. of Huntsville, Ala., unveiled their emulators earlier this month at the National Computer Conference in Anaheim. Their predecessors have been beset by legal challenges from Data General, but the new competition is confident it can avoid those obstacles.

The Nova emulators' introduction follows last month's introduction of several IBM-compatible mainframes to compete with the computer stand on its own ground [Electronics, May 11, p. 81; May 25, p. 93] and Amdahl Corp.'s earlier success with its IBM-compatible machines.

Among minicomputers, the Nova is the most attractive to emulate, the new contenders say, because of its popularity, primarily with original-equipment manufacturers and systems houses: the estimated demand is close to 15,000 Nova minis a year. This popularity has also fostered development by independent companies of Nova-compatible software and peripherals.

"There is a lot of software available that is compatible with the Data General Nova that we can buy," says Cathy Raftery, product marketing manager for Lear Siegler's VDP series. "The Digital Equipment Unibus is more complicated." Since Ampex already supplies OEMs with Data General-compatible add-in memory, disk drives, and tape drives, it was natural to offer the computer, he adds.

"Our Data General-compatible memory was well received and we were already known as a proven supplier," Sroka says. "We now offer our OEM customers one-stop shopping. Looking at the way the add-in business was expanding, we saw that we must supply it all."

Like his competitors, Olin King, president of SCI Systems, intends to concentrate on OEM customers. "I won't compete head to head with Data General for end users, but to the OEM I'm offering speed and flexibility," he says.

The Mercury 3 minicomputer from SCI uses standard Schottky transistor-transistor logic and has the speed and instruction set of the Nova 3, he says. The Mercury has a three-processor architecture that provides for concurrent handling of memory, input/output devices, and arithmetic/logic functions and can support 128 kilobytes of directly addressed memory.

**Models.** Lear Siegler's VDP 410 computer, which emulates the Nova 1200, can support 64 kilobytes of memory, has a 200-nanosecond instruction cycle time and uses Fairchild's 9400 series of 4-bit-slice microprocessors. Without software, it sells for $3,500. The VDP 1000 system, which includes the computer with a 10-megabyte disk, plus the ADM-3 cathode-ray-tube terminal, a 300-series 180-character-per-second bidirectional matrix printer, and a virtual-memory operating system, is priced at $18,000.

Ampex's Model 12 minicomputer also emulates the Nova 1200, using bit-slice technology from Advanced Micro Devices. It can handle as much as 128 kilobytes of directly addressed memory, has a 300-ns central-processing-unit instruction cycle, and is priced at $3,975 in OEM quantities with a five-slot chassis and 64 kilobytes of memory.

**Emulator.** Lear Siegler's Cathy Raftery says there is a lot of software available that is compatible with the Nova minicomputer.
memory. A computer with 64 kilobytes of memory will cost about $5,000.

Danger. But hanging over the business is a threat: lawsuits. Digital Computer Controls, Keronix, and Fairchild Camera and Instrument Corp. have all introduced units compatible with the Nova instruction set and were promptly sued by Data General for patent infringement and theft of trade secrets. A Data General spokesman says it won its case against Digital Computer Controls, which it later acquired. The others still market their Nova-compatible units, but the lawsuits are pending.

The new entrants claim they can avoid lawsuits because their machines' internal designs are different from Data General's, even though their computers are compatible with the Nova instruction set, memory organization, and I/O architecture. By offering operating systems and programming-language compilers developed by independent software houses, they will help customers avoid violating their Data General software licenses.

Not pleased. However, Data General's senior marketing vice president, Herbert Richman, is not flattered by all the imitation. The firm's lawyers are studying the situation, he says.

"We've been so successful with that particular product that people are trying to get on the bandwagon. It demonstrates we have the most elegant computer architecture. But we'll maintain our rights and file suit where we feel we've been violated."

A former Data General competitor, Phil Goodman, previously marketing vice president at Digital Computer Controls and now marketing vice president at Digi-Log Systems, agrees that the Nova emulator market is a good one. As he points out, "When DCC was acquired by Data General they had revenues of about $20 million."

He feels that Data General's acquisition of the firm left a market need that the new competitors hope to fill. But he warns that the market may become oversaturated. "They're all thrashing after the DCC customer base. It's a large pool of sharks snapping at a small school of fish."

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the development of prototype systems; its development budget has leaped from $25,000 two years ago to today's $250,000. The team will install another six systems and plans to solicit proposals for 25 more by the end of the year.

"The techniques have been here for years," says John P. Corrunker Jr., chassis quality assurance supervisor at Ford and the manager behind the firm's push to contactless inspection. "But industrialization—making the equipment live in our manufacturing environments—is very recent." He cites a pair of television cameras that Ford installed four years ago in an Indianapolis plant. "The program was successful for several months," he says, "and the equipment is still there, but it hasn't worked for years."

Now, however, buoyed by the reliability of recent installations, Ford is steering more of its plants to optical inspection. "For all new gauging programs, we are quoting both contact and contactless systems, and we're recommending that our divisions go with an automated, noncontact system," Corrunker says. And though the firm is studying contactless inspection approaches that use such instruments as an audio spectrum analyzer to listen for unusual gear noises, optical systems account for the lion's share of the noncontact inspection techniques that it is funding.

Simple change. The optical systems also allow the company an inspection flexibility to which it is unaccustomed. Last month, for example, it equipped an axle-manufacturing line in Sterling Heights, Mich., with a microprocessor-based system that looks at the axle's ring gear to determine the axle gear ratio [Electronics, May 25, p. 44]. "As we start building different axles on the line, the only component in the system that we have to change is the programmable read-only memory that stores the look-up table," points out Dennis G. German, advanced gauging engineer at Ford.

Besides the axle inspection system, other Transmission and Chassis division installations include:

- A microfinish sensor in Ford's San Juan, Puerto Rico, plant that uses reflected laser light to look through grinding oil to check for a smooth finish on the input shaft of a power steering pump.
- A second laser that searches for a series of threads tapped into a ½-inch hole in the end of the same input shaft. From 2 feet away, the system's photodiode detector array counts the first eight threads, determines their direction and spacing, and checks for burrs, nicks, and broken taps.
- Another optical inspection system in the Sterling Heights plant that scans down the side of a bearing cup that is 3½ inches deep. It is looking for an undercut that is necessary to dissipate heat from the drive-shaft's U-joint bearings.
- A split-beam, scanning laser system in the Sharonville, Ohio, transmission plant that looks at each end of assemblies built there, ensuring that three 0.022-in.-thick washers are in place.

Too much. Although Ford has harnessed helium-neon lasers for most of its jobs, it is already beginning to turn to simpler, more reliable light sources. "In some applications, a gas laser is overkill," German says. "It offers a level of sophistication that we don't need." Even though the lasers the company opted for were in the milliwatt range, stringent Government regulations controlling them resulted in more red tape than the firm bargained for. Further, "we've had reliability and shelf-life problems with gas lasers," German adds. "Their manufacturing quality has simply deteriorated over the past few years."

For those reasons, most new optical systems at Ford probably will rely on more conventional light sources. The axle-inspection system, for example, was conceived using a laser source, but implemented with a pair of quartz halogen lamps normally found in film projectors. The firm is also toying with 10-cent tail-light bulbs to project profiles of parts on detector arrays or to light parts sufficiently for imaging with photodiode detectors. It has even found that light-emitting diodes will supply enough reflected light to spot some surface imperfections.
Probing the news

Instrumentation

New standard has long way to go

Lack of enthusiasm among makers of data terminals for interface specs designed to replace RS-232-C reflects feelings of customers

by Robert Brownstein, San Francisco bureau

It’s one thing to ordain a standard, but it’s quite another to sell it. The fact is, as makers of data terminals are finding out, that it is the marketplace that governs acceptance, here as in so many other cases.

The standard in point is actually a set of specifications that governs data-communications terminal interfaces. Written by the Electronic Industries Association’s subcommittees TR30.1 and TR30.2 as RS-422, -423, and -449, it is designed to replace the RS-232-C (see “Presenting a new interface,” below). But although interest in the new requirements is high, a survey of terminal makers shows that most do not yet offer it as an option. What’s more, they do not intend to do so until they feel some customer pressure for it. That pressure, they say, has yet to be exerted.

In contrast with how quickly the 8-bit, parallel-interface standard (IEEE-488) was adopted, the terminal-interface standard is off to a slow start. However, the new standard’s predecessor has been and still is the most widely used interface for serial data communications, whereas 488 had no entrenched standard to compete against.

Calling RS-232-C entrenched is putting it mildly: it is so pervasive that it is hard to make a good case for adopting the new standard unless the application specifications exceed the capabilities of the older one. “The new standard will become more accepted as designers realize they need greater distance and data-speed capabilities than are possible with RS-232-C,” states Walter B. McClelland, chairman of subcommittee TR30.1, which was responsible for the standard’s electrical specifications portions, RS-422 and -423. Functional and mechanical requirements are described in RS-449, written by subcommittee TR30.2, which is headed by Hal Folts of National Communications Service, Washington, D.C.

A. Philip Arneth, advisory engineer at IBM Corp. in Raleigh, N.C., who is chairman of EIA committee TR30, parent of the two subcommittees, says he expects the first real push for the new interface to come from Federal government requests for quotations on new equipment. IBM is one of the firms that does not offer the new interface in its data-terminal line, joining such manufacturers as Conrac Corp. and Ann Arbor Terminals Inc. On the other hand, some of the makers of cathode-ray-tube display terminals plan to offer it. One of them, Lear Siegler Inc. of Anaheim, Calif., intends to include it in its new ADM-42 and possibly the ADM-31 models, says Paul Michelson, design engineer.

Presenting a new interface

The new standard put together by the two subcommittees actually consists of three sets of requirements that, as a group, establish the full electrical, functional, and mechanical characteristics for the new interface. All three must be incorporated in designing either a single-ended or a differential interface for data-communications terminals.

The standard that is to be replaced, the RS-232-C interface, issued by the Electronic Industries Association in 1969, is a single-ended bipolar voltage circuit that can handle data rates up to 20,000 bits per second up to a distance of 50 feet. The RS-423 is also single-ended, but it extends the data rate to 300,000 b/s at 40 ft while offering 3,000 b/s rates at 4,000 ft.

RS-422, a differential balanced voltage standard, ups the data-rate capability to 100,000 b/s at 4,000 ft and all the way up to 10 million b/s over shorter distances. What’s more, the differential input gives the interface better noise-immunity characteristics, since noise appears as common-mode signals to the input and is rejected.

RS-449 is the third of the new group—it was issued last November—and is the functional and mechanical standard. It describes 30 interchange circuits and defines a 37- and 97-pin interface-connector pair, along with pin assignments, for connecting to data-terminal equipment and data-circuit terminating equipment.
Probing the news

by standards RS-422 and -423.

One snag delaying acceptance of the new standard is the problem of adapting it to digital party-line, or multipoint, data-communications systems, says Roy J. Levy, senior applications engineer for bipolar products at AMD. Levy says the committee’s standard did not address such use, but the higher data rates did create interest in the standard for this application.

Moreover, there has been some pressure from Europe, where the CCITT recommended V.10 and V.11, based on RS-422 and -423. The French pushed for a digital party-line capability, creating a need for three-state drivers, says Arneth, but 422 and 423 call for two-state types. The next meeting of subcommittee

TR30.1 is scheduled for July in Boston, and the subject of party-line applications is on the agenda, McClelland says, and a November CCITT meeting in Geneva is likely to consider the same topic.

The problem surrounding the new standard’s use in multipoint systems is related to common-mode voltage differences between drivers along the line. McClelland says that conferees will try to tighten allowable offset limits in the RS-422 specification (it is now 3 volts) at the Boston meeting and to iron out some of the other impediments to multipoint applications. “We will have some fairly sticky problems to overcome,” he admits.

In minis. At any event, Levy does not see the new interface being designed first into standard (up to 9,600-baud) data-communications systems. “I think you’ll see it in the next go-around of minicomputers because of the increased line length allowable,” he says. For 9,600-baud looping communication networks, RS-232-C is adequate, but a 4,000-foot line tied to a RS-422 interface would let the system poll an entire building, making it an attractive interface for the new mini systems, Levy believes. “I expect the new interface to back into the mass market slowly,” he adds.

Until there is a large demand for the new interface, it is unlikely that major terminal manufacturers will offer it. Even the smaller manufacturers, who might gain a market edge, have been vague about plans to offer the new interface. Zentec Corp. of Santa Clara, Calif., manufacturer of intelligent terminals, which offers it as an option with its ZMS 50 and ZMS 70 terminals, is not sure whether it works in a real-life system.

“We tested it and it appears to do the job,” says Lionel Martin, director of engineering, “but there are no computers out there with the interface to test it with.” Nevertheless, while updating the RS-232-C and current-loop boards, Zentec’s design engineer felt that he could accommodate RS-422 and -423 with little extra effort. As a result, the larger ZMS 70 system has the interface as a strap option, and the smaller ZMS 50 offers it as a board choice.

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Higher power ratings extend V-MOS FETs' dominion

Handling new highs in current and voltage, they are moving into rf amplifiers, switching power supplies, motor controllers, and audio amplifiers; high-efficiency switching amplifiers are likely

by Arthur D. Evans, David Hoffman, Edwin S. Oxner, Walter Heinzer, and Lee Shaeffer
Siliconix Inc., Santa Clara, Calif.

The banner of power v-MOS is being raised over more and more applications these days. Since the appearance of the first moderate-wattage power MOSFETs about two years ago, performance ratings for these field-effect transistors made with vertical-groove metal-oxide-semiconductor technology have climbed to a new high at both audio and radio frequencies. Low-frequency devices able to handle 400 volts at 4 amperes and 80 V at 12.5 A are now becoming commercially available, as are units capable of delivering up to 125 watts in the rf region.

These developments are opening up a whole new range of applications for power v-MOS, not only in rf amplifiers but also in switching power supplies, motor-speed controllers, and audio amplifiers, and for switching analog signals. What's more, at rf, v-MOS transistors are promising the realization of switching amplifiers that
can operate at efficiencies in excess of 90%.

With good reason, V-MOS FETS are competing for the same sockets as bipolar transistors in the power domain, where the latter have long held sway. In general, power FETS offer a number of performance advantages over equivalent bipolars (see "The inside story on power V-MOS," p. 110). All in all, these various strengths mean a V-MOS circuit that outperforms its bipolar counterpart in key respects.

Traditionally, switching power supplies operate at frequencies of 20 to 25 kilohertz; but within limits, the higher the frequency, the better the performance. As frequency increases, inductors or transformers become smaller, circuitry becomes less complex, weight decreases, and filter capacitors also get smaller, so transient response time goes down. Because of these advantages, power-supply manufacturers have recently been pushing operating frequencies up to the region of 50 to 60 kHz. Even higher-frequency operation would be desirable, but the relatively slow rise and fall times of bipolar power transistors have limited the ultimate switching speed.

**Higher efficiency for switching supplies**

V-MOS power FETS, however, can switch from 10 to 100 times faster than equivalent bipolars, and devices are now becoming commercially available that are able to switch 10 A of current in as little as 50 nanoseconds. For switching power supplies, that means smaller components, as well as improved overall efficiency. In the majority of switching applications, most of the transistor power loss occurs during the transition times. Because V-MOS transistors switch extremely fast, the power dissipated during transitions is reduced. Also, the high input impedance of these devices results in very low drive-power requirements, so switching supplies can operate more efficiently. In fact, typical steady-state input current is less than 10 nanoamperes, permitting power V-MOS transistors to be driven directly even from a complementary-MOS gate.

What is more, the safe operating area of these devices is not restricted by secondary-breakdown limitations and the temperature coefficient of their drain current is negative. As a result, V-MOS switching circuits offer better reliability than those using bipolars, and because of the absence of secondary breakdown, no voltage derating is needed as operating current increases. The simplicity of the drive circuitry required also helps to enhance reliability, and the improved efficiency means less heat sinking. Taken together, these factors add up to significant size and cost reductions for switching supplies built with V-MOS power FETS.

Furthermore, standard circuit configurations may be used for designing V-MOS inverters, several of which are illustrated in Fig. 1. For example, in the ringing-choke single-transistor dc-dc converter (Fig. la), a transformer couples a V-MOS blocking oscillator to a half-wave rectifier. Because of its low operating efficiency, such an inverter is used primarily in low-power applications. Also, the load receives power for only a small fraction of the oscillator cycle; ripple factor is therefore high, and a good deal of output filtering is required.

**Standard circuits for V-MOS inverters**

The two-transistor push-pull inverter (Fig. lb), on the other hand, delivers a square wave to the load, lowering the ripple factor and reducing output filtering requirements. Adding a transformer for the gate drive (Fig. 1c) prevents the output transformer from going into saturation, thus increasing overall supply efficiency. The operation of the single-transformer bridge inverter (Fig. 1d) is similar to that of the push-pull inverter, but it halves the voltage requirements of the transistors. To improve efficiency, the bridge inverter may also be implemented with two transformers.

When standard bipolar transistors are being used, self-oscillating inverters such as these are the best way to go if parts count must be minimized and efficiency is a secondary consideration. V-MOS transistors allow the designer to use the more efficient driven inverter type, like the one shown in Fig. 1e, without the large drive circuitry required by bipolars. With this type of circuit, the transformer does not operate in its saturation region nor does operating frequency vary with the load, so the design of the output transformer and filter may be optimized for efficiency. (Any of the self-oscillating configurations may be converted to a driven inverter by eliminating the gate drive windings on the transformer and substituting a suitable driver.)

Many of the characteristics that make power V-MOS attractive for switched-mode power supplies also apply to motor-control circuits. With the recent increases in
voltage and current ratings, V-MOS power FETs are now excellent candidates for use in motor controllers, where they offer the advantages of low drive power and high-speed switching, as well as eliminating the need for derating due to secondary breakdown.

**Motor controllers can be simpler**

In traditional motor controllers employing bipolar transistors, silicon controlled rectifiers, or triacs as the switching elements, the drive circuitry becomes very complex and consumes a lot of power. Because their beta drops at high output currents, bipolar transistors need high-current driver circuits, often involving the use of floating supplies for each phase of the controller. Similarly, triacs and SCRs require complex turn-on and turn-off circuitry, and they often perform unpredictably.

V-MOS power FETs, on the other hand, need only micro-watts of drive power, thus simplifying drive circuitry. Additionally, their fast switching and freedom from secondary breakdown improve efficiency, performance, reliability, and cost-effectiveness, just as in switching power supplies.

Figure 2 illustrates how simply a motor controller may be built with V-MOS transistors. It employs pulse-width modulation, via a quad micropower comparator, to maintain the set speed of a small fractional-horsepower motor, regardless of the load applied.

In operation, the reverse electromotive force of the motor serves as a speed indicator. This reverse emf, along with the dc set voltage, is fed into a difference amplifier. The output of the amplifier controls the pulse-width modulator, which supplies the gate drive for the V-MOS power FET. The efficiency of the circuit is very high, because the transistor operates in the switched mode rather than in the linear mode. In fact, for a 5-A, 120-V motor, efficiency is greater than 95%. Even multi-phase motor controllers may be designed with equal ease using V-MOS power FETs.

