Today’s world of communications contains an incredible variety of hardware, ranging from the simple tin-can telephone to the latest μP-controlled data-transmission system. Areas of major progress include optical communications, packaged microwave oscillators, microwave test equipment and active components. See p. 40.
Meet Bourns new Model 3386, a product that both buyer and engineer can love... with super adjustability that makes for easy, accurate trimming, AND at a budget balancing price. Most importantly, it's a BOURNS product... and that means QUALITY and PERFORMANCE you can believe-in, and SERVICE you can depend-on.

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Total range 6.5 8.5
Isolation (dB) Typ. Min.
Lower band edge to LO-RF 50 35
one decade higher LO-RF 45 30
Mid range LO-RF 45 30
Upper band edge to LO-RF 40 25
one octave lower LO-RF 30 20
Min. Electronic attenuation (20 mA) 3 dB
Signal, 1 dB compression level + 1 dBm
Impedance all ports 50 ohms

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For complete product specifications and agent listings see MicroWaves "Product Data Directory," Electronic Designs' "Gold Book" or Electronic Engineers Master "EEM."
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A sad spoof of PC artwork

I will start by saying that I enjoyed the laughs I got from Donald P. Dattilo's article, "Improve Your PC Artwork Techniques" (ED No. 25, Dec. 6, 1975, p. 72). My first comment is a generality: the article is of little technical value to a PC designer.

I am a supervisor of a PC design group for a company that manufactures batch terminals. About 90 percent of our boards are done at 4:1 because of registration problems at 2:1. We do not use paper for a grid because of its poor stability. We use a ghost grid that is printed on Mylar, and which drops out when the artwork is reduced. We never measure components for size because of variations among vendors. A company spec or data sheet that indicates largest size should be used.

I would question the ability of a designer if he constantly used cutouts or designated leads on transistors. The use of jumpers is costly and should be avoided.

All slashes, cuts and pinholes tend to catch and hold dust and dirt, which will photograph as a line or spot. Therefore, avoid marking the Mylar in any way.

The 0.062-in. minimum UL spacing is for high voltages. Putting tape in your mouth is poor taste. But it fits in with breaking off your Exacto blade to lift the stick-ons; waiting for your ballpoint pen to run dry so you can apply transfer lettering; slashing down the artwork with lacquer thinner; using the flip method for registration (that has to be a flop); or spraying the artwork with Krylon (Was that before or after the talcum powder dusting?)

Oh well, tape your reds and blues on opposite sides and keep your jumper straight.

Roger Anderson
592 Lincoln
Saint Paul, MN 55102

The author replies

I must honestly state that I enjoyed your satire. Your thoughts do show some degree of creativity.

But I am sorry to hear that your people are having problems with artwork done at a 2:1 scale. Maybe they should use a red/blue tape method to reduce their errors. All registration errors are eliminated with red/blue taping. Your comment on the use of a paper grid is correct; paper does have poor stability. Critical applications should make use of grids fused into temperature-stable glass.

The fact that you never measure components to obtain size information indicates a closed mind. Manufacturers' specifications have been known to be wrong.

I suggest re-reading the article without such a superior attitude; if you take the time to try some of the techniques described you might learn something new.

Donald P. Dattilo
President
Dattilo Enterprises, Inc.
9405 Doral Ct.
Louisville, KY 40220

More bits might be less good than less bits

The quote attributed to Dr. Gary Nelson ("If you're doing a job that requires 16 bits of precision for the computation, then, of course, that eliminates all the 8-bit processors.") in the February 2 issue (ED No. 3, p. 44) (continued on page 14)
does more than provide the industry's most complete line of rotary switches

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3. Test equipment assembly, combining phenolic switch sections, resistors and capacitors attached to PC boards, with concentric shafts, brackets and potentiometer.

4. Nine section Unidex switch with PC terminals at opposite sides for attachment to parallel PC boards.

5. Connector and harness assembly attached to four section 24 position Multidex switch.

6. Five section Multidex switch wired and terminated with customer supplied connectors.

7. Triple concentric shaft with dual detent, with potentiometer on inner shaft, rear bank of 3 sections on center shaft and 4 front sections on outer shaft.

8. Switch assembly for electronic test equipment assembled by Oak. Includes six switch sections, gear system potentiometer and special brackets.

9. Compact assembly controlling four 7.5A, 32V snap switches.

10. For PC board insertion, this Unidex dual concentric switch combines a PC board switch section, standard switch section and shielded variable resistor.

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13. Seven section dual concentric Unidex switch with PC board terminals and shielding between sections.

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17. Three 18-position sections, dual concentric switch with counting gear mechanism used for airborne equipment. Special brackets and gears assembled at Oak to customer's specifications.

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ACROSS THE DESK
(continued from page 7)
tends to reinforce the misconception that more bits are necessarily better than less bits.

Actually, of course, word size bears little, if any, relation to the precision achievable on a particular processor. An 8-bit processor can provide 8, 16, 24, 32 or even higher bit precision. The word size does play some part in determining the speed with which a desired precision can be achieved, but the instruction set and instruction execution time are far more important factors.

With regard to benchmarks, I tend to agree with the view that holds that "standard" benchmarks are of little value, because in most cases they bear little relation to the specific application at hand.

Alex Goldberger
Manager
Signetics
811 E. Arques Ave.
Sunnyvale, CA 94086

'Success story'—
The Czar's sequel

"The Czar's Consultant" (ED No. 1, Jan. 5, 1976, p. 75) was very interesting. Have you considered the sequel, in which his successors make a career out of obtaining information from the grass roots? One might call it "Success Story":

Following the breakup of the Czar's family-owned monopoly, there flourished a very brief period of competition. It was succeeded by a market takeover by Lenin & Co., a giant corporation, with representatives in all population centers, however small. Its many and varied sources of information were a key factor in acquiring a complete monopoly in the Russian market.

In fact, acquisition of information on possible competition became a major national industry. Even rumored possible competitors, however small, were quickly disposed of by tactics some of the foreign competition enviously called "ruthless."

