AUGUST 5, 1976
WHAT'S LEFT FOR RECEIVING-TUBE MAKERS?/67
How instrument users view the universal interface bus/70
A hardware approach to debugging microprocessors/106
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Electronics/August 5, 1976
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It's time to get to know Hewlett-Packard's family of high-performance isolators.
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Highlights
COVER: The rising star of fiber optics, 81
A number of small optical-communications systems have gotten off the ground, thanks to the growing availability and improved performance of optical-fiber cable, light sources, photodetectors, and connectors. But a major system must start construction before the market can seriously begin its climb to the billion-dollar level forecast for 1990.

Cover illustration is by Dennis Purdy.

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DETECTORS: P-i-n photodiodes '1'
Low-cost devices are less n transistor or avalanche diode

COUPLING: Star couplers plus
Star couplers do better systems with 20 or more

And in the next issue . The many uses of c . . . a high-perf popular 8080 r
Publisher's letter

Communicating from point to point along waveguides made of tiny optical fibers is no longer just an idea. It is rapidly becoming a practical method of pumping large quantities of data from place to place, especially in environments that are electrically noisy or already overcrowded with conventional cables.

On page 81, you'll find the beginning of a special report on optical-fiber communications. The 24-page special report consists of an overview of just what is happening now and nine articles covering components needed in a fiber-optic system.

The report was put together by our communications editor, Dick Gundlach, and the component articles were written by experts in the field. That's Dick, by the way, testing the strength of a new glass-fiber cable by tying knots in it, while Kenneth S. Kamm, of DuPont's Ptx Fiber Optics Materials Research and Development division, demonstrates its impact resistance.

Says Dick: "A staff scientist at ITI Electro-Optical Products division, Roanoke, Va., Charles Kuen Kao, has been called the father of fiber optics. It was Kao who, in 1966, then a research scientist at ITT's Standard Telecommunications Laboratories in England, speculated that if the losses were less than 20 decibels in fiber-optic waveguides they would find use in long-distance communications. He also projected that this would be possible by removing the impurities from glass. Even in 1968, though, fiber losses were as high as 10,000 dB/km.

The next big advance—really low-cost fibers in large production quantities—is taking place outside of the lab. Corning's recent announcement of step-index fibers with a loss of less than 10 dB and bandwidth capabilities of 20 megahertz in minimum lengths of 1 km at $1 per meter points out that both low cost and production capability in fibers is happening right now—just a decade after the idea."
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Circle 8 on reader service card

News update

The first leap of Reticon Corp. into the consumer-oriented market has made quite a splash, says John Rado, president of the Sunnyvale, Calif., company. Known for its image-sensing arrays and analog processing devices, Reticon about a year ago came out with a 1,024-bit n-mos bucket-brigade analog delay device priced at less than 1 cent per bit [Electronics, Aug. 21, 1975, p. 25]. The part, called SAD (serial analog delay) 1024, has been in volume production for nine months, says Rado. "SAD is very happy," he adds, noting that customers include organ manufacturers and companies involved in reverberation, speech compression, and music. For example, one application of SAD 1024 is in rock music—it makes one guitar sound like five. Now packaged in plastic, rather than the prototype ceramic, the device sells for less than $4 in quantities of 100,000 and up. Its dynamic range exceeds 75 decibels, bandwidth tops 100 kilohertz, sampling frequency is 1 to 2 megahertz, and harmonic distortion is less than 1%.

After three attempts to write a safety standard for test and measurement instruments [Electronics, Feb. 19, p. 8], Underwriters' Laboratories Inc. is going back to its well-worn drawing board once again. While few substantive changes are expected in the fourth version, UL has agreed with some industry comments that "safety should be an international concern and not just a national concern," says Don Mader, engineering group leader in the electrical department at UL's Melville, N.Y., office.

It's redrafting standard UL 1244 to conform where possible with the wording, margins, indexing, indenting, and type of printing used by the International Electrotechnical Commission in its document, IEC 348. A new schedule calls for members of a coordinating committee, consisting of representatives of industry and UL, to rewrite UL 1244. A final draft is due to the UL for industry comment in November.

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Electronics

Circle 9 on reader service card
Once there was an engineer named Digital Don who was into gates and flops and stuff like that. Don was... well... he was consistent.

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Editorial

Inaction: the hidden ‘dumping’ danger

Faced with a threat to their markets, U.S. consumer-electronics companies have every right to expect a speedy hearing of their complaints by the U.S. Government. Regardless of whether Japanese TV-set makers are actually “dumping” their goods below cost in the U.S., American manufacturers should not have to fight Washington bureaucracy, battle red tape, or wait an unreasonable length of time just to be heard. But it seems they have to, and by the time the Federal Government acts—if it ever does—it may be too late for the protection that the trade laws were designed to provide.

Take just a couple of current cases. Nearly two years ago, Zenith filed an antitrust suit against 31 Japanese TV manufacturers. To date, that action has not even reached trial.

Last month, GTE Sylvania and its subsidiary, Philco, filed a complaint with the International Trade Commission that 13 Japanese companies have conspired since 1966 to monopolize the U.S. color-TV market. But the Treasury Department, claiming exclusive jurisdiction over dumping charges, says the ITC can’t handle the complaint. The result: no hearing on the issues—let alone action—until the Government decides who should do the hearing. The Treasury department, by the way, ruled that the Japanese were dumping TV sets in 1971. That ruling, however, led to no significant relief for domestic manufacturers.

It’s time for the Treasury Department, since it claims exclusive jurisdiction, to back up its claims with actions. A decision, whether it finds merit in the complaints or not, would be a step toward clarifying the situation. Further, if the complaints are borne out, it should take strong, decisive steps to close the gates on imports that are damaging domestic production capacity.

Optical fibers turn the corner

Fiber-optics communications, it is becoming increasingly clear, has passed that crucial threshold that divides a promising technology from a practical one. The necessary materials and components—from low-loss glass fibers to field-installable connectors—are now available, and available from a variety of sources. A number of applications, in the United States, Europe, and Japan, have by now removed any doubts about the feasibility of transmitting large amounts of data down the narrow glass waveguides.

To be sure, one of the remaining obstacles in the way of fiber-optic communications is cost. Yet recent strides and current development work are rapidly bringing per-meter costs down within competing distance of coaxial cable, and in all probability another few years will see fibers, on a downward price curve, competing on a per-meter basis with copper cables, which will probably continue their upward price trend.

What’s left, then, before optical fibers are assured a fundamental place in communications is the establishment of methods for unified, coordinated accumulation and transfer of optical-fiber knowledge. Probably the surest sign that optical-fiber communications is here to stay is upsurge in work on promulgating standards, on arranging for interchanges of technical papers and documents, and on worrying about training tomorrow’s engineers in the basics of fiber optics.

Yet these projects are just beginning and, in the headlong rush to bring products to the marketplace, are sure to be given fairly low priorities. It would certainly be a refreshing change, though, if standards setting and the updating of education came hand-in-hand with the technological progress rather than years later.
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Electronics / August 5, 1976

Circle 13 on reader service card
People

Art Fury counts on FETs with power at Siliconix

If custom design is successfully nudged to the side by high-volume standard integrated circuits at Siliconix Inc. of Santa Clara, Calif., 39-year-old Art Fury will be doing much of the nudging. Manager since last month of the new central marketing group, Fury will concentrate on applying Siliconix's vertical-metal-oxide-semiconductor field-effect transistor process, which promises considerable inroads into the bipolar power-transistor market [Electronics, June 24, p. 98].

Siliconix, which last year had sales of $30 million, has been a supplier of conventional field-effect transistors, analog switches, and linear integrated circuits. About a year ago, president Richard Lee began moving the company into large-scale digital integrated circuits, digital stopwatches, and digital voltmeters. But the new FET process probably holds center stage.

"Until recently, all FET structures were limited to low-current applications, leaving the multimillion-dollar discrete power transistors that were developed over the past 20 years to be dominated by bipolar technology," Fury says. "We intend to change that."

Early standards. If anyone can bring Siliconix's vertical-MOS products into a position of dominance, it's Fury, who came to Siliconix after a year as marketing director for digital ICs at Fairchild Camera and Instrument Corp. Before that, as an advanced-product planner at Signetics Inc., he stage-managed the introduction of the phase-locked loop and the NE-555 timer, both now industry standards.

Later, at National Semiconductor Corp., he was responsible for the introduction of the LM324 and LM339 quad operational amplifiers and the LX 5600 solid-state temperature transducer, which became industry standards, as well.

"The same thing can be done with vertical MOS," Fury asserts. "It makes multi-ampere, high-voltage, high-power MOSFET devices possible, with electrical and speed advantages over comparably rated bipolar devices." An enormous market potential exists, not only in the replacement of bipolar transistors, he continues, but also in new applications that can't be handled by available devices.

"If we do everything right," says Fury, "MOS power FETs have the potential of doubling Siliconix sales in a very short time. I plan to make sure we do everything right."

Solid-state relays: Theta-J's Rodriguez wants low cost

A lot of adjectives — like confident, knowledgeable and determined — describe Edward T. Rodriguez, the new chairman and technical director of Theta-J Relays Inc. He's out to shake up the staid old relay business by using the latest circuit and assembly techniques common in the semiconductor industry in order to slash solid-state-relay prices (see p. 120).

Rodriguez is determined that Theta-J eventually will be the first company to sell solid-state relays at close to $1 instead of today's usual $15. And he's thoroughly convinced that his semiconductor background — 11 years in power semicon-
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People

Theta-J, in Reading, Mass., was founded only last year by Allan Q. Mowatt. Rodriguez, 39, came to the company only two months ago from his post as product manager for silicon controlled rectifiers, triacs, and power transistors at Unitrode Corp., Watertown, Mass.

Good base. “I’m the only guy in this business with a first-hand semiconductor background.” Rodriguez declares. “I was applying semiconductor-circuit and assembly techniques eight years ago that others in the relay business are reading about in books now.” He’s also been working on solid-state relays on his own because of his interest in them for several years.

“We have to stop thinking about these devices as relays,” he continues. “Theta-J is really in the power-transistor and triac business because our solid-state relays are nothing more, really, than a triac, an SCR, or a power transistor— along with a photocell—in a box.”

Rodriguez is looking for ways to make some of the circuit devices serve as the boxes. And he’s already done this with a 10-ampere relay by making the triac housing the base of the relay package [Electronics, July 22, p. 35]. Moreover, the relay sells for less than $3 in quantities of 10,000.

Proprietary developments. But Rodriguez’ emphasis on price reduction does not mean that Theta-J merely has a bargain-basement approach to the products it designs and builds. There are also proprietary and patentable photocell and zero-switching-circuit techniques in Theta-J’s product line. It’s just that he feels “price will be the big hurdle to overcome, and while that philosophy demeans your technology, you have to accept it and assemble these products in just one minute, instead of 15 minutes.”

At Theta-J, he foresees that pick-up in production speed being reached “in the near future” so that solid-state units can be priced at $1.25 in quantity. And that is sure to draw his competitors’ attention.
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Electronics/August 5, 1976
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Meetings


Seventh International Symposium on Acoustical Imaging and Holography, IEEE et al., Howard Johnson’s Hotel at O’Hare Airport, Schiller Park, Ill., Aug. 30 - Sept. 1.


Comicon 76 Fall, IEEE, Mayflower Hotel, Washington, D.C., Sept. 7 - 10.

Communication ’76, listed in last issue’s Meetings column as scheduled for Sept. 7 - 10, in Essen, West Germany, has been postponed. No new date has been set.


Electro Optics/Laser ’76 Conference and Exposition, Industrial & Scien-
HP's new thermal printer just keeps purring along.

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Meetings

- WESCON—Western Electronic Show and Convention, IEEE, Los Angeles Convention Center, Los Angeles, Sept. 14-17.
- 22nd Annual Holm Seminar on Electrical Contacts, Illinois Institute of Technology and IIT Research Institute, Pick-Congress Hotel, Chicago, Sept. 21-23.
- Semicon/East 76, Semiconductor Equipment and Materials Institute (Golden Gate Enterprises, Santa Clara, Calif.), Nassau Veterans' Memorial Coliseum, Uniondale, N.Y., Sept. 21-23.
- APL76—Putting APL to work, ACM, Skyline Hotel, Ottawa, Canada, Sept. 22-24.
- Quality Testing Show, American Society for Nondestructive Testing (Columbus, Ohio), Shamrock Hilton Hotel, Houston, Tex., Sept. 28-30.
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National hit by digital-watch production problems

National Semiconductor Corp., which recently straightened out production problems in its calculator product line, is taking another beating from its consumer product division. This time it’s digital watches. **The problems are of such magnitude** that, according to Charles E. Sporck, president, “it will be difficult to make up the losses during the fiscal year ending May 31, 1977.” Because of this, Sporck expects current quarter sales-operating rate to fall below the company’s fourth fiscal quarter ending May 31.

The problems are in two areas—watch module assembly, harmed by a four-week plant shutdown, at the Bangkok, Thailand facility, and more seriously, costly and still unresolved front-end yield problems with the company’s new watch-chip designs that are being readied for the next generation of low-cost watches. Although the company isn’t commenting, this new C-MOS single-chip design was being billed internally as National’s answer to Texas Instruments’ I^2L watch chips. Nevertheless, according to Scott Brown, director of marketing for consumer products, the division has enough production capacity on hand to meet all commitments through Christmas.

Pulsar sees solid, if not staggering, digital-watch sales . . .

Meanwhile, Time Computer is busy developing a microprocessor-based digital watch set for introduction in the coming year. “The key to the microprocessor watch is not that it is going to perform many more functions, although it can, but rather that it can perform virtually anything wanted, depending on how it’s programed,” says Bergey. A single microprocessor chip with appropriate inputs and outputs can provide multiple functions: calculation, an alarm, interval timing, or whatever is wanted. The Pulsar unit will use commercially-available microprocessors programed with custom software.

. . . and readies watch based on microprocessor

The 1976 worldwide market for solid-state digital watches will be 9.5 million units, less than half that predicted by some semiconductor houses, estimates John M. Bergey, president of Time Computer Inc. in Lancaster, Pa., which makes the Pulsar digital watch. U.S. sales of solid-state watches are expected to be 60% of the total, or about 7.6 million units, he says, noting that last year 3.5 million digital watches were sold worldwide. “The market will continue to expand rapidly,” and by 1980 worldwide digital watch sales will be about 53 million units, with U.S. sales representing 40% of the total, or about 21 million watches, he predicts.

Intercity buses are moving toward automated inspection

Harris Corp.’s PRD Electronics division in Syosset, N.Y., is working with Greyhound Corp., Chicago, to develop a computerized bus maintenance system that automates inspection procedure for engine, electrical, and air-conditioning systems. A prototype PRD-built microprocessor-controlled diagnostic unit and associated cable/sensor assemblies is being evaluated by Greyhound, which is gathering data on how the system detects and isolates faults. After a two month evaluation, a decision will be made on large-quantity purchases of the system, which PRD has tabbed BMS 1000.
Marines get OK for AV-8B Harrier development tests

The Marine Corps has cleared another hurdle in its push to acquire several hundred AV-8B Harrier vertical/short takeoff and landing fighters for its light-attack mission in the 1980s. Deputy Defense Secretary William Clements has approved the Navy's plan for a basic flight demonstration phase of the development program. The new plane, an improved version of the British AV-8A, would be produced jointly by McDonnell Douglas Corp., St. Louis, with developer Hawker Siddeley Aircraft Ltd. of the UK as principal subcontractor. With improved electronics, including an angular-rate bombing system, and other aerodynamic changes, the AV-8B is expected to nearly double the performance capabilities of the original model.

NASA's shuttle gets first solid-state power controllers

The first airborne solid-state power controllers have been delivered for NASA's space shuttle orbiter, being built by Rockwell International. Westinghouse Electric, which developed the controllers, says each of the 600 solid-state units can remotely switch power loads—as well as function as thermal circuit breakers and current limiters—with 10 times the reliability of their electromechanical predecessors, even though they are one-half their size and weight. By combining thick-film IC technology and hybrid, bare-chip packaging with mean power transistors for high-power ratings, Westinghouse says it has come up with six different dc controllers with ratings ranging from 3 to 20 amperes. The highest power units approximate a cube measuring 1.75 inches on a side and weigh 5.1 ounces.

LEDs to light up Ford vehicles

Watch for Ford Motor Co.'s first use of light-emitting diodes, but don't look on the instrument panel. Instead, the device—molded into a waterproof acrylic lens—is designed to throw a ring of amber light around the key locks on the driver and passenger doors as the exterior door handles are lifted. The system also turns on all the car's interior lights. The illuminated-entry feature is controlled by an integrated circuit, protected by discretes and mounted under the dash, that also turns off the lights after 25 seconds or when the ignition key is turned. The module is continually biased, but draws only a few milliamperes of current.

Data General makes its minicomputers another step larger

With its new Nova 3/D, Data General Corp. is stretching its 16-bit Nova 3 minicomputer line upward, topping the earlier 3/12 [Electronics, Oct. 16, 1975, p. 32] by including a 32-kiloword memory board and memory protection. The machine also allows users to run dual operations, such as a multiterminal data-entry program in the foreground and a remote job entry or local batch program in the background, without having the programs affect each other. The memory board, which measures 15 inches square, uses 144 of Data General's own 4-kilobit n-channel MOS chips, which have 700-nanosecond cycle times. At the same time, the Southboro, Mass., company is introducing its own line of terminal printers, including a 60-character-per-second unit.
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World Radio History
Copper tape set to carry IC chips

Motorola Semiconductor is counting on the copper to eliminate the contamination problems of film carriers.

After declining to use film carriers for its integrated-circuit chips since the automation technique was introduced commercially about four years ago, Motorola Semiconductor Products has come up with a new approach.

Instead of plastic film, the Motorola division is using “film” made from a thin sheet of copper. And in a Scottsdale, Ariz., plant, it is running a fully automated line for mass-bonding to the copper 14- and 16-lead complementary-metal-oxide-semiconductor and diode-transistor-logic IC chips. The chips on the copper tape are then bonded to lead frames for dual in-line packages.

To cut labor costs, makers and users of large volumes of integrated circuits may bond the chips to reels of film, then use automated equipment to handle the chips and bond them into packages [Electronics, Dec. 25, 1975, p. 61]. But the film carrier, which combines copper interconnects fastened to a film base, can cause problems: when sealed into an IC package, the organic film material can contaminate the chip and threaten its reliability.

However, the copper approach does have disadvantages. Chips cannot be tested on the copper tape, as they can on the plastic film, because the copper serves as a common link to all the chips. Also, the insulating film serves as a protective medium and support, whereas the copper tape needs an extra protective layer.

“We are aiming this approach at any high-volume IC chip line like TTL logic, as well as some of the popular linear operational amplifiers,” says John Carey, Motorola’s product-marketing engineer for saturated logic. “And we’ve received a lot of interest from hybrid manufacturers who want the chips on the copper tape. Any standard die can be accommodated.” Motorola is willing to supply the chips in this way, he says, but details of price and chip types have yet to be worked out.

However, the chips on the tape would sell for somewhere between the price of a finished plastic dual in-line package and a bare chip.

The Motorola etched strip assembly, or MEA, technique is the first all-copper tape carrier to be announced, but at least one other IC house, National Semiconductor Corp., is also working on one.

In the MEA process, the IC interconnect patterns are etched in the solid copper tape, and then pretested chips with built-up copper-pad protection bumps are gang-bonded to the tape. Next, a plastic layer is placed over the bonded chips, and the two layers of material are reeled up. The plastic simply protects the chips and the copper interconnect. To apply the chips, the tape is then fed to machinery that peels away the protective plastic layer and gang-bonds the outer leads of the IC patterns to lead frames. After this step, the frames are molded into DIPs, which are cut apart and tested.

Eliminating the chance of contamination by the plastic is important enough to Motorola for it to have delayed introducing film car-
riers for more than a year while the copper-tape assembly line has been proving itself, Carey says.

Medical

Respiration rate cues pacemaker

A cardiac pacemaker controlled by the wearer’s breathing rate has been developed at the University Clinics of Bonn, West Germany, and will soon undergo animal tests.

Together with a respiration sensor that’s located at the pleura of the lungs, the new device exploits the relationship between respiratory rate and heartbeat. And, within certain limits, the device adapts its operation to the patient’s physiological conditions.

A pacemaker keeps a sick heart going by supplying pulses to it at a fixed rate, typically around 70 pulses a minute. Most pacemakers furnish these pulses on demand—when the heart itself is too weak to beat. But, good as they are, these systems have a shortcoming: with a constant set frequency, they cannot satisfy the need for a faster heart beat when the patient is undergoing physical exertion.

This lack of variation has led Dr. Hermann D. Funke at Bonn University’s Surgical Clinic to develop the respiration-controlled, frequency-variable pacemaker. The device provides heart-stimulating pulses at a frequency that’s always about four times higher than the respiratory rate.

With this 4:1 proportion, the device operates between about 60 pulses a minute when the patient is breathing at the slow rate of 16 times a minute and at 146 pulses a minute when breathing is more than twice as fast.

Funke, 34, a surgeon as well as a life-long electronics hobbyist, designed the new pacemaker entirely on his own—he even put it together with a soldering iron. “Within the next six months, an electronics firm will miniaturize the unit and produce several implantable versions for trials on dogs,” he says. He won’t say when his pacemaker will be tried on humans. Moreover, he would like to add a “demand” capability for his pacemaker.

Ceramic sensor. For sensing respiration, Funke uses a piezoelectric ceramic transducer that picks up the pressure at the pleura, the serous membrane covering the lungs where pressure varies as a function of inhalation and exhalation. The sensor, shown in the photograph at the bottom of the page, is housed in a flat silicone-rubber package about 6 millimeters thick and 25 mm in diameter. Its output, a signal of 2 to 3 millivolts proportional to the respiratory rate, is applied to the pacemaker.

The signals first go to an impedance-converter/amplifier stage and then to a four-transistor monovibrator acting as a frequency-voltage converter.

At the vibrator output is a 1-microfarad capacitor that charges to a voltage level proportional to the respiratory rate. A pulse generator puts out a signal having a frequency that is proportional to the voltage across the capacitor. This signal is the output that serves to stimulate the heart.

Time lag. Designed into the pacemaker is a response lag of about 60 seconds. This, Funke explains, prevents abrupt changes in respiratory rate—changes that are often caused by coughing, for example—from affecting the pacemaker’s output.

By tailoring the resistor values and by designing the monovibrator with a certain switching time, the stimulation frequency is prevented from exceeding 146 pulses a minute. And a diode in the capacitor’s charge path insures that the frequency does not fall below 60 pulses a minute, the lower limit.

The pacemaker is powered by four mercury cells, each rated at 1.35 volts. The unit consumes about 3 microamperes in its quiescent, that is non-implanted, state. When implanted, and pulsing, it should require about 8 microamperes.

U.S. activities board releases game plan

A $1 million-plus proposal aimed at the professional and career concerns of its members has been completed by the Institute of Electrical and
comments from outside the institute.

"Being willing to stand up and take
time and energy to take them and the leadership. Mulligan
the institute and will even seek
complained of a gulf between them-
their reaction, is a prime objective of
understanding that their ideas will be
committees across the country. It
go for comment to all chairmen of
sections and professional activities
are the tasks that appear to lead the
into a more activist career role
than in the past. For example, under
the heading of professional status
improvement, the activities board
calls for "higher standards for gradu-
ation and entrance into the profes-
sion" as a means of enhancing the
electronic engineer's professional
image. There's also a plan to define
the role of engineering technologists
more narrowly, to reduce the tenden-
cy in industry to replace engineers
with less-well-prepared and lower-
paid technical-school graduates.

Nevertheless, the tasks stop short
of calling for the direct control of the
quality and quantity of engineering
graduates. And it presents an
approach to age discrimination
abuses that is without much in the
way of teeth.

The plan, under development
since January by the activities board,
whose members are also on the
IEEE's board of directors, now
goes for comment to all chairmen of
sections and professional activities
committees across the country. It
will also be printed this month in
Spectrum, the IEEE's publication.

As much feedback as possible
from members, no matter how harsh
their reaction, is a prime objective of
IEEE vice president of professional
activities and activities-board head,
James H. Mulligan, Jr.

"It's important for all members to
understand that their ideas will be
heard and considered," he says.

While IEEE has often claimed in
the past to be open to input from the
grass roots, many members have
complained of a gulf between them-
selves and the leadership. Mulligan
is not only aware of this feeling—he
maintains that he is not adverse to
ruffling the usually calm exterior of
the institute and will even seek
comments from outside the institute.
"Being willing to stand up and take
criticism is a start toward improved
communications," he says.

Mulligan expects the plan to be a
springboard into the 1977 program.
He also intends to modify the 30-
plus-page document on the basis of the
reactions he receives.

The five goals under which the
different tasks are grouped seek to
improve financial and economic ben-
efits for members (five tasks with a
budget for staff and research ex-
enses of $201,300); improve career
conditions and opportunities (eight
tasks and $158,900); improve profes-
sional status (three tasks and
$31,900); improve communication to
members of the activities board's
aims, activities and accomplishments
(four tasks and $114,100), and
improve relations with Government
"and other interfaces" (four tasks and
$225,800). Four other tasks bring the
total to $1.067 million, which, the IEEE says, will be
expended during 1976.

### Consumer

**I^2L for camera shutter relies on available light, needs no battery**

A camera circuit made of integrated
injection logic is being developed
that is sensitive enough to run off a
photocell and so is not a drain on the
battery conventional electronic cam-
eras must have.

The I^2L circuit, a light-to-frequency
converter, could be the heart of an
inexpensive timer for the camera
shutter. It has been built by a
supplier of custom integrated cir-

Kodak's Cranston connection

Micro Components Corp. is the former integrated-circuit operation of
Amperex, subsidiary of North American Philips. Officials at Amperex bought
the manufacturing facility in Cranston, R.I., and set up their own company
when Amperex made the decision to get out of the integrated-circuit
business four and a half years ago. This occurred during the business
downturn at that time, when Sylvania, General Electric, and Westinghouse
Electric also abandoned the commercial production of integrated circuits.
The new owners of the Amperex facility chose the new name and continued
to supply ICs to Eastman Kodak Co. for control of the Instamatic camera
shutter—business Amperex had won.

Alfred S. Budnick, president, says MCC's large-volume delivery on the
Instamatic contract was the clincher when Kodak sought suppliers of a
similar circuit for the recently introduced Instant unit, MCC, National Semi-
conductor Corp., Santa Clara, Calif., and Vactec Inc., Maryland Heights, Mo.,
also supply the circuit.

For the Instant camera, MCC puts the two chips—a photodiode and linear
IC—in an eight-pin clear-plastic miniature dual in-line package. The unit
performs four functions: It selects one of two possible apertures, depending
on ambient light levels, times the automatic shutter, and indicates low light
levels and low battery power.

Budnick says Micro Components has delivered millions of the circuits to
Kodak. And the numbers of delivered circuits jump to many more millions
when the circuits that the company has supplied for the Instamatic camera
are taken into account.
opened by a photodiode when it is struck by the incident light. This tiny current is enough to drive the converter to produce an output of 400 to 500 millivolts, peak to peak, at frequencies ranging from 100 hertz to 1 megahertz depending on the light intensity.

**Demo wafer.** So far, Micro Components, which claims to be the major supplier of integrated circuits for the Eastman Kodak Co.'s fast-development camera [Electronics, April 29, p. 31], has produced only a demonstration p-i wafer that includes the light-to-frequency converter, among other devices. But Andrew Durrette, vice president for engineering, is confident that an integrated injection logic IC using the technique can be produced and sold for from 50 cents to $2, compared to between $2 and $5 for a more conventional approach.

The converter circuitry on the demonstration wafer includes a photodiode detector that drives a seven-stage ring oscillator built with p-i transistors functioning as inverter gates.

**Current control.** The ring oscillator is current-controlled. Durrette explains that a voltage-controlled oscillator, the more conventional device when it comes to converting current to frequency, is harder to build in p-i.