**Switching analog signals**

Next to amplification, the switching of analog signals is the most important function performed by discrete semiconductors today. And in the realm of analog switching, the V-MOS transistor comes very close to being ideal. Besides low linear on resistance, it offers high off resistance, high speed, isolation between the control input and the signal path, and clean switching (no contact bounce).

The low on resistance minimizes power dissipation. In switching raw power, it is very important to system efficiency, and both SCRs and triacs generally do a good job in this kind of application. However, in switching analog signals, although power loss is still important, the more fundamental problem is nonlinearities in the switching element that can alter and distort the signal. All current-injection devices, whether bipolar transistors, SCRs, or triacs, suffer from nonlinear currents that introduce error voltages in series with the analog signal, as illustrated in Fig. 3a. In contrast, the V-MOS transistor is free of offset voltage. Being a majority-carrier device, its on-condition properties are determined by bulk silicon, which is inherently linear.

Although it is generally true that electromechanical relays and switches provide the lowest on resistance (merely milliohms) of any electronic device, they are prone to a tremendous increase in contact resistance with the number of operations. But V-MOS transistors main-
3. To switch analog signals. Bipolar transistors and thyristors introduce error voltages in series with the analog signal being switched (a). V-MOS transistors are free of offset voltage. They may be used to build a bidirectional analog switch (b) or even a solid-state relay (c).

tain the same on resistance throughout their lifetime. Moreover, even though relays and mechanical switches provide the highest overall off isolation, V-MOS devices, because they are metal oxide semiconductors, offer the same kind of isolation between control input and signal path. Typically, dc off leakage from drain to source is in the nanoampere range, and ac leakage is just as low, with off isolation about 60 decibels at 10 megahertz.

Furthermore, V-MOS power FETS can carry the high peak currents needed for charging and discharging reactive loads—a capability that is especially important in analog-to-digital converters, sample-and-hold circuits, and integrators. A more subtle advantage of power V-MOS is its wide dynamic range: it can switch easily over seven decades of current, without the buildup of contact oxide or the erosion of electrodes typical of mechanical switches. This wide range is particularly useful in audio switching applications, where good linear performance must be maintained for signals ranging from 1 microvolt to 50 V. In contrast, current-injection devices have trouble at low signal levels because of the inherent offset voltages generated by the pn junctions.

Employing the V-MOS transistor as an analog switch is easy. The motor-speed control of Fig. 2, for instance, is a suitable circuit for a unidirectional analog switch. For a bidirectional switch, level-shifting circuitry is needed, as shown in Fig. 3b. Making the equivalent of a solid-state relay, though, requires high common-mode noise isolation from the analog signal path. This could be achieved simply by using a toroidal transformer for the isolation scheme, as in Fig. 3c. Or instead, voltage-output opto-couplers could provide the isolation, thanks to the micro-watt drive requirements needed to turn the V-MOS switch on and off.

Linear amplifiers that perform better

The characteristics of V-MOS power FETS also make them well suited for use in the output stages of linear amplifiers that must deliver considerable power to a load, such as a loudspeaker or a motor. Moreover, V-MOS amplifiers tend to be easier to design and more rugged, and in many respects they perform better than their bipolar counterparts. Also, now that high-current, moderately high-voltage V-MOS transistors are here,
4. **In audio amplifiers.** Power FETs serve as the output devices for an 80-W audio amplifier (a) that holds transient intermodulation distortion to virtually unmeasurable levels. V-MOS’s fast switching speed also makes it practical to build a 100-W class D amplifier (b).

Audio and servo amplifiers built with these devices are economically competitive with the more standard designs using bipolar transistors.

One of the most important advantages power V-MOS transistors brings to linear amplifiers is lack of thermal runaway. In a bipolar amplifier, an increase in the temperature of an output device will cause it to conduct more current, and the increase in current raises the power dissipation, which in turn further raises the temperature. Indeed, if nothing is done, the current will continue to increase until the transistor is destroyed—the victim of thermal runaway.

Although some thermal-feedback mechanism is usually employed to reduce the drive to the power device when it heats up, the feedback is not totally effective because of the difficulty of measuring chip temperature exactly, as well as the time it takes for the change in chip temperature to reach the sensing element. To allow for these deficiencies, bipolar transistors are usually operated at less than their optimum quiescent current, with...
The inside story on power V-MOS

From the designer's viewpoint, V-MOS power field-effect transistors combine the high-power, high-voltage, and high-current capabilities of bipolar transistors with the high-frequency, high-gain, high-input-impedance, and linear-transfer characteristics of short-channel metal-oxide-semiconductor FETs.

Essentially, V-MOS transistors avoid the problems of turnoff delay (caused by minority-carrier storage in the base region) and secondary breakdown and current hogging (due to the positive temperature coefficient of emitter current) that are inherent in bipolar transistors. Similarly, power V-MOS devices bypass the current limitations of the conventional lateral MOSFET, because their channels are arranged so that the current flow is vertical instead of horizontal. Vertical arrangement permits the back of the V-MOS chip to serve as the drain terminal, thus yielding more conducting channels per unit of top surface area.

Vertical

In fact, current flows vertically in both the V-MOS power FET (b) and the bipolar transistor (a)—from the source to the drain in the former and from the emitter to the collector in the latter. Indeed, in some respects, the vertical structures of the V-MOS power FET and the double-diffused epitaxial planar bipolar transistor are similar. They both have n⁺, p, n⁻, and n⁺⁻ layers, and current flows from the surface n⁺ layer to the substrate n⁺ region. Moreover, they both generate an n⁻ epitaxial space-charge region that results in high collector or drain breakdown voltage.

The operation of these two devices, however, is quite dissimilar. The bipolar transistor turns on when its emitter-base junction is forward-biased and minority carriers are injected into the base. These carriers diffuse through the base region to the high field at the collector junction. Reducing the emitter-base voltage to zero stops the injection of carriers into the base, but collector current continues to flow until the minority carriers stored in the base region diffuse to the collector-base junction and are swept out. This delay in turnoff, which is usually referred to as the

minority-carrier storage delay, limits the operating speed of the bipolar transistor.

In contrast, the n-channel V-MOS transistor turns on when its gate-source voltage becomes positive, creating a channel that provides a conducting path from the source to the drain. Since the only current needed to charge the gate capacitance is that required to create the channel, the input resistance of the V-MOS power FET is high. Furthermore, there is no minority-carrier storage, so turnoff is fast. In comparison, the turnoff time of a bipolar power transistor is typically on the order of 1 microsecond, whereas that of a V-MOS power FET is generally less than 10 nanoseconds for about 1 ampere of current.

Moreover, with a bipolar transistor, a localized hot spot on the chip causes an increase in current through that area that, in turn, produces a localized increase in power dissipation and a further increase in temperature. In the presence of a moderately high collector voltage, this situation can result in a destructive secondary breakdown, which is probably the major failure mode of switching bipolar power transistors.

No thermal runaway

On the other hand, a localized hot spot in the V-MOS power FET causes the current through that area to decrease, thus lowering the dissipation. As a result, V-MOS transistors may be paralleled for increased current handling and higher power rating without the need for negative-feedback resistors to prevent current hogging and thermal runaway. When driven into saturation, the V-MOS power FET exhibits an on resistance that has a positive temperature coefficient. If one device tends to take more than its share of the load current, that device's on resistance will increase as temperature rises, thus forcing part of its current to be shunted to the other devices in the circuit. Therefore, if several devices are connected in parallel, current sharing tends to be self-equalizing.

In the conventional MOSFET (c), current flow in the conducting channel is parallel to the surface of the chip. Typically, spacing between source and drain is on the

the result that performance is compromised somewhat.

In contrast, V-MOS transistors behave in just the opposite way when they heat up—a temperature increase reduces device current, thereby decreasing power dissipation and pushing the temperature back down. No thermal feedback is required, and V-MOS transistors easily operate at quiescent currents 5 to 10 times higher than those of bipolar. The higher operating current lowers signal distortion, especially at high frequencies.

The same behavior that protects V-MOS power FETS from rising temperature also guards against unusual operating conditions, like a short-circuited load. An instantaneous overload causes current through the V-MOS device to decrease as its temperature increases, protecting it long enough for a fuse to blow. Conversely, the positive temperature coefficient of a bipolar transistor aggravates the overload condition, causing the device to destroy itself long before the protection fuse has a chance to respond. A fast-acting electronic fuse—of the output-current-limiting form—may be built into the bipolar amplifier, but it requires extra circuitry and often results in a compromise between good performance and adequate protection. The compromise is especially noticeable when highly capacitive loads, such as electrostatic speakers, are being driven, since they require high peak currents at high frequencies. V-MOS FETS can deliver these peaks without the threat of destruction.

What is more, V-MOS linear amplifiers provide superior high-frequency performance for both open- and closed-loop operation. Unfortunately, bipolar transistors trade off high frequency for ruggedness—high-frequency devices are prone to secondary breakdown, whereas devices having a large safe-operating area sacrifice frequency response. With power V-MOS, no such compromise need be made—slew rate may be more than 100 V/microseconds, which is two to five times faster than that of bipolar amplifiers, yet open-loop frequency response can be greater than 400 kHz, an improvement by a factor of about four to eight. Far from being superfluous, this superior high-end performance means better sound quality when reproducing transients in audio amplifiers.
order of 5 to 10 micrometers. Decreasing this channel length so as to boost transconductance reduces drain-source punchthrough (breakdown) voltage. Smaller spacing also makes processing more difficult, because a combination of diffusion and photomask processing controls the source-to-drain geometry.

However, in the V-MOS power FET, current flow is vertical, or perpendicular to the chip surface, so that channel length is controlled by diffusion, as opposed to masking. Consequently, high transconductance may be achieved by making the channel short—say, less than 2 μm. Furthermore, the addition of an n<sup>-</sup> epitaxial layer, which provides a space-charge region at the drain end of the channel, permits a high drain-voltage rating. This low-carrier-concentration region also reduces output capacitance and drain-gate feedback capacitance—both important advantages for high-frequency operation.

**V-shaped channels**

The channels of the V-MOS power FET are parallel to the wall of the V groove through the p-type body. Since the slope of the V is precisely determined by the crystalline structure of the silicon, the channel length is determined by the difference between the diffusion depths of the p-type body and the n-type source. Both walls of the V serve as channels, so that a single gate metal stripe controls two channels. The resulting short channel provides high current per unit of channel width, as well as a linear relationship between drain current and gate-source voltage.

Although the n<sup>-</sup> epitaxial layer adds a component to the on resistance of the V-MOS transistor, it does result in a number of performance advantages. Besides high drain-source breakdown voltage and reduced output feedback capacitances, this layer keeps output conductance low and threshold voltage independent of drain voltage. In part, the thickness and resistivity of the n-type epitaxial layer determines the drain breakdown voltage. Higher voltage ratings may be achieved at some increase in the on resistance of the device.

Another advantage of V-MOS transistors is their nearly constant transconductance, since distortion is caused by variations in this parameter. While the transconductance of V-MOS FETS hardly changes above a certain drain current, the transconductance of bipolar transistors is directly proportional to their collector current. The reduced distortion permits a V-MOS amplifier to be designed with less feedback circuitry.

**Other advantages**

Added benefits of power V-MOS include its high input impedance at audio frequencies, which eliminates the need for high current gain in the driver stages. Also, since the V-MOS transistor has a voltage-controlled input, a zener diode between its gate and source is all that is required to effect output current limiting.

How do these various benefits translate into practice? Figure 4a shows a simplified schematic of an 80-W audio amplifier using V-MOS FETS as output devices. Because of their low distortion, the amplifier requires very little negative feedback to provide a good overall distortion figure. The reduced negative feedback results in improved amplifier stability at high frequencies, as well as a transient intermodulation distortion that is virtually unmeasurable. (The latter occurs when negative feedback is temporarily nonexistent during high-frequency transients, so that the high-gain driver stages operate open loop and consequently overload.)

Several components are unique to the V-MOS design. For example, the variable resistor in the output stage provides local feedback from the drain to the gate of the lower of the two power FETS, making the common-source configuration behave as a source-follower, similar to the operation of the upper power FET. Adjusting this resistor reduces the even harmonic distortion by balancing the gain of the two output FETS. The zener diodes limit the amount of possible gate-source enhancement drive on the output devices. In the event of a short-circuited load, these diodes hold drain current to a value below the absolute maximum rating of the transistors—until the fuse blows.

Power V-MOS also makes it possible to build class D
audio amplifiers, which has been difficult in the past. Because of their minority-carrier storage time, bipolar transistors require a delay in the drive circuitry to ensure that the upper and lower devices in a totem-pole output are never on at the same time. This delay not only complicates the driver but also adds to the distortion of the amplifier.

The introduction of suitable v-mos transistors means class D audio amplifiers of higher quality and lower cost. The fast switching speeds and the absence of storage time of v-mos devices improve the frequency response, eliminate the need for delay circuits in the driver, and reduce the total distortion. Furthermore, the low drive power needed by v-mos transistors simplifies amplifier design. For example, Fig. 4b shows a 100-w class D audio amplifier built with v-mos devices. Its high switching frequency of 500 kHz results in low distortion, a small output filter, and improved transient response.

A real winner at rf

But where power v-mos promises really to outshine bipolar technology is up in the rf region. Aside from its outstanding switching advantages, this process offers inherently low sideband noise, as well as the singularly outstanding benefit of unconditional stability when subjected to severely mismatched load conditions. In other words, v-mos transistors can successfully withstand any mismatched condition, unlike most bipolar transistors, which are considered fail-safe only when menaced by well-defined mismatched conditions. Additionally, because v-mos has low Q feedback capacitance, out-of-band parasitic responses are exceptionally low.

With v-mos, it is possible to build broad-band high-gain amplifiers simply. For instance, the circuit shown in Fig. 5a offers a bandwidth extending from 40 to 200 MHz and a flat gain of nearly 12 dB. Of special note is the simple transformer input coupling for broad-band performance. Another unusual characteristic common with v-mos as noted earlier, is wide dynamic range. Saturated output occurs at approximately 3 w, with a two-tone, third-order intermodulation interception point of +47 dBm.

V-mos transistors give rf amplifiers another advantage, as well: unlike high-frequency bipolar transistors, they are not generally hampered by high reverse feedthrough. The neutralized, small-signal, 200-MHz amplifier of Fig. 5b, for example, not only delivers high forward gain of 18 dB at a 1-w output but also holds reverse feedthrough to −50 dB.

Because they are not subject to minority-carrier storage, v-mos fets make high-efficiency switching-type rf amplifiers practical. These switching amplifiers are class D, E, and F types. Theoretically, efficiency cannot extend beyond 50% for class A amplifiers and beyond 78.5% for class B, and typically it is 85% for class C. In contrast, a theoretical efficiency of 100% is the hallmark of switching amplifiers, although of course it is unattainable in practice—with bipolar transistors, because of their storage time and saturation voltage, and with fets, because of their relatively high on resistance. However, the performance of switching amplifiers built with v-mos transistors has been impressive, with a 5-w class E unit operating at an efficiency of 90%.

The direction that power v-mos will take in high-frequency applications is clear. Within the year, v-mos fets delivering a usable output power of 40 w or more will be successfully competing for inclusion in the radio-common-carrier markets at low-band, high-band, and ultrahigh frequencies. For military communications, power fets will find wide application in the popular 220-to-400-MHz band, where output power of 10 to 40 w will be available. Use at microwave frequencies is not out of the question either, for v-mos power fets can deliver useful power at frequencies of over 1 gigahertz.

5. Up at rf. Unconditional stability is what V-MOS delivers at rf, even for severely mismatched load conditions. Power FETS are making it easy to get broad-band performance from 40 to 200 MHz with 12 dB of gain (a), as well as to attenuate reverse feed-through by 50 dB in a 200-MHz amplifier (b).
The shift from minicomputers to microcomputers in data processing has been paralleled by the shift from boards and modules to microcircuits in data conversion. By now, complete microprocessor-compatible data-acquisition systems are available as single plug-in hybrid or monolithic components. Eight-bit performance has been the limit, though, with the hybrid devices being much faster though less economical than the monolithic converters. For 12-bit performance, users have had to turn back to bulky modules or else interconnect two or more hybrid circuits.

Getting down to one package

But a new 12-bit hybrid data-acquisition system is offering users the convenience and cost savings of a single integrated-circuit-compatible package, together with the high performance and reliability of a hybrid circuit. Besides multichannel capability, the device includes address decoding logic, an adjustable-gain instrumentation amplifier, a sample-and-hold circuit, a 12-bit successive-approximation analog-to-digital converter, control logic, and three-state output buffers for interfacing with a microprocessor data bus. It is manufactured in two versions, the HDAS-8 handling eight differential inputs and the HDAS-16 handling 16 single-ended inputs.

Housed in a hermetic 62-pin ceramic package, the device meets all the requirements of MIL-STD-883A, class B. To shrink its overall size, as well as optimize the internal layout and make external access easy, the pins are arranged around all four sides of the package, instead of in two parallel rows. The use of ceramic instead of metal keeps cost and especially weight down.

With such a complex hybrid, internal power consumption, of course, must be minimized. An equivalent modular unit uses about 4.5 watts, which in the hybrid's 62-pin ceramic package would push the temperature at the chip-mounting surface 50°C above ambient.
1. The device. Hybrid data-acquisition system (a) delivers 12-bit data for 8 differential or 16 single-ended input channels. A few simple connections (b), and the hybrid will automatically address the input channels sequentially for a system throughput rate of 50 kHz.

Finally, in a move that reduces device complexity as well as temperature rise, as many of the internal thin-film resistors as possible are placed directly on the ceramic substrate, and not on separate chips of glass, silicon, or ceramic. With either technique, there will always be a resistor-to-conductor interface. But making a resistor part of the substrate eliminates the two wire-bond interfaces at its terminations, making wire-bond weakness a less likely cause of failure.

How the device operates

The circuit configuration (Fig. 1a) for the device is a fairly common one for a data-acquisition system. At the front end is an analog multiplexer having either 8 differential or 16 single-ended channels, which may be addressed randomly or scanned sequentially. Following the multiplexer is an instrumentation amplifier that extracts the input signal from common-mode noise. The gain of this amplifier is adjustable (through an external resistor) from 1 to 1,000, so that the maximum expected range of the input signal becomes ±10 volts at the amplifier output for optimum dynamic range.

A precision sample-and-hold circuit then buffers the selected signal, holding its level constant during the actual conversion. The output of the sample-and-hold
serves as the input to a 12-bit a-d converter, which produces a binary number that is the digital representation of the selected analog input. For flexibility in data-bus organization, three-state logic elements, which are configured in 4-bit bytes, buffer the digital data output from the a-d converter.