Board chairmen came and went, but the monopoly, bolstered by the excellently developed market research techniques and a large and effective sales force, prospered for more than a half a century. Oh, it was true that the vast resources of the country were being inefficiently employed. The agriculture was unable to feed the people adequately. And the standard of living was suppressed.

But the mastery of information-gathering and advertising, the continually improved tools of persuasion that were in the hands of the sales force, the high level of investment in the training of an export sales force—and firm barriers against foreign competition—not only enabled them to convince the domestic customer base that it felt satisfied, but also made for an increasing foreign market.

Although there are stresses and strains, the successors of Lenin & Co. are creeping up on the unwary foreign competition, who are foolishly cutting off their sources of information (which they deem unethical), and tools for their sales force (which they consider immoral). Their competitors will learn a lesson—too late—when they find their market has been undercut and they are about to share the fate of Nicholas.

Dan Sheingold
Analog Devices, Inc.

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Model 9300 has a standard tape speed of 125ips, with data densities of 200/556cpi or 556/800 on the 7-track unit and 800cpi, 1600cpi or 800/1600cpi on the 9-track transport. The format is NRZI/PE.

Model 9300 is not only quick and quiet — it’s very competitive. That’s quite a lot, considering the Kennedy quality.

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Wang introduces a mini, drum plotter and printer

In a continuing effort to become a significant factor in the small computer business, Wang Laboratories, Tewksbury, MA, has announced a host of new additions to its product line. These include:

- The 2200 PCS “plug-in” series of portable minicomputer systems, which are designed to compete with IBM’s Model 5100, the Tektronix 4051 and Hewlett-Packard’s 9825.
- A µP-based “virtual drum” plotter, the Model 2272, and a 120-character-per-second serial matrix printer, the Model 2231W.

Wang’s 2200 PCS series consists of full minicomputers completely contained within a 55-pound desktop console that plugs into a wall socket.

The PCS consists of 8-k bytes of random-access memory and 42.5-k bytes of read-only memory, a 9-in. CRT display with full alphanumeric (upper and lower case) keyboard and a tape cassette for data storage or program loading. The 8-k system will sell for $5400 and is expandable to 32-k bytes of RAM ($9000).

The Wang plotter, which is priced at $2900, is somewhat unusual in that the drum does not rotate. On most drum plotters, the drum rotates with the paper attached, according to senior marketing VP Ned Chang.

Because of the physical inertia of the drum, faster plots can be obtained by rotating only the end sprocket mechanisms, which secure the plotting paper. The Wang plotter moves the paper instead of the drum. This design approach, Chang says, the company was able to use small motors in its plotter.

Most drum plotters also use analog servo motors and linearizing circuitry that requires frequent calibration. Chang explains, “Since the source of the X and Y coordinates is digital anyway, we decided to send the coordinates directly into an 8080 µP that digitally linearized the motion by controlling small dc stepping motors.”

By adding a ROM to the µP, Chang added, it was possible to generate an alphabetical character set for labeling plots, thus relieving the processor that drives the plotter.

The 2272 plotter can accept paper up to 17-in. wide and can optionally plot up to three colors, with a resolution of 0.005 in.

Wang’s new serial printer forms characters with a 7 × 9 dot matrix compared with a 5 × 7 dot matrix on most other printers. Chang says the printer is designed to appeal to users that are driving 30-cps printers beyond the product’s limits but who could not justify the expense of a 165-cps unit.

Wang’s 2231W printer will sell for $2900.

Test modules with LEDs check out PC connects

A set of low-cost 14 and 16-pin IC test modules outfitted with one LED for each pin, provide a superior means of testing PC-board wire-wrap interconnections.

Using these modules, it is possible to verify the continuity of a wiring chain (a sequence of common connections to a pin), according to Ralph Curtis, electronic engineer at the Naval Research Laboratory (NRL), Washington, DC.

It is also possible to detect missing wires or open connections, as is possible with standard methods of continuity checking. And unlike regular methods, the NRL test can indicate whether there are short circuits or extra wires, Curtis says. He was aided in the development of the LED test module system by NRL engineers Alan Pezzulich and William Byrne.

The NRL approach is simple, as Curtis explains it. One terminal of each of the 14 or 16 LEDs on a module is connected, through a dropping resistor, to an individual pin. The other ends of the LEDs are tied together in a common connection.

One side of a 5-V battery is connected to the common LED termination, and the other side of the battery is connected to a probe.

The PC card to be checked is filled with the appropriate test modules. Then using the probe and the special list, which was developed from the basic wire-wrap list, the connections common to each chain on the list can be verified.

If all connections are good, all the LEDs tied to that chain will light up. If there is an open, the LED remains dark; when LEDs light up that should be dark, an extra wire or short is indicated.

150-V Schottky power diodes developed at GE

Schottky rectifier diodes developed by General Electric Co., Schenectady, NY, are reported to operate as high as 150 V—a maximum voltage more than four times higher than that of Schottky rectifiers now on the market. In addition, the diode’s specifications are now more reproducible from one diode to the next.

Both improvements have been achieved by a new technique, developed by GE, to form platinum silicide on a silicon mesa base. A sputtering process is now used, in contrast to the conventional method of evaporation and heating in a
Latent fingerprints matched to databank

A system has been developed that can match fingerprints picked up at the scene of a crime (latent prints) to prints stored in a database. This is the first system of its kind with automatic print-matching and the ability to match from partial, imperfect prints.

"We don't even have to have the central features of the print to make a pretty good match," says Lou Waggoner of the Indentification Systems Organization at Rockwell International in Anaheim, CA. The system looks for matches of print minutiae (points where fingerprint ridges end or fork).

An operator seated at the system's console places the latent print in front of a TV camera. An enlarged view of the print is displayed on a TV monitor and the operator uses an electronic vectorized cursor to mark the minutiae of interest.

A two-level search is then initiated. The first level takes two to three seconds and breaks down the file to be searched according to a variety of descriptors, such as finger-pattern type, sex, crime, year of birth and others.