The seven-stage unit oscillates at a frequency directly proportional to the light level; if the light input to the photodiode is doubled, the diode's current output doubles, and so does the output frequency. The oscillator includes a buffer amplifier whose output can drive a load—a field-effect transistor or some other high input-impedance device.

**More to be added.** When the light-to-frequency converter, which measures only 12 by 36 mils, goes beyond the demonstration stage, FL counting circuitry will be added to complete a device needed to control the camera's shutter timing. The whole circuit will then be put into its own monolithic chip in the type of transfer-molded clear plastic package used for the circuit supplied by Micro Components to Kodak.

The complete controller for the camera will still need battery power for operating the shutter, but Micro Components points out that its IC approach will substantially reduce the power required, boosting battery life.

Charles Grandmason, the company's vice president for marketing, says a circuit made with a more conventional approach but in other respects comparable to the FL light-to-frequency converter requires—in addition to a battery or power supply—the photodetector, voltage-controlled oscillator, digital-to-analog converter, a counter, operational amplifier, and a gate. Micro Components does it simply with the photodiode, ring oscillator, output buffer, and counting circuitry.

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Zenith appears to be only set maker to adopt new color tube for TV line

Despite mixed reactions from other television-set manufacturers, Zenith Radio Corp. intends to go it alone if need be in using its new 19-inch Able color-picture tube in TV sets. And the first sets to use the tube are entering production.

The other set makers, though impressed with the tube's tri-potential gun and in-line, self-convergent design [Electronics, March 18, p. 39], are unsure about shifting to the tube's 100° deflection angle from the conventional 90°. They disapprove of the tube's larger glass shell and its shadow mask, which were developed jointly by Zenith and Corning Glass Works. They also question whether they'll realize the savings that Zenith claims the new tube's automated production makes possible. But Zenith isn't worrying.

**Another first.** Says Karl H. Horn, Zenith's senior vice president for engineering and research in Chicago: "Our objective in the three major areas—gun, deflection angle and glass—was always to improve the product and reduce costs for our own product line. Previously Zenith was the first with the Chromacolor negative-guard-band tube, and the rest of the industry went along with it. The same will be true with this tube."

Regarding a tri-potential gun for large-screen tubes, there's little question that the industry will come around to Zenith's approach. (In-line, self-convergent tubes are already found in small-screen receivers.)

Almost everyone who has evaluated the tube has praised its improved picture resolution. The three distinct potentials produce extended-electron-field lenses that create a smaller spot on the screen. Indeed, both GTE-Sylvania and RCA's Picture Tube division have announced plans to build in-line color tubes with tri-potential guns. And set makers like Magnavox Corp., Admiral Group of Rockwell International and Quasar Electronics Corp. agree the picture improvement warrants a shift away from the present delta-configuration bi-potential guns for large-screen sets.

General Electric's Television Business department, however, has rejected the Zenith tube. According to Fred Welner, general manager of the department, a three-month technical and cost analysis led GE to conclude there was no improvement in perceived picture quality.

But it may be a couple of months yet before it's clear how the industry will go in using the 100° deflection angle offered by Zenith. Horn argues that 100° is an optimum tradeoff between the 90° used in the U.S. and the 110° used in Europe for reduction in spot size (12.5% smaller compared to 90°), power consumption, and distortion at the edges.

**Not too different.** RCA's J. J. Brander, vice president of television engineering for the Consumer Electronics division in Indianapolis, disagrees: "90° and 100° deflection tubes are not different enough to make the change. What you gain in some performance specifications, you lose in the increased tempera-
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ture of the chassis, increased cost of components to protect solid-state devices from higher tube voltage, and increased power demand.”

But if the choice depended on the glass alone, Zenith would have a lemon on its hands. Nary an encouraging word can be found in the industry for the tube envelope. In Japan tube makers have been cautious, but have tended to side with U.S. firms regarding the glass.

Comments Richard Kraft, vice president of engineering for Quasar Electronics Corp., Chicago: “I feel that the tv industry will reject the new glass simply because we don’t see the cost reductions. The mechanical tolerances on the new glass are not as tight as for standard glass, so if we were to relax the tolerances on standard glass to the same degree, the same cost savings could be had. In addition, the new tube has over an inch larger face plate on the 19-in. set, and some cabinet tooling would have to be changed to accommodate the tube.”

Horn responds that Zenith has not had to retool to fit the Able tube into its cabinets. “In two to three years you will see the assessment of the industry. Competitors say we’ve goofed, and maybe they’re right. But we will take odds we’re right.”

**Military**

**Avionics for CP-140 to top $200 million**

By combining the advanced avionics of its carrier-based S-3A Viking submarine hunter with its long-range P-3 Orion airframe, Lockheed-California Co. has come up with a $697 million 18-plane package for Canada.

Lockheed-California vice president R.R. Heppe says “it’s the largest single export sale” in the company’s history. And Canada’s order for 18 of the new planes, designated the CP-140, will provide more than $200 million in avionics business for U.S. and Canadian avionics and ground system suppliers.

But Lockheed is not out of the woods yet, despite its success in working out an agreement with Canada for 1980-1981 delivery of the new planes. “We still must negotiate subcontracts for the avionics,” says CP-140 deputy program manager Phil Sullivan. However, some of the S-3A avionics and sensor makers may complete production and shut down lines before Lockheed will be ready to install the subsystems. So the subcontractors may be asked to restart lines or “build the equipment and hold it for us,” says Sullivan.

Three suppliers of CP-140 electronics hardware have already been named. Biggest of these is Litton Systems Ltd., which will provide two ground systems known as DIAC—data interpretation analysis centers—used to analyze and support CP-140 missions. Along with a ground-support computer complex from Sperry Univac, the price tag for these systems is put at $35 million. General Dynamics Corp. will build the ground-support system known as HAIS—hybrid automatic test set—which Sullivan says could cost less than $10 million.

**Canada’s share.** Litton’s subsidiary is also among the Canadian suppliers who will displace U.S. vendors for on-board systems. Under the contract’s provisions, Canadian companies get nearly $415 million in business from the program. Litton will provide the LN-33 inertial guidance, and Canadian Marconi, the Doppler navigation system. Singer Kearfott has been the U.S. supplier of both these systems. Similarly, CML Electronics Ltd. will displace Texas Instruments as supplier of the AN/ASG-50I magnetic-anomaly-detection system used on the P-3.

But all is not lost for TI. It will provide the AN/APS-116 radar that’s on the S-3A as well as the forward-looking infrared system. Other S-3A equipment to be used include Sperry-Univac’s AN/AK-10 computer, Lear Siegler’s automatic flight-control system, and IBM’s AN/ALR-47 electronic countermeasures system, used in conjunction with Sanders Associates’ OL-82 acoustic data processor.

Cubic Corp. will provide the AN/ARS-2 sonobuoy reference and positioning system used on the P-3C, while Rockwell’s Collins Radio Co. will continue as supplier of radios, the AN/ARC-153 and the AN/ARC-156 systems. Similarly, Loral Electronics will supply the cathode-ray-tube displays.

**B-1 ECM gear begins tests**

While advanced-procurement funds for production of the Air Force B-1 bomber are still under fire in Congress, development of the controversial system’s avionics continues. The Senate recently postponed
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News briefs

FCC sends Bell back to 900-MHz drawing board
The changes proposed by Illinois Bell Telephone Co. in its $23.5 million plan to develop a 900-megahertz cellular land-mobile communications system have made the Federal Communications Commission decide to reject the entire plan unless the company provides additional technical, operational, and financial data. In its first technical proposal on the system [Electronics, Jan. 3, 1972, p. 100], American Telephone & Telegraph Co. and its Illinois affiliate proposed a system made up of hexagonal cells for the Chicago metropolitan area; each cell was to have had a four-mile radius and three directional antennas at alternate corners, enabling frequency reuse at distances of about 18 miles. The FCC says Illinois Bell now proposes to substitute eight-mile cells with a taller omnidirectional antenna at each cell center, limiting frequency reuse to two of the proposed 10 cells every 48 miles.

Moreover, the FCC says channel separation has been reduced to 30 kilohertz from the 40 kHz originally planned. And the 11.88 megahertz of spectrum spread over 21 MHz conflicts with the FCC’s earlier authorization of no more than 12.5 MHz in two contiguous blocks of 6.25 MHz each for the development system’s base stations and mobile units.

The FCC also charges that Illinois Bell has failed to give adequate detail about its proposed $23.5 million cost figures. The company has 60 days from the July 20 decision to decide whether it will amend its application with additional data, or apply for a limited developmental cellular system for technical testing purposes. The FCC made clear it is still interested in seeing a test of “the sophisticated, small-cell configuration envisioned” earlier.

NEC, Intel join in cross-licensing agreement
The initial result of a worldwide royalty-free patent cross-licensing agreement between Nippon Electric Co. Ltd. of Japan and Intel Corp. will be compatibility between the two companies’ microprocessor products. The agreement covers all semiconductors, but both companies are strong in microprocessors and memory devices. In fact, NEC Microcomputers Inc., Nippon’s Bedford, Mass., subsidiary, is at present aggressively marketing LSI memory products and an 8080A microprocessor line in the U.S.

Cambridge Memories ceases operations
Hit by a cash shortage when lending banks demanded repayment of $16 million in loans, Cambridge Memories Inc., Bedford, Mass., has suspended all operations. The manufacturer of IBM-compatible add-on memories has furloughed 350 persons.

until February expenditure of $1.05 billion for the first three production models and other advanced items when a new Administration will occupy the White House, but the move may be defeated in the House. Nevertheless, system suppliers remain optimistic and are pursuing their development programs hard.

One such contractor, Cutler-Hammer, Inc.’s Air division, Deer Park, N.Y., has begun test and evaluation of its $57 million effort on a radio frequency surveillance/electronic countermeasures system for the Rockwell International aircraft. Air’s technology developed for USAF’s Aeronautical Systems division is looking far beyond the present political hassle.

“We are preparing for the year 2,000 by designing a system with the flexibility to change parameters via software, as new threats come on the scene,” says Michael J. Philbin, Air’s B-1 program manager.

The defensive system, which had to be designed from the ground up to achieve such programmability, will detect the electromagnetic environment in which the B-1 flies, categorize the detected signals, establish the degree of danger that the signals represent to the aircraft, and deter-
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For Intellect 8/Mod 80

iCOM's FD360-51 gives you a plug-in interface which connects to a standard Intel imm 8-61 i/o card. Powerful FDOS-II software is included. Only 8K of RAM is required. Hundreds of Intellect-8 users rely on iCOM floppy disk systems to speed their 8080 development. Complete cost for a dual drive system is just $3000.

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mine the jamming action to be taken. And then, it automatically controls the jamming. "It's a totally new concept and approach," declares Hans Peot, chief of the Air Force's B-1 Avionics division at Wright-Patterson Air Force Base in Ohio. With present countermeasures systems, Peot notes, a change in threat dictates a change in both hardware and software.

**Brand new.** The **A**ll system has about 70 black boxes of nearly 35 different types. Philbin claims it "is really the only brand-new integrated avionics subsystem on the B-1 aircraft."

However, the boxes are spread all over the aircraft because the defensive system is a Johnny-come-lately. "The offensive system was already located by the time we got started on the program," explains **A**ll's 42-year-old program manager. "Whenever we found a nook and cranny, we put a black box."

**A**ll is using microprocessors to process a lot of data that must be handled quickly, such as categorizing detected signals as friend or foe. The devices for doing this are high-reliability versions of commercially available microprocessors in three line-replaceable units. "The microprocessor-based **R**I**S** allow us to use a general-purpose computer as simple as Litton's LC-4516D [16-bit, 32-kiloword central processing unit] to do some of the slower routine functions," says Philbin.

In June **A**ll's effort was expanded with an additional $2.1 million for "closed-loop" testing of the system. Its purpose is to ensure compatibility among the various emitters and receivers before it all is placed aboard an operational craft.

The tests are also to give the service the option of moving up the defensive system's production schedule to avoid retrofitting the systems to B-1s that precede it off the assembly line.

**Hot mockup.** The countermeasures system will be tested on a hot mock-up of an operational B-1 at a facility at Edwards **A**ir Force Base in California. Threats will be simulated from a tower, and isolation will be measured to determine if the system's transmit and receive antennas are interfering with other systems. "If they are, we will then come up with some blanking techniques so that we don't jam ourselves," says Peot.

Regarding income from the system, "**A**ll could realize $1 billion in sales spread over eight to 10 years," says Philbin. As currently planned, this would include defensive systems for more than 240 B-1s, spares, manuals, and ground equipment that the firm expects to develop and build in-house. About 30% of **A**ll's funding would go to its three principal subcontractors: Litton Industries for the central computer, Northrop Corp. for terminal-threat antennas operating at classified frequencies, and Sedco Systems Inc. for phased-array transmitter antennas.

**Problems slight on Viking mission**

So far, the problems that plague any unmanned space mission have proved to be small and easily corrected for the Viking I spacecraft. Now sitting on the surface of Mars, 213 million miles from earth, the craft is busily transmitting television pictures, both in color and black and white, after orbiting the planet for an extra 16 days (until July 20), looking for a smooth place to land.

Potentially, the most serious trouble was a steel pin that jammed its all-important mechanical arm that is to scoop up samples of Martian earth for lander instruments to analyze. This pin, which should have dropped free when the arm was extended from the craft, instead hung in the undercarriage that supports the arm and shovel-like soil-collector head.

Engineers at both Jet Propulsion Laboratories, which is running the project from Pasadena, Calif., and Martin-Marietta Corp.'s Aerospace division in Denver, ran a series of tests on full-scale models that spotted the problem. To correct it, JPL sent a series of new commands to extend the arm farther, or about 14
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Now, with the launch of the second Marisat, the new maritime communications satellite system blankets the sea lanes in a 120-million-square-mile area of the Atlantic and Pacific. For the first time, ships can communicate clearly and without interruption with other ships and with shore bases. The two Marisat spacecraft -- built by Hughes for COMSAT General Corporation -- are relaying high-quality voice, telex, facsimile, and data transmission. Vessels flying the flags of 10 nations already are equipped for satellite communications. The U.S. Navy also is leasing a substantial portion of Marisat's capacity for its fleet communications needs.

Men at sea have depended in the past primarily on international Morse code and radio telephony that often was disrupted and delayed by adverse weather conditions, signal fading, or crowded frequency channels. The Marisat system has eliminated these delays.

Marisat earth stations in Connecticut and California, interconnected with terrestrial networks and linked by 24-hour voice and data lines to COMSAT General's Washington, D.C., control center, complete the Marisat satellite system.

Digital watch modules with three new features have been introduced by Hughes. One is both a regular watch and a stopwatch (or chronograph) which measures to 1/100th second. Another module, in addition to the usual time and date readout, displays a pre-programmed message of up to four five-letter words. Custom modules with special commercial messages or slogans are available.

A wrist watch that's also a nine-function calculator is the third new type in the Hughes line. The solid-state electronic module, which measures only 1.4 by 1.25 inches, features an eight-digit LED display for both calculator and watch functions. The keys of its standard calculator keyboard can be pressed with a pencil point. Hughes does not market a watch to consumers, but is the largest producer of modules for watch manufacturers.

Hughes needs systems-level engineers: Sonar Systems -- design and develop surface and subsurface ASW tactical and surveillance sonar systems for Undersea Systems Laboratory....Special Projects -- engineering analysis of foreign air defense communications, command and control systems. Evaluation of C3 networks and system performance evaluation. Requirements: BS or higher degree, U.S. citizenship. Please send resume to: Engineering Employment, Hughes Aircraft Company, P.O. Box 3310, Fullerton, CA 92634. An equal opportunity employer.

The location of enemy artillery can be pinpointed in seconds with the U.S. Army's new AN/TPQ-37 artillery locating radar. Its three-dimensional antenna scans the horizons with a pencil-shaped beam which moves so fast it forms an electronic barrier that can detect incoming projectiles as they rise above the horizon. These are tracked and their trajectories are back-plotted to locate the firing weapons, often before the first shell hits the ground. A contract for further development and for limited production of 10 ALRs has been awarded to Hughes.

The ALR can be deployed quickly and set up in 30 minutes. It has two main units: an antenna trailer towed by a 5-ton truck which carries the transmitter, receiver, and generator, and an operations unit housed in a standard S-280 shelter mounted on a 2½-ton truck. The shelter has room for two operators and a supervisor, although one man can do the job if necessary.
Electronics review

inches, and the pin fell to the Martian surface. Viking's television cameras later showed the pin.

Low power. Another problem caused the lander's ultrahigh-frequency transmitter, which sends TV signals to the Mars orbiter for subsequent retransmission to earth to transmit with only 1 watt of power instead of the planned 30 watts. Because of this weakness, it took longer for the orbiter to acquire the signal, cutting the total time available for transmitting to earth. But after about three days, the transmitter began to correct itself. JPL engineers say this is evidently another "one of those anomalies" that happen in space.

The last of the "glitches" bothering the Viking craft, still uncorrected as of last week, is an inoperative seismometer. A locking mechanism that caged the instrument during the 11-month space journey and landing, refused to let go, even after repeated commands from flight directors at JPL. Some engineers speculate that the defect was caused by a wiring or electrical failure.

Careers

EEs wanted: $50 reward

As demand in semiconductors and minicomputers picks up, so does the demand for experienced engineers and programmers. But they're in short supply wherever their would-be employers are heavily concentrated—Silicon Valley and Orange County in California, as well as Boston.

As an incentive, several manufacturers have begun offering bounties to employees who bring in these scarce people. Among them, Fairchild Camera & Instrument Corp. is giving its employees "Fairchild Needs You" T-shirts and buttons to wear and is promising them clocks, digital watches and electronic games, in addition to a $50 cash award for each engineer hired.

Doug Cooper, director of corporate staffing at the Mountain View, Calif. firm, says the company is looking for 100 engineers because of a "general upturn in business." Design and process engineers are needed, as well as those experienced in bipolar, MOS and linear technologies. Warns Cooper: "We are going to see a critical shortage of experienced engineers in the industry."

Similarly, Bob Lo Presto, industrial relations vice president at American Microsystems Inc. in Santa Clara, Calif., says, "The industry is turning on again, and there aren't enough experienced people to go around." AMI is looking for 35 to 40 wafer-fabrication, MOS, design, production and other types of engineers and is "having to recruit in other areas" of the U.S.—as in fact is Fairchild. "It's hard to get a person from down the street to come here," without offering higher salaries, notes Lo Presto. Consequently, AMI has decided to reward employees with $100 per referral next month and $50 thereafter.

Further south in Orange County, General Automation Inc. in Anaheim is offering employees $100 per computer programer brought in, with emphasis on those with solid experience in industrial automation and systems work.

Meanwhile, Data General Corp. in Southboro, Mass, is finding it "a tight market" for people who are knowledgeable in the advanced state of the art. These are either coming out of school and in great demand or getting on-the-job experience and thus already employed, notes a Data General spokesman. However, Digital Equipment Corp. in Maynard, Mass., although also hiring, is encountering no problems in finding specialists in data communications input/output systems, computer-aided design, microprogrammed-logic design, and memory-test-equipment design, as well as assorted programmers.

Still other sectors with a heavy grouping of aerospace electronics firms seemingly are faced with an oversupply of engineers, though some hiring continues of highly experienced engineers in specific disciplines.

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![Figure 1](image_url)

**FIGURE 1** Typical High Temperature Reverse Bias Characteristics Vs. Time

The graph shows the typical high temperature reverse bias characteristics against time for a given condition (Vcb = 400 Volts, TC = 150°C).
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<td>Temperature Range:</td>
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The long-awaited expansion of class D citizens’ radio service from 23 to 40 channels, effective Jan. 1, 1977, left CB radio makers with multiple questions for the Federal Communications Commission. The FCC says it expects that industry queries on type-acceptance requirements, occupied bandwidth and modulation, and test-procedure rules will be answered in a bulletin to be issued not later than mid-August by the Office of Chief Engineer, headed by Raymond Spence.

On the marketing side, industry officials privately concede there probably will be significant discounting of unsold 23-channel transceivers. Stressing that its ruling is only an interim measure, the FCC says its Office of Plans and Policy and the Personal Use Radio Advisory Committee is still considering alternative spectrums at 220 and 900 megahertz for CB use. Manufacturers and the Electronic Industries Association are pushing for an additional Class E service in the 220-MHz region, while the National Association of Broadcasters opposes any expansion—including the present one—on grounds that it interferes with TV signals.

New 40-channel CB transceivers, the FCC has ruled, must raise harmonic radiation suppression to 60 decibels from the present level of 49 dB to cope with TV interference. “Should additional suppression be shown necessary,” the FCC ruling adds, licensees will “be required to insert low-pass filters on their transmitters.” The new channels will be between 27.235 and 27.405 kilohertz, the FCC says, with the 10-kHz spacing between channels unchanged from the present service. Similarly, all channels will be available for shared a-m/single side-band use, despite manufacturers’ requests for allocation of several new channels for SSB use only.

The FCC also has ordered that receivers made after Jan. 1, 1978, must limit spurious rf energy at the antenna terminals to 0.2 nanowatt, and hold chassis radiation to 15 microvolts per meter at a distance of 1 meter from the receiver. Manufacturers complain that the 0.2-nW limit is unnecessarily severe and the chassis-radiation measurement will be difficult to achieve. The FCC says that the rigid requirements are necessary to prevent interference with land-mobile telephone systems that are also used on highways. Sets made after Jan. 1, 1977, however, will only be required to meet limits of 2 nW at the antenna, and 5 μV/m radiation measured 3 m from the chassis.

Other requirements laid down by FCC: deletion of 27.085 MHz as a calling-only channel, inclusion of Part 95 of FCC rules and forms 505 and 55-B with each new transmitter sold, prohibition of the use of add-on devices to increase the range of existing transmitters, and the engraving of a serial number in each CB chassis to aid in identifying stolen equipment.

Addenda

Watch for Aeronutronic Ford to be named winner in the competition with TRW for the Intelsat V, the International Telecommunications Satellite Organization’s next generation of communications satellites . . . National Science Foundation director Guyford Stever has been nominated by President Ford, as expected, to head the new Office of Science and Technology Policy, which replaces the science advisor’s office eliminated under President Nixon.
Washington commentary

Color-TV imports: confusing jurisdiction with justice

Reformation of the Federal bureaucratic system promises to become a major issue in the 1976 national election. It should be. The bureaucracy is fat, inefficient, and represents an enormous drain on Federal funds that could be spent more productively elsewhere.

In addition, the existing bureaucracy produces unbelievable delays in the administration of justice for taxpayers while agencies wrangle over jurisdictional issues. One of the most recent examples involves the pending charges, brought before the International Trade Commission by GTE Sylvania and its Philco subsidiary, that color-television receivers are being dumped on the American market by Japanese manufacturers acting in conspiracy [Electronics, July 22, p. 42]. Consideration of the issues is hanging fire while the ITC and the Treasury department try to resolve who's in charge.

The ITC-Treasury flap is characteristic of the bureaucracy’s confusion of jurisdictional issues and the job of dispensing justice. In this case it is America’s color-television producers who are the losers. They are no longer amused by the line that Washington’s bureaucrats refuse to look out the window when they get up in the morning because it would leave them with nothing to do when they get to the office.

Color television is the last major home-entertainment electronics market where domestic production is still a significant factor. But the number of manufacturers is steadily declining. Before makers of monochrome sets either shut down or moved offshore, the U.S. had 28 TV manufacturers of all types in 1960. By 1969 that number had halved. Last year it was down to 10, and three of these are foreign-owned. And most of these 10 are increasing their investments in offshore color production facilities.

It is time for Treasury to realize that domestic color-TV production is ready to flee America just like monochrome TV, home and auto radios, and high-fidelity components. Certainly it has the data in its own files to document those losses to the domestic economy.

If Treasury Secretary William Simon believes the policy of the Ford Administration is to maintain good relations with Japan at the expense of one more segment of American industry, then he should say so. If not, Simon should notify his staff that they should stop busying themselves with time-consuming jurisdictional disputes that do no more than protect their own jobs. Their first priority must be to get on with the work of adjudicating swiftly the issues raised by the taxpayers who pay them.

Jedec: a new approach to microelectronics standards

Since its formation in 1958, the Joint Electron Device Engineering Council has worked successfully with the components manufacturers that make up its membership to register more than 15,000 discrete semiconductor devices. But about a decade ago when Jedec, a joint effort of the Electronic Industries Association and the National Electrical Manufacturers Association, moved to develop standards for integrated circuits, manufacturers stayed away in droves.

Happily, there are signs that is changing. One Jedec committee has developed a standard for B-series complementary metal-oxide semiconductors. From C-MOS the council proceeded to develop a flexible, two-level approach for microelectronics that permits manufacturers to list devices with Jedec using a 12-digit code and data from their own house numbering systems. Optionally, a manufacturer can also register devices to a precisely defined industry standard.

Now Jedec faces an even greater challenge as it tries to make 16,384-bit random-access memories functionally interchangeable. That effort gets under way on Aug. 10 at Santa Clara, Calif., with the meeting of eight major manufacturers at the Marriott Hotel. It won’t be an easy task for American Microsystems Inc.’s Joseph McDowell, who chairs Jedec’s JC-42 committee on integrated-circuit memories. But the list of registrants is impressive. In addition to AMI, they include Advanced Micro Devices, Fairchild Camera, Intel, Mos-tek, Motorola, National Semiconductor, and Texas Instruments. “Assuming we all don’t get into a fist fight,” McDowell laughs, there will be other meetings of JC 42 downstream.

Why the change? Customer pressure is part of it, says Jedec staffer Jack Hessman. And Jedec is taking a more flexible approach to the problems of standards—one that it likes to call “harmonization of specifications.” That European expression may prove too big a mouthful for Americans to swallow, yet it represents a significant advance toward the development of interchangeable and less costly parts that can only contribute to the further expansion of electronics into new markets. —Ray Connolly
They stay out front with Motorola's M6800 Family

TRW
Programmable terminals in TRW's new 2001 POS system allow each store its own unique personality. They're interactive. They lead operators step-by-step through transactions, authorize credit, compute difficult calculations, and give customer receipts with word descriptions. They also provide information for management reports. The 2001 POS system relies on Motorola's M6800.

HEWLETT-PACKARD
Improvement in analog parameter measurement of voice bandwidth data circuits is the object of Hewlett-Packard's 4942A Transmission Impairment Measuring Set. It has automatic self-check, master/slave control, automatic system capability, and it's portable. Microprocessing gave the system minimum power consumption and size. M6800 gave it the required analog hardware interface and desired master/slave control.

RUSCO
Rusco Electronic Systems' CARDENTRY 500 is far more than just a site-access security system for more than 20,000 separate identities. It's programmable, so lost cards are ruled out at the touch of a button. It also monitors alarm systems, reports personnel in—out status, automatically locks and unlocks locations, manages copy machine usage, and more. Microprocessing is by the M6800 Family.

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Matsushita's MOS image sensor cancels spurious signals to optimize pictures

The matrix-type MOS image sensor is likely to be popularized as the result of a modification of this area device to cancel spurious signal components. Without these spurious signals, its video signals faithfully reproduce the original images. The device, developed by Matsushita Electronic Corp. in Japan, cleans up the picture because it is built in a line-correlation configuration.

The device, similar to sensors built by others, is available with a matrix of 64 by 64 elements on a chip 5 millimeters square. A larger device, tentatively planned to have 250 by 250 elements, is also being developed by the company, which is jointly owned by Matsushita Electric Industrial Co. and Philips Gloeilampenfabrieken of the Netherlands. That chip will probably be 10 mm square. The number of elements and resolution are at present limited by practical chip size and cost.

Canceling. Matsushita engineers say their device has a true signal-to-noise ratio of 40 decibels or more because it substantially eliminates two spurious signals that tend to plague these image sensors—the pseudo-image signal and dark current, which corresponds to the drain current when the device is not lit.

The sensor is free of blooming, which company engineers say is a grave disadvantage of competitive sensors made of charge-coupled devices. The blue response is also superior to that of CCDs, most of which are covered with a thick layer of polysilicon that somewhat degrades blue response.