The hybrid is very easy to use, as is evident from the simplicity of the circuit (Fig. 1b) needed to acquire eight differential inputs. A few straightforward connections, and the HDAS-8 delivers 12-bit binary data at a rate of 50 kilohertz from eight sequentially addressed channels, each having a ±10-v signal range. Since no gain resistor is used, the amplifier’s gain is unity. A single strap selects bipolar operation (+10 v), and another strap from R delay to the +5-v supply selects the internally allotted delay time for the multiplexer and the amplifier to settle.

To obtain continuous scanning of the input channels, the user need do nothing at all to the address control inputs. With its end-of-conversion flag tied to the strobe input, the device will acquire data continuously at the maximum rate. For self-strobe operation, though, the rise time (from 10% to 90%) of the +5-v supply (when power is first applied or interrupted and then reapplied) must be less than 10 microseconds, or else a latchup may occur. For reliable operation, the user should examine the EOC flag and apply a STROBE signal when it is required. Even supply-bypass components are included in the package.

Protection

A good part of the device’s ruggedness is due to overvoltage protection circuitry for the multiplexer. A 1-kilohm resistor on each channel input limits the current flowing through protection diodes and, in combination with stray nodal capacitance, limits the rise time of large spikes so that the diode can clip them before they do any damage. Even without using any external components, protection is assured to 20 v beyond the ±15-v supply voltages.

Adding a series resistance to each input can increase protection up to a diode current limit of ±10 milliamperes. But large values of input resistance are not altogether desirable. Besides raising the input noise, they increase the settling time of the instrumentation amplifier for changing input signals, as well as the multiplexer’s recovery time from switching transients.

Expanding the channel capacity of the hybrid requires just one external component, connected as shown in Fig. 2a. This hookup converts the HDAS-16 from a 16-channel single-ended unit into a 16-channel differential part. In fact, channels may be added almost without limit at very little cost, as Fig. 2b illustrates. Here, with the addition of just 15 multiplexers and one logic device (a one-of-16 decoder), the HDAS-16 acquires 256 channels of low-level analog signals. In this application, the unit compares the outputs from 256 temperature-sensing

2. Easy channel expansion. One external component converts the HDAS-16 into a 16-channel differential part (a). Adding 15 multiplexers and a single logic decoder accommodates 256 input channels (b). For throughput faster than 50 kHz, more hybrids are needed (c).
3. Handling high-frequency inputs. To acquire signals beyond the mid-audio range requires a sample-and-hold circuit for each channel (a). For a nonrepetitive high-frequency signal, a delay line and a string of sample-and-holds slice the input into 16 pieces (b).

diodes with the output of a single reference diode.

Indeed, the hybrid is built to be expanded—it can handle up to 65,536 channels with the addition of only 17 logic circuits. The unit's multiplexer-enable line is what makes this possible. Left alone, it is high, and the internal multiplexer is enabled. But when pulled low, it disables the internal multiplexer and frees the amplifier input lines for external multiplexer control.

Although the circuit of Fig. 2b is an economical way to handle 256 channels at a 50-kHz rate, that throughput may not be fast enough for some applications. A faster throughput of 800 kHz is easily achieved by interleaving 16 hybrids into 256 channels (Fig. 2c). This circuit is actually just as simple as the slower one, for it still requires only one external decoder device. Because the hybrid uses three-state data outputs, all 16 units can be tied to one data bus and enabled one at a time during the delay period preceding the next conversion while the data from the last conversion is still valid.

Both the HDAS-8 and the HDAS-16 are ideally suited to acquiring data quickly from many sources, with two provisos: the sources should all have similar maximum signal levels, and the highest frequency components of the signal sources must be in the low audio range. When the signal sources have dissimilar ranges, the dynamic range of some signals will be less than optimum because the gain of the differential amplifier will be set to accommodate the largest signal range. This limitation is normally overcome by using prescaling amplifiers, which also serve as convenient low-impedance signal line drivers and as filter points to reduce unwanted power-line signals and the like.

Acquiring high-frequency signals

When the signal sources are to contain high-frequency components that the data-acquisition system must recognize and acquire accurately, a very fast track-and-hold circuit or, better yet, a true sample-and-hold should intercept the signal and hold it for a precisely controlled time. Once the signal has been processed by the multiplexer, the amplifier, and so on, its bandwidth and phase delay are no longer precisely known. Figure 3a shows one way to do real-time analysis of input signals having frequencies up to 25 kHz. With this circuit, to retain precise information as to the time of sample, 16 fast sample-and-holds simultaneously sample the input signals, and the data-acquisition system digitizes the held analog value on each input channel.

Beyond 25 kHz, the inability of the hybrid to generate two data points per cycle of the input signal violates the Nyquist criteria of signal sampling. When repetitive events need not be analyzed in real time—for example, when synchronized sampling heads provide sample snatches with varying delays—the frequency limit extends to the bandwidth of the sample-and-hold circuits. But for real-time analysis of nonrepetitive signals, another approach is needed.

Radar pulses are a common example of nonrecurring pulses that contain critical target data that must be analyzed in exceedingly fine detail in real time. To handle them, the HDAS-16 data-acquisition system requires just a tapped delay line and a string of fast
4. Putting amplifier gain to work. It is even possible to turn the HDAS-16 into a 16-bit a-d converter by applying the input signal to the internal amplifier’s inverting input. Here, the amplifier-input-low line is being viewed as a high-impedance, transient-free signal input.

Sample-and-holds, as noted in Fig. 3b. In effect, the sample-and-holds slice the radar pulse into 16 easy-to-digest pieces, while the delay line causes each sample-and-hold to retain the analog information at incremental times following the synchronization pulse. Meanwhile, the hybrid can address and digitize each input slice at a comparatively leisurely pace, producing a 12-bit binary word for each of the 16 slices at a word rate of 50 kHz. Clearly, there is a limit to the number of sample-and-hold circuits that may be addressed and digitized before hold-capacitor droop problems destroy analog signal accuracy. This limit may be circumvented by adding more hybrids to the circuit, at any rate until system cost reaches that of a real-time video converter.

To increase resolution up to 16 bits

Besides being useful as a video a-d converter, the HDAS-16 may be operated as a 16-bit a-d converter. Unlike the HDAS-8, in which the two multiplexer outputs are both committed to the amplifier’s inputs, the HDAS-16 has only one multiplexer output so committed. It is tied internally to the amplifier’s noninverting (high) input, leaving the inverting (low) amplifier input for the user to connect, for example, to the signal source common. (In any event, the user must of necessity return eventually the signal source common to the hybrid’s signal or power common.)

Another way of looking at the HDAS-16’s amplifier-input-low line is as a high-impedance transient-free signal input, as illustrated in Fig. 4. Wired in this way, the HDAS-16 operates as a 16-bit a-d converter. Fifteen resistors, precisely matched and equal in value, divide the internal 10-v reference into 16 equally spaced voltages, so as to bias the input channels into 16 contiguous windows. The amplifier will only amplify the difference between the input signal and the selected channel voltage. (With R gain at 1,333 ohms, amplifier gain is 16.)

Only one channel address will be associated with an in-range 12-bit data word, and all other channels will yield all zeros or all ones. When the address of the selected channel is used as the top 4 bits and the resulting conversion data as the bottom 12 bits, the HDAS-16 generates a 16-bit complementary binary data word. For input signals in the audio-frequency range, the channel address will change by no more than one count from one conversion to the next, so that no more than two conversions are ever necessary to obtain valid data. This means that the HDAS-16 will typically deliver 16 bits in 20 microseconds, or 40 μs maximum.

When high gain is needed

Some applications require both high gain and multi-channel capability. However, when the gain exceeds 20, the hybrid’s amplifier needs more than the internally allotted 9 μs for settling to within 12-bit accuracy. Even though the signal inputs may change slowly, the amplifier sees the multiplexer output as a fast-changing step function, with changes occurring whenever the multiplexer address changes.

The amplifier, then, must have enough time to settle fully in response to these abrupt changes before a conversion takes place. Suppose, for example, the ampli-
Odds and ends. Charge-pump loop (a) cancels troublesome offset errors for all time and temperature. A twin circuit could be used to cancel gain errors also. Register file (b) creates memory location for HDAS-16, so data access is independent of the hybrid's status.

Dealing with accuracy errors

Many users of data-conversion devices are puzzled by the seeming inconsistency of specifications for relative accuracy and absolute accuracy. But distinguishing between the two is not all that difficult. In brief, relative accuracy is a measure of a device's differential linearity and monotonicity, while absolute accuracy reflects the unit's gain and offset stability. Furthermore, relative accuracy requires that similar components do the same thing with time and temperature, whereas absolute accuracy requires that a component does not change with time and temperature—a requirement that flies in the face of reality.

As it advances, process technology will continue to reduce accuracy errors, but it will always come closer to optimizing relative than absolute accuracy. Certain circuit techniques, however, permit doing away with absolute-accuracy errors altogether. For example, the simple one shown in Fig. 6a cancels offset errors, and a twin circuit could be used to cancel gain errors as well. This technique uses a charge-pump loop to hold absolute errors below measurable levels for all time and all temperatures. When data (offset voltage) appears on channel zero, the transconductance amplifier receives a bias-set pulse for 5 µs. If the data is zero, this amplifier sinks (or sources in the case of non-zero data) a current pulse to the integrator that minutely adjusts the hybrid's zero. At null, there is an imperceptible ±1-pulse hunt traded off against capture time.

In a microprocessor-based system the time needed to digitize analog data can become very long with respect to the processor's cycle time, particularly if the data-conversion device is a reasonably priced unit. This time difference causes all sorts of software problems that require complex interrupt schemes to solve. But, in fact, the delay is totally unrelated to the need for fully updated signal data, and the data-conversion device is usually quite capable of generating digital data at a fast enough rate to satisfy most signal-analysis requirements.

One simple way to work around the delay is to insert a multiple-port register file between the data-conversion device and the digital processor, as shown in Fig. 6b. Essentially, the register file creates a memory location for a continuously scanning HDAS-16. Data access is fast, free, and independent of the hybrid's status. Thus, the hybrid generates new data words at 50 kHz and updates a 16-word file at a rate of over 3 kHz. Meanwhile, the digital processor can request and retrieve data at normal memory-access speeds without disturbing or waiting for the data-acquisition system.
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Circle 119 on reader service card
Programmable multiplier needs no combinational logic

by Noel Boutin
University of Sherbrooke, Electrical Engineering Department, Quebec, Canada

The frequency multiplier circuit proposed by R. J. Patel [Designer’s Casebook, March 16, p. 119] can be vastly simplified for applications where the duty-cycle of the output waveshape must or may be kept low. Specifically, no combinational logic is needed for a frequency multiplication of N, and only one comparator is used in place of the N-1 comparators required in Patel’s circuit. A programmable voltage reference, which can be just a potentiometer, a digital-to-analog converter, or a keyboard [Designer’s Casebook, Dec. 22, 1977, p. 80], can be used to set the multiplication ratio desired.

The modified circuit is shown in Fig. 1. Two one-shots are fired on the positive edge of each input pulse, \( f_i \). The input signal may have almost any duty cycle.

Emanating from the transconductance amplifier is a sawtooth waveform, which has a period determined by \( M_2 \). The one-shot drives one input of an OR gate that switches gate \( G_1 \) on at regular intervals. Connected to the other input of the OR gate is the output of a comparator, which turns on \( G_1 \) and resets the ramp whenever the value of the sawtooth amplitude exceeds the value set by the programmable reference voltage at the comparator’s inverting port. This operation is shown in the timing diagram of Fig. 2 for multiplication ratios of 2, 3, and 4, respectively. Thus frequency multiplication is achieved by the feedback signal from the comparator, not by the use of combinational logic, which derived the output wave from the input signal in Patel’s circuit.

1. Simplified. Circuit can achieve frequency multiplication without using logic or more than one comparator (see text). Multiplying signal is derived from input wave and comparator, which periodically resets sawtooth each time the ramp itself exceeds a present reference voltage.

2. Two, three, four... Frequency doubler (a), tripler (b), and quadrupler (c) are easily synthesized by adjusting the ratio \( V_{max}/V_{ref} \) with the programmable reference source. Output signals are pulses, but may be converted to square waves by adding a flip-flop operating as divide-by-2 counter to comparator output.
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SY2332 4096x8, 450nsec (2716 compatible)
SY2364 8192x8, 450nsec, 24 pin

Electronics / June 22, 1978
number, \( N \), of equally spaced spikes that appears at the output of the comparator during each period of the input signal is given by \( N = \frac{V_\text{max}}{V_{\text{ref}}} \), where \( V_\text{max} \) is the maximum voltage that would be reached if the feedback signal were not present.

If a symmetrical output (square wave) is required, a flip-flop operating a divide-by-2 counter can be added to the output of the comparator. It will also be necessary to adjust the multiplication ratio to twice the desired value (2\( N \)) in order to recover a square-wave output frequency of \( N f_\text{in} \).

Designer's casebook is a regular feature in Electronics. We invite readers to submit original and unpublished circuit ideas and solutions to design problems. Explain briefly but thoroughly the circuit's operating principle and purpose. We'll pay $50 for each item published.

---

**Resistor matrix orchestrates electronic piano/tone generator**

*by Hsi Jue Tsi*  
*National Taiwan University, Taipei, Taiwan*

Combining an eight-by-eight-resistor matrix that is programmed to generate 64 different frequencies with control circuits that send each tone in sequence for half-second intervals, this unit makes a tuneful electronic music box. It can also serve as a programmable tone generator for testing purposes, in which case the number of tones may be extended to 512.

In this circuit, the resistor timing element in an assignable multivibrator is periodically switched to a new value every half second with the aid of a multiplexer circuit. Serving as the multivibrator (or tone generator) is the versatile 555 timer, which can generate frequencies over a range of 100 hertz to 5 kilohertz.

Timing resistors are switched into the R.C network with the aid of two CD4051 multiplexers, as shown. Each device has three address ports that are updated by a 4020 counter, which is in turn stepped by an oscillator normally running at 2 hertz. If, for example, all outputs of the 4020 are low, the common ports of the 4051s will be

---

**Tuning up.** Music box/tone generator uses programmable resistor matrix to generate 64 tones in sequence, each for a 0.5-second period. Oscillator clocks 4051s, which in turn place each of 64 resistors in timing network of 555. Output of timer is shaped by a 4098 one-shot and suitable integrator network for click-free output during switching. Matrix can be programmed in 10 minutes if counter is available.
connected to row 1, column 1, of the matrix and R₁ will be in the 555's timing loop. As the counter steps through all locations, R₁–R₆₃ in turn set the frequency of the 555.

The output of the 555 is a train of square waves. To avoid the key clicks that occur each time the frequency of a tone is changed, the square wave is rounded off, being converted to a sawtooth wave with D₁, R₂C₁, and R₃C₂. Note that the 4098 monostable multivibrator connected to R₅ aids greatly in controlling the attack-delay characteristic of each waveform at the output; it applies a gradual turn-on bias to D₁ initially and then a turn-off bias after about 0.4 second. This 4098 is driven by the 4020. R₅ and C₂ integrate the 4098's output pulse, then C₂ discharges, enabling the device to bias the diode as described. A second 4098 one-shot is used to reset the 4020 so that resistor R₀ will be immediately accessed on power-up.

**Double-balanced mixer has wide dynamic range**

by Carl Andren, Eric Heinrich, and William Mosley
E-Systems Inc., St. Petersburg, Fla.

This double-balanced mixer is ideal for use in frequency-division-multiplexed systems and because of its extremely wide dynamic range will also find use as the baseband mixer in phase-shift-keyed demodulator circuits. Operating linearly on input signals extending from 5 microvolts to 5 volts at frequencies from dc to 1 megahertz, the circuit owes its wide range to a combination of factors, notably a balanced output-stage configuration, low offset voltages in its switching circuits, low local-oscillator feedthrough, and the low-noise output of the active devices used. The mixer has the additional advantages of a very low output impedance and extreme stability over a wide temperature range.

The mixer is shown in the figure. A₁, serving as a wideband buffer amplifier with selectable gain, routes input signal fᵢ toward A₂ through the CD4016 quad analog switches. The CD4016, which contains four transmission gates, is turned on through A₃ by a local oscillator signal (which equals, in this case, 2fₒ), alternately switching A₂ between its inverting and noninverting modes. This action varies the gain of the amplifier from +1 to −1, so that the amplifier performs a chopping (mixing) operation on the input signal.

The input signal, fᵢ, is thus translated into a frequency of fᵢ ± fₒ at the output of A₂. Mixer balance is achieved by using the combination of a symmetrical driving source for the switches (Q and Q output of the 4013) and a symmetrical input circuit for amplifier A₂. Thus the local oscillator (carrier) will be effectively suppressed at the output—feedthrough will be 60 decibels below the amplitude of the fᵢ signal. Double-balancing ensures that the input-signal feedthrough will also approach the −60-dB value.

An added benefit of A₂'s balanced input circuit is that the switch-transient feedthrough is reduced. This is because the pulses introduced to both ports of the op amp are about equal, and because the differential input voltage is therefore near zero, the output of A₂ is approximately zero for these transient components.

**Dynamic.** Mixer operates linearly over input-signal range extending from 5 µV to 5 V. Double-balanced circuit reduces local-oscillator and input-signal feedthrough to −60 dB below fᵢ. Switch-transient feedthrough is reduced by A₂'s balanced input circuit.
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<table>
<thead>
<tr>
<th>NPN</th>
<th>PNP</th>
<th>VCEO</th>
<th>SOA</th>
<th>hFE</th>
<th>1K Price</th>
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<td>MJ2955A</td>
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<td>20 - 70 @ 4 A</td>
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<td>20 - 70 @ 3 A</td>
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<td>2N3773</td>
<td>2N6609</td>
<td>140</td>
<td>1.5 A @ 100 V</td>
<td>15 - 60 @ 8 A</td>
<td>1.46</td>
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<tr>
<td>2N4547</td>
<td>—</td>
<td>120</td>
<td>1.5 A @ 60 V</td>
<td>10 - 60 @ 2 A</td>
<td>0.76</td>
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<tr>
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<td>20 - 100 @ 2 A</td>
<td>1.80</td>
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<td>MJ15016</td>
<td>120</td>
<td>3 A @ 60 V</td>
<td>20 - 70 @ 4 A</td>
<td>0.89</td>
</tr>
</tbody>
</table>

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Factoring in software costs avoids red ink in microprocessor projects

In selecting a microprocessor for a system, attention must focus on the costs of programming, development systems, and memory types

by Phillip Hughes, National Semiconductor Corp., Santa Clara, Calif.

Selecting a microprocessor for a system design is a serious business, for the choice can mean the difference between success and failure, profit and loss. However, many of the criteria involved are not readily apparent. Of course, such engineering considerations as selection of speed and word length are relatively simple to handle. But there are factors that do not show up on data sheets yet strongly influence costs for better or worse.

Consider, for example, startup costs. Such decisions as selection of the level of the language in which programming will be done and choice of a development system will affect the cost of programming.

1. Programming efficiencies. Microprocessor memory-use efficiencies vary with the type of software language and program size. Assembly-language efficiency depends on programmer experience. But a compiled high-level language, on the other hand, has a curve that varies with program size.