The second level takes about six seconds per finger and includes a minutiae match. Each print is scored by the system on a 0-to-1600 scale ranging from worst to best match.

A 1029-line high-resolution monitor is used for the display. The system includes a Data General Eclipse C/300 computer with 128 k of core, a 90-M byte moving-head disc drive, a 1-M byte fixed-head disc drive, a magnetic tape drive and a 300-lpm line printer.

It takes about 10 k of memory to store a single print.

Waggoner points out that a hardware matcher is under development that will eliminate the need for the operator picking out the minutiae at the CRT. It will upgrade the system speed to about 200 to 300 matches per second.

The first system has just been installed at California's Dept. of Justice in Sacramento. Initial tests will use a 13,000-person fingerprint file.

Largest solar-energy plant to be built

The largest solar energy installation in the world will soon be constructed by Sandia Laboratories, Albuquerque, NM, under a grant from the United States Energy Research and Development Administration (ERDA).

The facility will consist basically of a boiler mounted atop a 200-ft high tower surrounded by an array of more than 300 large tracking mirrors. The mirrors, or heliostats, will reflect the sun's rays onto the boiler, producing about 5 MW of thermal energy, which will be converted to about 1.5 MW of electricity.

Currently, the largest operating solar installation is a research solar furnace at Odeillo, France, which produces 1 MW of thermal energy.

The Sandia facility will initially be used to test components for a much larger solar-power pilot plant now being designed. This plant would generate about 10 MW of electricity, an amount sufficient to supply the electrical needs of a town of 10,000 people.

The Albuquerque test facility is expected to be operating at 1 MW by late 1977 and at full power in 1978. It will be located adjacent to Sandia's environmental testing area, about six miles south of the Labs' main tech area on Kirtland AFB.

30-second diagnostic test developed for cars

An automotive diagnostic system that requires no engine connections and that can check out vehicle malfunctions in 30 seconds has been designed by L. Robin Hulls and two fellow engineers at RCA's Automated Systems Div., Burlington, MA.

The system uses a sensor that can be placed either in or near the vehicle's exhaust pipe. It is connected to a special electronic tracking filter that processes the received signals. The unit can also be used at such other vehicle points as the air intake to the manifold or the crankcase breather, Hulls says.

The test is performed by accelerating and decelerating the engine to determine its speed and acceleration rate. This information is fed into a diagnostic unit with a built-in microprocessor, which automatically computes engine horsepower. If when testing a diesel engine, for example, you learn that you're not developing the proper horsepower you know immediately that something is wrong and you need further tests, Hulls says.

Part of the further testing might be to look at harmonic signals generated in the exhaust pipe which would indicate a bad cylinder.

If the engine did give you the proper horsepower you'd know there was no point in testing the compression or fuel rate.
This new microprocessor controlled reader/spooler will read 1000 characters per second, and still provide stop on character. All of its reader/spooler functions, such as starting, stopping, rewind speed (1500 c/s), data output, and interface timing are controlled by a program stored in its microprocessor memory. Its other advantages lie in the areas of reading reliability, high speed stopping, programmed soft stopping, the spooler system, and equipment reliability. It also includes step and slew modes, and a priority interrupt mode.

And like other EECO readers it boasts LED and phototransistor optoelectronics, a step motor drive, a full tape-width barrel sprocket, handshake interface logic, and TTL and DTL compatible electronics. But wait, we can't sell you one now, because it won't be shippable until after the National Computer Conference.* We're telling you now just so you can make plans. The best is yet to come.

*First public showing.
We started by redesigning a CRT. And ended with the fastest, easiest way to build microcomputer systems.

The AMI 6800 MDC architecture is so far ahead of the competition they'll have to change their whole development philosophy to catch up.

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The standard AMI Microcomputer Development Center consists of the 80 char. x 25 line CRT, the dual floppy disk with disk operating system, S6834 EPROM programmer,
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We're the original "little light" people.
USAF warns on spread of Soviet satellite stations

The spread of Soviet Molniya satellite-communication systems was among strong warnings to Congress delivered recently by a Pentagon spokesman at hearings on the fiscal-1977 budget.

The first Molniya satellite was launched in the mid-60s for the Russian ICBM system; three others were orbited later.

Hardened command and control stations are now being deployed throughout the USSR, East Europe and Mongolia, but the most important top-level centers are still dispersed within an 80-mile radius of Moscow.

Among system improvements reported by USAF Gen. George Brown, chairman of the Joint Chiefs of Staff, are the use of Zhdanov and Admiral Senyavin, both Sverdlov-class light cruisers, as seaborne command-and-control centers. And Brown says airborne command posts have already been used in crisis situations. The general predicts they will grow in importance with Soviet communication and computer-technology advances.

Military inches into fiber optics

The military is beginning to convert to fiber optics, says H. Tyler Marcy, assistant secretary of the Navy for research and development.

He told Congress the Navy is presently rewiring the navigation and weapon-delivery system of an A-7 aircraft, replacing 302 wire connectors—totaling 4832 ft of wiring—with 260 feet of multiplexed fiber-optic conductors. The number of cables will be reduced from 300 to 13. The weight of the cable and connectors will be reduced from 82 lb to 3.6 lb and parts cost from $7900 to $1100.

The major obstacle to the use of fiber optics, he reported, has been the unavailability of affordable, off-the-shelf components with suitable performance. To offset this deficiency, the Navy is encouraging industry to increase fiber-optic development efforts.

Noting that connectors, couplers, detectors and pressure-bulkhead penetrators are being produced, he says the application of multimode-optical-bundle technology offers a low-risk approach to military applications in the shortest possible time. A decided plus, according to the Navy, is that only a minimal level of skill is needed for maintenance.

Integrated IR-system for satellites may detect aircraft

Integrated infrared-sensor systems to detect aircraft by satellite may soon be made possible by silicon charge-coupled devices, according to Dr. Charles Heilmeier of the Department of Defense.

The director of the DOD’s Advanced Research Projects Agency, Heil-
meier made the prediction in Congressional testimony on behalf of the record $246 million budget his agency has requested for fiscal 1977.