Drive and peripheral circuits are simple. What's more, the 64-by-64 bit device with low-power shift registers for scanning dissipates only 15 milliwatts, which minimizes temperature, thereby keeping the drain-leakage current low.

Matsushita sources say that CCDs often require eight mask-alignment operations, which makes for low yield, while MOS devices require only five or six alignments. The one disadvantage of MOS devices is the relatively large area per element.

Scanning. Basically, the sources of the p-channel MOS transistor elements making up the matrix behave as photodiodes. All the elements in a single horizontal row are selected by a signal applied to the gates of all the elements in that row. To select an individual element in a row, a signal is applied to the gate of a MOS switch inserted in the line connecting the drains of the elements in the column and the sense amplifier. In the horizontal scan, the MOS switches are selected in order. In the vertical scan, the rows are selected in order.

To cancel spurious signal components, the configuration was modified by connecting alternate elements in each column to two separate output lines and connecting each pair of output lines to two MOS switching transistors. One transistor is connected to the inverting input of an operational amplifier, and the other to the noninverting input.

Around the world

Satellite terminal built for remote areas

West Germany's Siemens AG is offering an inexpensive mobile ground terminal that can be installed in remote areas to pick up signals from communications satellites. The terminal accommodates both color and monochrome television transmissions, as well as radio. Only 4.5 meters in diameter, the terminal's antenna is small enough for easy transport to remote locations. Since the antenna dish comes in four sections, the whole station can be moved by truck or plane almost anywhere. The 500-kilogram terminal can be installed in hours, and its wide beam enables the antenna to do without a tracking system.

The terminal, developed with the support of West Germany's Ministry for Research and Technology, is intended primarily for reception of radio and TV programs via the two Symphonie Franco-German experimental communications satellites. The first terminal is already being tested near Kigali, capital of the central African republic of Rwanda.

The antenna system consists of a far-field cassegrain antenna with the main reflector 4.5 meters in diameter and a hyperbolic subreflector 61 centimeters in diameter. The antenna-feed system is a corrugated horn offering optimum symmetry and broadband characteristics that allow it to be operated simultaneously in the 4-gigahertz reception band and the 6-GHz transmission band.

Visual device enables mutes to communicate

An electronic means of visual communications for people incapable of speech is being produced and marketed by Diode B.V., a subsidiary of International Rectifier Corp. in Utrecht, the Netherlands. The portable battery-operated system, the Elkom 2, has a small display to show typed text and a keyboard containing 40 keys.

The speaker and listener sit opposite one another so that the single nine-character display is simultaneously visible to both by means of a triangular Plexiglass prism over the screen. As the keys are pressed, characters are projected onto the display, which shows enough of most words for readability as the letters shift from right to left. The 5-by-7-dot display, made up of light-emitting diodes, operates at the rate of 50 cycles per second; illumination time is 2.4 milliseconds. The device contains a standard 2,048-bit memory.
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Monolithic Memories

54 Circle 54 on reader service card
Electronics/August 5, 1976
Microwave link to span 83 miles from West Berlin

AEG-Telefunken has won a contract from the West German Post Office to build a line-of-sight microwave link to hop the 83 miles between West Berlin and Gartow, on the West German border. The link, to be operational by mid-1979, necessitates towers as high as 340 meters—40 meters higher than the Eiffel Tower—to clear the earth's curvature without repeaters. For political reasons, repeaters won't be installed in the intervening East German territory. Since World War II, tropospheric scattering techniques at super-high frequency has been the sole means of microwave communications between West Berlin and West Germany.

BBC research makes blemish remover for CCD TV cameras

Although semiconductor makers must solve many problems with charge-coupled-device imaging arrays before they can produce a color-television camera of studio quality, the British Broadcasting Corp. research department already has wiped out one problem. The researchers have rid pictures of white spots caused by mysterious dark currents in individual CCD cells. The solution: log the location of misbehaving cells into an electrically erasable read-only memory so that interpolation circuitry can block out the failed cell's output. To get the picture value, the cell's output is interpolated from the two adjoining ones. Although it is not perfect—it cannot handle a cluster of failed cells—ROMs could be built into CCD arrays so that each array could be corrected for life.

Brightness doubled in Hitachi TV set by mask focusing

A color-television tube nearly twice as bright as its predecessors will appear in sets marketed late this year or early next year by Hitachi Ltd. The brightness gain, which comes from pushing almost double the usual number of electrons through the tube's shadow mask to the phosphor-dot screen, is achieved by applying a voltage difference between the mask and screen. What's more, a high 24-kilovolt potential on the electron guns, which have two unipotential focus main lenses in cascade, makes possible excellent focusing with the three guns arranged in the 29-millimeter neck. A lower 12-kV potential on the shadow mask still provides enough scan magnification so that the tube, which has a 110° deflection angle, can be scanned with about the same power as a conventional 100° tube.

IBM expects OK for switched net throughout France

IBM France expects the Postes et Télécommunications agency to allow it to establish a countrywide transit switching network for automatic switching of its IBM 3750 private branch exchanges. PTT approval, expected in September, will allow IBM to interconnect by high-capacity leased lines its central Paris offices, its manufacturing plant in Montpellier, its research and development laboratory in La Gaude, and other company installations.

The company hopes to begin integrating its switching system in December, and the network is scheduled for completion in 1978. The network will provide the installations with the same facilities as the 3750 offers in-house, including multiparty conversations, paging services, and other functions. More important, it could pave the way for other companies to implement similar networks for their installations in France.
Inductors avoid magnetic coupling on thin films

A family of tiny fixed inductors for reflow-soldering to film circuits is being built by Siemens AG with new ferrite packages that avoid magnetic coupling with adjacent components—often a critical problem in closely packed film circuits. The ferrite material, called Siferrit, has specific resistance as high as $10^9$ ohm meters. The new component, the B78008, comes with inductance values from 0.1 to 470 microhenries at quality factors between 30 and 70. Its package has an area of 4 by 3.2 millimeters and is 3.5 mm high. It provides a magnetically closed circuit with extremely low stray fields.

Plessey plans CCD, magnetic-bubble, and holographic memories . . .

A broad-based assault on the high-technology-memory market is being mapped by Plessey Memories, which now is offering evaluation models of a 256,000-bit magnetic-bubble-memory system. Expected soon to become a commercial product, the memory consists of 16 16-kilobit dual in-line packages mounted on a printed-circuit board with interface circuitry. Likely to follow are 16-kilobit charge-coupled-device memories, even though not unusual current-leakage problems have delayed the buried-channel, three-phase metal-gate devices.

In development is an archival holographic-memory system employing a specially developed page composer and Kodak ultra-sensitive photographic film with a conventional laser-activated holographic system.

. . . and CCD delay lines for filters and audio uses

Add Plessey Semiconductors to those manufacturers eyeing a market in charge-coupled-device delay lines for signal processing. This fall, Plessey plans to offer evaluation models of 256-bit and 340-bit analog devices aimed at radar and filter applications. These devices, with a maximum 5-megahertz frequency, are to be followed by a 512-bit delay line, also to be made at the Allen Clark Research Centre. Also in development for the consumer market is an inexpensive audio delay line with on-chip clock generation.

Dutch cities turn to microprocessors to control traffic

Cities in the Netherlands are turning to automobile-traffic-control systems built around microprocessors. The fifth Dutch city to install such a system is Eindhoven, home of Philips, the system supplier. In addition to coordinating traffic control, the Eindhoven system displays recommended vehicle speeds at six intersections. One rather complex intersection requires constant modification of the control sequence because of numerous changes in traffic patterns. And even when communications between controllers fails, the controller at each intersection continues to operate autonomously.

Hitachi shares its wire-bonding skill

Japan's Hitachi Ltd. has revealed to Motorola Semiconducter in the U.S. its technique of automated wire-bonding. This technology is being shared as part of the deal last November that grants Hitachi nonexclusive rights to produce the M-6800 microprocessor and joint development of higher- and lower-level microcomputer systems. For the past two years, Hitachi has been using groups of as many as five wire bonders under the complete control of minicomputers.
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Circle 66 on reader service card
60 million units should be sold this year, compared to peak of 182 million in 1957, as RCA closes Harrison plant

by Bruce Le Boss, New York bureau manager

RCA Corp.'s decision to close its Harrison, N.J., receiving-tube plant on April 30—three months earlier than planned—not only marked the end of an era that spanned five decades, it also had major ramifications for surviving manufacturers, suppliers, and consumers.

Few can question the decision of RCA, the leading maker of receiving tubes, to cease manufacturing for a market that has declined by almost 80% since 1966. Yet the firm's departure as a producer of most high-use receiving tubes and as the sole source for more than 100 less-used types has led to worries over shortages, longer lead times, higher prices, and deterioration of receiving-tube quality.

What's left of the receiving-tube market today primarily is a renewal/replacement market that is but a shadow of its former self. Still declining from a peak of approximately 182 million units in 1957, the replacement market last year was down to about 68 million units. Estimates for the current year set the market at about 60 million units.

Decline. "It's inevitable that the replacement market will continue to decline," says Joseph Haimes, a vice president at RCA'S Distributor & Special Products division in Cherry Hill, N.J., and a veteran of the firm's receiving-tube business. "There are no new tube-based TV sets, other than a few hybrids, that are going on the market. And as the public scraps their old TV sets, the replacement market will continue to go down further."

The decline in the replacement market has been surpassed only by that of the OEM market. Since it peaked at an estimated 273 million units in 1953, it has plummeted to approximately 8.6 million units in 1975, and a further drop to 4.6 million units is forecast for this year. "For all intents and purposes the OEM market has been wiped out," says Haimes.

The remaining two segments of the receiving-tube business—the export and Government markets—were never actually that big, notes Haimes. The export market hit a peak of 24 million units in 1954, and the Government segment hit its high of 43 million units three years later. The two segments this year are projected at 5 million units and 17 million units, respectively.

In its heyday, RCA'S receiving-tube operations encompassed three additional production facilities in the U.S., with plants in Cincinnati, Indianapolis, and Woodbridge, N.J., as well as offshore plants in Mexico and Brazil. The Harrison plant, where RCA produced over 3 billion receiving tubes, was the last and largest of the domestic tube-producing facilities. RCA is trying to sell the Mexican plant, which produced about 7 million tubes annually, and it plans to phase out tube operations in Brazil, where approximately 15 million tubes were made annually, says Haimes.

Who's left? RCA'S withdrawal as a producer of receiving tubes leaves GTE Sylvania and General Electric as the principal U.S. manufacturers in the business; Westinghouse and Raytheon have previously ceased production. RCA will follow in Raytheon's footsteps by continuing to merchandise tubes—buying and selling RCA-branded units after it depletes its current inventory.

In addition to Raytheon, which sells tubes made by Nippon Electric Co. and Matsushita Ltd., the primary Japanese manufacturers, the U.S. market is filled with a host of
suppliers. Amperex is buying and selling tubes made by its N.V. Philips affiliates and others, and International Electronics Corp. and International Components Corp. are selling tubes produced offshore, as are many others. Also OEMs, such as Zenith, Motorola, and Magnavox, as well as major retailers, such as Sears, Roebuck & Co. and Montgomery Ward, are merchandising tubes.

As a result of the abundance of suppliers, and RCA’s arrangements to transfer production to other makers, Haimes doesn’t consider that RCA’s departure as a manufacturer will seriously affect the supply situation. For example, RCA alone made the Nuvisor, a thimble-size, metal-ceramic tube that was RCA’s low-cost response to transistors about 12 years ago. Recognizing the need for someone to continue to supply Nuvisors for replacement in television receivers and government equipment, RCA reached an agreement with Sylvania for the sale of machinery, parts, raw materials, work in process, and technical data related to the manufacture of Nuvisors and certain other sole-source receiving tubes that were produced at the Harrison plant. Nuvisor production is being set up at Sylvania’s Emporium, Pa., facility, while the manufacture of more than 50 other types of tubes for which RCA was the sole source is being shifted to Sylvania’s automated production plant in Altoona, Pa.

Commenting on Sylvania’s plans to supply the market with Nuvisors, Roger Slinkman, senior vice president for the Electronic Components group, notes that Sylvania recognized that its ability to serve the market depended on the purchase of certain machinery, tools, and parts. “That taken care of, we have already made delivery commitments to customers. We are proceeding according to plan, with few exceptions, and plan to be making shipments by the end of this year,” Slinkman says.

Meanwhile, RCA expects to fill most of the military’s requirements this year for Nuvisors, as well as for certain metal tubes, but the military is skeptical. At the Defense Electronics Supply Center (DESC) in Dayton, Ohio, Col. William Warren, the production manager, is concerned about the delivery of certain tubes for which RCA was the sole source, noting Sylvania is “not yet on stream.”

This void in some metal tubes critical to military applications will partially be filled by General Electric, says Al M. Penrod, manager of marketing for receiving tubes at GE’s plant in Owensboro, Ky. “As a result of the RCA pull-out, GE is going back into the metal-tube business, at least producing the popular ones, to serve the military market,” notes Penrod.

Other than for some of those RCA sole-source tubes, Penrod says, there will be no availability problem. “Both Sylvania and GE can supply the world’s needs from now on to evermore. And if either one of us decides to drop out, the other could handle the world’s requirements by itself,” he states.

Shortages seen. But Robert Knight, marketing manager at Raytheon’s Distributor Products operation in Burlington, Mass., predicts that availability will become a problem and that there will be shortages of many critical types. “As the market shrinks, there will become less of a market for certain low-use tubes. Therefore, manufacturers will become less willing to produce quantities sufficient to achieve manufacturing efficiencies,” he says, noting that most factories need at least 10,000 units of a given type to break even on that tube.

“A manufacturing manager who goes out to produce a tube, if he produces just 3,000 or 4,000 units, he’s just getting the bugs out. These were the units that used to be taken out for the renewal market, with the debugged units that followed in the run going to the OEMs, who were much more critical,” Knight adds.

Distributors. So far, RCA’s departure as a producer of receiving tubes doesn’t seem to have had any immediate effect on distributor operations. Frank Visconi, president of Westchester Electronics Inc. in White Plains, N.Y., a major RCA distributor, says there has been no impact on tube availability yet, “largely because RCA is still shipping out of inventory.” But Visconi assumes a problem in obtaining an adequate supply of RCA-branded tubes, so he has taken on a second line.

Jack Socolow, president of Northeastern Radio Warehouse Inc. in the Bronx, N.Y., another large RCA-tube distributor, doesn’t expect the RCA action to encourage the remaining two U.S. manufacturers to raise prices beyond what might be considered the usual increases. “That’s because you have a company like Zenith, which purchases all of its tubes from outside sources, and they’re very price-competitive and aggressive in the market.”

Raytheon’s Knight expects upward price pressure because competition is being decreased. This, in turn, could result in the loss of certain business at the consumer-dealer level. “If people get greedy and prices go up too high, then consumers will begin to throw away their old TV sets. It’s already happening to black-and-white TV. Rather than pay $6 to $8 each for several tubes, plus a service charge by a technician, the consumer can go out and buy a black-and-white TV for $70 today.”

Helping to temper the rate of expected price increases could be some downward pressure by some of the peripheral suppliers who might dump their products on the market. “This could be the next phase following upward prices,” says Knight.
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Standard interface gains fans

But some prospective users are concerned about slow speed of bus, and one even objects to $250 licensing fee

by Andy Santoni, Instrumentation Editor

“The pioneers got their lumps, but now they’re committed,” says Bob Brannon. That’s how Brannon, product-marketing manager at Hewlett-Packard Co.’s Data Systems division in Cupertino, Calif., summarizes the experience of many users of the standard instrumentation-interface bus, IEEE 488, now that systems employing the bus are up and running.

“It simplifies our job as systems designers,” says Ralph Prall, manager of support-equipment engineering at Singer Co.’s Kearfott division in Little Falls, N.J. As would be expected, Kearfott engineers had problems using the system the first time around, says Prall. The interface-bus software they wrote for an HP 21 MX minicomputer did not work as expected, he says, and that called for a major rewrite. “But HP worked very closely with us to solve the problem, and we’re satisfied with the results. We’re going to continue to use the standard interface; it looks like an economical solution to many of our problems.”

Brannon adds that difficulties with the minicomputer hardware and software that drive the standard interface also caused HP to take a second look. That reassessment resulted in a new version of the interface card and a greatly expanded software package, the 59310B [Electronics, May 27, p.145]. “We think we’ve licked the problems of the earlier version,” says Brannon.

Learning, “I see few real problems, other than that people are still in the early phase of using it,” says David Kaufman, senior project engineer at Data Precision Corp. in Wakefield, Mass. Among the limitations often discussed by prospective bus users is the maximum data rate of 1 megabit per second across the interface on any signal line.

Says Kaufman, “We are very much concerned about the speed of the bus, and we are attempting to make the unit operate at as high a rate as the controlling microprocessor will allow. The bus itself is not the limiting factor in most systems; hardware has often been more of a limitation than bus capacity.”

Kaufman notes that if the circuitry between the instrument and the bus cable operates slowly, it would appear that the bus itself is slow. In its interface cards, says Kaufman, Data Precision is using an 8-bit microprocessor that will operate more rapidly than the 4-bit microprocessors some of its competitors are using. Kaufman says his company plans to offer a 488 bus interface as an option on its systems-oriented instruments.

Option. Howard Painter, marketing manager of GenRad Inc.’s Electronic Instrument division in Concord, Mass., agrees that the bus is a good idea, “but it does have speed limitations. Some of our customers might want more speed, so they’d prefer parallel outputs instead of a serial output.” Painter says that, in the future, GenRad will design systems with a bus option, but won’t include it as a standard part.

Henry Reineke, vice president of operations at Wavetek, San Diego, says that, while acceptance is growing rapidly, it is not yet “revolutionary,” or at the 50% point of all potential users. Reineke says that although 10% of Wavetek’s ship-

What the standard covers

Based on a concept developed by Hewlett-Packard Co., the standard instrumentation interface bus has been adopted by the United Kingdom’s Institute of Electrical and Electronics Engineers (IEEE Std. 488-1975) and by the American National Standards Institute (ANSI MC1.1-1975). The interface also is in the final stages of approval as an International Electrotechnical Commission standard [Electronics, Jan. 22, p. 8]. It is often called the general-purpose interface bus (GPIOB) or, because it employs the American Standard Code for Information Interchange, the ASCII bus.

The standard defines the bus’s physical connector, the roles of the interconnecting bus wires, thelogic conventions, format, and timing of control and data signals, plus the other factors necessary to operate in a communications link. The objective is to simplify the interconnection of instruments and peripherals, including computers, voltmeters, and card readers, made anywhere in the world.

In operation, each device linked via the interface is connected in parallel to three buses. The data bus transfers both data and addresses among the devices in a bit-parallel, byte-serial fashion. The transfer bus controls the transfer of data on the data bus. The control bus performs such control functions as channeling a service request from a device to attract the attention of the controller, and it handles the remote-enable instruction that tells a device to respond to remote programing rather than to its own.
ments last year were bus-compatible, 30% to 50% of the units shipped this year are so equipped.

German assessment. For Rohde & Schwarz in Munich, West Germany, Tonio Fruehauf, head of the firm’s design laboratory for automated test equipment, remarks: “System speed is no limitation because the interface bus is used only in analog equipment, and not in digital systems.” About half the instrument systems made by the company are bus-compatible.

Much the same comment comes from Siemens AG, which is getting ready to deliver bus-compatible analog test systems during the second half of this year, as well as from Wandel & Goltermann, also a German producer of test equipment primarily for communications systems, which is now developing bus-compatible systems. Both also agree that the speed limitation is not a drawback.

French opinion. Yves Le Peutrec, an instrumentation-marketing engineer for Compteurs Schlumberger, admits that the 1-Mb/s maximum speed could be a handicap, but estimates that some 20% of instrumentation buyers want programmable, bus-compatible instruments. Schlumberger will offer bus compatibility on all its new programmable instruments, either standard or optional, starting this year.

Art Bjerke, engineering manager at Systron-Donner Corp., Concord, Calif., says his firm will make the 488 standard bus “available as an optional assembly in many of our instruments” and already builds bus compatibility into some products. Bjerke says the standard is convenient “for people who are not able financially or technically to put together a system.” Systron-Donner’s Norm Whita agrees: for small systems, “it’s fine. But in a big system, where you’re pumping a lot of data around, it may be useless. It only moves as fast as the slowest instrument, and that may not be good enough for assemblers of big systems.”

This drawback, along with the cost added to each instrument to achieve interface compatibility, makes the standard interface too expensive and cumbersome for com-

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merical test systems like those made by Teradyne Inc. of Boston, or Instrumentation Engineering of Franklin Lakes, N.J. When a number of nearly identical systems are to be built, a more custom interface system may be preferred. James P. Sutter, director of corporate marketing at Datatron Inc. of Irvine, Calif., notes that the standard interface is "not applicable to our hard-wired, dedicated-computer approach."

Testing. Nonetheless, some vendors of commercial test systems are using the standard instrument interface. For example, Faultfinders Inc. of Latham, N.Y., incorporates compatibility with IEEE-488 in its latest in-circuit and functional automatic test system, the model FF303. Controlled by a Data General Nova minicomputer, the FF303 includes bus compatibility to simplify expansion or alteration of the tester by the user, says Fred Schwedner, manager of electrical engineering at the firm.

The major fault Schwedner finds in the standard is the complexity of its documentation. "It's a bewildering document," he says, pointing out the over-reliance on state diagrams and mnemonics to explain simple operations.

And Clark Crocker, manager of advanced-instrumentation development for engineering-data-conversion systems at Analogic Corp. in Wakefield, Mass., doesn't like the idea of paying a license fee to use an industry standard. Crocker says standards that benefit the entire industry should be free to use.

Reasons. Discussing these two complaints, Don Loughry, corporate interface engineer at HP in Palo Alto, Calif., explains, first, that the document is complex and written at a high technical level "because it was written as a reference, not for training." As for the licensing requirement, Loughry says that the terms are quite reasonable. "For a single payment of $250, you get a royalty-free license to use the bus," he says. Anyone can purchase such a license, he says, then use the standard interface on any number of products.

Reporting for this article was provided by Pamela Leven, Judith Curtis, Larry Armstrong, John Gosch, Arthur L. Erikson, and Larry Waller.
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Companies

For ITT, staying at home pays

Semiconductor chief Heinz Roessle says that decision to automate in Europe rather than go offshore has kept operation healthy

For Heinz Roessle, deputy general manager of the ITT Semiconductor group, one of the factors in the formula for success is automated production. Not that other companies haven’t done the same, but at ITT Semiconductors, mechanization and automation have become articles of faith. Perhaps nowhere is as strong as effort being made toward automation as at the group’s European facilities, headed by Roessle.

And the figures show that the effort has paid off. Mainly as a result of automated processes, per-employee sales at the European facilities now stand at $50,000 a year. This level, Roessle says, compares with $40,000 to $45,000 for the group as a whole and with around $30,000 for the semiconductor industry generally. Furthermore, automated processes have helped the group to operate profitably, even during the recent slump.

Roessle, a soft-spoken yet aggressive executive, is directly responsible for ITT’s three semiconductor companies in Europe—in Footscray, England, Colmar, France, and Freiburg, West Germany. Last year, they accounted for nearly $100 million worth of sales.

By far the biggest member of the group is Intermetall GmbH in Freiburg. The company, which accounts for more than half of ITT Semiconductors’ worldwide business, is one of Europe’s largest producers of solid-state devices for consumer applications. It pioneered in diode tuning for television sets in the mid-1960s and is among the leaders in developing wireless remote control, digital tuning, and electronic channel selection for television receivers. Intermetall is also Europe’s largest producer of MOS circuits for consumer uses. Roessle, a 19-year veteran of the semiconductor industry, recently discussed his views on a variety of subjects with Electronics. Here are excerpts of that discussion:

Q. Why did you decide in the late 1960s against shifting manufacturing operations to the Far East?
A. For one thing, we already were designing the products to lend themselves to low-cost automated-production processes. For example, transistor and L/C systems were designed for automatic-bonding techniques. Another reason was to be near our customers and to keep logistics costs low. Further, we wanted to hold inventories down. This way, there would be fewer risks, as regards product mix and obsolescence.

Q. How does being near your customers benefit you?
A. Consider plastic transistors, for example. It’s easy to get such standard devices in the Far East, but many of our customers, especially consumer-equipment makers, must react fast. This they can do best when their component suppliers are nearby. So, even with standard devices, being close to the user has a bearing on orders. Our market share, even for standard devices, is considerable. As for specialized consumer products, it’s even more important to be near the user.

Q. How much are you spending for automation?
A. That’s continuing process. But I would say the ITT Semiconductor group spends something like $2 million a year just for developing the means for automation and mechanization. Compared with total sales, the $2 million may not sound like much, but most firms spend a smaller percentage. More important than the actual amount, however, is where the money is put to use, and I believe we have spent the money where it does us the most good.

Q. Who develops the automation equipment?
A. We do that ourselves because, in most cases, the equipment cannot be bought outside when we need it.

Q. For all your efforts in streamlining production, is there room for more automation?
A. Sure. We have more development projects going on. In one, a single person supervises three or more machines used for fully automatic circuit production. Let me emphasize that the person’s function is purely supervisory.

Q. Is the level of automation you have achieved attainable at other semiconductor companies?
A. Stay at home. For ITT Semiconductor’s Heinz Roessle, automation is profitable.
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International Crystal Manufacturing Company, Inc.
10 North Lee, Oklahoma City, Oklahoma 73102

Probing the news

ductor houses? Could they readily adopt your techniques?
A. It's not all that easy. Mechanization requires an experienced staff of mechanical engineers and a good team that can maintain the machines. In this respect, the Black Forest region with its long tradition in precision-instrument making, exemplified by its clock and watch industries, has benefited us a lot. Certainly, a high degree of mechanization is possible at other firms. But first they must change their production philosophy. There must be a strong will to become a factory — I mean a factory in the traditional sense of the word — a production facility where battles are fought over fractions of pennies.

Q. Is ITT Semiconductors developing any new technologies or refining existing ones?
A. No. We are not interested in developing technologies just for technology's sake. Our main goal is to develop products using MOS, C-MOS, LSI, and the like.

Q. Are you gravitating toward any particular technology?
A. Not at all. If a technology lends itself to economical fabrication of a certain product, we will use it. Occasionally, we will settle for a more sophisticated technology if it enhances production. Take channel selection and ultrasound remote-control of TV sets. Here, we decided on silicon-gate over the simpler metal-gate processes because it runs well in our factories in volume device production. Our philosophy is to develop a product with which we think we can get a good market share. The technology is secondary.

Q. What are your near-term plans in microprocessors?
A. We don't intend to develop a microprocessor of our own. Rather, our aim is to cooperate with a company that already has knowhow in the field and then go to market with a common system. Many of our own LSI circuits, like those designed for TV remote control and channel-number storage, and our ICs for coin-operated, worldwide dialing phones, already have the complexity of microprocessors.
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Electronics/August 5, 1976
Probing the news

Military electronics

Slimmer Samso maintains strength

Internal reorganization and more work by outside contractors enable Air Force missile organization to add to work load

by Larry Waller, Los Angeles bureau manager

The Air Force’s Space and Missile Systems Organization sports a leaner profile these days, and it is working to stay that way. The reason, of course, is the familiar duo—zooming costs and budget hold-downs—that is whiplashing everyone has also forced the big missiles and space-research outfit to trim down.

One indication of what Samso calls “doing more with less” is the cut in its worldwide staff, which has been reduced nearly 20% from 6,500 in 1970 to about 5,200 today. Another is its budget, almost equal to 1970’s $2.15 billion, but with more than one third of its value lost to inflation.

Samso’s belt-tightening started eight years ago, explains the present commander, Lt. Gen. Thomas W. Morgan, who adds that the squeeze stems mostly from soaring “people costs,” as it does throughout the Air Force. In the 1970s, Samso faced a thorny combination of austere budgets and a growing workload. But now, Samso, based in El Segundo, Calif., oversees “14 major activities, which is up 50% over the past few years.”

Further complicating the bind are the demands to put state-of-the-art technology into advanced programs and the Air Force’s absolute-reliability requirement for weapons systems. Together, these necessities defied a simple solution by across-the-board cutback, according to Morgan.