Other important options include choosing between a read-only memory and a programmable ROM and deciding whether to go for a single-chip microprocessor as against the multichip solution. Finally, two important questions that must be settled are: is a true second source available? And what would be the impact on spares, maintenance, and training should the microprocessor selection be changed sometime during the system’s life?

Essentially, all of these factors hinge on the costs involved. Thus the designer must have a clear picture of these outlays as he settles upon a microprocessor for his system. The discussion that follows will give an idea of
where the dollars go in making these six decisions.

As well as affecting startup costs, the choice of a programming language influences the speed of evaluation and the amount of memory needed. The question here is which level of language to look at. There are essentially three choices: assembly language, macro-assembly language, and high-level language.

Selecting a language

Assembly language, the simplest available, is a one-for-one symbolic equivalent for machine code. A major advantage is that it simplifies address calculations. With an assembler, an experienced programmer will produce a 30% more efficient code than can a novice, as Fig. 1 suggests. Memory-use efficiency in the figure is defined as the number of bytes of memory required for a program in software language, with 100% efficiency assigned to a program in assembly language created by an experienced programmer.

There is one important difference between assembly language and macro-assembly language: the latter can define strings of instructions that can be called by just one symbol. This convenience shortens coding and eliminates errors. The savings in programming costs over assembly language will run between 5% and 20%, depending on the experience of the programmer. However, selecting a macro-assembler has no effect on evaluation speed or efficient memory use.

A high-level language will permit the programmer to code in terms related to everyday English and mathematical expressions. The source statements that the programmer writes can be translated into machine code and specialized subroutines added. The outcome is a package compiled from several routines and machine-language statements.

The compiler and the size of the program determine the relative efficiency of this programming method. For small programs, efficiency is relatively low, because the specialized subroutines are used only once or twice. Figures 2 shows that, as a program grows, memory-use efficiency can climb to 90%.

Efficiency above 100% can be achieved with an interpreted high-level language. Such programming is actually accomplished at two levels: the programmer writes in high-level language, and the interpreter, which is written in assembly language, reads the program and executes it directly. This two-level technique slows execution by a factor of five, but in systems such as data logger and position controllers, this slowdown is unimportant.

However, an interpreted language is highly efficient for very short programs. The cutoff point for 8-bit microprocessors is about 5 kilobytes. This will permit a high-level source program of something under 1 kilobyte, and an interpreter program of around 4 kilobytes.

The investment in a development system is the largest sum to be paid out at the beginning of a project. The
largest variable item is programming cost, which depends on the language level selected and the development system used.

Starting from scratch, the minimum cost for a development system will be between $2,500 and $3,500, for an assembler, a random-access memory, and a teletype writer interface. A midrange system of a central processing unit and a teletypewriter interface will cost between $5,000 and $7,000. The high-end system cost will be between $13,000 and $18,000, depending on what peripherals and options are included.

Programming costs

For a low-cost development system, programming costs will run about $10 per instruction of fully debugged assembly code. Efficiency will rise 10% to 20% with a midrange or high-end development system because of the extra features that help create the program, such as an editor, and that translate it into machine code, such as an assembler.

Even at the low end, it pays to look for a system with a good macro-assembler, since experienced programmers will put it to good use. When settling on an expensive system, it is sensible to ensure that it will work with more than one kind of processor. Such versatility will help write off the large initial investment over more projects.

The cost of programming in assembly language follows the curves of Fig. 2. Clearly, for a one-time project that involves less than 4,000 words, a low-cost development system is appropriate. If programs grow larger or more numerous, the more expensive systems should be acquired. Keep in mind that these costs are usually underestimated, especially when the programming is being started from scratch.

If the initial choice is for a high-level language, the development costs take on another aspect. With an interpretive language, an expensive development system is unnecessary, because programming may be done interactively on the system under development. A line of source code contains the equivalent of about 40 assembly statements and will cost about $20 a line to write, debug, and document. The only interface that is needed is one for a teletypewriter.

Choosing a compiled language means that a high-end development system must be used. The estimated cost of an average line of compiled code consisting of 40 assembly instructions will be around $50 for writing, debugging, and documenting. Moreover, the development system's cost will be at the top of the scale, because of the extra RAM required for a compiler. In fact, a system using 64 kilobytes of RAM can cost over $20,000.

Once the size of a program and the number of systems to be produced have been determined, it is relatively easy to choose between a ROM and a PROM in terms of basic costs. Figure 3a compares the cost structure of typical 1-K-by-8-word ROMS and PROMS and a 2-K-by-8 ROM.

3. PROM vs ROM. Unit price of PROMs is always higher than that of comparable ROMs as shown in (a). With a customer’s masking charges added to the device cost of a ROM (b), a PROM is cost-effective in quantities below the 75-unit level.
Since the price difference between the two ROM types is about $1.50, the cost per kilobyte for the larger type is almost 50% lower. Projecting this trend, the cost per kilobyte for an 8-K-by-8 ROM is less than $1 in quantity. Of course, there usually is a mask-manufacturing charge, which is another $500 to $1,000 for a minimum quantity ranging between 250 and 1,000 units.

**Weighing ROM vs PROM**

An example will bring the ROM/PROM option into focus. For 250 systems with a 2-K program size, the larger ROMs plus a $1,000 masking charge will total about $4,000, with a small savings if the smaller 1-K memories are used. Now, comparing the unit costs of the 2-K ROM including mask charges and of the 1-K PROM shows that the masked memories will be cheaper than the programmable chips if more than 75 systems are to be built (Fig. 3b).

However, there are some drawbacks to the choice of a ROM over a PROM. For instance, turnaround time can be from 8 to 10 weeks. In addition, there is always the chance that the specified ROM pattern might contain errors, and the complete program debugging necessary for safety's sake takes about $1,000 in extra testing.

For certain systems with relatively large volumes, the single-chip microcomputer is an excellent choice. In quantities of 50,000 to 100,000, a 4-bit single-chipper will cost between $3 and $6, and an 8-bit device between $6 and $10. The costs for similar systems realized with discrete integrated circuits will be between $12 and $18.

If the 4-bit chip offers adequate performance, there is no way the 8-bit device or any multichip processor can compete. The price differential is just too great.

The choice most designers are likely to be facing, however, is between one-chip and multichip 8-bit solutions. Factors that come into play include production volume, memory size, number of interface pins, interface signal levels, and expandability.

**Looking at one-chip vs multichip computers**

When fewer than 10,000 systems are involved, the single-chip computers are simply too costly. However, this situation could change in the future.

As for memory size, the single-chipper requires an added component for each memory increment. In the multichip family, on the other hand, it is easy to move from a memory chip with a capacity of 5 kilobytes up to one with a capacity of 8 kilobytes. Moreover, the central processing unit can control as much as 64 kilobytes of memory itself.

Interfacing the single-chip microcomputer to a relay or display has its disadvantages, too. In most cases, the output is not enough to drive external devices, so drivers must be added. Then the price and parts-count advantages of the single-chipper quickly erode. In addition, I/O port pins must be committed to the interface, limiting the amount of input/output available.

Still another disadvantage of the single-chip system is the difficulty in expanding computer power without adding another processor and more ROM, RAM, and I/O. With a multichip processor in a bus-oriented systems, it is easy to double the computing power by adding a second processor and modifying the program. Interfacing remains the same, and communication between processors is simple.

Taking these factors into account, multichip processors look cost-effective with a production volume of less than 10,000 systems a year (Fig. 4). Until the crossover point with single-chip unit costs drops to the 1,000 level, multichip solutions will pay for medium-volume systems.

**Considering second sources**

No matter what microprocessor is chosen, it must have an alternate source of supply. There really are three kinds of alternate suppliers, often lumped together: the second source, the alternate source and the "designed-it-ourselves" source.

A second source will have received masks, process information, and engineering help from the chip's developer. An alternate source gets masks and process details but no engineering assistance. He may have difficulty coming up to production speeds.

The third type of source is one who builds his own version of another's design. Such parts must perform at least as well as and preferably better than the original to overcome the disadvantage of lack of official recognition. However, it pays to be wary of this source, since a user is in effect getting a single-source product. Such a buy can be risky if the product uses new technology.

Along with second sourcing, another factor often
ignored is the impact of a choice of a new processor on spares, maintenance, and training. A new microprocessor type may require expensive modifications in these areas, so the apparent gain in employing a better device may disappear.

The contributions to unit cost of many of the factors discussed and shown in the figures can be expressed in one simple equation:

\[ C_T = \left( \frac{S_u + \frac{\text{ROM}}{V}}{F_e} \right) \times (R_c + \text{SYS}) \]

where
- \( C_T \) = total package price
- \( S_u \) = startup costs
- \( V \) = production volume
- \( \text{ROM} \) = kilobyte capacity of the ROM
- \( F_e \) = memory-use efficiency
- \( R_c \) = ROM cost per kilobyte
- \( \text{SYS} \) = cost of the rest of the system.

**Figuring costs**

For example, a product is conceived that will be produced in 1,000 units. The manufacturer has no prototyping system, but he can get an expert programmer. System specifications call for a ROM capacity of 2 kilobytes. With the help of the curves in Figs. 1, 2, and 3, a table can be generated to estimate \( C_T \) for each of three alternative language approaches: interpreting, compiling, or simple assembly. The table shows that for such a system, the assembler and compiler are competitive with the interpreter, despite their higher startup costs.

Clearly, the software aspects of system design with microprocessors bear heavily on device selection. Careful attention to the areas of concern outlined in this article can spare the system designer a nasty surprise when it comes time to tote up final costs.

---

**Table: Calculating Unit Package Price**

<table>
<thead>
<tr>
<th>Item</th>
<th>Interpreter</th>
<th>Compiler</th>
<th>Assembler</th>
</tr>
</thead>
<tbody>
<tr>
<td>( S_u )</td>
<td>$2,000</td>
<td>$20,000</td>
<td>$20,000</td>
</tr>
<tr>
<td>( F_e )</td>
<td>42%</td>
<td>50%</td>
<td>100%</td>
</tr>
<tr>
<td>ROM</td>
<td>2 kilobytes</td>
<td>2 kilobytes</td>
<td>2 kilobytes</td>
</tr>
<tr>
<td>( R_c )</td>
<td>$10 for 2 K</td>
<td>$10 for 2 K</td>
<td>$10 for 2 K</td>
</tr>
<tr>
<td>ROM/Fe</td>
<td>5 K</td>
<td>4 K</td>
<td>2 K</td>
</tr>
<tr>
<td>ROM R_c/Fe</td>
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<td>$20</td>
<td>$10</td>
</tr>
<tr>
<td>Su/V</td>
<td>$2</td>
<td>$20</td>
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</tr>
<tr>
<td>SYS</td>
<td>$15</td>
<td>$15</td>
<td>$15</td>
</tr>
<tr>
<td>( C_T )</td>
<td>$45</td>
<td>$55</td>
<td>$45</td>
</tr>
</tbody>
</table>

**Graph:**

- Discrete central processing unit, 2 K Programmable read-only memory, random-access memory, 32-bit input/output
- Price break: use ROM
- Single-chip microcomputer plus extra I/O
- Single chip

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* P-13949 E Amendment 2; P-55617 B Amendment 1; G-55636 B Amendment 1.

Circle 133 on reader service card
CCDs bring solid-state benefits to bulk storage for computers

Series-parallel-series structure gives extremely dense charge-coupled-device memory, now commercially available

by Bruce Threewitt, Fairchild Camera and Instrument Corp., Mountain View, Calif.

In less than three years, the capacity of charged-coupled-device memory chips has zoomed from 9,216 to 64-k bits. This rapid growth—greater than that of the MOS dynamic random-access memory—can be attributed to several factors:

- Compatibility with established metal-oxide-semiconductor technology.
- High packing density, resulting in low cost.
- Low power dissipation, giving higher reliability.
- Fewer contacts per bit, resulting in better yield.
- Faster access time (latency) than magnetic storage memories and faster data rate than large MOS RAMS.

Of this list, perhaps the single most important factor for CCD success is that the fabrication technique is the same as that used to manufacture high-volume n-channel MOS devices. Consequently, designers can put their years of experience with a familiar process into play, thus shortening the learning time usually required for a new technology.

Of course, CCD memory is a low-cost alternative for bulk memory, not a replacement for high-speed RAM. General computer architectures can use caches for stor-

1. Tight organization. Series-parallel-series architecture provides a high-density and cost-effective organization for CCD memories. Basically, memory consists of a group of shift registers that move data in serial form at input and output, and in parallel in between.

2. Big memory. The Fairchild F464 CCD memory is organized as a 65,536-by-1 bit format in 16 blocks of 4,096 bits. To select one of the blocks to read, write or read-only, four transistor-transistor-logic-compatible address bits are provided.

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ing data in block form, which need not be accessed randomly. Since a computer usually performs operations sequentially, it can tolerate the serial organization of a CCD device. In this case, data rate (the reciprocal of memory cycle time) is more crucial than random-access time, thus making the simpler, cost-effective serial-access memory more practical for bulk storage than RAM. Charge-coupled devices now fill the gap between magnetic and random-access memories at a cost 3.5 to 5 times less per bit than RAMs.

**CCD-memory architecture**

With such a young technology, there are a number of architectures and clocking schemes under investigation. Fairchild believes that serial-parallel-serial is the best organization for high-density, cost-effective CCD memories. SPS combines the performance and density benefits found in other charge-coupled-device architectures with even more significant density improvements and suitable latency when compared to magnetic media.

Development of SPS architecture (Fig. 1) is in keeping with the goal of replacing magnetic bulk-storage memories with semiconductor memories. Briefly, SPS works like this. Data is entered into a serial input register at frequency \( f_i \). When the register is full, a series-to-parallel conversion occurs, and data is shifted in parallel at frequency \( f_p/n \) where \( n \) is the number of bits that the serial register will hold. At the other end of the parallel register, a parallel-to-series conversion takes place, and data is shifted out at frequency \( f_s \).

The structure is extremely dense, since the series-to-parallel and parallel-to-series conversions require no overhead logic within the SPS block. These conversions are accomplished by four external clocks: two phases for the serial registers, which also are buffered and used in the parallel sector, and two for the conversion. The two conversion clocks are connected only to the interfaces between the serial and parallel registers.

Since this conversion is a low-capacitance function, the external input capacitance of these two phases is very low. And since the serial register clocks only drive \( 2n \) bits per block, this clock capacitance is also relatively small. These four low capacitances make interfacing to transistor-transistor logic simple, with standard low-cost drivers being used.

Another advantage, in power dissipation, accrues from the much lower frequency of the internal parallel phases \( (f_p/n; \text{typically } n=64) \) relative to the serial register clocks. Thus they can be buffered on the CCD memory chip without dissipating significant power.

**The F464 64-K CCD memory**

The F464 CCD memory (Fig. 2) is the first commercially available semiconductor bulk-storage device. Bits are organized as 65,536 by 1 in 16 randomly accessible blocks of 4,096 bits. Four TTL-compatible address bits are provided to select one of the 16 blocks for read and write-only operations.
Each shift-register block is implemented using an interlaced SPS structure in which two electrodes of the serial input register serve two parallel shift registers (Fig. 3). The input register transfers data to the odd-numbered parallel registers and then, on a second scan, transfers the next 32 bits of data to the even-numbered parallel registers. As a result, each serial input register stores 32 bits using 64 electrodes that service 64 parallel shift registers. In a conventional SPS structure, each bit of the serial shift register serves only one parallel shift register. Using the interlaced scheme, this width may be equal to that of only one electrode; hence the packing intensity is doubled.

To further enhance the packing density, an eight-phase ripple technique is used in the F464's parallel register to shift the data. In a synchronous two-phase clocking system (Fig. 4a), two CCD electrodes are required to store one bit of information. In a ripple system (Fig. 4b), the density averages a little more than one electrode. In general, the number of electrodes, \( n_b \), required to store one bit is given by:

\[
\frac{N}{N-1}
\]

where \( N \) is the number of ripple clocks.

As the number of ripple phases increases from two to eight, the number of electrodes required to store 1 bit is reduced from 2 to 1.14. Thus, when the eight-phase ripple system is used, packing density is almost twice that of a two-phase system.

In addition, the ripple technique reduces the number of transfers required to move a packet of data from the input of a parallel shift register to the output. In an \( M \)-bit shift register, the number of required transfers is \( M \times n_b \). Thus, a 63-bit shift register needs only 72 transfers in an eight-phase ripple system, compared to 126 transfers in a standard two-phase system. This obviously minimizes signal degradation that is due to charge-transfer inefficiency.

Another advantage of the ripple technique is the reduction of average leakage current per bit. The charge collected is reduced in proportion to the number of electrodes required to store a bit.

F464 operation

The 16 blocks, each consisting of a 4,096-bit SPS shift register for data storage, are randomly accessible using four address inputs (\( A_0 - A_3 \)). The data in every block advances at the same rate of 1 bit per cycle. Each block has its own reference-charge generator, sense amplifier, input/output logic and CCD input circuit. The data-in (\( D_{\text{in}} \)), data-out (\( D_{\text{out}} \)), and write-enable (WE) circuits are common to all blocks and are activated by the chip-select (CS) signal to minimize standby power. The memory
requires four MOS-level clocks (Fig. 5). The two high-frequency clocks, \( \phi_1 \) and \( \phi_2 \), run at a frequency equal to the data rate and control the movement of data within the input and output series registers of each 4,096-bit block. These clocks also control all the peripheral MOS circuits. The two low-frequency transfer clocks, \( \phi_{T1} \) and \( \phi_{T2} \), transfer charge from the serial-to-parallel and parallel-to-serial registers of each block.

Interlacing of the data is achieved by first transferring data from the input serial register into the parallel registers when the charge packets are under the \( \phi_1 \) gates, then reloading the input register with the next 32 bits and transferring this data when the charge packets are under the \( \phi_2 \) gates. Parallel-to-serial transfer is accomplished in a similar manner. Thus, to achieve proper transfer phasing, the two transfer clocks must be asymmetrical around a 32-cycle interval but symmetrical around a 64-cycle interval.

The \( \phi_{T1} \) and \( \phi_{T2} \) clocks are skewed to achieve correct bit storage in each block. When \( \phi_{T1} \) occurs during \( \phi_1 \) time, \( \phi_{T2} \) occurs during \( \phi_2 \) time, 1.5 cycles prior to \( \phi_{T1} \). When \( \phi_{T1} \) occurs during \( \phi_2 \) time, \( \phi_{T2} \) occurs during \( \phi_1 \) time, 2.5 cycles before \( \phi_{T1} \).

**Four operating modes**

In the standby, recirculate-only, mode (CS low) shown in Fig. 6(a), the contents of all 16 blocks are recirculated automatically, and the device disregards the WE, address, and D\(_m\) inputs. The output latch goes into the high-impedance state after the trailing edge of the \( \phi_1 \) clock. Minimum power dissipation occurs when the device is operated in the recirculate mode with minimum \( \phi_1 \) and \( \phi_2 \) pulse widths at the lowest allowed frequency.