"The same mass-production technology used for silicon ICs can be applied to the production of integrated infrared sensors," Heilmeier said. "Thousands of single chips can be packaged into multimillion-element systems.

"Integration of signal processing into detection chips allows clutter discrimination to be performed automatically at the IR receiver, and will eliminate the costs and time delays caused by using large, ground-based computers."

He said the agency had recently developed such a device, called a CCD*, that contained hundreds of detectors.

Even though the sensors are scanning wide areas, the large number of detectors can spot very small signals, making it possible to spot not only ballistic-missile launchings, but individual aircraft, he said.

New procedures for closing military bases

In the wake of the politically-motivated closing of military bases that was widely alleged during recent years, new procedures have been drawn up. No longer can Pentagon brass summarily close a base as they could in days of yore.

The National Environmental Policy Act now requires that environmental impact statements be drawn up first. Employment, housing, public schools, the tax base, and so on must all be considered along with pollution, population and traffic factors.

Capital Capsules: The General Accounting Office, in a recent review of material shortages, looked at the electronic component situation and found producers saying government contracts, once their number one source of income, are now a minor portion. This, GAO warns, will compound problems for government contractors: they'll have less leverage with producers in the future. . . . The Air Force says air tests of the Air Force Boeing E-3A airborne warning-and-control-system aircraft will be finished in April, nine months ahead of schedule, and then the AWACS aircraft will go into the avionics test phase. One of the four already equipped began extensive tests of surveillance and command and control last year. A major question of aircraft performance was flight behavior with the 30-foot diameter radome atop the modified 707's fuselage. . . . The Energy Research and Development Administration is seeking proposals to conduct an 18-month research program for communications systems that are capable of automating load-management and power-distribution systems. . . . The Defense Communications Agency is seeking sources for a study and test validation of the characteristics of jitter accumulation in a pulse-stuffing time-division multiplexing network. Wanted are sources familiar with the analysis of the response of phase lock-loop circuitry to time-variant stimuli and application of PCM digital multiplexing to large-scale communications systems. . . . Another well-known Defense Dept. agency is slated for the history books by September. That's the date the Weapons Systems Evaluation Group will cease to exist, although it could come sooner. The Defense Dept. says that the group is no longer needed since the military services are now structured to perform the analyses and evaluation. About 65 people will be shifted to other jobs, DOD says.
Tektronix Minis...

Eight oscilloscopes that go anywhere

Now you can take oscilloscope measurement capability anywhere, even to remote or hard to reach places. This means faster, more thorough on-site repairs of electronic equipment and fewer callbacks. To the top of the ladder, into a utility access tunnel, onto an industrial catwalk, to a remote research site — ultra-portable TEKTRONIX Miniature Oscilloscopes go virtually anywhere you can go.

Only Tektronix offers you a choice of eight miniature oscilloscopes for the performance/weight combination best suited to your application. Bandwidths range from 500 kHz to 35 MHz for servicing equipment as sophisticated as mini-computers or complex industrial control systems. Model 335 offers by far the highest performance of any 10-pound oscilloscope: 35 MHz, dual-trace, delayed sweep, 1mV/div sensitivity, delay lines on vertical inputs, variable trigger hold-off and more. Two models (3½ pounds, 500 kHz and 10 pounds, 10 MHz) feature storage, a unique capability among miniature oscilloscopes. One 3½ pound model combines an oscilloscope with a precision digital multimeter. All 3½-pound models and two of the 10-pound models operate on internal batteries as well as ac. Unique two-level insulation between case and earth ground makes the 3½-pound models excellent choices for waveform measurements at elevated voltages. And proven Tektronix quality, ruggedness, reliability, and service mean more trouble-free measurements, few problems, and fast, reliable service if you need it.

For on site assistance in selecting the best miniature oscilloscope for your application, contact your local Tektronix Field Engineer. Or, for a descriptive brochure on our comprehensive portable oscilloscope family, write Tektronix, Inc., P.O. Box 500, Beaverton, Oregon 97077. In Europe, write Tektronix Limited, P.O. Box 36, St. Peter Port, Guernsey, Channel Islands.

For technical data circle #281
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For off-the-shelf delivery, call your local Amphenol Industrial Distributor. Your competitors may have already discovered his great service—so should you. Give him a call. Or for more information (and spec sheets on our pots and trimmers) contact: George Boyd, Connector Division, Bunker Ramo Corporation, 2801 South 25th Avenue, Broadview, Illinois 60153. Phone: (312) 261-2000.

When you can connect it and forget it...that’s quality.
A mini manufacturer warns, 'Beware the microcomputer'

Dave Methvin, president of Computer Automation, Irvine, CA, presents his views here for Electronic Design readers.

A couple of years ago many experts, particularly in the financial community, thought that microcomputers would eventually wipe out the minicomputer business. Well, of course, that didn't happen. A year later they thought the microcomputer would wipe out the low-end of the minicomputer business. And, of course, that didn't happen either. Here we are a year later, still chugging along, and people are beginning to realize, I think, that the micro isn't really a minicomputer and that it has a limited capability.

The minicomputer companies, DEC, Data General and ourselves, for example, we're not about to run away from the low end of the business. For a time there was even some discussion of the possibility that minicomputer companies will have to move up into bigger machines and start nipping at IBM's heels and so on.

Well my attitude is a little different in that we, and I think DEC and Data General felt that way also, would move our product farther and farther down that price curve and put a lid on how far microcomputers could go before they bump into the minicomputer companies with their established product lines, their software services, sales force, etc.

In fact, that's happened with Data General's recent introduction of its low-end microNova line.

It turns out that if used properly, there is no (continued on page 32)

Complete development system for 8080 priced under $4000

A stand-alone development system for writing, debugging, and executing programs on the 8080 µP, the Model 8-16 costs $3850 and is offered by Microkit (2180 Colorado Ave., Santa Monica, CA 90404. 213-828-8539).