Strategy. Without sacrificing performance, Samso’s strategy became one of trimming and reorganizing internally. It also began hiring outside contractors for its operating jobs, especially to replace its own “blue-suit” Air Force contingent. “We just cannot afford the luxury of having all blue suits,” Morgan admits. “We would like it otherwise, but it’s not cost-effective.” As the result, today’s service complement numbers less than 3,400—600 fewer than in 1970.

At the same time, marked changes were transforming the important System Program Offices, each of which had previously operated as a division unto itself, to manage a Samso project. “The Air Force philosophy always was that each SPO was entirely independent, with its own engineering, finance, and other support,” he notes. But as new programs appeared without additional funding, “we had to man them out of our own hide,” and existing offices were raided.

Setting up pooled support functions for all SPOs helped meet the staffing gap. Samso, particularly, went to outside contractors to run its extensive launching and tracking responsibilities, which include Vandenberg Air Force Base and Air Force satellite control.

Through consolidation and repogramming, overseen by a manpower review board instituted last year, enough personnel were raised, in fact, to staff the brand-new programs. These were the Navstar global positioning system [Electronics, Oct. 15, 1975 p. 39] and the defense dissemination system, a top-secret project about which Samso is saying nothing.

Supervision. But there was no thinning out or pooling of the basic technical responsibility for each program. “We’ve drawn the line at
"engineering" for each program, Morgan stresses.

To strengthen supervision and transfer of technology throughout Samso, a new directorate of Advanced Space Programs was formed earlier this year, and it includes the former technology office. Its charter includes "looking across all programs for quality assurance," which Morgan calls a consideration of overriding importance for all programs.

The reliability of solid-state electronic devices in space still causes headaches, even after intensive and continuing efforts to improve procurement and testing. Today, Samso has been operating devices for five years or more in orbit, compared with nine months early in the programs.

Stringent fabrication standards, identification of each component, and testing at every level—from the individual part to the entire system—get the credit, Morgan explains. "Many systems work well on the ground, but in space, contaminants float loose and short out circuits," he complains. The new directorate is charged with pursuing ever more rigorous control and testing programs.

Sophistication. In looking over Samso’s range of programs, in which exotic technology is commonplace, the commander describes the laser-satellite system as probably "the most advanced communications system ever to be built." Designed to provide the ultimate capability for the Department of Defense, it employs lasers to link orbiting satellites with each other and to ground stations.

Among other characteristics, the system is expected to transmit and receive 1 billion bits of data per second, about 20 times the rate of present commercial satellites, and it simultaneously handles about 50,000 voice or 12 color-television channels. A late 1979 evaluation launch is planned by Samso.

Morgan took over Samso late last year after an earlier hitch in 1971—72 as vice commander. Even with this experience, he says the complexity of Samso operations required "at least three months for me to catch up."
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Electronics / August 5, 1976
The advances made in the last year in fiber-optic communications have delighted even the most optimistic. New systems have done better than expected in rigorous field trials. Improved components—more efficient light sources, less noisy photodetectors, and more rugged cables—have become available off the shelf. Single-fiber cables, plus matching connectors, are starting to surface, while production techniques are attracting the kind of attention that's the due only of nearly mature technologies.

Commercial applications, in fact, have leapt into prominence, both in the U.S. and overseas, and the military remain as dedicated as ever to the pursuit of the interference-free, lightweight attractions of fiber-optic systems. For the time being, to be sure, cost remains a problem. Other difficulties include a lack of standards (though several groups are already at work in this area) and the unfamiliarity of the wider engineering community with such a new technology. However, there seems to be no doubt that by the 1980s optical fibers will often be a practical alternative to copper wire.

When that time comes, one of the major fiber-optic users will be the telephone system, and John deButts, chairman of AT&T has apparently firmly committed the Bell System to developing fiber optics. "I anticipate that by the early 1980s cables of glass..."
fibers will be carrying thousands of simultaneous messages between major switching centers in our cities," he recently stated. The fibers not only offer large bandwidths for such multichannel transmissions but, more important initially, they easily interface with existing telephone equipment. With their lower losses, too, repeaters can be more widely spaced than is possible with present conductive-cable systems. This aspect is also attractive to Bell Canada. It will probably use fiber optics to obtain repeaterless connections between telephone exchanges, according to W. C. Benger, group vice president of Northern Telecom Ltd., a major supplier to the Canadian telephone company.

For large data-processing systems, on the other hand, the large bandwidth capability and the freedom from electromagnetic interference are perhaps the biggest attractions of optical-fiber cable, which is already being used to link central processors to peripherals. The absence of the spark hazards of electrical signals will be a major asset in many industrial processing applications. Other applications will be won over, eventually, by the cost savings of glass fiber over coaxial cable.

In sum, the appeal of fiber optics is multifaceted and could (say the top analysts) rocket demand to billion dollar heights before the 1980s are out.

The actuality

This vision of the technology's future gains substance from several systems already in existence, particularly an experimental fiber-optic telephone link started by Bell in Atlanta, Georgia, last January. There, a team from Bell Laboratories and Western Electric managed to put together, using as many as 18 low-loss splices, a 10.9-kilometer repeaterless link. The system encountered no problems when transmitting data at 44.7 megabits per second. Average loss of the cable when in place was 6 decibels/km—2 db better than the design goal. The experiment proved that it's possible to run fiber-optic links long enough to avoid the need to put repeaters in manholes every mile or so, as is necessary with coaxial-cable systems in large metropolitan areas like New York or Chicago. Just as important, the link interfaced successfully with existing telephone equipment, as the technology will have to do when it first enters the present telephone network.

Also eliminated by the experiment was the uncertainty whether practical connectors could be produced to splice together
in the field cable containing 144 separate fibers, each a mere 2 mils in diameter. The answer was a kind of club sandwich connector, with a dozen 12-fiber ribbons as the filling and 13 precisely grooved aluminum chips as the slices of bread.

Another fiber-optic system carries television signals. TelePromTer Manhattan Cable Television Cable Inc. just recently installed an 800-foot fiber-optic link to carry cable TV signals from a roof antenna to its head-end equipment 34 floors below. And General Telephone and Electronics Corp. is firming up plans for its scheduled field trials later this year that will carry actual commercial voice traffic between operating telephone exchanges in Califomia. It will use cable made by General Cable Corp. of Greenwich, Conn.

Over in France—to focus on just one major overseas application of fiber optics—the Centre National d'Etudes des Télécommunications has already completed one experimental digital transmission system. (It's the start of an ambitious effort to develop the hardware and systems know-how that the government-run telephone network will need for the fiber-optic links it plans to have in full service by the mid 1980s.) The CNET's first optical system used 3 km of Corning fibers and, after running for some 20 months at 2 mVb/s, has been modified to accept data at 8.4 mVb/s. Now the CNET also has parts of a 3.4-mVb/s system working and hopes to have firm specifications for its first trial system by early 1978, with operation starting in 1980.

Nor have the military, back in the U.S., been idle. All three services were from the beginning attracted by the small size, light weight and freedom from interference of optical fiber—all major concerns aboard aircraft or ships or for secure tactical and strategical links under water or on land. The Navy and Air Force naturally concentrated on data busing for signal transmission in aircraft and on ships, while the Army is concerned mostly with secure land communications links.

More specifically, a fiber-optic sonar link recently underwent trials aboard a submarine [Electronics, May 27, p. 39], while a fiber-optic telephone system has now operated without failure in the fiber-optic portion for three years aboard the U.S.S. Little Rock. “Fiber installations have proved very successful,” sums up Don Williams, program manager at the Naval Electronics Laboratory Center in San Diego.

Williams estimates that the 450 pounds of copper wire now used in fighter aircraft could be replaced with only 50 pounds of fiber cable. In the Navy A-7 aircraft, for example, 13 optical-fiber cables have supplanted 115 wire signal channels representing 302 separate conductors, almost a mile of electric cable being replaced with only 224 feet of fiber. Williams also points to the fiber-optic link used between antenna and transceiver of the AN/PPS-18, a general battlefield-surveillance radar. “If funding comes through, this would be the first military system to go into production using fiber optics.”

As for the Army, its budget for fiber-optic development in fiscal 1977 has increased “significantly” over last year, according to Larry Dworkin, acting chief of advanced techniques at the Army Electronics Command, Fort Monmouth, N.J. He points to several contracts they are close to letting—one for field-deployable optical-fiber cables for use in ground tactical and strategic telecommunications, and another to develop connectors for six-fiber cables that can withstand the rigors of military environments.

According to Dworkin, RCA has a contract with the Combat Surveillance and Target Acquisition Laboratories to investigate high-radiance light-emitting diodes and lasers operating in the 820-nanometer range that is typical of fiber-optic systems. He also adds that the Army is about to embark on its first major production-type commitment—an investigation of methods of manufacturing light sources (111- and lasers) and photodetectors (silicon p-i-n diodes and avalanche photodetector devices).

Meanwhile, the Air Force is developing, among other things, multiple fiber-optic systems with optical switching at data rates of less than 50 mVb/s.

Great growth

It's a result of this kind of work that fiber optics has aroused industrywide interest. Individual applications, particularly in computers, will be described later. Overall, so encouraging are the signs that Gnostic Concepts Inc., a Menlo Park, California-based market-research firm, is predicting that the world market for fiber-optic systems will grow to over $1.58 billion by 1990. Jeff D. Montgomery, Gnostic's vice president, foresees initial growth in applications where the unique advantages of fiber optics justify its slightly higher price. But within the next decade or so he predicts an explosive growth in the use of optical components in production systems. “In the U.S. this number should reach $64 million by 1980 from a little over $1 million in 1975, and should jump to $833 million by 1990,” says Montgomery. At that time he sees the major markets as follows: commercial communications will account for 74% of those applications, up from 54% in 1980; commercial computers, although dropping from 17% in 1980 to 9% in 1990, will have a much larger volume, and the market for industrial process control will remain steady at 7%, but again this will account for increased dollars.

Martyn F. Roetter, technical director of Arthur D. Little Inc.'s program on optical technology and markets, pretty much agrees with the major growth areas singled out by Montgomery. However, he points out that much of what happens worldwide
will depend on the policy set by Bell in the U.S. and the telephone companies overseas. He thinks it will be 1981 before Bell is sufficiently convinced that fiber cables in the ground can last 20 years and implement such systems. However, he does see new computers introduced within the next several years and industrial control systems as nearer high-growth areas.

As part of its investigations, Arthur D. Little is developing digital and analog optical-fiber communications systems to carry voice, data and video signals for short-haul use. This the firm sees as the most promising near-term application of fiber optics. "We feel that the benefits and applications of the technology cannot be realized without a greater understanding and experience in design, construction, testing and total costing of such systems," says Herb Elion, Arthur D. Little's program manager. And, one might add, greater understanding and experience of the components of fiber-optic systems.

The components

Even though light sources and detectors, splices and connectors are essential elements in fiber-optic communications, it's been the optical fiber that has paced its progress. And only as the cost of the fiber becomes competitive with existing coaxial cabling, will fiber-optic technology really catch on, whether in industrial control systems as nearer high-growth areas.

For some high-performance applications even now, optical-fiber cable is preferable to existing coaxial transmission systems. For example, presently available coaxial-cable loss in a 1000-ohm-system can be as high as 30 dB/km, whereas for the same bit rate a graded-index optical fiber has a loss of about 5 dB/km. Low-loss optical fibers with increased bandwidth capability in lightweight cabling make them ideal for communications links where crowded cable ducts now pose a problem—the lower signal attenuation allows longer cable runs before any signal processing is needed. In weight-sensitive applications, over a ton of wire cables can be replaced with fiber cables weighing less than 1% of that. Moreover, wherever miles of cable are used in conjunction with low-level digital signal transmission, electromagnetic interference becomes a horrendous problem. Here, interference-free optical fibers eliminate the costly transformer isolation and cable shielding needed for conventional wire conductors.

Different direction

With the rapid progress being made in fiber-optic technology, attention is shifting from the more theoretical aspects to operational and manufacturing problems. For example, the emphasis is now less on reducing the loss of fibers and more on the production of fibers with tighter tolerances and low-cost cables that are rugged in the field. A number of good, low-cost p-i-n detectors are already available, but the development direction is toward low-voltage avalanche photodetectors for more demanding applications. Still missing are economical light sources with long life, which are essential to all potentially major users, especially the telephone companies.

And one of the biggest problems is the scarcity of inexpensive yet reliable single-fiber-per-channel connectors suitable for use by unskilled workers in the field. Within the last year both metal- and plastic-shelled connectors have been available for bundle fibers, but only recently have commercially available single-fiber-per-channel connectors surfaced. These connectors are designed to couple fiber to fiber, fiber to source, and fiber to photodetector.

Setting standards

With the very small diameter of single fibers, connector tolerances in the order of 0.1 mil are required to keep losses low. This, in itself, creates production problems, but with fiber and cable dimensions not yet tight enough and the proliferation of different fiber sizes from many different manufacturers, most connector makers feel they cannot design inexpensive, practical devices until the fiber makers get together on some standard. That would have to involve companies such as Corning, ITT, Galileo, Valtec, Fiber Communications Inc., Du Pont, Polyoptics, and Fiber Optic Cable Corp., as well as several overseas suppliers.

Sets of standards, in fact, are needed for all fiber-optic components, not just for fibers and connectors. Several agencies

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**Fiber optics in the car**

Fiber-optic communications systems are not only immune to the high noise levels of automobiles—they can reduce cabling harness weights, material cost, and processing time. An experimental fiber-optic harness system has been developed by General Motors Engineering to transmit vehicle control signals over a single-optical-fiber link, instead of over conventional wires. Such a system, perhaps built into the steering column or into a modified turn-signal control arm, would transmit separate signals over the fiber to an optical receiver, which would then convert them into electrical signals so as to switch on headlights or control turn signals, windshield wipers, and the hazard blinker. Such a system, once it passes the experimental stage, should open up a tremendous market for fiber optics.

3. Atlanta connection. Cable connectors used in Bell's optical-fiber experiment interleave layers of precision-grooved aluminum chips (dark areas) with rows of fibers. The complete splice accurately aligns all 144 fibers in each cable.
4. Light coupling. The tiny optical fiber can be seen as it enters the Bell Laboratories' experimental transmitter module. The light generated by the source is coupled with not only the fiber but also a feedback circuit on the substrate to maintain constant output.

5. Matched pair. Sperry Univac's fiber-optic receiver and transmitter were designed to replace existing wire transmission systems. The receiver shown uses hybrid circuitry on substrates: p-i-n photodiode mounts in a conical ferrule that attaches to the substrate.

6. One of a kind. The first optical-fiber connector to be MIL-qualified was developed by the Naval Electronics Laboratory Center for use with fiber-bundle cables and is fully compatible with other fiber-optic components and hardware under development by the Navy.

- Bell Labs
- Electronic Industries Association
- Society of Automotive Engineers
- The Electronic Industries Association, Washington, D.C., has a task force concerned with all phases of development and trends in fiber-optic terminations and junctions. This group, chaired by Philip Dann of IBM Federal Systems, Oswego, N.Y., is committed to meeting the Department of Defense's goal of having standards available by 1980. And DOD itself has in operation a tri-service group working to develop standards for all the services for fiber-optic systems.
- At the Society of Automotive Engineers, too, another group is developing test procedures for optical-fiber cables. Under the guidance of W.D. Watkins of the Naval Avionics Facility, Indianapolis, Ind., this group will supply information to DOD to enable it to issue preliminary military specifications on optical-fiber cables in 1977. There is close liaison among groups.
- As for sources, reliability is also a headache. For practical optical-communications applications, their lifetimes should reach at least 100,000 hours and, although extrapolated test data for both lasers and LEDs points to this being possible, the big question is when. Work on the problem is in progress at Bell Labs, which has the formidable task of developing practical long-lived lasers for the Bell System's greater-than-20-year life requirements. And such companies as RCA, IBM, ITT, Monsanto, Spectronics, Laser Diode Laboratories, Plessey, GI, and Fairchild are among those that have LEDs and laser sources commercially available.

The cost factor

Second only to the need for standards is the problem of cost. A major contractual commitment to a large-scale system or systems needs to be made, whether by Bell, IBM, or the military, since otherwise it's likely that practical components will remain expensive and not widely available.

The cost of today's fiber-optic components doesn't reflect what could happen in a volume business. A go decision by the telephone company, for instance, would trigger a tenfold shift downward in the cost of fibers, says Charles J. Lucy, general...
manager of the Telecommunications Products division of Corning Glass Works, Corning, N.Y. "Graded-index fibers with under 5-dB loss and greater than 500-mi bandwidth could cost as little as 5 cents per meter in 500,000-km lengths in about five years," claims Lucy. This is close to the cost of cabled copper wire today, and the cost of copper is certain to have risen by then. And Richard A. Cerny, marketing manager for advanced fiber communications at Valtec Corp., West Boylston, Mass., thinks there will be sufficient demand by 1978 to bring prices down to around 25 cents per meter for cabled low-loss fiber channels. Prices now range from about $1.50 to $2.50/m of graded-index-fiber cable in quantities of up to 50 kilometers. Step-index fibers are less expensive.

According to Martyn Roetter of Arthur D. Little Inc., lasers could drop similarly to about $25 each in production quantities of 100,000. He bases this prediction on what has happened with other microwave devices.

The Navy's Don Williams is in full agreement with this kind of thinking. "It will not be long before we can compare fiber and wire costs on a foot-by-foot basis," he says. But even now, he emphasizes, optical fiber is economically superior if the larger perspective of life-cycle costs is taken into account. He points to a life-cycle/economic study, part of the A-7 Aloft program, that considered all the tradeoffs involved in using fiber-optic systems as against twisted-pair wire and coaxial-cable counterparts. It found that the optical-fiber bulkhead and cable connectors are not only half the cost of equivalent coaxial terminations, but the assembly time of optical-fiber cable and connectors takes 30% less time than with coaxial components. This included stripping the cable from the fiber bundle, gluing and polishing the fiber ends, and assembling the cable to connectors.

All this performance and cost data adds up to a technology in which just about all major computer manufacturers should be interested. And they are. Optical fibers offer them the large bandwidth needed to move massive blocks of data at high speeds and then throw in small size and weight, too. The ease of installing optical-fiber cable compared to multiple coaxial cables, along with its immunity to the large electromagnetic interference levels in and around computers, are other factors in its favor.

**The computer connection**

Computer hookups need wires routed through conduit to prevent sparking, and it costs about $4/foot to lay conduit. Fibers don't need conduits. In fact, no wiring changes are required to equip some existing computers with optical-fiber links.

Consequently, fiber optics will be widely used for interconnecting mainframes and peripherals. Moreover, the trend toward distributed data systems is certain to create the need for much greater bandwidth as numerous intelligent terminals, minicomputers and more memories are all interconnected. Initially, though, a computer could have a hybrid interface with one or two parallel coaxial lines and the remainder in serial fiber optics.

Du Pont, for instance, is looking into replacing the four-wire cable and conduit connecting two Digital Equipment Corp. PDP-11 minicomputers with two optical-fiber channels.

And Sperry Univac's Fiber Optic/Hybrid Component Development Group at St. Paul, Minn., is looking into using the miniaturized fiber-optic digital transmitter and receiver modules it is developing for the Naval Electronics Laboratory Center for the interface of peripheral equipment with fiber optics, especially in display terminals.

(Both transmitter and receiver modules were designed to be compatible with TTI signal interfaces and were packaged for bulkhead mounting to replace twisted-pair wire or coaxial-cable transmission systems. The receiver module includes back-to-back mounted substrates for the amplifier circuitry. The p-i-n diode photodetector is mounted in a conical reflector ferrule which attaches to the substrates. The other end mates with an optical-fiber cable. The transmitter module is physically similar to the...
receiver. It uses a hybrid driver circuit mounted on ceramic substrates and, for military environments, is hermetically sealed in a cylindrical case similar to the receiver.

Many overseas companies are thinking of fiber optics in terms of high-capacity telecommunications lines. U.S. companies are more inclined to look at fiber-optic links as replacements for short-haul trunking and lower-priced communications systems now, although eventually they will displace existing high-capacity lines as well. But at present, the main thrust is towards telecommunications applications like interoffice trunking and commercial applications like short-haul data transmission between computer peripherals, machine tools, and programmed instruments.

Other applications abound

One such system designed by AEG-Telefunken of Germany, called V300P, is already on the market [Electronics, Feb. 20, 1975, p.40]. And a follow-up system intended for high bit-rate color-TV signal distribution within large apartment buildings is in the works. Other applications for the system are to link computers and peripherals, to distribute CATV signals, or to carry signals from sensors to a process-control computer.

In Japan, fiber optics is being considered for telecommunications applications and has actually been used to control power facilities. The cables are threaded through tunnels containing high-voltage power lines and will replace microwave systems whose signals are often blocked by tall buildings and the like [Electronics, Aug. 7, 1975, p.45]. Nippon Electric Co. Ltd. carried out a field test recently in the high-voltage power station in Tokyo.

To round out the list, an experimental optical-fiber communications link is planned for the city of West Berlin jointly by Germany's post office authorities and ministry for research and technology [Electronics, Nov. 13, 1975, p.56].

Off the shelf

Within the last year analog and digital fiber-optic systems have been offered by many companies, such as ITT's Electro-Optical Products division, Roanoke, Va., and Harris Electronic Systems division, Melbourne, Fla., not to mention Meret Inc., Santa Monica, Calif., Spectronics Inc., Richardson, Texas, Bell Northern Research, Ottawa, Canada, Valtec Corp., West Boylston, Mass.

Typical examples come from ITT and Harris. ITT's system is capable of data rates of up to 25 mb/s over several hundred feet. Input and output are ITT-compatible with amplitude-regenerated data out. The analog system has one wideband channel, plus two narrowband channels that are fm-multiplexed onto the wideband channel so that only one optical channel is needed for transmission. Harris's 32-channel digital data link, on the other hand, is geared to computer-to-peripheral installations of up to 1,500 feet at data rates of 16 mb/s.

Perhaps Charles P. Sandbank, manager at the advanced Communication Systems division of Standard Telecommunications Laboratories, Harlow, Essex, England, sums it up best. "Fiber optics was once a matter of 'if to' and 'when,' but it will soon be a matter of 'when' and 'how much.'" Worldwide commitment is very great indeed. And the rugged low-cost fiber cables and other needed optical components are just about here to support the accelerated growth that's now happening. It's therefore important that design engineers become familiar now with all available components for such systems.

The necessary knowledge

It's partly the sheer unfamiliarity of fiber optics, in fact, in addition to its still rather high cost and the lack of standards, that is delaying the widespread adoption of this exciting new communications technology. Potential users need a better understanding of what fiber optics can do for them, and system designers need to overcome their resistance to change—much as an earlier generation did in making the switch from tubes to transistors.

To help remedy this state of affairs, the following nine articles will bring the engineer up to date in fiber-optic technology. They detail what's available in fiber-optic components and how to work with each of them. All are written by leading experts in their respective fields and have been structured to give the engineering community an in-depth, timely perspective on fiber cables, light-emitting and laser diodes, connectors, photodetectors and optical coupling techniques.

Subsequent issues of Electronics will include articles that focus on the systems design considerations with fiber optics. They will translate user specifications into systems, and their focus will be on the steps needed to specify optical fibers and components that best fit the overall requirements for both analog and digital fiber-optic communications systems.

Reprints of this Special Report, incuding the following nine articles, will be available at $3.00 each. Write to Electronics Reprint Dept., P.O. Box 669, Hightstown, N.J. 08520. Copyright 1976, Electronics, a McGraw-Hill publication.
FIBERS
High-performance cables achieve zero failure at rated tensile strength
by R. Love
Corning Glass Works, Corning, N.Y.

Optical waveguides have come far since 1970, the year in which fiber attenuation was finally brought within range of high-speed data-transmission requirements. Today, some commercial large-bandwidth graded-index fibers achieve an attenuation of only 5 dB/km—a quarter that attained in the laboratory six years ago. In the meantime, light sources have also been improving, and by now it seems generally agreed that single-fiber system configurations represent the best cost-performance tradeoff for most applications.

A rugged optical-fiber cable with six single fibers introduced in 1975 proved cost-competitive with coaxial cables in a number of communications applications and, in many cases, offered much better system performance. Now second-generation single- and multiple-fiber cables reduce incremental fiber attenuation due to cabling to less than 2 decibels per kilometer and, for the first time, are warranted for zero failure at the rated tensile strength. The important parameters of several optical fibers recently introduced by Corning Glass Works are listed in the table.

Starting from strength
Glas is inherently much stronger than metal—tiny strands of glass theoretically can withstand tensile loads upwards of a million pounds per square inch of cross section. But in field use, glass has seldom revealed much more than a hundredth of the fracture strength predicted of it. This strength, it has now been determined, is severely limited by the presence of infinitesimal surface flaws, and fracture always involves two independent processes: flaw initiation, and flaw propagation. Because of the random nature of flaw depth and spatial distribution, the probability of failure for a glass fiber depends upon its length. Also, since failure always occurs at the weakest flaw, or deepest crack, two seemingly identical fibers of equal length will not fail at the same stress level, or at the same time for an equally applied stress, unless the weakest flaws are also identical in depth.

In short, the strength of optical fibers, unlike that of copper wire, is an inherently statistical phenomenon. Therefore conventional strength parameters such as tensile strength or yield stress are not easily applicable to them.

A better approach is to characterize glass fibers in terms of their failure probability, by carrying out fast-fracture and time-to-failure experiments on a large number of fibers of the same gauge length. From the resulting data, failure probability for various combinations of applied stress, time, and fiber length can be derived on the basis of fracture-mechanics theory.

Alternatively, a minimum time to failure under constant load may be specified if fibers have been subjected to on-line screen testing. This involves applying a uniform tensile stress to the fiber at the time of manufacture and prior to final reeling. Survival of the screen test guarantees that no flaws greater than a certain depth exist in the final fiber, since otherwise failure would have occurred.

From the viewpoint of fracture-mechanics theory, screen testing sets the initial condition on flaw depth. If other material constants are known, the minimum time to failure as a function of applied stress can be calculated. Screen-test stress levels required to guarantee zero failure in 20 years are plotted as a function of service stress. This approach to characterizing fiber strength doesn’t depend on fiber length. The long-term service stress for zero failure is analogous to the yield stress properties of copper wire in electrical cables.

Microbends multiply losses
During the early phases of optical cable development, it was observed that numerous "microbends" (small axial distortions in fiber geometry) caused a significant

<table>
<thead>
<tr>
<th>Product No.</th>
<th>Index profile</th>
<th>Minimum bandwidth (MHz at 1 km)</th>
<th>Maximum attenuation, λ = 1200 nm (dB at 1 km)</th>
<th>Core diameter (μm)</th>
<th>Numerical aperture (× 0.02)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1150</td>
<td>Graded</td>
<td>200</td>
<td>10</td>
<td>62.5</td>
<td>0.16</td>
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<tr>
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<td>62.5</td>
<td>0.16</td>
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<tr>
<td>1151</td>
<td>Graded</td>
<td>400</td>
<td>10</td>
<td>62.5</td>
<td>0.16</td>
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<td>Graded</td>
<td>400</td>
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<tr>
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<td>Step</td>
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<td>10</td>
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<td>0.18</td>
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<tr>
<td>1128</td>
<td>Step</td>
<td>20</td>
<td>10</td>
<td>85</td>
<td>0.18</td>
</tr>
</tbody>
</table>

Corrugated fiber diameter (μm) 125 ± 6  EVA buffer diameter (μm) 250 ± 25
increase in fiber attenuation. Microbends tend to continually couple light energy back and forth between low- and high-order modes. The latter are more highly attenuated and may even be scattered out of the fiber entirely. Continuous axial distortions, as small as 1 micrometer in amplitude and spaced 1 millimeter apart, are sufficient to cause 20 dB/km of incremental attenuation.

(It is important to distinguish between this effect and the attenuation due to “bending” losses described on page 91. An occasional small-radius bend in a fiber merely radiates out higher-order modes, occasioning a low, one-time loss. Provided light energy is not coupled back into these modes, no further increase in attenuation will result when additional bends are encountered.)