In the read-recirculate mode of Fig. 6(b) (WE and CS high), the data from the selected block is presented to the output buffer immediately following the leading edge of \( \phi_2 \). It appears at the output (D\(_{out}\)) after a delay equal to the access time \( t_{ac} \). Thus, the access time is referenced from the leading edge to the \( \phi_2 \) pulse and is independent of the duration of \( \phi_2 \).

The output buffer is latched by the trailing edge of \( \phi_3 \), and output data remains valid at the D\(_{out}\) pin until the end of the \( \phi_1 \) clock pulse in the next cycle. D\(_{out}\) then goes into the high-impedance state until the access to the next bit occurs. The data in all 16 blocks recirculates automatically.

**Read-write mode**

In the read-write mode (WE low and CS high), the output data from the selected block is available at the output pin, as in the read-recirculate mode; however, the recirculate path of that particular block is disabled. Input data present at the D\(_m\) pin during \( \phi_2 \) is written into the selected block by the falling edge of \( \phi_2 \), while the other 15 blocks automatically recirculate their contents.

The functional timing diagram for the read-write mode is shown in Fig. 6c. The four addresses (A\(_0\)–A\(_3\)) and CS are buffered when \( \phi_1 \) is high. The trailing edge of \( \phi_1 \) latches the information and disables the addresses and chip-select buffers to prevent changes that occur on these pins from entering the internal circuitry when the \( \phi_1 \) clock is low.

The WE dynamic buffer is unconditionally preset during \( \phi_1 \) time. In the read-only mode, WE remains high, disabling the buffer. In the write model WE may go low before or after the trailing edge of \( \phi_1 \), and the WE buffer is activated by \( \phi_1 \) or WE going low, whichever occurs later. The D\(_m\) buffer, which is disabled during \( \phi_1 \) high time, is enabled when WE buffer is activated. Therefore in the write mode, the data must be valid before \( \phi_1 \) or WE goes low, whichever occurs later.

**Simple mode**

The read-modify-write mode (CS high, WE high and goes low) is simple because the memory is always in the read mode whenever CS is high. Since the access time is referenced to the leading edge of \( \phi_2 \) and the setup times of WE and D\(_m\) are referenced to the trailing edge of \( \phi_2 \), this mode of operation requires only an extended \( \phi_2 \) high time to provide the required modify time.
B. Operating modes. In a standby mode (a), data in all 16 blocks of the F464 CCD memory recirculates, and device ignores write commands and address or data inputs. In read-recirculate mode (b), data appears at output after delay equal to access time, and write-enable and chip-select go high, following leading edge of $\phi_1$. Comparable timing diagram for the read-write mode is shown in (c).

The F464 CCD memory operates over a 1-to-5-megahertz range with power dissipation of less than 3.5 microwatt per bit in the active mode at 5 MHz and less than 1 $\mu$W per bit in the standby mode at 1 MHz. Typical capacitance on the TTL-compatible inputs—addresses, CS, WE, and $D_{in}$—is only 5 picofarads. On the 12-volt clocks, capacitance is 100 pf ($\phi_1$ and $\phi_2$) and 30 pf ($\phi_{T1}$ and $\phi_{T2}$). Use of CCD techniques, interlaced SPS architecture, and an eight-phase ripple scheme results in a chip of less than 40,000 mil$^2$ that fits neatly in a standard 16-pin, 300-mil-wide, dual in-line package.

The buried-channel CCD process, using SPS architecture coupled with proven Isoplanar n-channel silicon-gate technology, is a strong contender for bulk memory because of its high density and its low cost per bit. The 64-K CCD memory is an excellent vehicle for demonstrating workable techniques that can be used in larger memories, such as 256-K and 1-megabit sizes. All indications point to 256-K CCD memories by late 1979 or early 1980 at costs under 10 millicents per bit.
Eliminating
time-base errors
from oscilloscope
measurements

Delta-time models take the uncertainty out of measuring nanosecond intervals, says Part 2 of Electronics' series on time and frequency measurement

by Jerald B. Murphy
Hewlett-Packard Co., Colorado Springs (Colo.) Division

For most of their existence, oscilloscopes have been used to study those waveform parameters that can be determined from the shape of the traces displayed, like noise on analog control lines, ramp linearity, and amplifier response. But with the tremendous growth of digital systems and techniques, the emphasis has shifted to time-related parameters.

No longer can a few nanoseconds be ignored. The synchronization and timing of control signals, data, and propagation delays have become of paramount importance, making transition times, the width and period of pulses, and clock phasing the typical measurements of interest. And as digital systems' operating speeds have increased, so has the need for more accurate timing measurement—and so has the emphasis on the performance of an oscilloscope's horizontal axis.

In general, a basic oscilloscope can measure time intervals with an accuracy of ±3% of full scale. That is to say, with the oscilloscope's main sweep set to a rate of 10 nanoseconds per division, the uncertainty of a measurement read on the face of the cathode-ray tube is ±3 nanoseconds.

Contributing to this not inconsiderable figure are all three elements of the instrument's horizontal deflection system: the single-ended sweep generator, the wideband power amplifier, and the CRT. However, efforts to improve matters have focused on the last two, since if their effects could be ignored, the scope's accuracy would equal that of the sweep generator and fall well within just 1% of full scale.

Why this should be so is made immediately obvious by an inspection of the two types of time-base errors that

This is part 2 of the continuing "Microseconds and megahertz" series, which is designed to bring engineers up to date on the latest techniques of time and frequency measurement. Part 1, which appeared in the March 30 issue, pp. 81-88, covered the use of digital counters and timers. Followup articles will describe other modern instruments like microprocessor-controlled spectrum analyzers, triggering oscilloscopes, and time-base oscillators.
1. Error sources. Slope-angle and slope-linearity errors of ramp cause a deviation from ideal response shown in (a). Slope-angle errors (b) are due to a deviation from the specified ramp angle. Slope-linearity errors (c) are due to nonlinear changes in the sweep-ramp path.

These errors are the source of the inaccuracy. Both slope angle and slope linearity are involved (Fig. 1).

Slope-angle errors are the result of a deviation from the specified sweep ramp angle of the kind shown in Fig. 1b. This causes the beam to travel across the screen at speeds directly proportional to the erroneous ramp angle, so that there is a linear change in the sweep time between the graticule markers.

Slope-linearity errors are due to nonlinear changes in the sweep ramp path, such that the accuracy of a time-interval measurement changes at various places on the sweep ramp as shown in Fig. 1c.

Both these errors can usually be traced to the horizontal power amplifier and CRT. The power amplifier interfaces the single-ended sweep generator to the CRT plates, but because of the high sweep speeds required in modern scope applications, it must have a large bandwidth and therefore cannot escape the distortion typical of wideband power amplifiers.

The CRT's contribution to the total error stems partly from the near-field interference of the beam's magnetic field with the electrostatic field of the plates at the ends of the sweep and partly from nonlinearities in the tube's expansion lens system.

One answer

The delayed-sweep oscilloscope, originally introduced in the late 1950s by Tektronix as its type 535, minimizes the effects of the errors associated with the horizontal power amplifier and the CRT. This is done by causing the oscilloscope to act as a null detector. The center of the screen serves as an offset reference position for the start and stop points of the delayed time interval, and readings of the two points are made by adjusting a 10-turn delay-time control. The first reading is subtracted from the second to obtain the time-interval measurement, and at the same time the errors consistent with both readings virtually cancel.

This kind of oscilloscope uses two relatively independent sweep generators to produce the main and delayed sweeps. The faster delayed sweep may be started at almost any point along the slower main sweep ramp (Fig. 2). A precision dc voltage is compared to the rising voltage of the main sweep ramp, and when the two are equal, a trigger pulse starts the delayed sweep.

Figure 3 indicates the clumsiness of this technique. After bringing the starting point of the time interval
3. Clumsy. Delayed-time measurements are arduous and prone to user errors. After bringing the designated start and end points to the center of the screen (see top and center photographs), the difference between points must be measured with the delay-time control and then multiplied by the main-sweep time-base speed to yield the actual time interval (bottom left and right photographs). The accuracy of the measurement, however, will normally be within 1% of full scale if no user errors are made.
being measured to the center of the screen, the delay-time control is read \(T_1 = 1.86\) divisions. Next, after being adjusted so that the interval’s end point aligns with the screen center, the delay-time control is read again \(T_2 = 3.98\) div). Then the difference between the two is multiplied by the main sweep speed to yield the time interval in the proper units (microseconds, in this case):

\[(2.12\ \text{div} \times 0.5\ \mu\text{s/div}) = 1.06\ \mu\text{s}\]

The uncertainty of this measurement is the uncertainty of the reading due to the sweep generator plus the uncertainty of the full-scale measurement due to the 0-turn delay time control, or:

\[\pm(0.5\% \text{ of reading} + 0.1\% \text{ of full scale}) = \pm[0.005(1.06\ \mu\text{s}) + 0.001(5\ \mu\text{s})] = 10.30\ \text{ns}\]

This is an accuracy of within \(\pm 0.972\%\) of reading.

Evidently, the delayed-sweep oscilloscope is more accurate than a single-sweep oscilloscope. But it requires very skillful handling, and even then the mechanical gear loop of the 10-turn delay potentiometer limits the accuracy of the readings made with it.

The two-marker delta-time system

Hewlett-Packard Co. therefore introduced a two-marker delta-time system in 1975 that greatly improved both the accuracy and ease of making delayed-sweep time-interval measurements. The system was first incorporated in the HP model 1722A, later in the HP 1712A, 715A, 1725A, 1742A, and 1743A oscilloscopes and the DM44 option on the 400 series, as well as in the 7B85A option in the 7000 series by Tektronix. Besides giving less leeway to operator error, the two-marker delta-time system can simultaneously display two events separated in time and eliminates the effects of signal drift from the measurement.

The two-marker delta-time system also uses the horizontal power amplifier and CRT as a null detector, but it adds a digital voltmeter to display the time-interval measurement instead of requiring the operator to gauge the position of the delay-control knob.

The two-marker delta-time system displays two delayed-sweep markers on alternate sweeps (Fig. 4). The first time the main sweep ramp occurs, the voltage level of the start time delay is compared to it till they meet and trigger a delayed sweep that starts at the beginning of the time interval being measured. The next time around, the voltage level of the stop time delay eventually meets the ramp and produces a second delayed sweep starting at the end of the time interval. The start and stop delayed sweeps are displayed alternately, but so rapidly that the start and stop markers appear to be presented simultaneously. The difference between the start and stop voltages is an analog of the time interval being measured.

Three-step operation

The two-marker delta-time system requires only three basic steps of its operator:

1. Set the start and stop markers to the beginning and end of the waveform (Fig. 5).
2. Select the delayed sweep and adjust the stop marker to

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8. Jitter. Short-term variations of a time parameter with respect to a reference (jitter) are measured much like any other periodic phenomenon when an oscilloscope is used. Period jitter (left) and width jitter (right) are easily measured by technique discussed in the text.

and the stop marker is adjusted for overlap.

Width jitter may be present in the modulator of a radar transmitter or a computer handshake flag signal. It is measured in the same way as period jitter, starting with the basic width-measurement technique. The delayed-sweep traces are overlapped and the horizontal jitter is measured on the CRT and multiplied by the delayed-sweep time-base setting (Fig. 8, right).

Interchannel measurements

Interchannel measurements of time intervals are also made in a straightforward manner on a delta-time system. Such a dual-channel capacity makes it easier to measure repeatable propagation delay, setup time, hold time, and response time. In the alternate-display mode, the start marker will be displayed on one trace and the stop marker on the other.

The A Start/B Start switch selects the vertical channel upon which the start marker will appear. For example, to measure the lead time between the clock pulse on the upper trace of Fig. 9 and the data pulse on the lower trace requires the start marker to be on the A trace (A Start mode). But to measure the time the clock pulse remains high after the leading edge of the data pulse has occurred requires the start marker to be on the B trace (B Start mode). Once the start and stop markers are in place, though, the procedure is the same as for a single-channel measurement.

With dual-channel measurements there might be a small fixed offset delay due to difference in probe length. This error can be easily measured by connecting both probes to a common node and measuring the offset.

Transition times can also be measured much more easily and with greater confidence with delta-time oscilloscopes. Here, the vertical controls are adjusted to obtain a five-division display, and the delayed-sweep mode is selected. Then the start control is adjusted till the 10% level of the trace crosses the vertical graticule.
10. Changing times. Transition time is measured by delta-time system by using five-division display (left) and displayed-sweep mode. Start control is adjusted until trace’s 10% level crosses vertical graticule (center), stop control till 90% level crosses it (right).

11. Second-generation delta-time system. Crystal oscillator is timing reference. Pulses are counted from the start of main sweep, triggering first delayed sweep. Then they are counted again till the second delayed sweep. The difference is the time interval.

Two additional sources of error affect the accuracy measurements of transition time. The first is nonlinearities in the vertical axis of the CRT, which unlike those in the horizontal axis have not been nulled and from which very small errors, in the 20-to-50-picosecond range, can be expected. The second source of error also derives from the vertical system and is due to the fact the observed transition time is approximated by the square root of the sum of squares of the transition times of the oscilloscope, signal, and probe. This error can generally be ignored if the oscilloscope’s rise time is at least five times faster than the transition time to be measured.

In the first delta-time systems, however, no attempt was made to improve on the accuracy of the third major element in a scope’s horizontal deflection system—the main-sweep generator, which produces the ramp voltage output that supplies the instrument’s time-base reference. The optimum accuracy this generator can yield is within 0.5% of reading.

Changing the timing reference

A second-generation delta-time system introduced by Hewlett-Packard about a year ago uses a 100-megahertz crystal oscillator instead of the main-sweep generator for its timing reference and then further enhances this 10-ns resolution by means of time-interval averaging. As a result, the 1743A attains an accuracy of within 0.002% ±1 count of the reading displayed on its five-digit panel meter, offering timing resolutions of 1 ns and 100 ps for measurement ranges of 5 ns and 0.5 ns per division, respectively.

Such a crystal-reference delta-time system operates somewhat differently from its analog counterpart. The main-sweep trigger enables a counter that sums the crystal oscillator’s pulses until disabled by one of the delayed-sweep triggers (Fig. 11). The first time this happens, the pulses are counted from the start of the main sweep to the beginning of the start marker, which triggers the first delayed sweep. The next time, they are counted till the stop marker triggers the second delayed sweep. Subtracting the first count from the second yields the time interval.

Other advantages of this crystal-referenced delta-time system include:

- Self-triggered measurements, where the instrument automatically tracks changes in the signal without operator intervention.
- First-pulse measurements, allowing asynchronous signals like software-generated pulses to be measured by a delayed sweep starting at the same time as main sweep. (The fact that the main sweep no longer supplies the timing reference is what makes this possible.)
- Recalibrated sweep measurements, the vernier being used to calibrate the horizontal CRT axis to, say, the clock periods or whatever other units apply to the system under test.
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Mismatched waveguide calibrates VSWR scope display

By James B. McDonald
Commercial Engineering Associates, Princeton, N. J.

By using a variable attenuator to provide a selectable mismatch on a microwave transmission line, an automated check of the waveguide's voltage standing-wave ratio can be made over a wide range of frequencies with just an oscilloscope and a sweep-frequency generator. The mismatched waveguide serves to calibrate the scope face for various values of the VSWR so that when the attenuator is removed and an actual antenna load is connected, the system VSWR may be directly and immediately observed for the desired band of frequencies scanned by the sweep-frequency generator.

The adjustable waveguide mismatch is made by placing a short circuit across the output port of the variable attenuator, as shown in Fig. 1. It will be observed that the VSWR at the attenuator's input port will depend only on the setting of the attenuator, as is seen from the standard equation for the VSWR and the plot of its curve.

The scope face is calibrated for one or more VSWR values by overlaying it with a sheet of transparent material like acetate and tracing on the overlay the lines of the VSWR that are produced by the various attenuator settings as the sweep-frequency generator scans over the required frequency range (Fig. 2a). The range of frequencies swept can be 1 to 4 gigahertz at 5 to 10 GHz, otherwise known as the X band.

When the VSWR for an actual load (antenna, filter, cavity, etc.) is plotted versus frequency, it may then be compared with the reference VSWR (Fig. 2b). Note that the sweep-frequency rate will not affect the accuracy of the VSWR measurement.

The variable attenuator can also be used to create a mismatch in coaxial lines that are used in microwave systems. All that is necessary is to place a coax-to-

1. Attenuation versus VSWR. Voltage standing-wave ratio at input of short-circuited waveguide attenuator is a function of attenuator setting only. Thus attenuator can serve to calibrate scope for displaying VSWR value as a function of frequency for antenna systems.

2. Reflections. Waveguide reflectometer displays line of constant VSWR (1.5-to-1) versus frequency (a), and line is used as reference for measuring VSWR with actual loads (b). Sweep-frequency rate does not affect accuracy of VSWR measurements.
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**Industrial counter handles widely varying intervals**

by Rudolf E. Six  
*The Detroit News, Electronics Department, Detroit, Mich.*

The time intervals between consecutive events in industrial processes can often vary over several decades, creating a problem if their values are to be stored in a microprocessor-based system. Normally, a great many input/output ports would be needed to handle, say, the 24 significant bits needed to represent a 10-second interval measured with a 1-megahertz clock. But this counter requires only 10 output lines to represent intervals ranging from 1 microsecond to 10 seconds, making it easy for a 16-bit data system to process a 24-bit binary number.

Wiring a set of 4-bit counters, $A_1$-$A_7$, as a one-decade divider is what makes it possible for fewer lines to be used. At the start of a measurement, a string of 74160 counters immediately begin to divide down a gated 1-MHz clock signal into seven decades of time ranging from 1 microsecond to 10 seconds in duration, as shown. The outputs of $A_1$-$A_7$ are then presented to $A_8$, the 74152 eight-to-one multiplexer.

$A_{10}$ and $A_{11}$: two 74161 binary counters, are incremented once each microsecond until their combined count reaches 99. $G_1$ moves low at this time. On count 100, $G_1$ moves high and presets $A_{10}$-$A_{11}$ to a count of 10, and steps the multiplier counter $A_9$. $A_9$ enables $A_8$ to advance to the next decade position ($D_1$ to $D_{10}$). $A_{10}$-$A_{11}$ now counts at one tenth of the rate it did before $A_8$ was stepped to $D_{10}$.

The process continues until such time that the measurement interval is terminated. On the seven binary-count lines will be a binary-equivalent number that is

---

**Line reduction.** Counter that measures time interval between two events over a range of 1 microsecond to 10 seconds needs only 10 output lines to display the results and store them in a microprocessor-based system. System resolution is adequate for most applications but may be increased if an extra 74161 is cascaded with the $A_{10}$-$A_{11}$ counter, at a cost of three more output lines.
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W. J. Kolff, M.D., Ph.D., Professor of Surgery; Research Professor of Engineering; Director, Institute for Biomedical Engineering; University of Utah

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Electronics / June 22, 1978
related to the number of pulses in the gated clock signal. The actual (decimal-point) magnitude in microseconds, milliseconds, etc., is determined by the remaining three multiplier output lines, which indicate the decade value (D₀-D₇) as a three-bit binary number.