The system comes with 8-k bytes of memory (expandable to 32-k), alphanumeric CRT display, an ASCII keyboard and two cassette-tape units. A special recording technique used in the 8-16 permits data transfer to the cassettes at the rate of 2000 bps. Software includes a monitor debugger, editor and assembler.

The CRT display holds 960 characters formatted as 24 lines of 40 characters. Since the display is refreshed directly from the main memory, the screen can be updated at a 20,000 character-per-second rate. The video terminal's keyboard is a full 53-key reed-switch unit.

Other features of the system include memory-write protect (for each 1-k page of memory and under software control), a crystal-controlled programmable real-time clock (with 32-µs resolution) and interrupt-driven I/O. All I/O devices including real-time clock can interrupt the CPU and all interrupts can be masked under software control. The system also has 8-level vectored interrupt.

In addition, the development system has a bootstrap loader in PROM, two EIA RS-232C serial interfaces (one for a modem and one for teleprinter), and a 1-Mbyte's DMA mode.

Delivery is 15 days.
MICROPROCESSOR DESIGN

(continued from page 31)

conflict at all between a \(\mu\)P and a minicomputer, as far as I'm concerned. Microprocessors, such as the 8080 or some of the other popular \(\mu\)P chips, are extremely powerful for very small tasks where you don't get into massive programming systems. They're a little bit difficult to program as compared with the traditional minicomputer, but work hand in glove with minicomputers when used properly. In fact, we have customers who use both \(\mu\)Cs and minicomputers.

Accepting \(\mu\)P limitations

If you understand what the limitations are on a micro and use it within those limitations you can be happy with it. Where we have seen a lot of grief is where users don't really understand what a micro is and what it is not.

A company starts out thinking its task is not very difficult, partly because its engineers are so excited about the idea of getting their hands on these little chips and playing games. Technical people love to diddle. So they have a tendency to be a little over-optimistic on the programs they're going to embark on. After awhile things start to grow on them. And that "one-time engineering charge," that "one-time software charge" they were talking about isn't one-time at all. It's continuing. Not only is it continuing, it's growing.

We've seen instances where companies have just sunk a bundle of money into this approach, only to have to scrap it entirely and start over using a minicomputer. They simply underestimated the task completely.

They learned the hard way. The next time they may be able to use a \(\mu\)P properly and a minicomputer properly and know the difference between the two and where to stop with one and start with the other. Designing with microcomputers turns out to be more expensive than some people think. We have had customers who've been that route and use minis now. In fact, a bit of a backlash has developed. A few weeks ago I ran across a company where the edict was, "Thou shalt not use a micro for anything." The engineering departments were flatly told, you don't use \(\mu\)Cs, period. The guys who sell those \(\mu\)Ps aren't going to point out all the pitfalls you can get into. I think part of the reason they're not going to point them out is that when the customer gets into trouble, there's only one solution—namely, add a little more software and a little more memory.

The \(\mu\)P is nothing more than a vehicle to sell memory chips. If you add up the total market for CPU chips, it's pretty damn small. But if you add up the market for the memory chips they want to hang onto those \(\mu\)Ps, it's pretty big. And so we have silence on one side and a whole lot of optimism on the other.

Sometimes if you get back and talk to the engineering people (and it's off the record) you'll find that in many cases they have really been burned using \(\mu\)Ps. One of our customers actually fired their engineering group—on one of the programs using an 8080, I believe.

They went on and on and just couldn't get it to do the job. Not because of the \(\mu\)P, I'm not knocking that at all. The group was just trying to make it do something it was never designed to do. The program was started over again using one of our minicomputers. In fact, that mini cost them about $10,000. Now that's a pretty big price gap.

What it really means is that those guys should never have even looked at \(\mu\)Cs. It wasn't a matter of price. It's just that the \(\mu\)C couldn't do the job. And that was the engineering group's mistake. It had nothing to do with the \(\mu\)C's quality.

An awful lot of guys who haven't used computers in their products before see this little hundred or two-hundred dollar \(\mu\)C and say: "Gee, how can we go wrong? It's so cheap. We really ought to do it." So they step in with both feet. Now that's good and bad. It's bad in the sense that they can really get burned. And it's a costly way to learn a lesson. On the other hand it's good, because it drags guys into the industry and gets them acquainted with computers.

There is quite a difference between micros and minis in another respect.

Upward-compatible minis

Minicomputer houses sell relatively low-cost minis. If the customer's task outgrows that mini, he can step up to the next model. And when that one is outgrown, he can step up to the next one. He doesn't have to scrap anything he's done in the past.

With micros what you are seeing is a customer starting out with, say, an 8080. And if his task grows a little bit, or he has underestimated it, where does he go? When he runs out of gas on the 8080, what's next? Incidentally, now that there are 16-bit \(\mu\)Cs on the market, that's what I would use if I were going to try to come up with a computer product of some sort.

I think the minicomputer houses will continue to bring their product down in price. When we announced the Naked Mini, the world thought that was the end of the road for minicomputers. They thought we couldn't make them any cheaper. And, of course, that hasn't happened. I've been saying all along that we'll continue to lower
Is our new HP-91 an engineering work of art?
Or just a beautiful investment?

Time will tell. For the moment, let’s just say it’s an original. The first battery-operated (AC-DC), fully portable (40 oz.) printing scientific.

It performs all math, log and trig calculations.
The latter in radians, degrees or grads. It does hours/minutes/seconds arithmetic and conversions, rectangular/polar coordinate conversions, and more.

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Factorials, accumulations, 2-variable mean and standard deviations, linear estimates and regressions.

You can scarcely notice the 3-mode thermal printer.
One switch lets you decide to print everything, data entries and operations only, or nothing. For occasional printing, there’s a PRINT x key.

The keyboard’s buffered.
The printer catches virtually everything, no matter how fast you play the keys. (The number keys are set up just like adding machine keys, by the way, so you can work them without looking.)

You can calculate up to five hours on battery power, assuming you use the printer 20% of the time. And you can count on trouble-free performance.

You can print the contents of all registers:
the stack only (the HP-91 uses our RPN logic system with 4-register stack); the six stat registers only; or all 16 storage registers.