To minimize microbending losses, optical cable is designed to mechanically isolate the fibers from small material or geometrical irregularities in the cable structure. In this, the new second-generation optical cables are particularly successful—any of the fibers listed in the table can be cabled with less than 2-dB/km excess attenuation. They are encapsulated in ethylene vinyl

Looking into fibers

Although three types of fiber exist—single-mode, step-index multimode, and graded-index multimode—only the last two have gone public. Single-mode fibers can propagate optical signals with a very low loss at extremely large bandwidths but are still in the research stage.

Of the other two, the less costly step-index fiber consists of a glass core of uniform refractive index surrounded by a cladding glass of slightly lower index of refraction. The more costly graded-index fiber has a core with a refractive-index profile that is radially symmetric and approximately parabolic in shape, being highest at the center of the core and decreasing parabolically till it matches the cladding refractive index at the core-clad interface.

Light launched into the core of either fiber at an angle less than the critical acceptance angle (numerical aperture) is reflected internally upon striking the core-cladding interface and therefore continues to propagate within the fiber core.

In both step- and graded-index fibers, the light signal is carried in a large number of modes, each with a characteristic velocity and propagation time. Graded-index fibers, however, because they minimize the propagation delay differences between various modes, can handle large bandwidths. As a rule of thumb, commercially available step-index fibers can handle data rates of up to 50 megabits/km, and graded-index fibers up to 500 Mb/km. The as-yet experimental single-mode fibers are capable of still greater things—more than several gigabits per kilometer.

As with electrical conductors, the signal-transmission properties of optical waveguides are characterized in terms of attenuation versus frequency. This transfer function depends on fiber attenuation (absorption and scattering) and signal dispersion (pulse spreading).

Both parameters depend in part on fiber materials. For example, absorption in the near-infrared portion of the spectrum is due mainly to OH radical vibration bands. On the other hand, Rayleigh scattering from the thermal fluctuations of constituent atoms is the primary scattering mechanism. Spectral attenuation curves include the effects of all these parameters.

The spectrum width of the light source and material dispersion in the fiber determine pulse spreading. For example, a 1-km length of a doped-silica optical fiber driven by light-emitting-diode with a spectral width of 50 nanometers exhibits a pulse spreading of approximately 3 nanoseconds. With laser diodes having spectral widths of about 2.5 nm, pulse spreading drops to about 0.3 ns.

To determine the transfer function of an optical fiber, attenuation and pulse spreading measurements are carried out on a standardized but arbitrary length, usually 1 km. The transfer function of an available Corning fiber results from superimposing the signal dispersion, which depends on frequency, on the fiber attenuation due only to scattering and absorption of light.
acetate to isolate them mechanically and buffer them against any small geometrical irregularities or distortions found in the jacketing or reinforcing components. The encapsulation also helps protect the fibers from damaging impact or abrasion during the reeling and handling operations. Their rated tensile strength is based on fiber screen-test stress, which may be derated with respect to time and applied load. As a rule of thumb, long-term (more than 20 years) tensile stress rating for zero failure is about one third of the fiber screen-test stress (Fig. 1).

Virtually any degree of tensile strength or crush resistance can of course be provided by appropriate reinforcing components and armoring. But just as in wire cables, ruggedness must be traded off against cable flexibility and cost.

Coax contrasted

Optical cables are installed in the ground in much the same manner as wire cables, except that a longer pull length for the same rated tensile strength is possible. For example, Corguide cable can be pulled through straight ducts longer than 1 km. This is because frictional forces are proportional to cable weight, and optical cables of the same diameter as coaxial cables are approximately four times lighter.

Moreover, beyond bandwidth requirements of a few megahertz, graded-index fiber cables are far superior to all but the most expensive, largest-diameter, coaxial cables. And lower-bandwidth-capability step-index fiber cables outperform all but RG-17/U coax cables up to 100 MHz.

Also the dielectric nature of optical fibers makes them immune to electromagnetic interference. They do not conduct electricity, thus avoiding ground loop problems and offering a degree of transmission security. Moreover, in ordinary cable environments, optical cables show much less change in their transmission properties (attenuation, pulse distortion) than their metallic counterparts.

Performance data shows that optical cable is superior to coaxial cable on a single-channel basis, above a few megahertz. In addition, 10 or more fibers (channels) can be packaged in a single cable the size of RG-63/U with cross talk more than 80 dB down over a 1-km length. Cost on a per-channel basis now ranges between $0.60/ft and $2/ft for optical cables compared to $0.15/ft to $1.50/ft for coaxial cables.

FIBERS
Simple testing methods give users a feel for cable parameters

by R.B. Chesler and F.W. Dabby
Fiber Communications Inc., Orange, N.J.

Mechanical as well as optical characteristics play an important part in the design of optical-fiber systems. In particular, it's necessary for the designer to understand how to prevent mechanical stresses from breaking fibers or causing too much attenuation and how to check cable parameters like tensile strength, attenuation, and numerical aperture.

The risk of breakage is perhaps the major concern of the optical-fiber user, though the availability of cabled fibers has certainly made it less of a worry. Basically, fibers break under too heavy an axial load or when bent in too small a radius. The two breakage modes are related, and determining one breakage point sets the level for the other.

Stress levels

From the cross-sectional area of the fiber and the minimum safe bending radius, the maximum load bearing capability of an unjacketed, uncabled fiber can be calculated. Increasing a fiber's cross-sectional area makes it stronger but also, by increasing its radius, r, limits its minimum bending radius, \( R_{min} \), before breakage. The relationship describing this tradeoff is:

\[
S_r = \frac{E}{r/R_{min}}
\]

where \( E \) is Young's modulus, typically 10^7 psi.

For an uncabled low-loss fiber, which consists of a core and cladding to protect the core material, a reasonable maximum tensile load-bearing level, \( S_r \), is 50,000 pounds per square inch for about a 1-km length. The tradeoff of tensile strength with minimum safe bending radius usually limits the diameter of commercially available fiber to between 2 and 8 mils. A 3.5-mil uncabled fiber, for example, can be tied into a circle less than \( \frac{3}{8} \) inch in radius.

One common method of measuring the tensile strength of uncabled fiber is to clamp a length of fiber at both ends and measure the load needed to break the fiber. This method has the advantage of stressing the entire length of fiber between the clamps. Considerable care, however, is required to assure that clamping or misalignment of the clamps does not cause premature failure of the fibers under loading.

If the necessary stress-measuring equipment isn't available, an alternate approach yields usable data. In this method the fiber is tied into a simple overhand knot. Then, as the knot is tightened, the resulting circle is monitored. The minimum safe radius occurs just before the fiber breaks. From this value and the fiber radius the maximum tensile load-breaking ability of a fiber can be easily calculated from the above equation.

Cabling each fiber individually increases its load-bearing capability. At present, several materials are commercially available for cabling low-loss optical fibers.
in fiber-bundle, multi-fiber and single-fiber cables. Currently, single-fiber cables with diameters as small as \( \frac{1}{2^0} \) in. can withstand tensile load-bearing levels of 475 pounds—better than some multiple-fiber and fiber-bundle cables.

Besides fiber breakage, bends cause losses. They increase the attenuation by reflecting out of the fiber core some of the many light modes that should propagate within it. As these modes encounter a region of bends in a fiber, they enter the core-cladding interface at a larger angle than the one critical for total internal reflection.

The leakage becomes more pronounced as a fiber-core diameter increases or as numerical aperture decreases. But reducing the core diameter to minimize bending loss results in less light being coupled to the fiber—coupling efficiency being proportional to the square of the core diameter. Increasing the numerical aperture also decreases bending loss, but reduces the information-carrying capacity of an optical-fiber waveguide.

In general, commercially available, low-loss optical fibers with glass core and cladding have numerical apertures of between 0.1 and 0.3. Commercial fibers with higher values of numerical aperture have higher attenuation, which in the case of glass-core, plastic-clad fibers, increases drastically in humid or watery environments.

**Flat finish**

Optical polishing of fiber ends is used only for terminating fiber bundles (see p. 99 and p. 101). With single-fiber cable, cleaving the ends is fast and easy and all that’s necessary. Properly cleaved surfaces are flat and perpendicular to the fiber axis and are well suited for coupling to sources and detectors or to other lengths of fiber.

The first step in cleaving a fiber end is to remove any cabling or jacketing material from 3 or 4 inches of fiber. Next the bare fiber is grasped at two points, about half an inch apart, between the thumb and forefinger of each hand. This half-inch section is held taut and gently drawn across the hard edge of a suitable scribing surface, such as a sapphire crystal, so as to scratch the glass fiber but not break it. Then a gentle tug will snap the fiber at the scratch. The fiber must be pulled straight without any bending.

The quality of the cleaved surfaces is then checked under a microscope. A good cleave also produces a circularly symmetric output light pattern when light from the fiber viewed on a screen about a foot away.

The cleaving technique works well for fiber diameters up to approximately 5 mils. Fibers with larger diameters must be bent around a mandrel and cleaved under tension. Simple instruments and tools for fiber cleaving are available commercially.

**Looking for loss**

Comparing the magnitude of transmitted light power at two points along a fiber waveguide eliminates the need for measurements of absolute optical power and light coupling efficiency. The typical setup shown in Fig. 1 makes it possible to determine the attenuation spectrum over an entire length of fiber.

Both ends of the entire length of optical fiber, \( L \), to be evaluated are cleaved. One end is mounted in a movable holder, which is later adjusted to maximize the light input to it, and passed through a mode-stripping liquid placed near the input measuring point. Mineral oil or any other liquid with a refractive index close to that of the cladding (between 1.42 and 1.47) may be used. Doing this eliminates the unwanted “cladding” modes—those launched into the fiber because the numerical aperture of the input light beam is greater than the fiber’s numerical aperture. This arrangement gives a fairly uniform illumination of all the desired fiber waveguide modes.

The other end of the fiber is placed into an output holder near a detector located in a light-tight chamber. The fiber holder at the input end of the length of cable is then adjusted to maximize detector current as read on the nono-ammeter, and the maximum amount of photodetector current for each wavelength of interest selected.

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1. **Finding fiber loss.** This test setup makes it possible to find the attenuation of a long length of fiber directly, without having to worry about measuring either the absolute optical power of the source or the efficiency of the light-coupling arrangement.
by the input monochromator is recorded.

To obtain a consistent set of maximum readings at the desired wavelengths, several readings must be taken, with the fiber being cleaved at the detector end after each readout to eliminate inaccuracies caused by bad cleaves, dust particles on the fiber end, etc. Isolated low readings will occur because of imperfectly cleaved fiber ends, and these should be discarded.

The fiber is then cut about 3 meters from the input end of the fiber without disturbing the positioning of the input end so that the same coupling is maintained. The cut end of the 3-meter-long section is then cleaved and placed into the output fiber holder. Again, measurements at other wavelengths of interest are repeated to obtain another set of consistent data. From these two sets of data, the attenuation, $A$, expressed in dB/km, of the entire fiber length less 3 meters is calculated for each wavelength:

$$A = \frac{10 \log_{10} f}{L}$$

where $L$ is the final length of fiber in kilometers less the 3-meter section that was cut from the initial length of cable, and $f$ is the ratio of the measured input optical power to the measured output optical power of any particular wavelength of light. For cables longer than several hundred meters, $L$ can be assumed to be the initial cable length.

The numerical aperture of an optical fiber waveguide describes the maximum angle about the fiber axis through which light can propagate in the fiber. It is defined as the sine of the half-cone angle of the rays measured in air, and it generally varies with fiber length, because of fiber attenuation characteristics that modify the initial distribution pattern of the light.

**Numerical-aperture measurement**

Most manufacturers specify the numerical aperture of low-loss fibers by measuring the radiation pattern of a 3-meter-long fiber with all modes excited. This can be done simply and without elaborate equipment. The fiber is excited in the visible region, and the light emerging from the end is displayed on a screen placed several inches to a foot away. A solid circle of light is seen if all fiber modes have been excited; if not, a ring of light results.

Since the boundary of the circle of light is not perfectly sharp, some convention for determining the edge must be adopted. A common choice is the point where the light intensity is 10% of the maximum value. Actually the eye makes a good discriminator, and all that need be done is to measure the diameter or the circle of light with a ruler. Dividing that number by twice the distance from fiber end to the screen gives the value of numerical aperture.

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**SOURCES**

**High-radiance LEDs have linear response to analog inputs**

by F.D. King

Bell Northern Research, Ottawa, Canada

For optimum performance, a fiber-optic communications system depends heavily on a light source that can efficiently couple maximum power with adequate bandwidth into the optical fiber. Its wavelength should suffer only minimum attenuation in the fiber and should match the maximum responsivity of the photodetector.

Both light-emitting diodes and laser diodes are highly compatible with doped silica fibers and silicon photodetectors, so the decision which to use depends on other system requirements. LEDs, unlike laser diodes that suffer modal instability, can produce a much more linear power output, making them better suited for analog applications. They also cost less and are much less affected by temperature changes than laser diodes. On the other hand, they are not as fast, and their output power is spread over a wider angle, so that less of it succeeds in entering an optical fiber.

To be more specific, gallium-aluminum-arsenide LEDs produce light at high efficiency (10%) at an 840-nanometer wavelength where the attenuation of silica fiber is as low as 2 decibels per kilometer and the responsivity of silicon photodetectors is a high 0.55 ampere/watt. Their output power is 5 to 20 milliwatts either in a 120-by-40 beam (edge-emitting type) or in a Lambertian pattern (surface-emitting type). Fiber coupling loss is high—for a fiber with a numerical aperture of 0.14, losses are about 14 dB for edge emitters and 19 dB for surface emitters. Only the best (and most costly) LEDs can be modulated at rates of 200 megahertz.

Typical laser diodes, on the other hand, can be modulated at speeds up to 1 gigahertz. They also produce from 5 to 20 mw over a 40-by-10 beam with a loss of about 3 dB when coupled into a fiber with a numerical aperture of about 0.14.

**Different types**

High-radiance LEDs designed for optical communications, as already indicated, either surface emitters (usually those of the “Burrus” type first developed at Bell Laboratories) or edge emitters (developed at Bell Laboratories). Although the edge emitter is inherently capable of better coupling efficiency (especially with a cylindrical lens) than a surface emitter, the inferior coupling efficiency of the surface emitter is more than compensated for by its higher total radiated power. Both are shown in Fig. 1.

The most promising use a double-heterojunction design, being fabricated by sandwiching a thin active
1. Charting coupling loss. Power coupled from a LED into an optical fiber depends on the numerical aperture of the fiber. Typical LEDs produce light over very wide beam patterns that make the fiber’s light acceptance angle and placement critical.

2. Determining distortion. Source linearity is very important in analog systems. From curves taken at different modulation depths for several BNR LEDs, it is possible to determine the optimum dc bias for minimum total harmonic distortion.

### Table 1

<table>
<thead>
<tr>
<th>BNR device</th>
<th>External quantum efficiency (%)</th>
<th>Radiant intensity (at 150 mA dc) mW/sr</th>
<th>Response time (10–90%) (ns)</th>
<th>Spectral half width (nm)</th>
<th>Max. power launched into 0.2 numerical aperture step index fiber, 150 mA dc (mW)</th>
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</thead>
<tbody>
<tr>
<td>A</td>
<td>7</td>
<td>3</td>
<td>14</td>
<td>25</td>
<td>40</td>
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<tr>
<td>B</td>
<td>4.6</td>
<td>1</td>
<td>4</td>
<td>88</td>
<td>45</td>
</tr>
<tr>
<td>C</td>
<td>2.3</td>
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<td>45</td>
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### Table 2

<table>
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<th>Characteristic</th>
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<th>BNR 7-2-A</th>
<th>Corning</th>
<th>BTL</th>
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<tr>
<td>Numerical aperture</td>
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<td>0.22</td>
<td>0.19</td>
<td>0.22</td>
</tr>
<tr>
<td>Core diameter (µm)</td>
<td>100</td>
<td>100</td>
<td>85</td>
<td>50</td>
</tr>
<tr>
<td>Type</td>
<td>Step</td>
<td>Graded</td>
<td>Step</td>
<td>Graded</td>
</tr>
<tr>
<td>Coupled power (µW)</td>
<td>370</td>
<td>280</td>
<td>340</td>
<td>140</td>
</tr>
</tbody>
</table>

Current density = 4.5 kA/cm² Emitting area = 65 µm diameter

Layer of gallium arsenide between two layers of GaAlAs that absorb no energy and (in the case of edge-emitter types) act as light guides. The peak emission wavelength of double-heterojunction GaAlAs LEDs can be varied from 850 nm to 780 nm by increasing the aluminum content with no significant change in device efficiency. This allows the system designer to match fiber and source for minimum attenuation. Both peak emission wavelength and half-power spectral width show little change with drive current.

On the assumption that a fiber-optic-system designer opts for a LED source, the best device depends not only on total coupled power but also on speed, reliability, spectral bandwidth, and device B for speed of response, whereas device C represents a compromise between the two. By reducing device capacitance, LEDs with response times of less than 2 ns have been fabricated.

These devices all have nearly linear light-versus-current characteristics up to 250 milliamperes in continuous operation and a 1-ampere, 10-microsecond pulse in pulsed operation at 10³ pulses per second. The temperature dependence of the light output of these devices is typically 0.2% per °C.

In wideband communication over long distances, chromatic dispersion in the fiber may limit repeater spacing. Because the velocity of light varies with wavelength, the different spectral components separate out as the light propagates down the fiber. The optical bandwidth-length product at which this effect becomes significant is determined by the spectral width of the light source. The spectral half-width of a typical BNR LED, for example, is 35–45 nm at 840 nm. This would limit the optical bandwidth-length product to 100 – 140 MHz-km.

The optimum coupling efficiency between a surface-
emitting LED and an optical fiber is usually obtained by butting the fiber to the emitting area. But extremely close butting is unnecessary if the light-acceptance cone of the fiber encloses all of the LED emitting area. This means that the ratio of source-to-core cross-sectional area can be optimized for graded-index fiber, whose acceptance angle is largest at the fiber axis and decreases with increasing distance from the axis. However, for a close-butted step-index fiber, making this ratio less than 1 does not improve coupling efficiency.

It would seem to follow from this that the numerical aperture of a fiber, which defines its acceptance angle, should be as large as possible, to maximize coupling efficiency. But values of more than 0.25 are seldom practical in long fiber links because modal dispersion also increases with numerical aperture. The power-coupling characteristics of a typical high-radiance LED used with several types of low-loss fibers are shown in Table 2.

The reliability of high-radiance Burrus-type LEDs has been investigated at room temperature, at elevated temperatures, and during temperature cycling. Uncapsulated devices, following a qualification test, have operated for longer than 3,000 hours at 3 kiloamperes per square centimeter and 130°C without any decrease in efficiency. Moreover, no change in efficiency was noted over temperature cycling (20 cycles, −40° to +80°C).

Packaged encapsulated devices with fibers attached that passed further qualification tests were operated at 3 kA/cm² and 25°C for 10,000 hours and temperature-cycled (5 cycles, −30° to +30°C) without degradation. Extrapolations from accelerated aging tests indicate that high-radiance Burrus-type LEDs should provide greater than $10^5$ hours of operation.

SOURCES
Laser diodes provide high power for high-speed communications systems

by J.T. O'Brien
RCA Electro Optics Division, Lancaster, Pa.

The trend to optical communications systems, "wired" with single fibers rather than bundles of fibers, puts a premium on the efficient coupling of source power into the fibers. The smaller optical aperture of the single fiber requires not only the higher source power of the laser diode but construction techniques that attach the fiber directly to a laser pellet. Meanwhile, laser diodes have their uses in high-speed, high-power systems using both fiber bundles and single fibers.

Two types

Gallium-arsenide and gallium-aluminum-arsenide laser diodes are available in single- and double-heterojunction structures. The double-heterojunction diode consists of a thin active layer of gallium arsenide, usually lightly doped with aluminum, sandwiched between two layers of GaAlAs. The single-heterojunction type has only one layer of GaAlAs along with the active layer of GaAs or GaAlAs. But the most important difference between them is the much higher data-rate capability of the double-heterojunction type (greater than 100 megahertz versus 100 kilohertz).

Single-heterojunction laser diodes are low-cost, off-the-shelf items used in low-duty-cycle applications requiring high output power. Peak radiant flux of these diodes is limited to approximately 1 watt per mil of emitting-junction width at a 200-nanosecond pulse width. For example, a diode with a 9-mil-wide junction, such as the RCA SG2007, is rated at a maximum of 10 w peak output. But because the diode's need to dissipate heat sets limits to its operation, a tradeoff between pulse width and pulse repetition rate must be made. Consequently, at a maximum pulse width of 20 ns and a maximum duty cycle of 0.1%, the repetition rate is limited to 5 kHz. At pulse widths on the order of 10 ns, repetition rates of 100 kHz are possible.

The double-heterojunction laser diode requires relatively low drive current and voltage (less than 400 milliamperes at 2 volts). Continuous or high-duty-cycle operation is possible at room temperature with power outputs in the 5-to-10 milliwatt range at less than 1-ns rise time. Analog or digital bandwidth capability exceeds 100 megahertz.

The semiconductor laser is essentially a line source with an emitting dimension of 0.08 mil times the emit-
2. Switching sources. With the transistor circuit shown, pulses as short as 10 nanoseconds at repetition rates of 100 kilohertz are possible, but peak current is limited. Silicon controlled rectifier switches produce higher current but at lower repetition rates.

3. Temperature-sensitive. The threshold current for the RCA laser types C30127 and C30130 increases rapidly above room temperature. At 60°C the peak output drops to half its room-temperature value, and in some instances lasing may stop.
dramatic improvement.

One problem with laser diodes is that relatively small changes in temperature can change their output significantly. As shown in Fig. 3, threshold current for RCA types C30127 and C30130 increases at temperatures above 27°C and doubles at about 70°C, while with constant current drive applied, the peak radiant flux at 60° drops to 50% of its room-temperature value. In fact, threshold current of the drive may increase sufficiently to prevent lasing.

Because of this heavy dependence of threshold current on temperature, the laser should be operated at some fixed temperature within its operating range temperature. A small thermoelectric heat pump will maintain the laser heat-sink temperature to within a few tenths of a degree over the expected ambient temperature range.

For analog systems, it is necessary to bias the device well above the threshold point and then superimpose the analog modulating signal on the dc drive current. Figure 4 shows a typical circuit used to measure the linearity and harmonic content of a laser diode when operated in the analog mode at 10 MHz. Approximately 350 mA of bias current is sufficient to provide a continuous output of 7 mw. A 30-mA peak-to-peak 10-MHz sine wave is coupled through capacitor C4 and the laser output measured with silicon photodiode. The first harmonic at 20 MHz is 40 dB below the fundamental.

Laser lifetime remains another problem. It must be increased to well beyond $10^5$ hours if the diodes are to find use in systems where 20-year reliability is essential. Actual laser-lifetime data isn't yet available, but data extrapolated from selected samples translates into a mean time between failures of 10 hours for some lasers with a heat-sink temperature of 22°C.

The third big problem area—efficient coupling of laser to fiber—should be alleviated with construction techniques that attach a short length of fiber directly to the laser pellet.

**CONNECTIONS**

**Well-designed splices, connectors must align fibers exactly**

by J. F. Dalgleish

Bell Northern Research, Ottawa, Canada

Splices for joining lengths of optical-communications cable in the field must provide low-loss, quick but permanent connections, and also be small, lightweight, and rugged. Except for the permanency, the same requirements hold for the connectors that couple the cable to terminal equipment.

Single-fiber splicing losses of less than 0.1 decibel have been reported in the laboratory but have yet to be demonstrated in the field. Nevertheless, total splicing loss in a given length of fiber both can and should be much less than the fiber attenuation.

The most critical parameter, variously called axial or lateral alignment, is also one of the most difficult to control. Slight offset between the two fiber ends dramatically increases optical loss (Fig. 1). Alignment accuracy in the order of micrometers is needed, thus requiring similar machining tolerances of the associated hardware.

One splicing technique in widespread use is the preci...

**1. Fiber offset causes loss.** Any slight offset between two fiber ends increases optical coupling loss. An axial displacement equal to half the fiber core diameter causes greater than a 4-dB loss; separating the fiber by that amount produces a 6-dB loss.
2. Fiber guide. A precision sleeve or tube that conforms exactly to the outer fiber diameter positions both fibers. Once both fiber ends are butted together in the splice sleeve, the sleeve ends are crimped into the fiber’s plastic coating.

Sleeve or tube, which, by conforming precisely to the outer diameter of the fiber, guides it into position and then holds it there. This requires individual handling of fibers and is most suitable for single fibers or small cables. Sleeves may be of metal or glass, and an entrance funnel aids fiber insertion. Once the fiber ends are prepared and the two fibers butted together in the splice, the outer jacket of the fiber is clamped or, in some cases, a metal sleeve is crimped around it.

A fiber splice developed by Bell Northern Research is based on this technique (Fig. 2). A stainless steel preform tube has a center alignment bore that fits the bare fiber diameter closely. The prepared fiber ends are guided into the alignment bore by tapered sections, and the ends of the splicing element are then crimped into the fibers’ plastic coating for permanent assembly. Because the plastic coating extends inside the tube, no other mechanical protection is needed. With a silicone fluid pre-injected into the splicing element, insertion losses average 0.3 decibel from a laser source.

Another technique reported by Bell Telephone Laboratories—the loose tube splice—may be suitable for field use because it uses inexpensive components. It exploits the self-aligning tendency of fibers in a “V” groove (Fig. 3). Prepared fiber ends are inserted into a rectangular tube already filled with index-matching epoxy. The fibers are slightly bent, forcing the tube to rotate so that their ends travel along a corner. Once butted together, the ends are held in place until the epoxy cures. Losses average about 0.1 dB when a laser source is used.

Connectors have an added requirement: they must be able to mate repeatedly without degrading too much in coupling efficiency or mechanical integrity. They should also be simple to use, like electrical connectors.

A single-fiber connector, developed by Bell Northern Research for use with plastic-coated multimode fibers, is a variation in the precision-sleeve splicing element (Fig. 4). The connector plug has tapered funnels at each end leading into a central alignment bore (the only critical dimension). The longitudinal position of each fiber is accurately located with respect to a reference surface on each housing. This is done using a special fixture. Both the plug and its mating jack are mounted separately on a fixture, and prepared fiber ends are inserted into each connector half until they butt against the fixture’s stops. Crimping the stainless-steel tubing into the fibers’ plastic coating holds them firm. When mated, the reference surfaces are in contact and the fibers are separated by a small gap.

During mating, the fit between plug and jack insures that the jack fiber enters the tapered opening of the plug. Once mated, the plug and the jack are

3. Self-aligning. The loose-tube splice, as it’s called, makes use of the self-aligning tendency of the fibers. When the fibers within the tube are slightly bent, the tube rotates, holding the fiber ends in place until an epoxy positions them permanently.

4. Variation on a theme. Bell Northern Research’s single-fiber connector adapts the precision-sleeve splicing principle. Once mated, the connector is only 2 centimeters long and, when unmated, the plug and jack housings protect the fiber as shown.
Typically, rematable insertion loss of the connector is 1 dB when an index-matching fluid and a LED source are used. Smaller losses have been reported with experimental connectors, but this device is more practical, in that its standard-diameter alignment bore can accommodate manufacturing tolerances in fiber diameter. When installed in prototype fiber-optic systems, both with and without index-matching fluid, these connectors showed typical insertion loss variations of less than 0.2 dB after being remated up to 100 times.

CONNECTIONS

Metal connectors protect fibers during termination and in the field

by K. J. Fenton
ITT Cannon Electric, Santa Ana, Calif.

Metal connectors that terminate or couple fiber bundles differ from single-fiber metal connectors both in the way they deal with fiber alignment, handling and protection and in optical end preparation.

Some requirements, though, are identical. Both types of connector must provide for terminating the jackets, strength members, and buffering materials used in fiber cables, and both must insure that loads applied to the cable are not transmitted to the terminated fiber. Moreover, optical-fiber connector designs must provide for protection of the fibers during termination and end preparation as well as after they are installed in the connector.