For example, an output of 01010001 on the binary lines combined with an output of 001 on the multiplier lines indicates a time interval of 810 μs between two events. After the computer has stored the information, a clear signal resets all the counters.

The resolution of the system (1 μs at the low edge, 10 s at the high end) is adequate for most applications, but it may be improved if an additional 74161 counter is cascaded to the A₁₀-A₁₁ circuit. This extension will increase system accuracy by 1 bit, but then three additional output lines will be required.

Three LEDs display response of null-detector circuit

by William A. Palm
Magnetic Peripherals Inc., Minneapolis, Minn.

Three light-emitting diodes provide a visual readout for this null-detector/bridge circuit that can be used to match resistors to within 0.5%. The LED display is better suited for production-line measurement purposes than an output meter, is lower in cost, and takes up less space.

Circuit operation is straightforward. Transistors Q₁ and Q₂ will both be on when bridge resistor Rₓ, the resistor to be tested, is approximately equal to Rₑ, the reference resistance, because the differential voltage at the input ports of the 741 operation amplifier is near zero. Thus the output of the 741 assumes its midrange value of 4.5 volts, and LED A turns on. At this time, the voltage dropped across A and the 100-ohm collector resistors connected to Q₁ and Q₂ ensure that D₁ and D₂ cannot conduct, and so B and C cannot light.

When the differential voltage at the inputs of the op amp increases or decreases because of a change in Rₓ, one transistor will turn off, and this action will divert all current through LED B or C instead, depending on the polarity of the input voltage.

The null-detector response is illustrated within the circuit diagram. Note that there is no single step-transition from one region to another, but rather two small regions where two LEDs may be on simultaneously. These regions correspond to a value of Rₓ that is about 0.5% to either side of Rₑ.

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.
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Engineer's newsletter

Why not cushion electronic packages with foam?

Getting high-density electronic products ready for shipping can be both expensive and troublesome. But a process that has been around since 1970, International Packaging Systems' foam-in-place system, is already cutting the cost and assembly time of protective packaging at firms like IBM, GE, and Superior Electric Co. of Bristol, Conn.

Two liquids, a polymeric foundation and a polyol resin, are mixed in and dispensed by a hand-held gun that an operator aims into a cardboard shipping box. The combined liquids create a foam that expands to roughly 100 times its original volume while forming a semirigid polyurethane foam. While the foam is still curing, the operator lays a 1.5-mil-thick polyethylene film over it, places the product on top, covers the product with another sheet of film, and then repeats the process to form a top cushion cap. The result is a two-piece polyurethane cocoon that forms a close-fitting, protective cube around the product.

By using this scheme for protective packaging of custom voltage regulators and stepping motors, Superior Electric has halved its packaging material costs and cut package assembly time by 80%. For further information on the process, write International Packaging Systems Inc., Brook St., Norwalk, Conn. 06851.

Use lossy chokes to cut vhf noise on TTL boards

Here's a solution to the noise problem on TTL power supply lines. Ilkil Kayihan of the Technical University of Istanbul notes that if you are not using an extremely wide-band (200–500-MHz) oscilloscope to monitor the noise on TTL or Schottky TTL supply lines, you may be in trouble. Good decoupling capacitors, even if placed at every IC package, cause a buildup of oscillations in the upper vhf range on those lines. In fact, the power supply traces on the printed-circuit boards form shorted pieces of transmission lines—actually resonators at vhf frequencies, which are shock-excited at every transition of the TTL output stage. Contrary to the general assumption, these lines are not lossy enough to damp such oscillations. Adding more decoupling merely shifts the frequency of oscillation.

The only cure is adding more loss in series with the line in the form of series resistance or, better yet, lossy chokes. Such chokes can be constructed by winding several turns of enameled wire through a lossy ferrite bead. Special six-hole cylindrical ferrite cores made from lossy material like the Siemens N22 material are particularly effective. These chokes should be placed in series with the supply lines of each TTL package and the package decoupled very close to its supply pins. Two packages can be fed over a choke. Lower-frequency decoupling is necessary at the voltage input to the circuit board.

My medical plan is better than yours

Ever wonder how your company’s benefits stack up against those of other companies in the electronic field? The Engineers Joint Council has just issued a new booklet called “Survey of Employee Benefits of Engineers.” Companies surveyed range in numbers of engineers from 7 to 20,000 and the benefit data applies to a cross section of over 90,000 engineers. It includes pension plans, health care, insurance, vacation, holidays, etc. The survey does not identify the individual companies that responded. Requests for copies of this $15 booklet should be sent to Mrs. Julie E. Gibouleau, Engineers Joint Council, 345 East 47th St., New York, N. Y. 10017.

Jerry Lyman
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Chip controls CRT displays' attributes

The n-MOS device also generates characters; with companion timing chip, it handles all display functions

by Bruce LeBoss, New York bureau manager

Several semiconductor makers have developed single-chip devices containing the logic functions required to generate all timing and control signals for presenting and formatting video data on cathode-ray-tube terminals. Now one such firm, Standard Microsystems Corp., has also developed a companion chip that integrates the logic needed to generate and alter the attributes of the character field.

Designated the CRT 8002 video-display-attributes controller, the 1-channel metal-oxide-semiconductor device will work with the firm's CRT 5027 video timing and control chip [Electronics, Feb. 17, 1977, p. 119] or with CRT timing/control chips from other manufacturers, says senior vice president Gerald E. Gollub. "Together, these two types of chips comprise all of the circuitry required for the display portion of a video terminal," he claims.

The 8002 is a 20-MHz-plus device made using Standard Microsystems' new Clasp process that fixes the data in the character-generating read-only memory at the end of the wafer-fabrication process [Electronics, May 25, 1978, p. 39]. In addition to generating 128 7-by-11-dot characters, the 8002 has modes for producing both wide and thin graphics, an external-input mode, four cursor modes, a high-speed video shift register, and logic for controlling field and character attributes.

Housed in a 28-pin ceramic dual in-line package, the 228-by-197-mil chip contains nearly 12,000 devices. Operating at 5 V and compatible with transistor-transistor-logic levels, it consumes 500 mw and has a
maximum access time of 400 ns.

Among the popular video-display attributes provided by the 8002 are reverse video, character blanking, blinking, and underlining. The character blanking rate is mask-programmable from 15 Hz to 1 Hz. For improved readability, the blinking has a duty cycle of 75% on and 25% off, compared with the common arrangement of 50% on and 50% off. Unlike many terminals, in which the underline bumps the character and is presented in lieu of it, “the 8002 displays both the character and the underline,” Gollub says. What’s more, the 8002 can provide a continuous underline as opposed to the common breaking-dash underline.

A novel attribute arose out of a need by such users of word-processing systems as law offices to retain documents in both original and edited forms. Called “Strike-thru,” this function strikes through the character with two parallel horizontal lines at full brightness, but, Gollub adds, “it doesn’t completely block out the characters or make them illegible.” The strike-through and underlining are similar but independently controlled functions that can be mask-programmed to any number of raster lines at any position in the character block.

The four cursor modes available with the CRT 8002 are underlining, blinking underline, reverse video blocking, and blinking reverse video blocking. Any one of these may be mask-programmed as the cursor function. The cursor blinking rate can be set similarly from 30 to 2 Hz, or twice that of the character blinking rate, Gollub notes. The standard 8002 will blink at 3.75 Hz for the cursor.

The 8002 has two mode-select lines that allow the chip to run in four modes that can be intermixed. The alphanumeric mode makes use of the internal 9,856-bit ROM to generate the standard ASCII set of 128 characters, which then pass through the attributes logic on the way to the 8-bit shift register.

However, an external-input mode is available for users with requirements for special characters, such as the degree or ohms symbol. In this mode, the eight address lines become data lines and the data bypasses the ROM and goes directly into the attributes logic and, subsequently, into parallel inputs to the shift register. “This gives you control of the shift registers on a dot-by-dot basis, and allows you to bring in special characters from an external ROM, programmable ROM or random-access memory,” Gollub says. External control also allows signatures to be put in, from a large RAM, he adds, as “is an attempt to provide flexibility in the circuit and not be preempted by special requirements that may develop downstream.”

The third mode, called thin graphics, enables the user to create single-line drawings and forms. The fourth mode, wide graphics, divides the character block into eight graphic entities, each of which is associated with 1 bit of a graphic byte. This provides 256 unique symbols to construct bar graphs and histograms, for example.

The 8002 will be available in three speeds. The standard 8002B will have a maximum shift register frequency of 15 MHz and will be priced at $30 for 1, $15 in 1,000-piece lots, and $10 in 10,000-unit quantities. A 20-MHz 8002A and 10-MHz 8002C will be priced 15% to 20% higher and 15% to 20% lower, respectively. Standard Microsystems is now providing samples, and production quantities are expected to be available by the end of September.

According to Gollub, the 8002 replaces from 10 to 15 transistor-transistor-logic packages used to perform address and attributes latching, as well as a ROM package. The chip is designed for use in dumb, smart, and intelligent terminals, a market estimated at 400,000 to 500,000 units this year and growing to 1 million by 1980, as well as high-end personal computers. The standard B version, he adds, is targeted for the 85% of the video terminals market operating below about 15 MHz.

Standard Microsystems Corp., 35 Marcus Blvd., Hauppauge, N. Y., 11787. Phone (516) 273-3100 [338]
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When it comes to instruments, high performance usually means high price. An exception to the rule is the model URV4 radio-frequency millivoltmeter from Rohde & Schwarz. Designed to sell for just under $2,000, the German company's detector-type instrument can measure voltages from 300 μV to 1 kV over the frequency range from 10 kHz to 2 GHz. Readings are presented in both volts and in dBm across a 50-Ω load. The dam measurements cover the range from −57 to +73 dBm.

A particularly attractive feature of the URV4, says Tilman Betz, head of the group that developed the meter, is its dual-display technique that presents measured values in digital and analog form simultaneously. The digital readout uses four 11-mm light-emitting-diode characters to read either decibels or voltage values. The analog display reads in decibels only; it is implemented by a row of light-emitting diodes and is logarithmically divided into 1-dB increments. The analog display spans 30 dB and uses a five-position switch to cover the instrument's full measuring range.

"Many of its mechanical and electrical parts and subsystems can be employed in other instruments in our production program, and that helps keep its manufacturing cost low," Betz explains. For another thing, since the meter is so new, it uses the latest components, such as large-scale integrated circuits and integrated analog-to-digital converters. "That, too, is a cost-reducing factor," Betz points out.

Other features of the URV4 are automatic nulling, ranging, decimal,
"Intel announces the first MOS PDP-11 memory with full parity capability, control status register and more—all on a single board."

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<td>Have an Intel representative call me at ( )</td>
<td>Send me information on the in-5034 memory for PDP 11/04s and 11/34s</td>
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Intel low-power MOS memory components reduce operating power to only 20 watts (12 watts in standby).

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Tester evaluates saturable magnetic cores

The model 305B magnetic core test set is a versatile instrument designed to determine the magnetic properties of saturable magnetic cores. It has five magnetic-drive ranges, from 0.3 to 30 gibberts full scale, and five core-response ranges, from 1,000 to 100,000 maxwells full scale.

The test set includes a fixture into which the core under test is placed, eliminating the necessity for winding coils onto the core. As a result, the
Decisions on the best approach to circuit board testing aren't easy. Should you buy a commercial tester or build your own? And if you decide to buy, which type would you select? A Manual tester? A comparison tester that uses a known good reference board? Or, a simulator-based system? Then there's expandability, vendor support and service support after warranty expiration to consider. After all, test equipment isn't a low-cost investment and you want assurance that you're able to deliver high-quality boards on time.

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Cores can be tested at eight frequencies: 400, 800, 1,600, 3,000, 5,000, 10,000, 20,000, and 30,000 Hz. Regardless of the test frequency, only one out of every 100 drive cycles is applied to the core. That is, the core flux remains at its residual value 99% of the time during all measurements. As a result, test results are similar to those obtained by conventional methods.

The 305B has coaxial jacks for connection to an oscilloscope so that the hysteresis loops of cores under test can be displayed. Its overall measurement error is no more than 5% for ambient temperatures from 55°F to 90°F and line voltages from 105 to 125 v. Under the same conditions, differential error is no more than 1%, so the instrument can be used in critical core-matching applications.

The 305B sells for $2,275 including the test fixture, cables, and a maintenance manual.

Mayberry Electronics Co., 1250 Industrial Ave., Escondido, Calif. 92025. Phone (714) 747-4940

Analyzer captures and generates digital waveforms

Built around a 32-location by 30-bit random-access memory, the model DSA600 digital synthesizer analyzer is a state-linear instrument that can capture and display up to eight input signals. It uses a row of light-emitting diodes to indicate the logic levels of the input signals at a given point in time. When any of the inputs changes its state, the display is updated and the precise time of
FOTOCERAM materials are replacing ruby wire-guides in high-speed, computer-controlled impact matrix printers. The printers operate by moving a single, vertical column of print wires across a horizontal line. Individual wires are activated in sequence to impact an inked ribbon against the paper, forming characters from patterns of dots. Those characters are generated at speeds up to 300 per second.

Precise vertical alignment of the print wires is extremely important. Up to now, many print-head manufacturers have used synthetic ruby wire guides because of their durability. Holes in the guide must be laboriously machined to less than 0.015 inch diameters, with a total tolerance within 0.001 inch. And the finished ruby guide must go through a polishing and assembly operation. It's an expensive proposition!

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Measure elapsed time by days, hours, minutes, seconds, milliseconds, microseconds or express time as a percentage of total (i.e. 14 seconds = 100.0%).

The transition is recorded. In this manner, 32 parallel states and their associated timing data can be acquired for subsequent study.

Automatic triggering allows the instrument to self-start on the first logic-state change on any input channel. Or it can be triggered externally by a predetermined word and two additional qualifier inputs. The trigger can be used either to start or stop signal-state storage and, hence, to capture pre- or post-trigger information.

The DSA600 also has a synthesis mode in which it can generate any desired digital signals. These may be programmed by the user or reproduced from signals that were previously captured.

The digital synthesizer analyzer sells for $6,250 and has a delivery time of 90 days.

Marketing Services, Gould Inc., Instruments Division, 3831 Perkins Ave., Cleveland, Ohio 44114. Phone (216) 361-3315 [353]

Active current shunt
includes output amplifier

Like most precision current shunts, the model 2575 contains an array of precision wideband resistors with full-scale voltage drops of 100 mv. Unlike the others, however, it also includes a high-accuracy output amplifier with a gain of 10 to provide a higher output level for driving thermal transfer standards.

Called an ac-dc active current shunt, the model 2575 has six precision resistors ranging in value from 1 milliohm to 100 ohms. The four-terminal noninductive resistors have 99.9% accuracy and have flat frequency responses that go beyond a kilohertz.

The shunt is designed for the 10°-to-40°C operating range and has a temperature coefficient of ±5 ppm/°C. It sells for $895 and is available from stock.

Valhalla Scientific Inc., 7707 Convoy Ct., San Diego, Calif. 92111. Phone (714) 277-2732 [354]
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Electronics / June 22, 1978
Our single microcircuit puts all kinds of electrical devices at your command. Appliances, car instruments, security systems, air conditioners, electronic games, industrial heating and refrigeration systems—all these and more can be controlled by our S2000 microcomputer. And, because we've packed so much onto one tiny chip, you can save a bundle over multi-circuit alternatives. AMI has been finding ways to cut our customer's costs longer than any other company in the business. Now we've created another economical way to get everything under control.

Take it to your leader, and the S2000, AMI's second generation microcomputer, may make your product a leader in its field. It's about as smart as a .025 sq. inch circuit can be and works twice as fast as any other 4-bit MPU. On board is a 256-bit RAM and a 1K x 8 ROM, a three-level subroutine stack, 7-segment decode, and both Touch Control™ and regular switch interfacing. Its high current output can drive LEDs, Triacs and SCRs directly. (We have a second version, the S2000A, for fluorescent displays.)

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The common problem of input current spiking due to transformer saturation or crossover switching has been dealt with by including a 900-kHz oscillator to drive the switching transistors.

Potential applications for the device include use in clinical, analytical, nuclear, and test instrumentation, as well as process-control applications. Use of the 722 with optically coupled isolation amplifiers can provide the complete system power and signal isolation often required in medical applications.

Not the least of the converter's attributes is its size; the entire package less pins measures only 1 in. by 1 in. by 0.3 in. In a ceramic 20-pin dual in-line package, the device sells for $30 each in quantities of 1 to 24.

Burr-Brown Research Corp., International Industrial Park, Tucson, Ariz. 85734. Phone Dennis Haynes at (602) 746-1111

V-f converters guarantee high temperature stability

The LM131A is the first voltage-to-frequency converter guaranteed to have a maximum gain temperature coefficient of 50 ppm/°C over the entire military temperature range of -55° to +125°C, according to its manufacturer. Like the five other members of the 10-kHz v-f converter series to which it belongs, the unit offers a guaranteed maximum nonlinearity of 0.01% whether it is used as a straight v-f converter or turned around for frequency-to-voltage conversion.

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Low-cost SCRs block up to 800 V

Aimed at ground-fault interrupters, units can handle high in-rush currents

Because of increasing consumer demand for protection against electric shocks, Joseph Pappalardo thinks he is onto a good thing with a new line of high-voltage silicon controlled rectifiers. Pappalardo, product manager for thyristors at Unitrode Corp., believes that the market for ground-fault interrupters—the devices that protect against shock—will be as big as that for smoke detectors.

The series, called the IP200, has voltage ratings of 100 V (IP200), 200 V (IP202), 400 V (IP204), 600 V (IP206), and 800 V (IP208). Pappalardo says each ground-fault interrupter uses at least one high-voltage SCR in its triggering circuit. But the IP200 series will find use elsewhere too. Among other possible applications are high-voltage relay and lamp drivers and high-voltage sensing, triggering, and detection circuits. In addition, the units are suitable for high-in-rush current applications, such as ignition circuits, photo flashes, and small motor controls.

The SCRs, housed in plastic, injection-molded TO-92 packages, have two features that Pappalardo believes set them apart from the pack: the peak forward-surge current rating is about double that of available competitive components, and the maximum on-state current rating is higher. The latter is 1 A rms, which Pappalardo says compares with about 0.8 A for other devices, and the peak forward-surge current is 15 A for 8.3 ms, versus 6 to 8 A for competing parts.

Maximum gate-trigger current is 200 µA, with typical gate current ranging from 10 to 50 µA, which is comparable to available components “and ideal for low-level logic triggering while still offering good dv/dt capability,” Pappalardo adds.

Sample quantities are available immediately, and volume deliveries take 4 to 6 weeks after receipt of order. Prices in quantities of 5,000 or more for the 200-V and 600-V units are 26 cents and 49 cents, respectively. But typical orders are expected to be much larger, and prices will be approximately 30 cents for the 600-V part, 21 cents for the 400-V unit, and 18 cents for the 200-V SCR.