The 10-digit display glows like a firefly.
The characters stand almost twice as tall as those on our pocket models.

You get uncompromising design, assembly, support.
Three things that have made believers of the million+ people who own personal-sized HP calculators. Three things that might turn the HP-91 into an engineering work of art. Over time.

Meanwhile, at $500.00, it’s a beautiful investment.
the price of minis and that will tend to put a lid on how far μC houses can operate before they bump into minicomputers. I consider that end of the market ours. Here we’ve showed the world how to do it. We’re not about to run away from it.

Advanced 8080-type μP boasts improved instruction set

The latest 8-bit NMOS μP, the Z-80 from Zilog (170 State St., Suite 260-A, Los Altos, CA 94022, 415-941-5055), uses 25 to 50% less memory for program storage and has much higher throughput than the 8080A—the μP that most resembles the Z-80.

The new CPU chip features 158 instructions and 18 internal registers including two index registers. Also, the Z-80 boasts instructions for bit manipulation and for memory-to-memory and memory-to-I/O block transfers and searches. Further the μP offers a wide range of addressing modes for tight and efficient coding.

Other CPU features include 8080A software compatibility; 4, 8, and 16-bit operations; 1.6-μs instruction execution speed; single 5-V supply, and single-phase TTL clock. The CPU costs $200 in sample quantities.

Peripheral and support circuits for the Z-80 feature the following: a programmable parallel I/O controller, counter timer, programmable parallel-serial I/O controller, and direct memory access controller. Except for the counter timer, which comes in a 28-pin DIP, all circuits including the CPU come in 40-pin DIPs.

Systems based on the new μP can be designed with the Z-80-based Development System, which includes a debug module, floppy-disc subsystem, and optionally, a CRT terminal, line printer or hardcopy terminal. Standard software packages available for the Z-80 system include assembler, editor, and file-maintenance system.

The development system costs $8990 and employs a single Z-80 for both the user’s hardware (user mode) and the system resident monitor (monitor mode). The single CPU chip performs all functions offered by competitive systems, which require two or three processors.

The system’s debug module allows pertinent user-mode transactions to be stored in real time and in an independent memory. The user can also cause any type of system transaction to suspend user operation and make the system re-enter the monitor mode. The complete record of all transactions preceding this suspension can then be conveniently displayed on the system terminal or listed on the line printer.

Other support tools encompass resident μC software, time-sharing programs, libraries and a PL/M-type of high-level language.

μC resident assembler comes on four PROMs

Microcomputer Associates (P.O. Box 304, Cupertino, CA 95014. 408-247-8940) now has a single-pass, resident assembler for the company’s Jolt microcomputer systems. The compact assembler, totaling 1024 bytes, comes on four 1702A-type PROMs and costs $99.50. The four PROMs alone, according to the company, are priced at more than $60. With the low-cost resident assembler, JOLT users no longer need to incur the potentially high costs of time-sharing services.
WOW! 12-Bit Binary and 3-Digit BCD DACs

Brand new from National . . . a family of precision, low-cost, digital-to-analog converters for a wide range of industrial and military applications. Our DA1200 Series is self-contained in a 24-pin DIP (molded or hermetic); just turn them on and they’re ready to go to work for you.

General features of the new DACs include both current- and voltage-mode outputs (0-2 mA, 0-10 V, ±10 V); ±1/2 LSB (binary), ±1/2 LSD (BCD) linearity; 1.5-µA current-mode, 2.5-µA voltage-mode setting times; precision, buffered, internal references (10.240 V binary, 10.000 V BCD); standard power supplies (+15 V, +5 V); TTL/CMOS-compatible, complementary binary or BCD input-logic formats; and expandability to 14 or 16 bits.

The DA1200/DA1201 are the 12-bit binary devices; the DA1202/DA1203 are the 3-digit BCD devices. Terrific specs, terrific parts. Ask for the data sheet and you’ll see what we mean.

TELEPHONE RELAY DRIVERS

Our high-voltage/high-current positive and negative voltage relay drivers have many features that make them nearly ideal devices. For example, we specify output leakage, over temperature, at an output of ±54 V (the polarity depends on the device). Again, we specify over temperature and at 5 mA, the minimum output breakdown; there’s even an internal reference, which doesn’t allow the output breakdown latching you’ll find in all other relay drivers, and which generally eliminates the usual need for external, inductive-transient protection; yet the output transistor is still fully protected.

TTL/DTL/CMOS compatibility; high-impedance pnp inputs; low power dissipation (typ., 90 mW with both outputs on); high output-voltage breakdown (typ., ±65 V); high output current (300 mA, max.) . . . all these and more make our DS3686 (positive) and DS3687 (negative) voltage relay drivers ideal in telephone relay applications. Check them out for yourself; see what you’ve been missing.

L117-Series Regulators Adjust to Your Needs

Announcing the one and only three-terminal adjustable voltage regulator on the market today! To change an output voltage, change a resistor value. Our L117/217/317 regulators are exceptionally easy to apply, easy to mount (TO-3, TO-5, and TO-220 packages), and feature line and load regulations better than those of fixed regulators.

Look at these specs:
- Output adjusts from +1.2 to +37 V
- Guaranteed 1.5-A output current
- Line regulation, 0.01% V, typ.
- Load regulation, 0.1 %, typ.
- Ripple rejection, 80 dB, typ.

And the chip includes full overload protection—current limiting, thermal overload, and safe-operating-area circuitry—which remains functional even when the adjustment terminal is disconnected. Even high-voltage supplies may be regulated because the chip floats; don’t exceed a 40-V output-input differential and you stay in business.

Our L148: The Only True Quad-741 You Can Buy

Yep, we’ve gone and done it and, in this case, more is definitely better. Our L148 Series is a true quad-741. It consists of four independent and well-isolated (120 dB), high gain, compensated op amps, and provides functional characteristics identical to those of the 741. Yet the L148’s total supply current (2.4 mA, typ.) is less than that of a single 741; and input offset and bias currents are very much less (typ., 4 nA and 30 nA respectively) than those of a 741. Input offset voltage of the L148 is 1 mV (typ.); all inputs and outputs are overload protected; and it’s pin-compatible with the L124.