Alignment critical

The alignment of a fiber bundle with a LED or laser diode source, photodetector, or other bundles is far less critical than the alignment of a single fiber for these same three connection areas. The coupling losses between pairs of fiber bundles as well as single fibers depend heavily on their degree of lateral (or axial) misalignment.

Rather less critical than lateral alignment is the size of the gap between prepared fiber ends (though there must be a gap), and less critical still, though still important, the angular alignment of their center lines.

In separable connectors it is extremely important that the prepared ends of the fibers do not touch since otherwise repeated matings of vibration and shock will chip and scratch the optical-fiber surface and degrade the optical efficiency of the connector. But the gap cannot be too large—if the coupling losses contributed by it are to stay within 0.2 decibel, it should not exceed 10% of the active core diameter of the fiber bundle or single fiber. This works out as a 75-micrometer (0.003-inch) gap for a typical 1,125-μm (0.045-in.) bundle or a 5-μm (0.0002-in.) gap for a 50-μm (0.002-in.) core for single fiber.

The loss characteristics for these gaps also vary slightly as a function of the numerical aperture of the bundle or single fiber. Angular misalignment within ±1° for bundles of optical fibers and half that for single optical fibers results in acceptable losses of from 0.1 dB to 0.2 dB.

For both bundle and single-fiber connectors, a chip-free, scratch-free, flat surface, perpendicular to the fiber centerline, is essential for good optical coupling. If any of these conditions is lacking, light scattering occurs at the fiber ends.

Fiber-bundle termination

A rather simple polishing procedure can produce a sufficiently good optical interface on a fiber bundle. When being polished, all of the fibers must be held rigid and adequately supported to prevent them from
chipping or cracking.

Usually, the fiber bundle is first stripped of its jacket and fiber buffering materials, and the exposed fibers are cleansed of lubricants and contaminants. For most cables, epoxy is applied to immobilize them, and the bundle is slipped into a termination device that packs it into a tight hexagon. The hex shape provides the optimum packing fraction (the ratio of the cross-sectional area of the fiber cores to the total area of the fiber bundle). At this point, the epoxy has cured, and any excess fiber length is cut off with wire cutters or scissors.

A two-step, wet-polishing procedure comes next. First a 400 grit abrasive is used to rough-polish the ends, and then a 0.03-micrometer paste applied with a felt wheel produces the final finish. The two steps take less than 1 minute. Additional polishing does not improve matters and often reduces optical efficiency because it may dome the fiber ends. The final step is to protect the prepared end with a thin, transparent cap supplied with the connector.

**Single-fiber termination**

The end preparation and termination for a single fiber is significantly different. The jacketing and fiber buffering materials are removed, as before, but the exposed fiber is then broken in a fixture to the precise length required. (Fixtures capable of producing the necessary controlled, consistent break have been developed by several manufacturers.) Also, the fiber end must be precisely located within the terminating device, and this critical step must be accomplished by other special fixtures.

Several manufacturers offer a variety of optical connectors for the termination of fiber bundles. Circular or rectangular in shape, these accommodate from 1 to 18 optical channels or combinations of electrical and optical channels. Several connectors in various sizes and mounting styles available from ITT Cannon (Fig. 1) couple standard LED or laser-diode sources to fibers, fibers to fibers, and fibers to photodetectors.

Coupling losses depend on the size and number of fibers in the bundle, the core-to-cladding ratio of each fiber, and the numerical aperture of the fiber bundle. Losses from fiber bundle to fiber fall between 2.5 decibels and 3.5 dB.

**Making a match**

Source-to-fiber and fiber-to-detector coupling efficiency, however, varies not only with the connector but with the device characteristics and how well the fiber is matched to either detector or source. For example, an edge-emitting laser produces a doughnut of light in the near field; if the fiber is placed in the middle, then no light is coupled into it. As for the connector's effect, using different types to couple commercially available light-emitting diodes and photodetectors to fiber-bundle cables results in a wide range of coupling losses—source-to-fiber bundle coupling loss can vary from 3 dB to 14 dB with off-the-shelf devices while fiber-bundle-to-photodetector coupling loss can vary from 0.5 dB to 8.5 dB.

In addition to selling just optical connectors, some manufacturers offer an economical bundle-termination service as well as complete cable assemblies. Most also plan to offer tooling and fixtures to terminate bundles in the factory as well as in the field.

2. New entry. Few companies as yet are marketing single-fiber-per-channel connectors, but this recently released connector from ITT Cannon Electric can be used to join two single fibers or to couple a photo or a LED or laser diode to the fiber.
Connectors for some single-fiber cables are presently offered on a limited quantity, special-order basis. In fact, the only types available at present are for cables containing either one or six functionally different fibers. The single-fiber-per-channel connector shown in Fig. 2 is a very recent introduction.

The coupling efficiencies of these single-fiber connectors vary with fiber type, overall fiber size, core size, and the numerical aperture of the fiber. Fiber-to-fiber optical losses also vary, depending on the quality of the fiber-end preparation and accuracy of termination location within the termination device. Typically, coupling losses of from 1 dB to 2.5 dB are expected in these connectors.

**CONNECTIONS**

Low-cost plastic connector speeds the polishing of fiber-bundle ends

by T. Bowen

Molded thermoplastic connectors are an inexpensive, fast, and reliable way of terminating fiber-optic bundles. Economically mass-produced, they weigh much less than metal parts and also interfere less with the optical polishing of the bundle ends. Any plastic smeared across the fiber surface during the polishing will be too soft to score them, unlike metal, and can easily be removed.

The connector shown in Fig. 1 is one of a series designed to further simplify the polishing process—in fact, as will be explained later, it can be installed in the field by people without special skills or training. Equally important, it optimizes packing fraction—the ratio of active cross-sectional area of optical-fiber cores to the total end-surface area of the bundle—and can handle the full range of fiber-bundle types and size from most major fiber-cable manufacturers.

It mates with either an input/output bushing that can house many standard light sources and detectors or with a splice bushing for terminating cables. For a dry splice—two face-to-face terminations separated only by air—insertion loss is about 3 decibels, a figure that falls to about 2 dB when an index-of-refraction-matching fluid is added as a coupling medium.

Before this connector can be attached to an optical-fiber cable, the cable's jacket must be stripped away and a generous amount of an epoxy or a cyanoacrylate adhesive applied to the exposed fibers. The connector assembly then slides easily onto the bundle, and the crimp ring attaches it to the jacket. The closing action of the specially contoured polishing bushing radially compresses the nose end of the ferrule, squeezing all the fibers together. This spreads the adhesive thinly,
allowing it to set up instantly and lock the fibers.

Next, with the special bushing still attached, the bundle is polished by being wiped across three separate grades of sandpaper with abrasiveness ranging from 320 grit to 600 grit. Then the fibers are simply wiped clean and the polishing bushing discarded. Extra polishing gains only a couple of tenths of a decibel.

In terminating plastic optic fibers, as in the DuPont PFX bundle, the process is even simpler. There is no need to remove the jacket or immobilize the fibers with adhesive or epoxy—the jacket material extruded around the soft plastic fibers holds them tight enough. In fact, because the connector assembly is attached to the jacket with a crimp ring, the use of adhesive can be eliminated from the end-termination procedure entirely. The remaining procedure is then the same as for the more brittle glass-fiber bundles.

Mating bushings provide the necessary alignment mechanism for source-to-bundle and bundle-to-detector coupling. To protect the optical interfaces from contaminants, an O-ring seated on the ferrule engages the face of the bushing when the parts are mated.

**DETECTORS**

**Inexpensive p-i-n photodiodes match fiber, source characteristics**

by P. H. Wendland, R. M. Madden, and B. Kelly

*United Detector Technology Inc., Santa Monica, Calif.*

The receiver portion of any fiber-optic system requires a photodetector that responds strongly to both the peak output wavelength of the source and the low-loss spectral portion of the fiber cable used. Just as important is the match between the detector and its amplifier. On the whole, these needs in most emerging systems seem better served by p-i-n diodes than by either phototransistors or avalanche diodes.

Silicon phototransistors are inexpensive—typically less than $1 each in large quantities. But their slow speed limits system bandwidth to less than a few megahertz, their poor linearity restricts their dynamic light-level range to about three decades and, worst of all, internal noise is an order of magnitude greater than in p-i-n photodetectors.

**Getting gain**

Avalanche photodiodes combine optical signal detection with internal amplification of photocurrent. But unfortunately, they also amplify noise—the avalanche mode creates it, and it reduces the internal signal-to-noise ratio.

However, the devices have their uses at the higher frequencies, because above 1 MHz system noise limitations are set by the preamplifier and not the detector. Also, though future devices may operate at voltages below 100 volts, today's units now need 200 to 300 V, so that a high-voltage power supply is required, and often a constant-temperature chamber as well.

All the same, avalanche photodiodes could prove useful in pulse-code-modulated systems, where the absolute level of the analog signal is not of major importance and the highly regulated power supply and a constant temperature chamber might therefore prove unnecessary. In amplitude-modulated communications systems, however, the effect of environmental and particularly temperature changes on avalanche diode gain would cause considerable problems.

High-performance p-i-n type silicon photodiodes have been in production for many years and cost less than $1 each. They exhibit nanosecond response times and can have a dynamic light-level range of 8 to 10 orders of magnitude at relatively low bias voltages. Their peak response between 850 and 950 nanometers matches well with the peak emissions of light-emitting diodes and the low-loss spectral regions of optical fibers.

These photodiodes are usually connected to a relatively low impedance to allow the photo-excited carriers to induce a photocurrent in the load circuit. (Photovol-
2. Typical circuit. The input field-effect transistor sets the overall noise performance of the photodetector-amplifier combination: Operating with 10-MHz optical-fiber links the circuit provides a signal-to-noise ratio of 5:1 for input power levels of 10 nW.

tonic mode operation with open-circuited terminals is possible, but gives logarithmic outputs and a slow response.) Geared for systems of less than 10 MHz, 30-ns p-i-n photodiodes are commonly operated at bias voltages of about 15 V to reduce carrier drift time and lower diode capacitance without introducing an excessive dark current.

Operating a reverse biased p-i-n photodiode into a low-impedance operational amplifier (Fig. 1) provides maximum linear dynamic range and fastest response. The basic limitations of this circuit lie with the amplifier, not the detector. Present operational amplifier technology restricts the bandwidth to about 5 megahertz at input noise currents corresponding to light levels below 10 nanowatts.

A reverse-biased detector creates noise, however. There is the shot noise caused by detector dark current and signal current, the Johnson noise of the feedback resistor, and the input noise voltage of the amplifier. In wideband applications, the noise voltage of the amplifier, \( e_n \), usually dominates. Its input noise voltage appears at the output, magnified by the ratio of the feedback resistance divided by the source impedance. At the higher frequencies, the capacitive reactance term of the source impedance predominates.

Critical components

Consequently, it's essential to minimize not only the input noise voltage of the preamplifier, but the input capacitance and noise bandwidth as well. Input capacitance has three components: amplifier input capacitance, detector capacitance and stray capacitance. The noise bandwidth is usually much larger than the signal bandwidth, and therefore it is essential that the amplifier bandwidth be made no greater than overall system constraints dictate.

Ideally, the preamplifier should raise the detector signal level to a magnitude that is easily manipulated by conventional analog or digital electronics without adding excessive noise or degrading the performance of the detector. The circuit shown in Fig. 2 typifies detector/preamplifier combinations available for use in fiber-optic systems.

The very low input impedance (10 to 50 ohms) of the transimpedance amplifier configuration is an ideal load line for the silicon p-i-n detector, assuring its linear operation and improving its frequency response. The amplifier, which acts as a current-to-voltage transducer, provides an output voltage equal to the photodiode current multiplied by the feedback resistance.

COUPLING

In systems with 20 or more terminals, star couplers outperform ‘tee’ types

by M. K. Barnoski
Hughes Research Laboratories, Malibu, Calif.

In a multiterminal fiber-optic communications network, light signals have to be tapped at intermediate points along the data bus. The problem is how to tap them most efficiently.

Currently, two fiber-coupling configurations are used for such data-distribution systems, one employing access or “tee” couplers and the other using a radial-arm or star coupler. The equations in Fig. 1 enable their performance to be compared in terms of the loss introduced between pairs of remote terminals by the distribution system itself. These equations show that, in a serial system with access couplers having a constant tap ratio, the optical power decreases as the signal travels through more couplers, while in a parallel system using a star coupler, the optical power is independent of the pair of system terminals being considered.

The distribution-system losses (omitting fiber loss) for both serial and parallel configurations are plotted as a function of the number of terminals in Fig. 2. Several different sets of parameters were employed for each format, including the use of multimode-fiber bundles as well as single multimode fibers. As a limiting case, curves are included for both parallel and serial systems when all couplers and connectors are assumed lossless. In
1. Coupling comparisons. The difference in performance between a serial distribution system and a parallel system is partly due to the terminal-to-terminal loss introduced between pairs of remotely spaced terminals by the distribution network itself.

In a serial system based on fiber bundles, the minimum access-coupler and connector-insertion loss will be limited by the packing-fraction loss of the bundled fibers. As a result, the steep curve plotted in Fig. 2, which uses an access-coupler loss of 2 dB and connector-insertion loss of 1 dB, is very close to what can be expected from fiber bundles having good packing fractions.

Nevertheless, with low-loss connectors and couplers for single fibers, serial-distribution systems should be able to handle at least 20 remote terminals without consuming an unreasonable proportion of the available power budget. For fewer than 20 terminals, the power savings achieved by the star system are not so very large.

However, as more terminals are added and use more of the available optical power budget, the picture changes. Receivers in a serial system must have not only a large dynamic automatic-gain-control range, to handle both strong signals from adjacent terminals and weak signals from remote terminals, but also low enough noise levels not to degrade the weak signals.

Since the parallel system needs only a single mixing point, it doesn't suffer signal-level or dynamic-range problems. The more constant signal level available with parallel systems minimizes the complexity of both trans-
mitter and receiver design. But the cost of this uniformity is offset by the additional amount of fiber cable needed. The star-coupled data bus, in essence, shortens the main bus length to a single-point mixer, but extends the length of each terminal arm.

A star coupler or optical mixer was basic to a prototype, fiber-optic multiterminal aircraft data link for carrying flight control signals from cockpit to controls. The optical bus operated for the full duration of a 40-minute flight test aboard an Air Force C-131 aircraft without any detectable errors.

The system used three terminals (one for redundancy) to multiplex and demultiplex 16 analog electrical signals (Fig. 3). It was "wired" with Corning fiber bundles, each containing 61 multimode low-loss glass fibers loosely packaged in an extruded polyvinyl chloride jacket. Two of these bundles entered each terminal, one for the transmitter and one for the receiver. Maximum terminal-to-terminal spacing was about 100 feet, but since each terminal in the system monitored its own transmission, the longest path traversed by an optical signal was 200 ft.

Commercially available components were used: gallium-arsenide light-emitting diodes as sources, silicon p-i-n devices as photodetector/amplifiers, and modified BNC connectors for input and output coupling. Nominal optical output power incident on the receiver photodiodes was $-28$ dBm. Source power was about $+11$ dBm. Although the optical bus was designed for a 10-megahertz bandwidth, the actual information transfer rate was determined by other system considerations and was only 0.5 megabit per second for all three transmission systems evaluated.

Although fiber bundles were used in this feasibility demonstration, a single-fiber configuration could service a network of 427 terminals (61 fibers times 7 bundles). For such a network, the distribution loss extrapolated from Fig. 2 would be 40 dB, assuming 1-dB cable connector loss and 7-dB star-coupler insertion loss.

However, in systems using a single fiber as a communication channel, it should also be possible to use serial distribution of data, since packing fraction loss is no longer a factor. Of course, adequate techniques of coupling between single fibers would first have to be developed.

One possible approach to fabricating such an access coupler (Fig. 4) parallels the techniques used in integrated optics. In essence, two multimode fibers are laid side by side and fused together for part of their length, and this fused region subverts (as it were) the tendency of each to keep all its light to itself. For in this situation, since light propagates in these fibers in many modes, the modes in one fiber mix with those in the other, producing coupling between mode groups. The exact degree of coupling is determined by the core-to-core spacing and the interaction length (the fused region). When one end of one fiber was excited with a laser beam, radiation was observed from the opposite ends of both fibers. For the coupler used in this experiment the ratio of power emitted from the access channel fiber to that of the main channel was 8%.

It's worth noting how neatly this approach avoids the need for the critical mechanical alignment tolerances that are essential in access couplers using conventional optical components like lenses and beam splitters. In fact, several research laboratories are currently investigating fabrication processes for such a "tee" fiber coupler. The preliminary results indicate that the insertion loss of single-strand access couplers could come down to about 0.1 dB or 0.2 dB, so all that remains is to produce practical low-cost versions of these experimental devices.
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SYSTRON DONNER
Multimeter measurements yield device-model parameters

by Martin A. Green
University of New South Wales, Kensington, Australia

In computer analysis of electronic circuits, the most frequently used bipolar-transistor models for dc conditions are derived from the well-known Ebers-Moll equations:

\[ I_E = -I_{ES}\exp(qV_{BE}/kT) - 1 \]
\[ + \alpha_R I_{CS}\exp(qV_{BC}/kT) - 1 \]
\[ I_C = \alpha_F I_{ES}\exp(qV_{BE}/kT) - 1 \]
\[ - I_{CS}\exp(qV_{BC}/kT) - 1 \]
\[ I_B = -(1 + I_C) \]

where \( I_E, I_C, \) and \( I_B \) are the terminal currents, \( V_{BE} \) and \( V_{BC} \) are the voltages between these terminals, \( q \) is the electron charge, \( k \) is Boltzmann's constant, and \( T \) is the absolute temperature. A positive value of current flows into the transistor; a negative value flows out of the transistor. Values of the Ebers-Moll parameters \( I_{ES}, I_{CS}, \alpha_F, \) and \( \alpha_R \) are usually required as program inputs [see "Modeling the bipolar transistor, part 1," *Electronics*, Sept. 19, 1974, p. 114]. These parameters, as well as the device beta, can be determined for any given transistor by measuring six resistances with a digital multimeter.

The method exploits the measurement technique commonly used on the resistance ranges of a DMM, which is, essentially, to pass a known constant current through the unknown resistance and measure the resulting voltage developed across it. The current passed, \( I_m \), depends on the resistance range selected and, typically, may vary from 100 nanoamperes on high-resistance ranges to 10 milliamperes on low ranges.

Preliminaries consist of determining the current through the unknown on the different ranges of the DMM and selecting the range where the current, \( I_m \), is reasonably near the probable operating current of the transistor. \( I_m \), multiplied by the full-range reading in ohms must equal a voltage large enough to forward-bias the transistor junctions (about 0.7 V for silicon devices).

All measurements described (except those of \( R_{e2} \) and \( R_c \)) must then be made on this range. After experimenting to find which direction of the probe connections forward-biases the transistor junctions, the following measurements are performed (see the diagram):

- Measure \( R_{e1} \), the forward-biased resistance of the emitter-to-base junction with collector shorted to base.
- Select a resistor with its nominal resistance near the value \( \beta_F R_{e1} \), where \( \beta_F \) is the estimated beta of the transistor in the normal forward mode of operation. Measure the exact resistance, \( R_a \), of this resistor.
- Measure the resistance between the emitter and collector while the emitter-to-base junction is forward-biased and \( R_{e2} \) is connected between the base and the collector. Call this value \( R_{e3} \).
- Repeat the above procedure with the transistor in its inverse connection, i.e., with the collector and emitter exchanged in the above description. Record the corresponding resistances \( R_{e1}, R_{e2}, \) and \( R_{e3} \).

From the Ebers-Moll equations, it is not difficult to show that the required transistor parameters can be calculated by the expressions:

\[ \alpha_F = 1 - (R_{e3} - R_{e1})/R_{e2} \]
\[ \beta_F = [R_{e2}/(R_{e3} - R_{e1})] - 1 \]
\[ I_{ES} = I_m/\exp(R_{e1}/r_e) \]
\[ \alpha_R = 1 - (R_{e3} - R_{e1})/R_{e2} \]
\[ \beta_R = [R_{e2}/(R_{e3} - R_{e1})] - 1 \]
\[ I_{CS} = \alpha_F I_{ES}/\alpha_R \]

where \( r_e \) is equal to \( (kT/q)/I_m \) and has a value in ohms of 25/I_m at temperatures around 17°C if \( I_m \) is expressed in milliamperes.

As an example, the following measurements were made upon a 2N3693 transistor using the 20-kΩ range of a Fluke 8000A DMM (except for the measurement of \( R_{e3} \)). The current through the unknown in this range was 0.1 mA, giving a value of \( r_e \) of about 250 Ω. The measured resistances were:

\[ R_{e1} = 6.080 \Omega \]
\[ R_2 = 216,000 \Omega \]
\[ R_3 = 10,630 \Omega \]
\[ R_4 = 5,620 \Omega \]
\[ R_5 = 4,770 \Omega \]
\[ R_6 = 9,760 \Omega \]

These readings yield the following values for the transistor parameters:

\[ \alpha_F = 0.979 \]
\[ \beta_F = 46.5 \]
\[ I_{ES} = 3 \times 10^{-15} \text{A} \]
\[ \alpha_R = 0.132 \]
\[ \beta_R = 0.152 \]
\[ I_{CS} = 2 \times 10^{-14} \text{A} \]

Inserted into the Ebers-Moll equations, these values allow the transistor performance to be predicted over a wide range of operating conditions.

At moderate to high current levels, parasitic resistances can influence the transistor performance [see "Modeling the bipolar transistor: part 2," *Electronics*, Oct. 31, 1974, p. 71]. This method of calculating \( \alpha_F, \alpha_R, \beta_F, \) and \( \beta_R \) continues to give accurate results. The value calculated for \( I_{ES} \) also will usually be accurate for values of meter current, \( I_m \), up to the likely maximum of 10 mA. However, the first expression given for \( I_{CS} \) is preferable to the alternative one that is given in brackets, because the high series resistances associated with the base and collector can cause the bracketed expression to be inaccurate.

---

**Spectrum analyzer aids fm deviation measurement**

by Glenn Darilek

*Southwest Research Institute, San Antonio, Texas*

The ordinary technique for measuring the frequency deviation of a frequency-modulation signal is the carrier-null method. The level of the modulating voltage is increased, or the modulation frequency \( f_{mod} \) is decreased, until the carrier level goes to zero—disappears from the screen of the spectrum analyzer. At that point, the modulation index, \( \beta \), equals 2.405, so the frequency deviation \( \Delta f \) equals 2.405 \( \times f_{mod} \).

But sometimes it may be necessary to determine the frequency deviation of an fm signal when the amount of deviation is not sufficient to use the carrier-null method. Also it may not be possible to vary the frequency or amplitude of the modulating signal in order to get a carrier null. In either of these situations, the modulation index, the frequency of modulation, and hence the frequency deviation can be easily determined by the technique described here.

The frequency deviation of a narrow-band fm signal can be determined quickly by observing the voltage ratio between the first sideband and the carrier, together with their frequency separation. These measurements can be made directly from a spectrum-analyzer display.

The amplitude-ratio measurement gives the modulation index, \( \beta \) of the signal. This index is defined as

\[ \beta = (\text{frequency deviation})/(\text{modulation frequency}) = (\Delta f)/f_{mod} \]

For narrow-deviation fm signals such as those in telemetry and communications links, \( \beta \) is equal to twice the ratio of the first sideband to the carrier. This relationship is accurate within 10% for \( \beta \) values below 0.8 (i.e., for the first sideband below the carrier by 8 decibels or more).

The amplitude of the carrier of any fm signal is proportional to the Bessel function \( J_0(\beta) \), and the amplitude of the first sideband is proportional to \( J_1(\beta) \). For small values of \( \beta \), however, \( J_0(\beta) \) is nearly equal to unity, and \( J_1(\beta) \) is nearly equal to \( \beta/2 \). Therefore,

\[ (\text{first sideband})/(\text{carrier}) = J_1(\beta)/J_0(\beta) = (\beta/2)/1 \]

or

\[ \beta = 2 \times (\text{first sideband})/(\text{carrier}) \]

As an example, assume that the carrier of a particular fm signal is set at an arbitrary level of 1.0. If the first sideband is at a level of 0.2, the modulation index is:

\[ \beta = 2 \times (0.2)/(1.0) = 0.4 \]

If a decibel scale is used, one simply adds 6 dB to the ratio and converts this sum to an amplitude ratio. For example, in the illustration, the ratio of the first sideband is 0.2, and the modulation index is:

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The frequency of modulation, \( f_{mod} \), is given by the difference in frequency between adjacent components, and for small values of modulation index \( \beta \), the numerical ratio of first sideband to carrier amplitude is \( \beta/2 \). Frequency deviation \( \Delta f \) of the fm signal is then found from \( \Delta f = \beta \times f_{mod} \).
band amplitude to the carrier amplitude is measured to be $-16$ dB, so

$$\beta (\text{dB}) = -16 \text{ dB} + 6 \text{ dB} = -10 \text{ dB}$$

Conversion of $-10$ dB to a ratio gives $\beta = 0.32$.

To find the actual frequency deviation, $\Delta f$, one must multiply the modulation index by the frequency of modulation. If the modulation frequency is not known, it also may be determined from the spectrum-analyzer display because the frequency separation between the carrier and the first sideband is equal to the modulating frequency. In the illustration, since the modulation frequency is 10 kilohertz, the frequency deviation is $10 \text{ kHz} \times 0.32 = 3.2 \text{ kHz}$.

Scope-triggered register freezes serial data

by Matthew L. Fichtenbaum
GenRad Inc., Concord, Mass.

The technique that uses the trigger and delay functions of an oscilloscope to latch a data bus at a particular time [Electronics, April 1, p. 103] may be extended to systems where data is transmitted or processed serially. Data from such systems as calculators and serial microprocessors may be easily captured and displayed under the control of a scope such as the Tektronix 465 or 475.

As shown in the figure, the hardware requires relatively few components. A serial-to-parallel shift register converts the serial data for display and serves also to count the bits that comprise a serial word. A second register stores the resulting parallel data and drives the light-emitting diodes that show the data. The circuit shown is for 8-bit serial words, but may be adapted for any word length by changing the number of bits in the two registers.

The scope should be operated in its A-intensified-by-B mode, with the A (main) sweep set to trigger on an event before occurrence of the data (any timing signal in the program). The B (delayed) sweep should be externally triggered by the same clock signal that shifts the serial data. The B sweep's starting time, indicated by the start of the trace's intensified section, advances one clock pulse at a time as the delay-time control is advanced. Since this time is the start of the displayed serial word, data at successive system cycle times may be displayed by advancing the delay-time control to make the intensified trace begin at these times.

Before the triggering event occurs, the A-gate scope output is low, and the serial register is preset with a 1 in the first bit and 0s in the remaining bits. When the scope triggers, the A gate goes high, removing the clear signal, but the register remains in the preset state.

When the delay-time interval is complete, the B sweep is armed to be triggered, and it triggers synchronously with the clock in the system. When B triggering occurs, the B-gate output enables the system clock to shift the serial register, shifting in the serial data.

After the proper number of shift pulses (in this case, eight), the 1 that was preset into the first bit reaches the last bit of the serial register (the Q4 output of the 74LS164). This inhibits further shift pulses and forces the register to hold the 8 bits of data just gathered.

At the end of the scope sweep, the A-gate output goes low again. This loads the data from the serial register into the display register to drive the LEDs and sets the serial register to its initial state again. The cycle may then repeat when the next trigger event occurs.

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Circuit steps program for 8080 debugging

by John F. Wakerly
Stanford University, Stanford, Calif.

Executing a program one step at a time is an important aid to debugging microprocessor systems. There are two basic approaches to providing a single-step capability. One method is to add hardware to provide a software interrupt after each instruction's execution, and the other is to provide a completely hardware-oriented "front panel" to give the capability to execute single instructions or memory cycles under hardware control.