Unitrode Corp., 560 Pleasant St., Watertown, Mass. 02172. Phone (617) 926-0404 [411]

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The TL431 is a three-terminal, shunt-regulator integrated circuit that is fully temperature-compensated over its entire operating temperature range. Its average temperature coefficient is 50 ppm/°C.

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Signals received by the chip are decoded using an input register, a digital-to-analog converter, and a hold circuit. Transmitted signals first enter a sample-and-hold circuit; a successive-approximation circuit formats the signal using the receiving section's timeshared d-a converter to generate values that are compared with those in the sample-and-hold circuit.

The 2910 has a 78-dB dynamic range and resolution equivalent to 12-bit linear conversion about zero; the 2911's dynamic range is 66 dB, with 11-bit equivalent resolution. Idle channel noise for the 2910 is typically 12 dBm. Samples, in quantities of 100 or more, are priced at $40.

Intel Corp., 3065 Bowers Ave., Santa Clara, Calif. 95051. Phone Rob Walker at (408) 249-8027 [413]

MICROWAVE TRANSISTOR

Linear and efficient

In the 2-to-5-GHz range, the half-watt HXTR-5102 bipolar transistor handles signals with minimal distortion and excellent efficiency. At a gain compression of 1 dB, the minimum power output is 26.5 dBm and associated gain is 6 dB. Class A power-added efficiency is 37% at 2
Now there's one less bridge to cross to get to your power supply.

Fairchild's new SH1705 makes it a whole lot easier to arrive at power supply designs. It's a 5 V, 5 A positive voltage regulator with a twist. There's a full wave diode bridge built-in.

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The SH1705 is in a hermetically sealed TO-3 package so it can fit into even the tightest squeezes on your PCB board. It features low dropout voltage across the regulator section. Internal current and thermal limiting. And 50 W power dissipation.

Bridging the gap between build or buy.

Until the SH1705, you had two choices. Build-up from discretes which is time-consuming and costly. Or buy a complete open frame power supply which is bulky and costly, no matter what your quantities are.

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12.5-A V-MOS FET
is available now

The VN84GA is the first member of an anticipated new family of high-power V-groove metal-oxide-semiconductor field-effect transistors [Electronics, June 8, p. 245]. With input power in the microwatt range, the device can put out 80 watts at low frequencies or 50 watts at 30 MHz.
The units come in TO-3 packages and are priced at $19.76 each for 1 to 99 units. The 80v, 2-A VN86HF, to come, will cost $1.13 each for 100 or more units.
Siliconix Inc., 2201 Laurelwood Rd., Santa Clara, Calif. 95054 [418]
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New products

Data handling

TV monitor has high resolution

19-inch color unit owes 1,000-line performance to its 0.31-mm-pitch CRT

The use of color monitors outside the television industry for such diverse purposes as weather mapping, biological thermographing, and high-quality graphics displays has created a demand for greater than standard image resolution. Designers at Ramtek Corp. have responded to this need by creating a 1,000-line monitor that allows users to address over 1.3 million picture elements.

The 1,280-by-1,024-pixel addressability of the set is made possible by the close spacing of individual color dots in the black-matrix three-dot cathode-ray tube. Pitch—center spacing between the dots—is only 0.31 mm. This is the highest density pitch currently available for a 19-inch-diagonal CRT.

The monitor operates with a video bandwidth of 50 Hz to 40 MHz, which provides faithful reproduction of incoming signals and ensures that resolution will not be bandwidth-limited. The incoming signals specified for the device are red-green-blue with composite synchronization on green, RS-343A being used as a guide. By means of a switch, the nominal horizontal line frequencies of 28.3 kHz, 31.2 kHz or 34.75 kHz can be selected. Other frequencies within the 28-to-36 kHz range can also be accommodated. The monitor's refresh rate is nominally 44 to 68 Hz. Horizontal flyback time is 5 to 8 μs, vertical is 600 μs.

Misconvergence measured within a circle having a diameter equal to the screen's vertical height and its center in the middle of the screen is less than 0.62 mm. Measured on a horizontal axis outside the circle, it increases to under 0.7 mm and at the screen's corners is less than 1.0 mm.

The monitor's low misconvergence results in an image that has sharply defined characters and good edge definition.

With a picture brightness of 20 foot-lamberts, the unit consumes 300 w operating from standard

Electronics / June 22, 1978

194 Circle 194 on reader service card
Now, the first data logger with get-up-and-go.

Take EMR's suitcase-sized COMPACT 3430 Data Logger away to those "difficult" sites where bulky equipment or hardwiring would be too inconvenient or costly. Just take it and leave it — anywhere, any time, for as long as a month. COMPACT's built-in battery and power source make it easy.

You can even take your pick of three models: one with a built-in line printer; one with a built-in cassette tape recorder; and one with a universal peripheral interface usable with a line printer, paper punch tape, teleprinter or modem. All three are microprocessor-controlled, providing keyboard programmability for up to 30 analog inputs and 20 (optional) digital status inputs, with any mix of voltage or thermocouple inputs.

As simple to use as a pocket calculator, COMPACT's pushbutton control eliminates plug-in modules, and lets you set individual high and low limits, specify channel input type, skip channels and select scan intervals. A choice of three modes lets you record all input data, out-of-limit conditions only, or inputs as they pass through the set limits. You can even print out alarm conditions.

For more details or a demonstration, call or write today.

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Circle 196 on reader service card

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Neon Glow Lamps

Circuit: AC 105-125
Series Resistance: 1.5KΩ
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Total Flux: 20mI[m] MIN.
Average Life Hours: 30,000

Clear-Green

Fluorescent Glow Lamps

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Series Resistance: 1.6KΩ
Nominal Current: 0.3mA
Total Flux: 120mI[m] DC: 130mI[m]
Average Life Hours: 30,000 DC: 40,000

Main Product

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New products

American or European ac power lines. It weighs approximately 100 lb and can fit into a rack space measuring 19 by 17.5 in. The set is also available in a tabletop cabinet or stylized case.

Prices for the 19-in.-diagonal CRT monitor begin at $9,900 with delivery 90 days after receipt of order. Quantity discounts are available, and a 13-in.-diagonal model can be provided on special order.

Ramtek Corp., 585 North Mary Ave., Sunnyvale, Calif. 94086. Phone Beverly Toms at (408) 735-8400 (361)

Dual-technology drive arrives with a price under $1,300

Among the latest moves by the hard-disk-drive manufacturers to attract floppy-drive users is the development of the combination Winchester and floppy drive [Electronics, April 13, p. 43]. The most recent arrival in the marketplace, the Marksman, claims to be the first 14-in. rigid-disk drive to be priced at less than $1,300 in quantity.

Average access time for the 17-megabyte, single-platter drive is 80 ms, and its track-to-track time is just 3 ms. Use of an integral microprocessor allows the stepper motor to slew at high speed with controlled acceleration.

The Marksman comes with a variable-frequency-oscillator data separator, has a power supply that is compatible with floppy drives, and accepts customer-designed formaters and controllers. Drive options include integrated controllers, offline exerciser, and rack mounting.

Initial delivery of the drive is scheduled for the third quarter of 1978, with production shipments...
Fill your computer needs with the industry's most professional microcomputers

#1 IN RELIABILITY
When you choose Cromemco you get not only the industry's finest microcomputers but also the industry's widest microcomputer selection.

What's more, you get a computer from the manufacturer that computer dealers rate #1 in product reliability.*

Your range of choice includes our advanced System Three with up to four 8" disk drives. Or choose from the System Two and Z-2D with 5" drives. Then for ROM-based work there's the Z2. Each of these computers further offers up to ½ megabyte of RAM (or ROM).

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- **Z-80A microprocessor** — operates at 250 nano second cycle time — nearly twice the speed of most others.
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Circle 198 on reader service card

Major UK Electronics Company seeks licensing/joint venture agreements

We are a specialist British company, a subsidiary of a major engineering group with worldwide business interests. We have expertise in computer control technology, both hardware and software, and the manufacturing skills necessary to build professional grade electronic equipment. For example, we have developed a mini computer and other digital equipment to provide a range of computer based machine tool control systems. We now plan to diversify and are seeking a partner with a high level of electronic engineering capability whose range of products is compatible with our own, in order to agree exclusive arrangements to manufacture and market electronic products in the UK and EEC.

If these objectives could be of interest to your company please write or telex to:

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Telephone: 04862 66576. Telex: 859310

HERBERT
NUMERICAL CONTROLS LTD

New products

expected to begin in October.
California Computer Products Inc., 2411 W.
La Palma Ave., Anaheim, Calif. 92801.
Phone (714) 821-2541 [364]

Rack-mountable tape system records 6,250 bits per inch

Introduced at the National Computer Conference, a vacuum-column tape-drive subsystem consisting of the T1940 transport and the F6250 microprocessor-based formatter utilizes group code recording to obtain a data density of 6,250 bits per inch. Unlike other high-density units, the transport measures only 24½ by 19 by 26 in. and fits easily in a standard rack, as does the 15¼-by-19-by-10-in. formatter.

The T1940 is available in configurations that transport tape at either 75 or 125 in. per second; the F6250 can handle up to four transports. As a team, they provide complete self-diagnoses, under either computer or manual control. Information is logged in the formatter for later computer interrogation to permit monitoring the system’s integrity.

The system, which automatically threads 10½-inch open-reel tape and accepts Easy-Load cartridges 1 and 2, is priced at $13,500 each in

196 Circle 258 on reader service card
New products

production quantities.
Pertec Division, Pertec Computer Corp., 9600 Irondale Ave., Chatsworth, Calif. 91311 [365]

Handheld logic analyzer observes, controls for $349

The ZT 488 is about the size of a standard engineering calculus text. But it weighs less—only 1 lb—and is a lot easier to master.

On its front panel, the unit can display logic transmitted on an IEEE-488 bus, including eight data lines, five control lines, and three handshake lines. Front-panel switches allow the user to set the data and control lines, and the handshake lines can be automatically controlled by internal logic or single-stepped by front-panel switches.

Requiring 5 V at 0.4 A, the ZT 488 comes with a 5-ft power cord and universal clips. It is available from stock.

Ziatech Corp. 10762 La Rota Dr., Cupertino, Calif. 95014. Phone Bert Forbes at (408) 996-7082 [373]

Programmable formatter takes on all comers

The model 61F-600 is a floppy-disk drive formatter that can be programmed to accommodate virtually any set of operating features and parameters. The unit allows selection of both single-density and double-density modes with both single-sided and double-sided operation. A single formatter can handle up to eight mixed-density disk drives with multiple formats. The 61F-600 sells for $850.

Applied Data Communications, 1509 E. McFadden Ave., Santa Clara, Calif. 92705. Phone (714) 820-3764 [367]

Controller prevents multiple-head aches

Having developed a four-head flexible-disk drive [Electronics, May 25, p. 180], PerSci is also offering a means to support up to eight of the units at one time: the model 1170 is a Z80-based controller that is compatible with IBM 2D, IBM 3740, and S-100 buses. In addition to managing up to 32 diskette sides to provide a formatted data capacity of over 16 megabytes, the stand-alone device will perform most of the housekeeping functions usually done by the central processing unit. File management functions include initialization, allocation and de-allocation of diskette space, error correction and retrying, and creation, deletion, renaming, and copying of files. Diagnostic testing can be managed, too.

Priced at $800 in original-equipment-manufacture quantities, the model 1170 is available for delivery in 60 to 90 days.

PerSci Inc., 12210 Nebraska Ave., Los Angeles, Calif. 90025. Phone (213) 820-3764 [366]
Data Systems' new, floppy disk system offers performance and storage equal to DEC's RX01, but uses half the space and costs 25% less.

Save money, save rack space and increase your system's reliability by selecting the DSD 110 for use with any DEC LSI-11 or LSI-11/2.

The DSD 110 provides 512K bytes of fully DEC-compatible storage in a 5 1/4" cabinet. While the DSD 110 saves you rack space, it also uses one less Q-bus slot than DEC's RX01.

All this is possible because the interface, formatting and controller circuitry, and hardware bootstrap have been combined on a single dual-wide card. This card, which is available separately, eliminates the need for DEC's REV-11 card.

To find out more about the low-cost, low-profile DSD 110, contact Data Systems today. A data sheet and price list will be forwarded to you immediately.

Data Systems Design, Inc.
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a new crystal clock oscillator
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For price list, rep list and data sheet, call Barney III at

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Department, 2553 N. Edgington, Franklin Park, IL 60131.

*1,000 price. Motorola and LOCO II are trademarks of Motorola Inc.
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**Type:** FM50, 75, 100 & 150  
PIV: 5,000, 7,500, 10,000 & 15,000V  
Average Rectified Current @25°C: 25 & 10mA  
Static Forward Voltage, 10mA @25°C: 10 & 20V  
Reverse Recovery Time (Max.): 300ns  
Case Size (Max.): FM50 & 75: .300"L x .120"D  
FM100 & 150: .400"L x .120"D

**Used in CRT Power Supplies.**

Our fast recovery multi-chip devices are especially designed for high voltage multipliers used in TV receivers and monitors.

**Type:** FM50, 75, 100 & 150  
PIV: 5,000, 7,500, 10,000 & 15,000V  
Average Rectified Current @25°C: 25 & 10mA  
Static Forward Voltage, 10mA @25°C: 10 & 20V  
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What puts SABRE X IRIG Tape Recorder/Reproducer above and beyond all others?
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With SABRE X you get keyboard-programmable (and re-programmable) microprocessor control of tape speeds, operating modes, end-of-tape, shuttle and search functions, even monitor/alarm and other diagnostic testing functions. It lets you set up your entire protocol in a fraction of the time needed for manual controls. A standard peripheral keyboard is all that's required. The SABRE X is also programmable from a complete computer system with peripherals such as mag tape, disc, etc. ... a standard feature no other IRIG tape recorder/reproducer provides. And that's just the start.

Another SABRE X exclusive is a tape transport with ten speeds electrically switchable from 240 through 15/32 ips for both record and reproduce, High Density Digital (HDR) Direct, or FM. As the only 4.0 MHz/track direct record and reproduce system available, SABRE X offers the most extended frequency range ... plus the industry's longest record time of 88.8 hours per tape reel ... plus the engineering capable of housing a full system's 32 record and reproduce channels in a single cabinet. We could go on ... but you get the idea: SABRE X is the state-of-the-art. For more information, call or write: Sangamo Weston, Inc., Sangamo Data Recorder Division, P.O. Box 3041, Sarasota, FL 33578 TEL: (813) 371-0811
Communications

Automatic system monitors network performance

Although all high-speed modems are constantly gathering data on transmission-line parameters to aid in the recovery of received signals, this data is seldom available to the operators of data-communications networks.

An exception is the Paradyne MP-48 modem—a 4,800-bit/second unit with dual microprocessors. One of its microprocessors handles such functions as equalization, scrambling, encoding, and filtering. The other provides dynamic information on transmission impairments and controls the modem processor when diagnostic tests are being performed.

Because the MP-48 makes its line-quality information readily available, it can be used as the basis of a network monitoring and control system. Such a system, capable of collecting data from 144 multidrop lines, has been developed. Called Analysis, it consists of a minicomputer-based central-site control unit, one or more MP-48 master modems, and up to several hundred MP-48 slave modems. The system automatically gathers, displays, and stores data using a low-speed (110-baud) noninterfering diagnostic channel.

Information on loss, noise, phase jitter, amplitude distortion, phase distortion, and other parameters is gathered from every drop on the network, assembled and analyzed for exception and alarm states, and displayed in conversational English.

A key benefit of Analysis is that it documents line availability, which allows users to recover the costs of unavailable lines. In some cases this can amount to thousands of dollars a month, according to product manager William Siegrist.

Analysis is available in two versions. The model CCB has a central-site control unit that contains a 16-bit minicomputer with 24 kilobytes of memory, a 1920-character cathode-ray-tube display terminal with a separate keyboard, a disk controller and two floppy-disk drives, and a 150-character-per-second printer. Prices for the CCB begin at $36,000. The model CCA omits the hard-copy printer, substitutes a light-emitting-diode readout for the CRT display, replaces the keyboard with a Touch-Tone entry pad, and makes other similar econo-
Fiber-optic connector
makes 1-dB losses possible

Although fiber-to-fiber losses of 2 dB are typical, values as low as 1 dB are possible with the model FOS fiber-optic connector. The single-fiber connector, which is available both as connector components and in complete cable assemblies, is designed to meet military connector specifications while in a mated condition. It will withstand an outdoor environment, the maker says.

Key to the performance of the connector is a precision ferrule that provides the necessary axial, angular, and gap alignments. Ferrules are available for fiber diameters from 100 to 150 μm (4 to 6 mils). In quantities of 100 and up, the connectors sell for $125 per mated pair. Delivery time is 8 to 10 weeks.

ITT Cannon Electric, 666 E. Dyer Rd., Santa Ana, Calif. 92702. Phone Richard L. Harmon at (714) 557-4700

Medium-speed facsimile unit has low rental tag

The Qwip Two facsimile transceiver is an inexpensive unit that can transmit an 8.5-by-11-in. page in either 2 or 3 minutes, depending upon the resolution required. The 3-min. transmission yields a resolution of 96 lines/in. in both directions; the 2-min. time reduces the resolution in one direction to 78 lines/in.

A key feature of the Qwip Two is its interrupt capability, which allows either the sender or the receiver to terminate a transmission. This capability is expected to save transmission costs by eliminating wasted messages. A second cost-saving attribute is a handshaking feature that allows the operator to know when both units are ready to send and receive.

This feature allows the sending of multiple-page documents without picking up the phone after each page.

Believed to be the lowest-priced facsimile transceiver of its type, the Qwip Two rents for $65 a month.

Qwip Systems Division of Exxon Enterprises Inc., 1270 Avenue of the Americas, New York, N. Y. 10020. Phone (212) 398-5151

Pigtailed IR emitter sells for $17.50

The FOE-7 pigtailed emitter assembly is an infrared unit with a bandwidth in excess of 20 MHz, a typical output power of 10 μW at a forward current of 50 mA, and a price of $17.50 (any size order). Useful for both analog and digital transmission, the FOE-7 has light rise and fall times of 25 and 15 ns, respectively. When pulsed with currents of 4 A, the assembly can put out as much as 200 μW of optical power.

Peak emission occurs at 900 nm with a spectral half-width of 50 nm. To transmit this wavelength, the pigtail consists of a fused silica core with silicone cladding and a black Tefzel outer jacket. The unit has an expected lifetime in excess of 50,000 hours. It is available from stock.

Radiation Devices Co., P. O. Box 8450, Baltimore, Md. 21234. Phone (301) 628-2240

Bell-compatible modem fits on single circuit board

Built on a printed-circuit board with an area of less than 100 in.², the model 208 data modem is a 4,800-bit/second unit offered in versions that are compatible with both Bell

Electronics / June 22, 1978
How fast can you accurately measure period or frequency of this waveform?