The gain-bandwidth product of the L148 is 1 MHz at unity gain; the other member of the family, the L149, is a decompensated, wideband amp —4 MHz for A_vinfinite = 5. Stability? Super; 60° phase margin for both parts at the gain figures just mentioned.

To sum up: the L148 and L149 quads are just what you’ve been waiting for. Multiple-741 and 1558-type amplifier applications cry out for this part. Wherever you need matched amps or a high packing density, the L148/L149 will do the job; where before you had to settle for one or the other, now you get both. That’s a little like having your cake and eating it too. Really.
New Bipolar PROMs
Ideal for High-Speed Systems

Our new 1024-bit PROMs are Schottky clamped; and this means high speed—a 30-ns (max.) enable-to-output delay and a 50-ns (max.) address-to-output delay into 30 pF across 3000. Organized as 256 4-bit words, the memories feature pnp inputs to reduce input loading, and two memory-enable inputs to control the output states. When both enable inputs are at logic zero, the outputs present the selected word; if either or both of the enable inputs are at logic one, all four outputs go to their high-impedance (off) state.

The memories are available in a Tri-State® version as the DM54S287/DM74S287, and in an open-collector version as the DM54S387/DM74S387. Both versions are available as either ROMs or PROMs, and are packaged in 16-pin molded and cavity DIPs.

Clock Modules

Just What the Doctor Ordered for a Really Good 'Movement'

National's MA1002 Series electronic clock modules get it all together for you on a single PC board; a MOS/LSI clock circuit; a bright, 4-digit, 0.5-inch LED display (hours, minutes, and blinking colon for seconds); and all necessary discrete components. All you add are a transformer, switches, and an earphone alarm-output to form a complete, pre-tested movement that's ideal for desk clocks, alarm clocks, clock radios, TV or stereo clocks, instrument panel clocks, etc.

Features of the MA1002 Series include a 12- or 24-hour format; 50- or 60-Hz operation with power-fail indication; brightness control; sleep and snooze timers; alarm-on and FM indicators; and fast and slow set controls. Additionally, direct (non-multiplexed) LED drive eliminates RFI, and the module's size—0.93-inch max. thickness x 1.375 H x 3.05 W—allows the finished clock a very compact design.

NSC's REL FETs: Now You Know Where to Go

National is now a REL FET supplier, a simple fact that many of you will be happy to know. We've received qualification on MIL-S-19500/428 for the JAN/JANTX/JANTXV 2N4416A, a part that's been very difficult to get ('til now).

You'll also like to know that we're qualified on MIL-S-19500/385 for the JAN/JANTX 2N4856 through 2N4861—the most popular JAN FETs in today's marketplace—and will soon be qualified on MIL-S-19500/195 (2N2608), 375 (2N3823), 431 (2N4091 series), and 476 (2N5114 series).

All this shouldn't surprise you. After all, we've had, for many years, a fine reputation for MIL-M-38510 parts. We're simply expanding. So whatever your REL FET needs, consider National to be your prime source. Tie in with the leader.

CMOS-Compatible Interface Components

We designed our DS3631/32/33/34 Series of dual peripheral drivers to be a universal set of interface components for CMOS circuits. This means that each circuit has CMOS-compatible inputs (high-impedance pnp transistors); high-voltage outputs (minimum breakdown, 56 V at 250 ?A); high-current operation (300 mA, max.) at low internal Vcc current levels, with base drive for the output transistor derived from the load proportionate to the needed loading—essential to reduce the load on the CMOS logic supply; and low Vcc dissipation (28 mW; both outputs on at 5 V). An additional bonus is that this family of peripheral drivers is also TTL-compatible at Vcc = 5 V.

Note, too that we've made the pinouts the same as those of our very popular DS75451, DS75461, and DS53611 parts. All of which means that with our DS3631 Series you can directly convert your present systems to our MM74C CMOS family, and end up with a terrific saving of power.

A Review of New Products and Literature from National Semiconductor

Fast Access Featured in Tri-State®, Si-Gate CMOS RAMs

National's first silicon-gate CMOS RAMs are here. Ideal in microprocessor, minicomputer, and mainframe memory applications, these Tri-State® memories are very-low-power devices with high performance: access times are only 250 ns, maximum. Intended for operation from a single +5-V supply, the memories retain their data at Vcc = 2 V. All inputs and outputs are TTL compatible; data outputs are of the same polarity as the inputs; and on-chip registers are provided.

The MM54C920/MM74C920 (22-pin DIP) and MM54C921/MM74C921 (18-pin DIP) are organized as 256 4-bit words; the MM54C929/MM74C929 (16 pins) and MM54C930/MM74C930 (18 pins), intended for larger systems, have a 1024 x 1 organization.
A Spinning Wheel Doth a Tachometer Need

While originally designed for vehicle tachometer applications, our new monolithic frequency-to-voltage converters turn out to have a wide number of uses. Besides tachometer-related applications in vehicle engines and motors in general—over/under speed sensing and control, speed switches, cruise controls, and automotive door lock, clutch and horn controls—our LM2907/17 ICs make dandy touch and sound switches, capacitance meters, and delay switches (it's not magic; to see how it's done, see the data sheet).

These circuits use the charge pump technique and offer frequency doubling for low-ripple and full-input protection. The load (to 50 mA) may be ground- or supply-referenced. Versions available offer single-ended or differential tach inputs, with or without an on-chip Zener regulator.

The transfer function of the circuits is easy to use: $V_{out} = f_{in} V_{CC} R C$, where $R$ and $C$ are external to the chip; linearity is 0.3% typ., ±1% worst case. New, interesting, and unique, our LM2907/17 will definitely make your life easier.