With the first approach, the user can write an interrupt service routine that allows register and memory to be examined at the system teletypewriter or terminal between instruction executions [Electronics, June 24, 1976, p. 105]. It takes advantage of the full power and convenience of a software-debugging package, but instructions cannot be single-stepped if interrupts are disabled, and single memory-reference stepping is not possible (there may be several memory references per instruction, and interrupts cannot take place in the middle of an instruction).

The circuit described here is the hardware-implemented "front panel," which enables the user to execute 8080 microprocessor programs either one instruction at a time or one machine cycle (memory or input/output reference) at a time. The circuit uses the READY input of the 8080 to stop the program at each instruction or machine cycle, as selected by the user. A push button then runs the program one step at a time. Between steps, the user can observe the machine state and the current instruction or data on the 8080 data, address, and control lines with a scope, logic probe, or permanent indicator lamps.

The single-step circuit shown in Fig. 1 assumes that an 8224 clock generator is used with the 8080. Without the single-step circuit, a ready signal (SYSREADY H) generated by the memory and I/O systems would be connected to the 8224 RDY IN input. For single-stepping, SYSREADY H (where H denotes active high) is ANDed with the signal GO H. If either signal is low during a memory or I/O reference, the 8080 will go into a wait state until both signals become high. If this circuit is used in a system that does not generate SYSREADY H, then the AND can be removed and GO H connected directly to RDY IN.

A 7474 edge-triggered D-type flip-flop, FF 2, generates the GO H signal. Proper operation of the circuit depends on the fact that a low input on the PR input of the 7474 produces a high output at Q, regardless of any of the other inputs, including CLR. (If both PR and CLR are low, then both Q and Q are high.) Thus, if STOP H is low, GO H is high, and the 8080 executes instructions at full speed. However, the 8080 holds WAIT H low just before every memory or I/O reference; thus, if STOP H is high, FF 2 is cleared by the low signal on WAIT H, the 8080 enters the wait state, and instruction execution is stopped. In the wait state, WAIT H goes high and allows GO H to be set high again by clocking FF 2 with the STEP H input. STEP H is the output of a single-step push button, and instruction execution does not begin until this button is pushed.

If only single-stepping at each machine cycle were desired, STOP H could be obtained from a simple switch to select normal operation or single-stepping. However, for single instruction stepping, FF 1 is used to detect the beginning of each instruction cycle—the instruction fetch. At the beginning of each machine cycle, the 8080 places a signal MI H on data-bus output D 5, which

![Diagram of single-step circuit for 8080](image_url)
indicates the first machine cycle (fetch) of an instruction. This signal is clocked into FF by STSTB; thus if M1H is high, STOPH becomes high, and the 8080 is stopped during the instruction fetch. The data bus contains the fetched instruction.

The PR and CLR inputs of FF₁ are used to determine the mode of operation. If MACHL is asserted (low), STOPH is held unconditionally high, and the 8080 stops at each machine cycle. If MACHL is de-asserted and INSTRH is asserted (high), then M1H is clocked into FF₁ to generate STOPH, and the 8080 stops at every instruction cycle. If both MACHL and INSTRH are de-asserted, then STOPH is held low, and the 8080 operates normally.

If the inputs MACHL, INSTRH, and STEPH are obtained from switches, they should be debounced. Figure 2 shows an economical debouncing circuit that uses a pair of inverters to debounce a single-pole, double-throw switch. The circuit shorts the high output of an inverter to ground for about 20 nanoseconds at each transition, but this short is not harmful.

An advantage of this circuit over conventional cross-couple NAND gates for debouncing is that three switches can be debounced with one 7404, as opposed to two with one 7400. Also, no pull-up resistors are used.

The single-step circuit can be easily modified for use with the Zilog Z-80 microprocessor. The Z-80 has a separate output pin for M1, which should be connected to the D input of FF₁. Since this polarity is the opposite of the 8080 M1 output, the STOPH signal should be obtained from the Q output of FF₁, and the PR and CLR inputs should be reversed. FF₁ should be clocked by the Z-80 input clock 4, and the RDYH signal should be connected to the WAIT input of the Z-80. Finally, the CLR input of FF₁ should be connected to MREQ+10RQ, which can be obtained from the MREQ and IORQ outputs of the Z-80 with a single 2-input NAND gate (one quarter of a 7400 package).

---

**C-MOS reset circuit ignores brief outages**

by Roger F. Atkinson
ITEC Inc., Huntsville, Ala.

If the voltage supply to a C-MOS circuit drops much below 3 volts during a power failure, a reset signal is necessary to initialize the logic and perhaps also to indicate that the power has failed. But, unlike conventional power-fail circuits, the reset should ignore transient interruptions that do not drop the supply below 3 volts, the level at which the logic states of the latches, counters, and the like may change randomly.

Such a reset signal can readily be derived. An isolated reference voltage is applied to the input of a Schmitt trigger having threshold voltages that are a function of the logic-supply voltage.

In the complementary-metal-oxide-semiconductor circuit shown, the Schmitt trigger is a National MM74C14. Diodes D₁ through D₄ and resistor R₁ establish a reference voltage of approximately 2.5 volts across capacitor C₁. D₅ isolates the energy-storage capacitor C₂ from the supply and from any higher-current loads such as relays and displays that are not needed during a power failure. D₆ assures that the reference cannot exceed the supply voltage by more than one diode drop.

When power is first applied, C₂ is at zero volts. As C₂ charges through D₅ and R₂, the reference at first exceeds the high threshold of the Schmitt trigger, causing its output to go low and thus resetting associated circuits. This signal remains low until the logic supply voltage (across C₂) is high enough (about 8 v) for the low threshold to exceed the reference and to switch the Schmitt high. During subsequent power failures—provided the logic supply voltage across C₂ remains above 3 v—the high threshold (about 80% of supply at low voltages) will remain above the reference, so that the Schmitt output will not switch when power is reapplied. However, should the supply fall so low that the high threshold is lower than the reference when power is restored, the Schmitt output will go low, thus resetting the C-MOS circuit when power is restored.

**Resets if necessary.** During brief interruptions of dc power, the charge on C₂ maintains voltage to C-MOS digital circuits, preserving their logic states. But if the power failure lasts so long that the voltage across C₂ drops below 3 v, the Schmitt trigger resets the logic circuits when power is restored.
the logic. The reset can activate a warning indicator.

R_2 and C_2 delay the rise of the logic-supply voltage, controlling the length of the reset pulse. Other CMOS Schmitt circuits might be used. To maximize endurance during power outages, resistive loads on the CMOS outputs should be avoided. The circuit shown allows an MM74C193 up/down counter to retain its count for more than 10 minutes.

---

**Timer IC paces analog divider**

by Kamil Kraus
Pizen, Czechoslovakia

The quotient of two analog voltages, \( V_x/V_y \), is required in many control and computation applications. This ratio can be produced by a circuit that consists of a voltage-to-frequency converter and an amplitude modulator, as shown in the accompanying diagram.

In the V-to-f converter, input voltage \( V_x \) drives a field-effect transistor through an operational amplifier. The FET operates as a voltage-controlled resistor to determine the frequency of a 555-timer astable multivibrator. The resistance of the FET is given by:

\[ R = \frac{V_p}{[(1 + R/B)I_xV_y - I_xV_p]} \]

where \( V_p \) is the FET threshold and \( I_x \) is the drain current when \( V_x \) is zero.

In this mode of operation, the capacitor \( C \) charges and discharges between \( V_x \) and \( V_y \) of \( V_{cc} \). Thus the output voltage of the timer varies from 5 to 10 volts if the supply is 15 volts. The charge and discharge times and therefore the frequency are independent of the supply voltage.

Input voltage \( V_x \) is applied to the inverting input of op amp A_2, which acts as the amplitude modulator. When the output from the timer (pin 3 of the 555) goes high, transistor Q turns on and grounds the noninverting input of A_2, so that the output from A_2 is \(-V_y\). When the timer output is low, transistor Q is off and the output from A_2 is \(+V_y\).

The output from A_2 is therefore \(-V_x\) during the charging time of the timer:

\[ t_c = \frac{0.693(R + R_B)C}{V_x} \]

and is \(+V_y\) during the discharge time of the timer:

\[ t_d = \frac{0.693R_BC}{V_y} \]

The average value of the output voltage from A_2 over the period of the timer is given by:

\[ V_{out} = V_x(t_d - t_c)/(t_c + t_d) \]

Substitution of the expressions for the charge and discharge times, and use of the relation for \( R \), yield:

\[ V_{out} = -V_x(V_y/(1 + R/B)V_y) \]

If \( R_B \) is made equal to \( V_y/2V_x \). For the 2N4222 FET, \( V_y \) is 15 volts and \( I_x \) is 15 mA, so \( R_B \) is 500 Ω. The value of \( C \) is 0.01 microfarad, as recommended by the 555 manufacturer. If the value of \( R_1 \) is 14R_2 as shown, the average output voltage, in volts, is:

\[ V_{out} = -V_x/V_y \]

Thus the mean value of the output voltage from A_2 is numerically equal to the ratio of input voltages \( V_x \) and \( V_y \). These voltages can have any values in the range from 0 to \(+10 \text{ V}\); the average of the output can be realized with an RC across the output circuit, or read on a damped voltmeter, or whatever the application requires.

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**Analog divider.** The mean value of output voltage is proportional to the ratio of \( V_x \) to \( V_y \). The 555 timer operates as a voltage-to-frequency converter, activating transistor Q, which controls the noninverting input of A. The output voltage of A can be averaged by any method convenient for the applications required.
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Making hermetic ceramic-to-metal seals can be easy

Two Sandia Laboratories scientists, Paul Wilcox and Gary Snow, have invented an improved method for making ceramic-to-metal hermetic seals. It's covered by patent No. 3,951,327, assigned to the Energy Research and Development Administration, which essentially puts it in the public domain—simply write to ERDA for permission to use it.

Here's how it works: after chemically cleaning the surface of the ceramic members, you put a wire-like metal gasket directly on one of the ceramic parts (no pre-metalization is needed) and heat the entire assembly till the gasket is soft enough to deform when the two ceramic members are pressed together. The gasket material should be related to the ceramic composition—for instance, an aluminum gasket would be suitable for sealing aluminum oxide. The procedure has been used at the Albuquerque, N.M., site for sealing quartz crystals in a ceramic flat-pack.

Wescon will bend your ear on microprocessors

Although the Sept. 2 issue of Electronics will carry a full preview of the upcoming Wescon technical program, it's worth noting even earlier that the Sept. 14-17 meeting in Los Angeles will be laden with papers on microprocessors. In particular, there will be some interesting discussions of both the military's efforts to standardize microprocessor types and trends in bipolar bit-slice devices. Two recently announced commercial minicomputers are based on the bit-slice types—Harris Corp.'s Slash/6 and Interdata's 5A6—which both use Advanced Micro Devices 2901 devices—and nearly every other minicomputer manufacturer is now studying the devices. The Wescon bit-slice session will include papers from four producers of the devices—Fairchild, AMD, Intel, and Monolithic Memories. Others include Texas Instruments and Motorola, which recently announced its emitter-coupled-logic high-speed device, the 10800.

Pythagoras and the hypotenuse . . . again

It seems that there are any number of ways to solve for the square root of the sum of two squared signals. Engineer's Newsletter has already carried three schemes [Sept. 18, 1975, p. 56, and Nov. 13, 1975, p. 142] involving again amplitude modulation, logarithms, and a combination of multiplication, division, and summing amplifiers.

Now, D.P. Franklin, a research and development consultant for the Systems and Weapons division of EMI Electronics Ltd. in Wells, England, has reminded us that more than seven years ago, in the British publication Electronic Engineering (Jan. 1969, p. 63), he described how the tried-and-true diode function generator can also be used. It produces an output that is a piecewise-linear approximation of the desired function. However, even without an excessive number of linear segments, he says, you can obtain moderate accuracies—say, to within 1%.

Program note

In the June 12, 1976, Engineers Notebook, Dan Sheingold of Analog Devices gave a procedure for calculating the resistances used in sum and difference networks. Now, he's written a program for the HP-25 calculator that computes the resistances for up to three positive terms and three negative terms. For a copy of the program, see Analog Dialogue, Vol. 10, No. 1, published by Analog Devices Inc., P.O. Box 280, Norwood, Mass. 02062.

—Stephen E. Scrupski
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New products

Calculator runs transceiver tester

System using off-the-shelf equipment and IEEE interface bus checks out citizens' band, police, fire, and other types of radio up to 1,000 MHz

by Bernard Cole, San Francisco bureau manager

Sales and production of radio transceivers for use below 1,000 megahertz are reaching new records. Although much of this increase results from the new popularity of citizens' band radio, most other transceiver markets are also strong—among them, police, fire, and commercial fm, as well as avionics and military.

But production costs are also continuing in an upward direction, and, in an attempt to stabilize these costs, many makers of radio transceivers are looking increasingly to test-automation. The choices to date, however, have been limited to two primary alternatives: high-volume-oriented, general-purpose, minicomputer-controlled test systems costing about $150,000, but flexible enough to work over a wide range of test conditions, and calculator-controlled special-purpose fixed hardware systems costing only $45,000 to $60,000, but more limited in their range of test conditions [Electronics, Nov. 13, 1975, p. 149].

Flexibility and low cost. By utilizing mostly off-the-shelf test equipment, along with some specially designed interface hardware using the IEEE instrument-interface bus, Hewlett-Packard has developed the $58,500 calculator-controlled 8950A transceiver test system, which combines the flexibility of the general-purpose minicomputer-controlled systems with the low cost of the special-purpose fixed-hardware systems. The combination of these instruments—the 8660A signal generator, the 436A power meter, the 3490A digital voltmeter, the 5345A counter, and the 3320 synthesizer—provides the capability of testing a-m and fm transceivers up to 1,000 MHz, covering the important new 900-MHz mobile fm band for which a considerable increase in activity is forecast. By contrast, present testers cover frequencies up to only 500 MHz. All instruments are linked through the digital interface bus for control and data. System control, says product marketing manager George Skidmore, is via the HP9830A calculator [Electronics, Jan. 22, p. 142].

Transmitters with output frequencies from 1 to 1,000 MHz and powers from 1 to 100 watts can be measured, says James Stinehelfer, project leader. An internal high-power attenuator is included for system self-calibration. Amplitude-modulation characteristics are measured from 1% to 95% depth and to an accuracy within ±3%. Audio output characteristics of the transmitter provide for accuracy within ±5% on audio sensitivity, with audio indicated to 25 kHz for a-m and 20 kHz for fm. Audio distortion is measured to within ±2% at 1 kHz by means of the total-harmonic-distortion technique. Squelch-tone frequency indication to ±1 kHz and hot-mockup primary power to 30 amperes are standard.

Receiver-test capabilities, says Skidmore, include sensitivity tests at 12 dB sinad (signal plus noise and distortion) for 1 kHz or with 20 dB quieting, and they can also be made at squelch threshold. Audio power output is measured to ±5% with a frequency response to 50 kHz; accuracy and audio distortion to

Electronics / August 5, 1976
New products

+1% at 1 kHz tone, and power is provided to 30 A for the receiver under test. System modulation-acceptance bandwidth is 20 kHz.

The model 8950A achieves maximum throughput and testing speed with a special interface and signal switch-adapter panel mounted at the operator’s shelf. With convenient access to other work-table arrangements, transceiver signals are switched to and from the appropriate system-test instrument. And primary power connectors at the panel allow specialized wiring harness to be interfaced at one place.

The fact that the 8950A uses a rack of mostly off-the-shelf instruments to achieve its performance may sound like a trivial distinction, but actually, says Stinehelfer, the user gets substantial performance flexibility as compared with the fixed-hardware system. “In a dedicated installation devoted to a single continuous production run, this advantage would not be too significant,” he says, “but no modern industrial strategy or product remains the same forever. Product change, specifications, and measurement requirements usually get tighter, and new frequency bands and modulations come into the picture.” And in most of the applications, the flexibility should be very attractive, he says.

Extendable. For example, Skidmore points to the 8660A signal generator, which can be easily extended to higher frequencies (up to 2,600 MHz) or to more sophisticated modulations (phase modulation, for one) as required. The 436 power meter, with the simple addition of other power sensors, can extend its measurements to 18 GHz, -70 dBm or 75-ohm systems. The 3490 DVM can serve as a flexible data-acquisition instrument under calculator control. Internal voltages of radios may be probed, or current and resistance values obtained. Nonradio test functions may also be envisioned, he says, such as environmental testing of battery drift in a qualification laboratory.

The 5345A counter, although only used in its 500-MHz mode, can also measure 2-nanosecond time intervals, pulse rf, event ratios, and periods. A wide variety of plug-ins convert the 5345 for measurements to 18 GHz. The 3320, a 13-MHz synthesizer, offers general-purpose flexibility, says Stinehelfer, for a variety of other tests on radios and their components. Filters, circuits, and audio subassembly modules, he says, could all be tested by a combination of the 3320 and the DVM, and the range of 0.1 Hz to 13 Hz covers most circuits in typical radio modules. “For a large-volume user, these additional capabilities may not be too important,” says Skidmore, “but for the medium-volume manufacturers, distributors, and service centers, this allows for amortization of the cost over a wider range of applications.

“It’s too easy to say software gives ultimate flexibility to the user,” he says. “But it’s true.” For example, a hardware fixed system might have a push button for sinad measurements, but that’s all it does, because it was only designed for sinad. In the HP8950A, sinad is measured by a software subroutine of iterative measurements using mostly the system DVM and generator. The subroutine is supplied as a debugged test routine and may be used as is, or modified for changes. HP furnishes test-sequence software modules as demonstration subroutines segmented by type of test. The user then writes simple programs to sequence the tests as appropriate and check test data against programmed limits or print out a test card. But beyond the supplied subroutines, says Stinehelfer, the calculator-based 8950A provides the capability to call on a variety of powerful computation routines, analyze data, store on cassette, print out, or tie in with higher-level management data bases in the factory.

Available now, the basic system, including the calculator, is priced at $58,500. A printer that is sold as an option and is designated the model 9871 costs $3,475.

The Teletype model 40 OEM printer.
When you look at it from price and performance, you'll find it difficult to look at anything else.

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We don't think any other printer can even come close to the model 40.

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Solid-state relays drop in price

New families of ac devices covering 0.75 to 25 amperes and dc models ranging from 0.5 to 10 amperes challenge electromechanical units

by Lawrence Curran, Boston bureau manager

In ac and dc switching circuits, solid-state relays are usually chosen over electromechanical units when long life is needed or when radio-frequency interference must be held to a minimum. Traditionally, however, solid-state relays have been considerably more expensive than electromechanical types, generally costing several times as much. But, through what might be termed rather unconventional designs, a young firm named Theta-J Relays is rapidly bringing the prices of solid-state devices closer to those of electromechanical units.

Only about a year old, the fledgling company is now offering what Edward T. Rodriguez, chairman and technical director, calls a supermarket of solid-state relays. The new family includes ac devices rated from 0.75 to 25 amperes and dc models covering 0.5 to 10 A. All the new relays sell for at least half the price of existing comparable units, Rodriguez notes.

New designs. For most types, the choice of control-voltage inputs includes: 4–8 V dc, 9–15 V dc, 16–32 V dc, or 120 V ac nominal. Control current is typically 15 milliamperes, making the units compatible with transistor-transistor logic. Output voltage ratings go up to either 280 V ac or 250 V dc.

"We're marching to a different drummer than other people in the business," says Rodriguez. Theta-J's approach is to reduce the labor costs of solid-state-relay assembly by means of special package and circuit designs.

Most solid-state relays employ optoelectronic semiconductors for isolation. Instead, Theta-J uses photocell optical coupling, which provides a minimum isolation of 1,500 V ac between input and output stages. Since the photocell is a bidirectional device, it needs no auxiliary circuitry as unidirectional light-emitting diodes and silicon photodetectors do, points out Rodriguez. Additionally, the proprietary photocell design is "far more sensitive" than semiconductor photocouplers, he claims.

And compared to conventional photocells, which require several milliseconds to switch, the Theta-J photocell responds in less than 1 ms, Rodriguez says. "We've made a turtle look like a rabbit in getting this faster switching," he observes.

In the dc models, the photocell provides inherent protection against switching spikes. All other solid-state dc relays are built with semiconductor optics, which switch in microseconds, says Rodriguez. That fast a switching speed can be a problem in dc relays because they are usually handling inductive loads, he points out. Large inductive spikes can be generated, dictating the need for transient-protection circuitry.

"With our photocell approach, however," says Rodriguez, "the rate of current change is so slow that the spike isn't generated, and we don't need that protective circuitry."

Special designs extend to the zero-crossover ac models, too. Like all zero-switching relays, these models do not turn on until the driving voltage sine wave is near its zero crossing.

The Theta-J patentable zero-switching technique, however, is a fundamental departure from existing methods because it makes use of a silicon controlled rectifier instead of a transistor, discloses Rodriguez. "We have a very lightly biased SCR that latches up and disables the entire control circuit at about the 10 V point in each half cycle," he explains. "This allows us to operate with microamps of current, compared to the substantial base-drive and collector currents required for a transistor. We just have to breathe..."
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Circle 121 on reader service card

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Meet the “low cost” Bowmar TP-3120 Thermal Printer

Available off-the-shelf, the new Bowmar TP-3120 thermal printer does a lot more than many of the others for a lot less. With a speed of 1.07 lines per second, this quiet printer continues to maintain its economical advantage by using low-cost, high contrast, non-smear paper. Small in size and cost, yet big in capabilities, it’s equipped with such Bowmar quality features as 12 position, dual read-out standard connector, right or left justification and 5x5 matrix design. Other highlights of the new Bowmar TP-3120 include:

- 18-Column Alpha/Numeric Printout
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- Low Power Consumption
- MOS Compatible
- Immediate Delivery

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Fort Wayne, IN 46809

New products

on the scr with nanoamps,” he adds.

The new line has 18 categories of ac devices and 13 types of dc units. There are both standard and zero-switching ac types, and because the biggest part of the market is at the 10-\(\text{A}\) rating, Rodriguez homes in on the 10-\(\text{A}\) ac units as the relays that will probably be most popular.

The standard version, which is designated the TA-1210, has a load voltage range of 90-140 volts ac. Maximum control current at the nominal control voltage (5 \(\text{V}\) dc) is 15 \(\text{mA}\). The zero-switching version of the same unit, the MA-1210Z, has the same output rating, but for a maximum control current of 7 \(\text{mA}\). The MA-1210Z sells for less than $4.50 each in quantities of 5,000.

Another ac unit that Theta-J expects to become popular as a solenoid or coil driver for high-power relays is the MA-1201, which is rated at 0.75 A. Its zero-switching counterpart is the MA-1201Z. Both of these devices have the same electrical characteristics as the 10-\(\text{A}\) units, except maximum control current is 7 \(\text{mA}\) for both. Prices are less than $3 each in quantities of 5,000.

**Dc family.** The dc devices that Rodriguez expects to be big performers are 0.5-\(\text{A}\) and 5-\(\text{A}\) units. The TA-0605, with a maximum load voltage of 60 \(\text{V}\), has a control current of 15 \(\text{mA}\); the ultra-sensitive model TA-0605S has a maximum control current of 1 \(\text{mA}\). The TA-0605 sells for less than $8 each in lots of 5,000. There’s also a 250-\(\text{V}\) version, the TA-2505.

The 0.5-\(\text{A}\) MA-06005, which is priced at $3 each in 5,000-unit quantities, can handle 60 \(\text{V}\) dc maximum. Another 0.5-\(\text{A}\) unit, the TA-25005, operates at up to 250 \(\text{V}\) dc.

The devices (see photo on p. 120) with lower current ratings are housed in Theta-J’s PowerDip package, which fits standard 16-pin DIP sockets or mounting holes; the high-current units are housed in a case the company calls J-PAK, which occupies less than 0.75 cubic inch.

Delivery time is four weeks.

Theta-J Relays Inc., 2 Linden St., Reading, Mass. 01867. Phone (617) 942-0390 [339]
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New products

Components

**Transformer isolates 20 kV**

Step-down unit holds leakage capacitance to mere 0.001 pF

The need for isolation in electronic equipment is a growing one, particularly in industrial and medical applications. Now there's an isolation power transformer from Stevens-Arnold that can satisfy the severe requirements of such applications as dc power transmission, mass spectrometers, X-ray equipment, and electron microscopes.

Originally designed to power the control circuitry for an 800,000-volt dc power transmission line, the unit provides an input-to-output breakdown voltage of 20,000 V dc. Between its primary and secondary, leakage capacitance is only 0.001 picofarad in either the forward or reverse direction. This kind of performance, says Ezra F. Stevens, president, is achieved through the use of heavy multiple shielding, in conjunction with flux-cancellation techniques.

Rated at 15 watts, the transformer is a step-down unit whose primary winding can accept either 120 or 240 V ac. The secondary, which provides 8 V ac at 700 milliamperes, includes a center tap of 38 V ac at 250 mA. Common-mode rejection is 100 decibels.

Surprisingly, the transformer's case size is relatively small, measuring only 4.28 inches long by 3.66 in. wide by 4.06 in. high. The leads for both the primary and the secondary are shielded. They are 24 in. long for the primary and 12 in. long for the secondary. The case itself is made of steel and is finished in black.

For quantities of one to nine, each unit is priced at $137.50. Delivery time is six weeks.

Stevens-Arnold Inc., 7 Elkins St., South Boston, Mass. 02127. Phone (617) 268-1170

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Trimmer capacitor is quiet and reliable

Most rotating-piston adjustable capacitors use a central mechanism to control the motion of the piston within a glass sleeve. Thus any misalignment between the axis of the mechanism and the axis of the sleeve can cause jamming and breakage. Or, if the clearances are made large enough to avoid this, the result can be wobble and microphonic noise.

A new type of rotating-piston trimmer overcomes these problems by eliminating the central mechanism and using the glass sleeve both as a dielectric and as a mechanical guide. Key to the operation of the trimmer is high precision in the dimensions of the piston and sleeve. The clearance between the two is less than 0.5 mil.

Called the NB (for no-bushing) line, the trimmers have the additional advantage of being inexpensive because they use only three parts, compared with six or seven for conventional trimmers. The NB is offered in seven standard sizes: the smallest covers 0.8 to 4.5 picofarads, and the largest spans 1 to 36 pt. Working voltage is 750 V dc. The lower-value devices have a maximum temperature coefficient of 100 ppm/°C while the larger can go as high as 150 ppm/°C. For quantities of 5,000, the prices range from $1.05 to $2.34 each.

Voltronics Corp., West St., East Hanover, N.J. 07936. Phone Richard J. Newman at (201) 887-1517

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Line of compact DIP switches includes spdt and dpst units

A family of 15 DIP switches includes four single-pole, double-throw styles incorporating from two to five circuits per package, four double-pole, single-throw units incorporating four, six, eight, or 10 circuits per package, and seven spst switches with from four to 10 circuits per package. All 15 switches mount on standard 0.100-by-0.300-inch centers, making them suitable for automatic insertion into printed-circuit boards. The series 206 devices have a maximum initial contact resistance of 25 milliohms, which will increase to no more than 50 milliohms after 10,000 cycles of switching 50 milliamperes at 24 V dc. The switches have a maximum nonswitching rating of 100 mA at 50 V dc. Dielectric breakdown between adjacent switches is 500 V dc minimum, capacitance is 5 picofarads maximum, and insulation resistance between adjacent switches or across an open switch is 1 gigohm minimum. Price
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Circle 125 on reader service card
New products

CTS Keene Inc., 3230 Riverside Ave., Paso Robles, Calif. 93446. Phone (805) 238-0350 [345]

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CTS Keene Inc., 3230 Riverside Ave., Paso Robles, Calif. 93446. Phone (805) 238-0350 [345]

Delivery time is six weeks.