The old way.
(About 5 minutes)

1. Find a scope and voltmeter.
2. Connect signal to scope.
3. Determine proper trigger points.
4. Connect signal to counter.
5. Select period or frequency function.
6. Select time base.
7. Set input voltage range.
8. Set input coupling to DC.
9. Connect voltmeter to trigger level output—if counter has output. (If not, good luck.)
10. Set desired trigger level.

The easy way.
(About 5 seconds)

1. Connect signal to Racal-Dana 9000 counter.
2. Push \( P \) or \( FA \) button.
3. Push \( TH \) button.
4. Push \( AU \) button.
The rest is automatic.

Now it's up to you.
You can continue to struggle along the old way. Or you can find out about the Racal-Dana 9000 Microprocessing Timer/Counter. The patented Auto-Trigger capability makes it the fastest and most accurate instrument in the world for the precision measurement of wave forms. Give us a call and we'll tell you how Racal-Dana systems technology can solve all your measurement problems the easy way.

RACAL-DANA
Circle #142 for Product Demonstration
Circle #209 for Literature Only

Racal-Dana Instruments, Inc., 18912 Von Karman Avenue, Irvine, CA 92715. Phone: 714/333-1234.
THREE REASONS WHY OUR NEW SWITCHERS ARE MORE RELIABLE THAN THE POWER SUPPLIES YOU'RE USING NOW.

The Sub-Modular Switcher family is a big breakthrough. Because the electronics are simple—just three boards: Input, converter, and output.

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Our internal modules don't use loose wiring or harnessing. The circuitry is integrated onto printed circuit boards, and joined by an interconnecting strip. The result is a power supply that's far less expensive—$1/watt for certain models in OEM quantities.

The Sub-Modular Switcher family is available in 22 models. So you can choose from single or multiple output versions, with power ranges from 50 to 300 watts.

To make sure each Sub-Modular Switcher lives up to its specifications, we computer test all its operational parameters. And you get a complete EDP test report with every one you buy. The Sub-Modular Switcher's calculated MTBF exceeds its 5-year warranty. In fact, Life Test data indicate that actual MTBF should be considerably greater than the warranty period.

So, if you're tired of expensive, unreliable switchers, write for our free brochure.

It'll tell you all about our Sub-Modular Switchers.

The ones built to keep you in power.

For further information, write to us on the East Coast at 211 W. Clay Ave., Roselle Park, New Jersey 07204, (201) 241-6077. On the West Coast, write to 401 Jones Road, Oceanside, California 92054, (714) 757-1880.

acdc electronics
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This is The End to sole-source .43" digits. The replacements are available now.

Litronix, 19000 Homestead Road, Cupertino, California 95014. Phone (408) 257-7910.

THE LIGHTS FANTASTIC

Litronix, an affiliate of Siemens.

Circle 212 on reader service card.
Instrument maker to sell its own trigger-pulse synchronizer board

Berkeley Nucleonics Corp., a Berkeley, Calif., instrument manufacturer for the last 13 years, is moving into the precision subassembly market. Stemming from the company's work in digital delay generators is the C-1000 Zepher (for zero phase error) board, which synchronizes trigger pulses at rates up to 20 MHz to an onboard 100-MHz crystal oscillator. The Zepher uses emitter-coupled logic to reduce synchronization error between the trigger and the clock to no more than 100 ps. Available now at single-quantity prices of $1,100, the subassembly is geared for such high-frequency applications as real-time signal processing.

Analog Devices second-sourcing 12-blt d-a converter

Add Analog Devices Inc., Norwood, Mass., to the list of alternate sources for the DAC80 12-bit hybrid digital-to-analog converter introduced a few years ago by Burr-Brown Research Corp. Though AD's DAC80 is a direct pin-for-pin replacement of the Burr-Brown part in a 24-pin epoxy-sealed dual in-line package, it cuts the chip count inside from 11 for the older hybrid to 3 and tightens some of the specifications. Differential linearity is improved from \( \frac{3}{4} \) to \( \frac{3}{4} \) least significant bit, for example, and lower digital input currents allow the circuit to run off any complementary-MOS gate without a buffer, as the older part requires. The AD DAC80 will sell for $18.50 each in hundreds and will be available late this month.

Easy D-type flip-flop implementation promised by semicustom chips

Master Logic and Interdesign, Inc., both of Sunnyvale, Calif., will be offering a 350-gate, semicustom complementary-MOS logic chip that features 32 locations designed for easy D-type flip-flop implementation. Master Logic's ML350 and Interdesign's MCD350 are identical parts, and the special design feature increases gate complexity by 70% with only a 30% increase in chip area, according to Charles Allen, Master Logic president. Larger C-MOS circuits usually require more D flip-flops for counters and shift registers; therefore, the companies designed in the new cells so that the user can make a flip-flop with only one instead of the previous two interconnected cells. Design costs are about 30% higher than for the 200-gate chip. The price of Master Logic's part is $13.

There's a new source for germanium power transistors

Germanium lives. Silicon Transistor Corp. of Chelmsford, Mass., is now manufacturing the pnp germanium diffused-alloy power transistors that General Motors Corp.'s Delco Division used to make for fast switching and power-amplifier applications. The DTG110A and DTG110B are both available from stock, priced from $2.20 in 100-and-up-quantities. Current ratings are 25 A pulsed and 15 A continuous, and \( BV_{CEO} \) voltages are greater than 70 V.

Price changes

Recent price changes have been announced:

- National Semiconductor Corp., Santa Clara, Calif., is cutting bi-FET LF13741N op amp from 50¢ to 33¢ and LF1374H from 75¢ to 43¢ in quantities of 100 or more.
- Kertron Inc., Riviera Beach, Fla., has reduced 2N6542 through 2N6547 high-voltage switching power transistors by 22%.
- Computer Applications Corp., Ames, Iowa, is reducing two versions of 6500 microprocessor cross-assemblers from $1,200 and $900 to $600 each. The new price includes test programs and one-year free support.
The big switch

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Switching power supplies are more efficient than linears. To produce a 200 watt output, a linear supply needs 400 watts coming in. A Gould switcher needs only 270. The switcher saves the 130 watts that the linear throws off in the form of heat.

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<th>2.3</th>
<th>3.5</th>
<th>5.5</th>
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<td>13</td>
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<td>60</td>
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<td>7</td>
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New literature

Make-or-buy LSI. All the steps required to design and build large-scale integrated devices can now be subcontracted; LSI technology is therefore within reach of companies big and small, concludes Anderson/Bogert, a Santa Clara, Calif., high-technology consulting firm in a 185-page report. Entitled “Vertical Dis-Integration,” it describes the key steps and details the factors that influence the make-versus-buy decision at each step. The prepublication price is $395 until July 5 and $475 afterward. Electronics Technology Publications, 10050 N. Wolfe Rd., SW #3, Suite 200, Cupertino, Calif. 95050

Voltage controls. Illustrations, engineering data, diagrams, and specifications for a line of standard voltage controls are offered in a 72-page booklet. Also included is a section on how to specify and order ac voltage controls. Staco Inc., 301 Gaddis Blvd., Dayton, Ohio 45403. Circle reader service number 422.

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<td>4.7 ± 0.7kHz</td>
<td>5.7 ± 1kHz</td>
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<td>12mA max. at D.C. 9V</td>
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<td>1.5~9V D.C.</td>
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- SOUND ELEMENT

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<td>4.6±0.0kHz</td>
<td>2.8±0.0kHz</td>
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<td>10000pF ±10%</td>
<td>20000pF ±10%</td>
<td>3000pF ±30%</td>
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<td>Input Volt.</td>
<td>±15V</td>
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New literature

Equipment," a six-page catalog, points out the key characteristics of nine printed-circuit-board machines and two automatic roll-soldering systems. Photographs of each machine and system are given. Union Tool Co., Warsaw, Ind. 46580 [423]

Microwave communications systems. A 17-page catalog provides information on several types of microwave communications products, including control and data-acquisition systems and components, baseband conditioning and interface components, and frequency-shift-keying data-transmission equipment. Daniel Applications Department, 1922 N. Helm, Fresno, Calif. 93727 [424]

Photomultipliers. "Photomultipliers for Applied Spectroscopy," a six-page product guide, describes a line of side-on photomultiplier tubes and integrated photodetection assemblies that are intended specifically for photometric and ratiometric applications. A bar graph depicts the spectral response range of the photomultiplier tubes. RCA, Box 3200, Somerville, N. J. 08876 [425]

Components. Electrical and mechanical specifications for six electronic component lines for use by original-equipment manufacturers are detailed in a 40-page catalog. Products covered include potentiometers, cermet resistor networks, and trimmers. Photographs and diagrams are also given. CTs Corp., 905 North West Blvd., Elkhart, Ind. 46514 [432]

Vacuum gages. Detailed descriptions, specifications, and ordering information for a line of vacuum gages in the 300/400 modular series are provided in a 25-page brochure available from CVG Products Inc., 525 Lee Rd., P.O. Box 1886, Rochester, N. Y. 14603 [427]

Relays. "The Relay Selection and Application Manual" gives a broad description of various types of relays—general-purpose, latching, sensitive, impulse, stepping, military, solid-state, and such time-delay types as thermal and solid-
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New literature

state, as well as hybrid, pneumatic, and motor-driven timers. Different sections cover the various aspects of selecting a relay type—contacts, coils, enclosures, terminals, and mountings. This 25-page manual can be obtained from Publications Department, Relay Specialties Inc., 13-00 Plaza Rd., Fair Lawn, N. J. 07410 [428]

Power supplies. Over 1,300 models of solid-state, regulated and unregulated, rack-mounted, miniature, and modular high-voltage power supplies are covered in a 13-page brochure. It gives the features, specifications, and options for each type of power supply. The brochure is being offered by Spellman High Voltage Electronics Corp., 7 Fairchild Ave., Plainview, N. Y. 11803 [429]

Display devices. A 35-page catalog gives details of several types of specialized cathode-ray tubes. Entitled “Display Devices,” it lists the general characteristics of the display devices and the specific operating characteristics for each type. Some of the CRTs are: instrument, information display, photeorecording, flying-spot scanner, display storage tubes, and radar display. A glossary of terms is also provided. RCA, Box 3200, Somerville, N. J. 08876 [430]

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New literature

Planar Reactor," a four-page bulletin, explains the DryAl process for plasma-etching aluminum and gives typical operating parameters for each step. It also discusses the handling of wafers before and after processing. International Plasma Corp., 31159 San Benito St., Hayward, Calif. 94544 [431]

Electromagnetic interference. The "Quiet Line Filter Handbook" will help an engineer understand electromagnetic interference and how to eliminate or prevent it. This 16-page booklet specifies several methods of preventing radiated interference, including grounding, shielding, and the use of balanced lines, twisted pairs, and coaxial cables, as well as how to prevent conducted interference by using various types of filters. Proper filter testing, installation, and application are also covered. AMP Capitron Division, Elizabethtown, Pa. 17022 [426]

Surge suppressors. A technical application note discusses the various types and uses of voltage surge suppressors, including RC circuits, silicon voltage limiters, metal oxide varistors, and selenium suppressors. It also points out the limitations of these devices. A table summarizes the performance data, giving such information as maximum average power loss, internal thermal resistance, maximum avalanche peak current, and the maximum allowed energy for nonrepetitive pulses. FMC Corp., Semiconductor Products Division, 800 Hoyt St., Broomfield Colo. 80020 [433]

Wire and cable. A 72-page guide "Wire and Cable Engineering Guide," is designed for use by electrical and electronic circuit designers. The guide contains information on conductor material and coatings, insulation, circuit identification, braiding, shielding, cabling, and jacketing. Cable design formula and a temperature conversion chart are also given. It sells for $10 per copy in the U.S. and Canada and $15 per copy elsewhere. Brand-Re: Co., Wire & Cable Engineering
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New literature

Guide, WC-78, P. O. Box 498, Willimantic, Conn. 06226 [435]


Rentals. Information on major microcomputer development systems and logic analyzers that can be rented is given in a comprehensive catalog. The products are: American Microsystems Inc.'s 6800 microcomputer development center, Hewlett-Packard's logic analyzers, Intel's Intellec series, Millennium's microsystem analyzer, Motorola's Exorterm and Exorciser, Pro-Log's programmable read-only memory programmers and systems analyzers; and Tektronix' microprocessor labs and logic analyzer. Weekly and monthly rates are provided. Longer-term, as well as daily and hourly, rates are available upon request. Microcomputer Rentals, 705A Lakefield, Westlake Village, Calif. 43161 [436]
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World Radio History
Companies

Norden, at 50, is feisty again

New emphasis on systems, focus on military work only, and exclusive minicomputer license lead to resurgence

by Bruce L'Erso, New York bureau manager

For Norden Systems Inc., life is beginning again at 50. The principal electronics subsidiary of United Technologies Corp., the once moribund firm is bursting with activity in its golden jubilee year. And as though to celebrate that anniversary, the former div- subsidiary, Dynell, has just been combined in Norwalk. Concepts Inc., a supplier of electronics for U.S. military aircraft. Over the past three years it developed an expertise in air-to-ground radar and surveillance systems and became one of the largest U.S. defense contractors. By 1972, the firm had about 3,400 employees and an estimated $100 million in revenues, mostly from major contracts for the fighter's displays and the port's radar, as well as a weather attack package.

Most important, you'll get a clear indication of the dynamic, secure future waiting for you at Norden Systems, Inc.—the principal electronics unit of United Technologies Corporation.

Openings in NORWALK for:

Display Systems Engineers
Experienced in overall display systems engineering including raster and stroke write, display processing and generation, scan conversion, flat panel and CRT display indicators, computer interfaces, microprocessor technology and hardware/software tradeoffs.

Radar Systems Engineers
Experienced in advanced airborne radar including synthetic aperture radar. Strong background in translating customer requirements into system configuration and proposal preparation.

Important news about

Norden Systems

If your specialty is listed below and you would like to consider a career with Norden Systems, call us or send your resume. We'll review your credentials and send you a reprint of the article depicted from Electronics Magazine. In this frank report, you'll read about our plans to market its small but highly successful commercial PDP-11 family. Nine months later, Norden introduced its initial offering, the middle-of-the-line PDP-11/34M (Electronics, Nov. 25, 1976, p. 50). It has since expanded the line with militarized versions of the LSI-11 single-board microcomputer and high-end PDP-11/70.

New areas. The military computer was the key to Scott's overall plan to broaden its basic product line, which had been quite narrow. For starters, he found two new growth areas, automated battlefield systems and shipboard surveillance and fire control system. He also expanded the scope of the firm's airborne weapons delivery systems.

C³ Systems Engineers
Minimum 5 years experience in command, control, and communications systems. Knowledge of Army or Marine communications and artillery procedures desired.

Sr. Mechanical Design Engr.
8 years experience military electronics high density packaging. Know PC, power supply, core memory packaging. Supervisory experience required.

Power Supply Design Engrs.
Experienced with multi-output and high current switched mode supply techniques for military equipment. Proficiency with magnetics and high voltage/power design.

To apply for any of the above positions, send resume or call collect to Mr. James E. Fitzgerald, Norden Systems, Inc., 308 Helen Street, Norwalk, Connecticut 06856. (203) 838-4471.
engineers

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DIGITAL SYSTEMS

Responsible for defining characteristics, evaluating new applications and developing customer documentation on evolving multi-line PCM subscriber pair gain systems, channel banks, multiplexers and repeatered lines. Should have electrical engineering background with experience in microwave or digital transmission systems. Must have BS in electrical engineering.

MICROPROCESSOR HARDWARE DESIGN & TESTING

Position requires BS with interest in design and testing of microprocessor based circuit hardware.

MICROPROCESSOR CHIEF PROGRAMMER

Real time programming experience. Knowledge of structured programming. BS MSEE education with experience preferable in communications and/or telephone switching.

I.C. DESIGN

Design of custom integrated circuits, analog and digital design and computer simulation desirable. Willing to train an engineer with some experience in discrete circuit design. Will work with Bipolar and N-MOS technologies.

PROCESS EQUIPMENT PROGRAMMING

Development of automatic programs for high speed laser trim and test of hybrid circuits. Solid background in linear or digital circuit analysis and ability to use microcomputer programming required.

DESIGN SUPPORT

Electrical engineers at various levels to maintain, modify and assist the current production of electrical designs in various product lines.

EQUIPMENT DESIGNERS

For physical design of proprietary products. Equipment Designers must have knowledge of electron mechanical packaging and/or printed circuit board layout. No degree necessary.

PROJECT ENGINEER

Responsible for analyzing contract orders for microwave and multiplexer systems. Determine exact details of equipment required to meet the contractual obligations. This includes office requirements for power, data, antenna, towers, and other ancillary equipment.

FIELD SERVICE ENGINEER

Job # GM-2. Will work closely with Development Engineers and trouble shoot with customers via telephone or in the field. Position requires responsible person, capable of exercising good judgment in customer relations and able to make independent decisions as necessary. Five years experience involved.

MICROCIRCUIT PRODUCTION ENGINEER

Position will include development and evaluation of thin film materials and processes plus the development of micro circuit packaging techniques for semiconductors used in telecommunications equipment. Applicant should have BS in Chemistry, Chemical Engineering or Materials Science. Experience in micro circuit technologies required. Job # BW2.

ENGINEERING WRITER

Job # FF-31. Responsible for defining characteristics, evaluating new applications and developing customer documentation on evolving multi-line PCM subscriber pair gain systems, channel banks, multiplexers and repeatered lines. Should have electrical engineering background with experience in microwave or digital transmission systems. Must have BS in electrical engineering.

ANALYST PROGRAMMER

To work in an IBM 370/148 SVS environment. Must have in-depth knowledge of COBOL, JCL, utilities, etc. BS or BA degree preferred. AA acceptable or related work experience.

STAFF ENGINEER, TOOL & MACHINE ENGINEERING

BS/MS in engineering or related field. Experience in tooling design for sheetmetal and small machine parts, the design of process and assembly equipment used for electronics manufacturing, and the design of unsophisticated production machines including electrical and air/hydraulic controls.

EQUIPMENT DESIGNERS

For physical design of proprietary products. Equipment Designers must have knowledge of electron mechanical packaging and/or printed circuit board layout. No degree necessary.

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The person we select will have responsibility for staffing and directing the image technology, solid state technology and the advanced equipment and automation departments. The person should be capable of organizing a central development group, chartered with applying advanced technology to future complex devices. Qualifications must include a minimum of ten years experience in the application of advanced semiconductor process technology. A portion of this experience will be involved with complex MOS devices manufactured in high volume. An appropriate PhD is preferred. Candidate must also be capable of proposing projects at senior management levels.

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Electrical Engineering Technology—
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California Institute of Technology,
Research Fellow or Senior Research Fellow position in the Power Electronics Research Group of the Electrical Engineering Dept., to contribute to theoretical and experimental studies of switching mode converters and regulators. Ph.D. required, with up to 10 years background in analog circuits and feedback systems, specific experience in power conversion preferred but not essential. Apply to: Prof. R.D. Middlebrook, 116-81 Caltech, Pasadena, CA 91125. An Affirmative Action/Equal Opportunity Employer.

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