Robles, Calif. 93446. Phone (805) 238-0350 [345]

Poly carbonate capacitors

A line of metalized polycarbonate capacitors, the series CMK, includes models that sell for as little as 6.5 cents each in lots of 5,000. This least-expensive unit has a capacitance of 0.01 microfarad ± 20% and a dc working voltage rating of 250 V. Other units have capacitances from 0.0027 µF to 6.8 MF, tolerances of 20%, 10%, 5%, and 2.5%, and working voltages of 100 V, 250 V, and 400 V. Housed in a flame-resistant plastic case that is unaffected by any solvent commonly used in electronic production, the series CMK devices have radial-lead construction. Lead spacings are 0.4, 0.6, 0.9, and 1.1 inches. Units are available from stock.

Seaco Inc., 598 Broadway, Norwood, N.J. 07648. Phone (201) 768-6070 [344]

Stripswitch measures only 0.3 inch high

A low-profile line of Stripswitches measures only 0.3-inch high enabling it to be used on printed-circuit boards racked at 0.5-inch intervals. The switches can be mounted directly to pc boards by hand, wave, or flow soldering. Single modules can be snapped together to form a multi-switch assembly of any desired length. This feature allows the mixing of different codes within a single assembly.

Available models offer thumbwheel or screwdriver setting with the legend located on top or side. Stops are provided, if necessary. Codes include 10-position binary-coded decimal, complementary BCD, plus and minus signs, and decimal. Prices start below $2 each for 1,000-piece

Polycarbonate capacitors sell for only 6.5 cents

A line of metalized polycarbonate capacitors, the series CMK, includes models that sell for as little as 6.5 cents each in lots of 5,000. This least-expensive unit has a capacitance of 0.01 microfarad ± 20% and a dc working voltage rating of 250 V. Other units have capacitances from 0.0027 µF to 6.8 µF, tolerances of 20%, 10%, 5%, and 2.5%, and working voltages of 100 V, 250 V, and 400 V. Housed in a flame-resistant plastic case that is unaffected by any solvent commonly used in electronic production, the series CMK devices have radial-lead construction. Lead spacings are 0.4, 0.6, 0.9, and 1.1 inches. Units are available from stock.

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New products

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Chip inspection is simplified

Operator keeps specimen under view during both test and pickup steps

A company that specializes in supplying semiconductor chips to hybrid-circuit manufacturers gains considerable experience in visual inspection of the chips. Semiconductor Services Inc., Salem, Mass., is such a company, and has found that visual inspection can be a slow and tedious process, often leading to error as operators reject good dice and let bad ones get by. To combat the problem, SSI has developed its own inspection station, the SSI-1000, which allows the operator to inspect and pick up rejects while maintaining a continuous view through the microscope.

James E. Hearl, SSI president, says that conventional microscope-inspection stations require the operator to view the chip through the binocular eyepiece, then take her gaze away from the microscope to remove a bad die—using a vacuum needle and unassisted vision. The frequent change from viewing through the microscope to viewing with the naked eye is slow, causes fatigue, and can result in the wrong die being removed from the carrier.

The SSI-1000 allows the operator to maintain her view through the microscope for both the inspection and pickup steps. An inverted-joystick control at the left is rotated around its own axis with the left hand to position the chip carrier under the field of view. A simple circular motion of the knob on the end of the joystick allows viewing of the entire chip, and, if it passes inspection, the operator rotates the joystick again with the left hand, indexing the stage holding the chip carrier from right to left and bringing the next chip into view.

If a chip is to be rejected, the operator uses her right hand to activate the vacuum pickup. The pickup arm uses vacuum force through a floating transfer tip, which moves through a combined arc and vertical motion, picking up the chip under inspection and automatically depositing it in a reservoir. At the end of a row of chips in the carrier, the operator manually indexes to the next row, still under microscope view.

The SSI-1000 is designed for both production and quality-control inspection, accommodates standard Fluowave chip carriers, and handles chips ranging from 15 to 500 mils on a side.

The complete station, including the Nikon 100× to 150× magnification microscope, sells for $1,795; the inspection platform with controls, for users who have their own microscope, is priced at $695. Delivery time is four weeks.

Semiconductor Services Inc., 1 Peabody St., Salem, Mass. 01970. Phone (617) 745-2450 [391]

Connectors designed for hazardous environments

Because they have no pins and jacks, inductive electrical connectors made by Pelcon Ltd. have no metal-to-metal contacts to short, arc, or deteriorate. The connectors can be mated in an explosive, deep-water, or other difficult or hazardous environment under load conditions. These connectors can handle analog signals, fm multiplexed signals, sensor information and fast-rise-time digital pulses. Coupling efficiency between the connector faces is said to be 95 to 99%, and the units can handle a wide range of power ratings.

Pelcon Ltd., P.O. Box 8143, Station A, St John’s, Newfoundland A1B 3M9, Canada [393]

Software package generates program for board tests

In-circuit inspection programs for digital-logic printed-circuit boards are automatically generated by a software package built by Zehntel and called D-PACT. Key to the automatic generation of software is the Isodrive digital inspection system that tests each logic element (such as gate, flip-flop, counter, and shift register), isolating it from the influences of neighboring digital and analog components. Using a bed-of-nails fixture and a low-impedance, fast-pulse-drive technique, Isodrive performs a functional truth-table examination directly at the input and output pins of each logic device on the assembly.

Because each element is treated independently, standardized test routines may be used for each type of logic function.

D-PACT software will be available for general use on Mark III Timeshare network software services

Electronics/August 5, 1976 129
New products

Benchtop system checks out multilead devices

A fully automated, user-programmable, bench-top system for high-volume testing of multilead devices, called the GR 2230, uses a powerful microcomputer, the Digital Equipment Corp. LSI-11. The 2230 evaluates, tests, and provides hard-copy data for both discrete and hybrid networks. Its versatility permits rapid mixed measurements on circuits containing resistors, capacitors, inductors, and diodes or transistors.

Networks can be tested from one point to any other point with built-in scanners under program control. Selective guarding via the scanner matrix can minimize the effects of stray impedance or isolate circuit elements between “buried nodes” on the unit under test.

In addition to testing single in-line and dual in-line-package networks, the 2230 can test functional modules such as voltage regulators and digital-to-analog converters. Device adapters for individual interfacing needs with ample space and electrical provisions for accommodating any required special circuitry add to the flexibility of the system. Prices start at $14,500.

GenRad Inc., 300 Baker Ave., Concord, Mass. 01742. Phone (617) 369-4400 [395]

offered by the General Electric Co. Program-generation costs are estimated at about $2 per integrated circuit chip.

D-PACT software is also available for Zehntel’s Troubleshooter 400 system, allowing program generation on the tester itself. D-PACT may be retrofitted to the 400 system for a price of $1,500.

Zehntel Inc., 2440 Stanwell Dr., Concord, Calif. 94520. Phone Craig Pynn at (415) 676-4200 [394]

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New products

Sensors' optical gate cuts parts count

High common-mode rejection of photocoupler simplifies design of high-speed circuits

High-speed optically coupled gates are being increasingly used as isolated line receivers and as interface elements in computer peripheral, microprocessor, and data-conversion systems. However, their high gain makes many of them susceptible to drowning in a sea of common-mode noise.

Eliminating common-mode interference is a major task in system design, and engineers have traditionally solved the problem by such methods as using twisted-pair lines, a shield, good printed-circuit-board layout, trick circuits, and surrounding the optically coupled gates with NAND or NOR flip-flops.

Now, however, Hewlett-Packard's Optoelectronics division is introducing a high-speed optically coupled gate, the 5082-4361, with a common-mode rejection 10 to 100 times higher than present devices. That capability allows designers to reduce component count in their systems by at least two thirds, HP says. In addition, says Gary Labelle, optoisolator marketing engineer, the 5082-4361 is priced only 30% to 40% higher than competing devices.

Like an earlier HP high-speed optical gate, the 5082-4360, the new device combines a gallium-arsenide-phosphide light-emitting diode and an integrated high-gain photodetector. It has a 5-milliamperre input current and a compatible supply.

But, unlike previous devices, the 5082-4361 provides a minimum guaranteed common-mode transient-immunity specification of 1,000 volts per microsecond, equivalent to rejecting a 300-V peak-to-peak sinusoid at 1 megahertz. Typical figures are more like 10,000 V/μs, compared to typical values ranging from 50 to 150 V/μs for other devices.

And compared with typical propagation delays of about 45 nanoseconds and output fall times of about 25 ns on earlier devices, the 5082-4361 has a typical propagation delay of 35 ns and an output fall time of 15 ns. The high common-mode rejection is achieved, says Labelle, by using an optically transparent, electrically conductive shield on the detector portion of the device. "The shield," he says, "shunts capacitively coupled input/output currents to ground so that the photodetector does not respond to them."

The shield, a continuous deposited film, covers all sensitive areas of the detector circuit (as shown in the white part of the photomicrograph). "This technique is more effective in improving common-mode rejection than other approaches, which rely on grounding photocathode p regions," says Labelle, "because a much higher conductivity can be obtained, and amplifier circuitry can be protected, as well. The resulting photocathode structure also has much less capacitance, and, therefore, higher operating speeds can be achieved."

The 5082-4361 is also suitable, says Labelle, for high-speed logic interfacing, I/O buffering, and as a line receiver in environments that conventional line receivers cannot tolerate. It is also recommended for use in extremely high-ground or noise-induced environments.

Maximum ratings include an operating temperature of 0°C to 70°C, a forward input current of 20 milliamperes, a reverse input voltage of 5 V, a supply voltage of 7 V, an enable voltage of 5.5 V, an output
Hewlett-Packard Co., Optoelectronics Division, 640 Page Mill Rd., Palo Alto, Calif. 94304 [411]

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- VSK 1520, 1530 & 1540-15A series in DO-4 metal stud cases. 600 mV (IF). 300A surge. 75mA (If) at Tc = 100°C.
- VSK 3020T, 3030T & 3040T-30A series. Center-tapped, common cathode, 15A per leg in TO-3 package. 630 mV (IF). 300A surge. 75mA (If) at Tc = 100°C.

All series have junction operating temperature range of -65°C to +150°C.

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Electronics/August 5, 1976

Collector current of 25 mA, an output-collector power dissipation of 40 milliwatts, and an output-collector voltage of 7 V. Available now, the devices are priced at $6.20 each in quantities of 1,000.

Hewlett-Packard Co., Optoelectronics Division, 640 Page Mill Rd., Palo Alto, Calif. 94304 [411]

IC has all control circuitry for switching power supply

The SG1524 is an inexpensive linear integrated circuit that contains all the control circuitry needed for a regulating power-supply inverter or a switching power supply. Included

in the 16-pin dual in-line package is a voltage reference, an error amplifier, a constant-frequency oscillator, a pulse-width modulator, a pulse-steering flip-flop, dual alternating output switches, and current-limiting and shut-down circuitry. Designed to replace 20 discrete components, the SG1524 almost reduces the design of switching power supplies to the selection of power semiconductors and the magnetic circuitry. Supplied in a hermetic ceramic DIP, the IC sells for $15.50 in quantities of 100.

Silicon General Inc., 7382 Bolsa Ave., Westminster, Calif. 92683. Phone E. Bentgen at (714) 892-5531 [413]

12-bit multiplying d-a converter sells for $8

Although it has only 8-bit linearity, the AD7531 multiplying digital-to-analog converter has 12-bit resolu-
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New products

High speed with voltage ratings up to 400 V and continuous current ratings up to 20 amperes. Minimum \( h_{fe} \) is 10 for the 400-V units, rising to 20 for the 300-V devices. With a supply voltage of 100 V and a collector current of 15 A, the transistors have a maximum turn-on time of 0.07 microsecond, a maximum storage time of 0.35 \( \mu s \), and a maximum turn-off time of 0.2 \( \mu s \). Other models, with collector-current ratings below 20 A, have similar specifications, but are somewhat faster. Prices, in hundreds, range from $13 each for a 15-A, 300-V unit, up to $20 for the 20-A, 400-V device. Delivery time is four weeks.

Genera Semiconductor Industries Inc., 2001 West Tenth Pl., Tempe, Ariz. 8521. Phone Betty Trenberth at (602) 968-3101 [417]

100-ampere transistor in TO-3 can has 500-W rating

Able to handle a continuous collector current of 100 amperes, the STC 9142 power transistor, although housed in a standard TO-3 package, has a power dissipation rating of 500 watts. At full current, the device has a minimum \( h_{fe} \) of 10, and turn-on and turn-off times of 2 and 5 microseconds, respectively. The transistor is intended to replace parallel arrangements of lower-power devices in series-pass regulators and in dc to medium-frequency amplifiers. It sells for $41.25 each in small quantities, dropping to $30 each in hundreds.

Silicon Transistor Corp., Katrina Rd., Chelmsford, Mass. 01824. Phone William A. Schromm at (617) 256-3321 [415]

4,096-bit RAM has 150-ns access time

Believed to be the industry's fastest 4,096-bit random-access memory housed in a 16-pin DIP, the MK 4027-2 has an access time of 150 nanoseconds and 111-compatible inputs. The memory features a \( \pm 10\% \) tolerance on all power-supply vol-
tages as a standard feature.

In addition to the usual read, write, and read-modify-write cycles, the MK 4027-2 is capable of page-mode timing and row-address-select-only refresh cycles. Page-mode operation reduces the access time to 100 ns with no increase in power consumption. RAS-only refresh is a simplified refresh operation that cuts power consumption.

The output of the memory will supply 5 milliamperes or sink 3.2 mA. In addition, it can work into capacitances as high as 100 picofarads. In 100-piece lots, the device sells for $24.20 each.

Mostek Corp., 1215 W. Crosby Rd., Carrollton, Texas 75006. Phone (214) 242-0444

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Power rectifier has recovery time of 35 ns

A fast, high-efficiency power rectifier, the IN5812, is believed to be the only such device on the market that combines ratings of 200 volts and 20 amperes with a reverse recovery time of only 35 nanoseconds. Other models in the 20-A series have voltage ratings from 50 to 150 V in 25-V increments. In addition to their extremely fast \( t_r \) specifications and high peak-inverse-voltage ratings, the rectifiers are noteworthy for their low forward-voltage drops—0.9 V at 10 A. Depending upon voltage rating, prices of the devices range from $8 each to $16.50 each in small quantities. In hundreds, the prices drop to $6.40 and $13.20, respectively. Delivery is from stock.

TRW Power Semiconductors, 14520 Aviation Blvd., Lawndale, Calif. 90260 [4-9]

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New products

Instruments

**Tester analyzes microprocessors**

Low-cost 32-channel recorder uses scope to display data in hexadecimal format

Logic analyzers have found a niche in testing and troubleshooting digital circuits, but their Os and Is or timing-diagram displays are less than optimum for examining microprocessor buses. The microprocessor analyzer, a variation of the logic analyzer, has been developed to meet the more specific needs of microprocessor hardware and software designers.

Scanoptik's Logicorder 32, for example, can handle 32 channels of digital data—enough for a microprocessor system's buses and a few auxiliary lines. The analyzer displays the activity in the unit under test in hexadecimal notation on the screen of a standard oscilloscope.

Priced at $895, the Logicorder 32 stores two "pages" of data, each page consisting of 32 words. It requires an external source of ±5-v power or can plug into a Tektronix TM-500-series mainframe.

Data is fed from the unit under test to the analyzer via three 16-conductor ribbon cables. Two of the ribbon cables handle data lines, and a third cable handles the clock signal, which can have a maximum frequency of 4 megahertz.

The microprocessor analyzer triggers a preset address, which can be either the first or last word on the display. The trigger can also be delayed by a set number of words so that the activity at any point in a microprocessor program can be examined.

The page number, the trigger address, and the number of words of trigger delay are displayed on the scope screen. In the manual mode, the entire display remains on the screen until the reset button is pushed. A new display appears when the address trigger and delay conditions are met. In the automatic mode, the display blanks after approximately one second, the analyzer waits for a new address trigger and delay, sets a new display, and the process repeats.

Scanoptik, Inc., P.O. Box 1745, Rockville, Md. 20850. Phone (301) 977-9660

**HP adds storage to 100-MHz portable scope**

Retaining all of the attributes of the earlier model 1740A, Hewlett-Packard's model 1741A oscilloscope also includes variable-persistence and storage capabilities. The scope is thus particularly well suited to the capture and display of single-shot and low-repetition-rate waveforms commonly encountered in digital circuitry. The variable-persistence mode is useful in integrating waveforms with low repetition rates into clear displays, while the storage mode is for single-shot events. An auto-erase mode allows the 1741A to produce single-shot displays sequentially at rates up to one per second. Frequency response of the 1741A ranges to 100 megahertz at a sensitivity of 5 millivolts per division. A 5X magnifier yields a sensitivity of 1 mV/division up to 30 MHz.

The scope uses a new cathode-ray tube and control electronics that produce a good trace-to-background ratio under most input conditions. A dynamic-feedback current-limiting circuit protects the CRT against burns. With this circuitry, the intensity may be increased for the viewing of fast traces with no danger that slow traces will then burn the screen. The 1741A sells for $3,950; delivery time is estimated to be 60 days.

Hewlett-Packard Co., 1501 Page Mill Rd., Palo Alto, Calif. 94304

**Portable meter tests transistors and FETs**

A portable version of the popular Cricket transistor/FET tester, called the Pocket Cricket, uses a patented phase-inversion test to identify good transistors and field-effect transistors. Transistors that pass the gain test cause the tester both to emit a test tone and to swing its meter pointer upward. After a device is known to be good, its polarity can be
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The standard current range is 350 amperes peak ac and dc. Response time is less than 50 microseconds and linearity is better than 2% of full scale. Other models are available to 2,000 amperes and to 100,000 amperes. For more detailed information, please use the inquiry card.

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Logic analyzer is microprocessor-oriented

The 1625A logic analyzer can be triggered like any other such instrument—by its 16 input channels or by an external signal. In addition, it can be triggered by a second set of 16 inputs connected to a microprocessor input/output bus. Combining features of timing-diagram and truth-table displays, the display on the 1625A contains a timing diagram and a movable cursor. A column of 1s and 0s to the right of the timing diagram displays the 1s and 0s of the data at the cursor position. A dashed cursor shows the position of the trigger word, while the trigger word and trigger address are displayed alongside the cursor data at the right of the screen. Capable of handling two logic families at the same time, the 1625A sells for $4,600. Delivery time is 60 days.

Vector Associates, Inc., 685 Station Rd., Bellport, N. Y. 11713. Phone Sheldon Bienstock at (516) 286-9000. [357]
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- For more information of complete product line see advertisement in the latest Electronics Buyers Guide
- Advertisement in Electronics International
- Advertiser in Electronics, domestic edition
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George F. Werner, Associate Publisher
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Regina Hara, Directory Manager
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Advertise your sales force to thousands of key decision makers in the electronics industry.

Have a ferrite delivery problem? Look to Permag.


Consult your Yellow Pages for address and telephone number of Permag near you.

33% more power to the people. Power/Mate presents Econo/Mate II. The open frame power supply.

Prices start at $19.95.

Now Power/Mate brings you 33% more power in the same package size with the second generation of our Econo/Mate series. The size is the same. the basic components are the same for easy interchangeability. But that's where the similarity ends.

Econo/Mate II adds features like dual AC primary and a plug-in IC regulator for improved regulation. And Econo/Mate II is tough.

Design computer, quality control and Power/Mate's experience helps ensure 100,000 hour MTBF even at this higher power output.

For all its features, Econo/Mate II is still, most of all, economical. We wouldn't call it Econo/Mate if it wasn't.

Econo/Mate II is in stock, ready for delivery. Send for our free brochure.

Electronic August 5, 1976

Electronics / August 5, 1976
SOLID STATE
3 WIRE SYNCHRO TO LINEAR D.C. CONVERTER

FEATURES:
• Develops a DC output voltage linearly proportional to a synchro angle over a ±180° range.
• Completely solid state with all of the inherent advantages over a mechanical system such as:
  - High reliability (since there are no moving parts)
  - Light weight—6 ozs.
  - Small size
  - All units hermetically sealed
• Wide temperature range operation
• Output short circuit protected
• Three wire inputs isolated from ground
• Units can be altered to accept different line to line voltages or different operating frequencies at no extra cost
• Not affected by reference voltage or power supply variations.

<table>
<thead>
<tr>
<th>UNIT</th>
<th>MAC 1422-1</th>
<th>MAC 1449-1</th>
<th>MAC 1458-1</th>
<th>MAC 1459-1</th>
<th>MAC 1460-1</th>
<th>MAC 1461-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>TRANSFER EQUATION</td>
<td>±1V/18°</td>
<td>±1V/18°</td>
<td>±1V/18°</td>
<td>±1V/18°</td>
<td>+1V/36°</td>
<td>+1V/36°</td>
</tr>
<tr>
<td>ACCURACY (+25°C)</td>
<td>±1/2%</td>
<td>±1/2%</td>
<td>±1/2%</td>
<td>±1/2%</td>
<td>±1/2%</td>
<td>±1/2%</td>
</tr>
<tr>
<td>ACCURACY (-25°C to +85°C)</td>
<td>±1%</td>
<td>±1%</td>
<td>±1%</td>
<td>±1%</td>
<td>±1%</td>
<td>±1%</td>
</tr>
<tr>
<td>L-L SYNCHRO INPUT (VRMS)</td>
<td>11.8 V</td>
<td>90 V</td>
<td>11.8 V</td>
<td>90 V</td>
<td>11.8 V</td>
<td>90 V</td>
</tr>
<tr>
<td>FREQUENCY (Hz)</td>
<td>400</td>
<td>400</td>
<td>60</td>
<td>60</td>
<td>400</td>
<td>400</td>
</tr>
<tr>
<td>FULL SCALE OUTPUT</td>
<td>±10V</td>
<td>±10V</td>
<td>±10V</td>
<td>±10V</td>
<td>±10V</td>
<td>±10V</td>
</tr>
<tr>
<td>OUTPUT IMPEDANCE</td>
<td>&lt;1Ω</td>
<td>&lt;1Ω</td>
<td>&lt;1Ω</td>
<td>&lt;1Ω</td>
<td>&lt;1Ω</td>
<td>&lt;1Ω</td>
</tr>
<tr>
<td>L-L INPUT IMPEDANCE</td>
<td>&gt;10K</td>
<td>&gt;30K</td>
<td>&gt;2K</td>
<td>&gt;10K</td>
<td>&gt;10K</td>
<td>&gt;30K</td>
</tr>
<tr>
<td>REFERENCE VOLTAGE (VRMS)</td>
<td>26 V</td>
<td>115 V</td>
<td>26 V</td>
<td>115 V</td>
<td>26 V</td>
<td>115 V</td>
</tr>
<tr>
<td>OPERATING TEMP. °C</td>
<td>-25° to +85°</td>
<td>-25° to +85°</td>
<td>-25° to +85°</td>
<td>-25° to +85°</td>
<td>-25° to +85°</td>
<td>-25° to +85°</td>
</tr>
<tr>
<td>D.C. SUPPLY</td>
<td>±15V</td>
<td>±15V</td>
<td>±15V</td>
<td>±15V</td>
<td>±15V</td>
<td>±15V</td>
</tr>
<tr>
<td>D.C. SUPPLY CURRENT</td>
<td>±75mA</td>
<td>±75mA</td>
<td>±75mA</td>
<td>±75mA</td>
<td>±75mA</td>
<td>±75mA</td>
</tr>
<tr>
<td>BANDWIDTH</td>
<td>10Hz</td>
<td>10Hz</td>
<td>OPT.</td>
<td>OPT.</td>
<td>10Hz</td>
<td>10Hz</td>
</tr>
<tr>
<td>WEIGHT</td>
<td>6 oz.</td>
<td>6 oz.</td>
<td>6 oz.</td>
<td>6 oz.</td>
<td>6 oz.</td>
<td>6 oz.</td>
</tr>
<tr>
<td>SIZE</td>
<td>3.6 x 2.5 x 0.6&quot;</td>
<td>3.6 x 2.5 x 0.6&quot;</td>
<td>3.6 x 3.0 x 0.6&quot;</td>
<td>3.6 x 3.0 x 1.0&quot;</td>
<td>3.6 x 2.5 x 0.6&quot;</td>
<td>3.6 x 2.5 x 0.6&quot;</td>
</tr>
</tbody>
</table>

A.C. LINE REGULATION
A new method has been developed which allows us to provide a low distortion highly regulated AC waveform without using tuned circuits or solid state active filters of any kind.

The result is a frequency independent AC output regulated to 0.1% for line and load with greater than 20% line variations over a wide temperature range.

FEATURES:
• 0.1% total line and load regulation
• Independent of ±20% frequency fluctuation
• 1 watt output
• Extremely small size
• Isolation between input and output can be provided

Specifications: Model MLR 1476-1
AC Line Voltage: 26V ±20% @ 400Hz ±20%
Output: 26V ±1% for set point
Load: 0 to 40mA
Total Regulation: ±0.1%
Distortion: 0.5% maximum rms
Temperature Range: -55°C to +125°C
Size: 2.0" x 1.5" x 0.5"

Other units are available at different power and voltage levels as well as wider temperature ranges. Information will be furnished upon request.

SOLID STATE SINE-COSINE SYNCHRO CONVERTER - NON VARIANT

This new encapsulated circuit converts a 3 wire synchro input to a pair of dc outputs proportional to the sine and cosine of the synchro angle independent of a-c line fluctuations.
• Complete solid state construction
• Operates over a wide temperature range
• Independent of reference line fluctuations
• Conversion accuracy—6 minutes
• Reference and synchro inputs isolated from ground

Specifications: Model DMD 1508-2
Accuracy: Overall conversion accuracy 6 minutes. Absolute value of sine and cosine outputs accurate to ±30MV
Temperature Range: Operating —40°C to +85°C, Storage —55°C to +125°C
Synchro Input: 90V RMS ±5% LL 400Hz ±5%
DC Power: ±15V DC ±10% @ 50mA
Reference: 115V RMS ±5% 400Hz ±5%
Output: 10V DC full scale output on either channel @ 5mA load
Temperature coefficient of accuracy: ±15 seconds/°C avg. on conversion accuracy ±1 MV/°C on absolute output voltages
Size: 2.0" x 1.5" x 2.5"
Units are available with wider temperature ranges and 11.8V LL, 26V reference synchro inputs. Information will be supplied upon request.
Now in the only full line of super low profile SIP Resistor Networks.

If you haven't designed in Single In-line Package resistor networks because of their high profile, take another look. THE HEIGHT ON BOURNS SIPs IS ONLY .190 INCH! And that's standard for all 6, 8 and 10 pin configurations with:

- 5, 7 or 9 resistors and 1 common pin
- 3, 4 or 5 isolated resistors
- 12 resistors, dual terminator (8 pin)

Now you can fit the same number of resistors into less area and yet maintain close P.C. Board spacing. Something you can't do when using other SIP networks with .250 or .350 inch high profiles.

And only Bourns SIPs offer the same reliable Krimp-Joint™ lead termination design as our DIP packages, high-copper alloy leads and uniform molded package design. With added features like MACHINE INSERTABILITY, COMPETITIVE PRICING AND DISTRIBUTOR AVAILABILITY — Why specify other than Bourns?

Bourns Krimp-Joint™ offers both a mechanical and electrical bond that lap or butt joint construction can't provide. The lead is crimped on the network element and a high-temp, reflow-resistant solder is used to prevent failure during wave soldering and in circuit thermal cycling and vibration.

FREE SIP and DIP SAMPLES!
Write on your company letterhead and let us know your requirements, we'll rush you a SIP or DIP resistor network sample and complete specifications.

TRIMPOT PRODUCTS DIVISION, BOURNS, INC., 1200 Columbia Avenue, Riverside, California 92507. Telephone 714 781-5415 — TWX 910 332-1252.

Circle 901 on reader service card
Type 9 CdS photoconductive material offers highest stability!

Stability at high temperatures and less light memory than any other CdS material are the chief characteristics of Clairex's Type 9 CdS. It also offers improved linearity and broader spectral response. Clairex photocells with Type 9 material are available in TO-5, TO-8 and TO-18 packages. If you have photocell stability problems, try Type 9 material.

Clairex® is the industry's specialist in "light" problems. Tell us your problem; we'll develop the solution. Call (914) 664-6602 or write Clairex, 560 South Third Avenue, Mount Vernon, New York 10550.