CLOCK CIRCUITS: Night and Day, These are the Ones

These MOS ICs provide all the logic needed to build many types of digital clocks and timers, notably desk and auto clocks, alarms, clock-radios, stopwatches, timers for industrial, photographic and appliance uses, sequential controllers, etc. The circuits have four display modes—time, seconds, alarm, sleep—and interface directly to LED displays.

The timekeeping function operates from either a 50-Hz or a 60-Hz input, and a power fail/return indication is provided. Outputs consist of display drive signals, a 59-minute presettable sleep timer (which can be used to turn off a radio), and a nine-minute snooze alarm. The display format is either 12 hours (with leading-zero blanking and AM/PM indicator) or 24 hours. These circuits, designated MM5384/5/6/7, operate from a single, unregulated supply (either 8-26 V or 18-26 V), and are packaged in 40-lead DIPs.

APPLICATIONS CORNER

Low-Voltage Reference Sources

We've had a number of inquiries from readers asking us how to use a three-terminal regulator as a low-voltage reference source, and how to make that source bipolar.

Our answer to these questions is that three-terminal regulators can be used in such a way, but to produce a lower-than-nominal regulator output requires a rather cumbersome amount of external circuitry.

A far better method makes use of our recently-announced LM117, a three-terminal regulator with an output that is adjustable from 1.2 V to 37 V (story on Page 1). Its use as a low-voltage reference source is shown in Figure 1.

By connecting the Set V pot to a negative reference the unipolar source of Figure 1 becomes the bipolar source of Figure 2. Pre-loading the output to a negative voltage is necessary because the LM117 is a positive-output regulator and cannot sink current.

Still another scheme—this one taken from our LM199 data sheet and shown here as Figure 3—uses the LM199 temperature-stabilized Zener in combination with an LM1084 op amp to provide output voltages to ±6.9 V.

MM74C908/918: Oldies But Goodies

We'd like to remind you about some very popular parts we've been making. They are the MM74C908/918; CMOS, dual, high-voltage drivers that are super parts now being offered at lowered prices.

The MM74C908/918 differ only in power dissipation. At a 70°C ambient, maximum dissipation for the 908 ($\theta_J = 110°C/W$, max.) is 0.7 W, while the 918 ($\theta_J = 55°C/W$, max.) will handle 1.4 W. Both parts feature a supply range of 3 to 18 V, a low output on-resistance of 8Ω (typ.); they can withstand 30 V in the off state; they will source 250 mA (min.) at $V_{OSS} = V_{CC}$ -3 V, $T_a = +65°C$; and have proved invaluable when interfacing normal CMOS voltage levels to relays, regulators, lamps, etc.

A Review of New Products and Literature from National Semiconductor

Electronic Design 8, April 12, 1976
NEW TRI-STATE® OCTAL BUFFERS
Use Low-Power Schottky Technology

Four new Tri-State® octal buffer ICs that employ low-power Schottky technology are now available in quantity from NSC. The DM81LS95/96/97/98 provide eight, two-input buffers in a single package. One of the two inputs is a control line that gates the output into the high-impedance state, while the other input passes the data through the buffer. Typically, power consumption is less than 80 mW per package with propagation delays less than 13 ns.

The DM81LS95 and 97 present true data at their outputs; the DM81LS96 and 98 invert the data. The DM81LS95 and 96 have eight common Tri-State enable lines, accessed through a two-input NOR gate. The DM81LS97 and 98 have two groups of four buffers each, each enabled by its own common line. Both commercial- and military-grade versions are available from stock.

A Review of New Products and Literature from National Semiconductor

A Compendium of Recently-Issued Literature (i.e., stuff to file)

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- LM148/9 Quad Op Amps, Page A, Col. 1
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- DB-4 Driving Burroughs' Bar Graph Display
- μSpec 3 Floppy Disc Operating System (and CRT Interface)
- μSpec 14 IMP-16 Utility Programs

INDEX

Welcome to National's concise, informative index of its extensive, in-depth literature. Whether you are a novice or an expert, this index is designed to help you find the information you need quickly and efficiently.

A REVIEW OF NEW PRODUCTS AND LITERATURE FROM NATIONAL SEMICONDUCTOR

A MICROPROCESSOR HANDBOOK FOR LOGIC DESIGNERS

We've just published a new book. It's called A Logic Designer's Guide to Program Equivalents of TTL Functions, and it's intended to help system designers make the transition from design in hardware to design in software.

While written primarily for current and potential PACE users (PACE is National's single-chip, 8/16-bit microprocessor), much of the text will be useful to anyone unfamiliar with microprocessors and software in general.

The handbook begins with the basics of microprocessing and software, then explains, in detail, the PACE instruction set and its use. More than two dozen simulations are described from both the hardware and software points of view. These simulations range from simple logic (AND gates, etc.) to complex subsystems (digital servo, digital tach, etc.), and are written in language familiar to TTL designers. A series of appendices—a glossary, a description of the hexadecimal number system, powers of two, and many more—concludes the handbook.

A Logic Designer's Guide to Program Equivalents of TTL Functions will be a unique and useful addition to any bookshelf of modern technology. The handbook costs $5.00, and may be ordered directly from National.
When you go shopping for D/A Converters, please swing by PMI. Ever since we opened our doors six years ago, we've been working hard to spice up our distributors' shelves with the widest line of monolithic DACs in the industry. 6-, 7-, 8-, 9-, and 10-bit DACs. Current or voltage outputs. Internal or external references. Routine MIL-STD 883A Level B processing, with Level A available. Guaranteed specs over full MIL Temp range. PMI pioneered monolithic DACs. It's only natural to find more here than anywhere.

And if DACs are new to you, lean on PMI's experience. We've helped designers and project managers put dependable PMI monolithic DACs to work in the most unusual spots. How can we help you?

Also, our price list, DAC data sheets and Ap. Notes are yours for the asking. Ask your distributor or call us at our store.

Precision Monolithics Incorporated
1500 Space Park Drive, Santa Clara, CA 95050
(408) 246-9222. TWX 910-338-0528.
Cable MONO.
Optics and $\mu$Ps begin to affect system design
Two relatively new technologies—microprocessors and optics—have begun to dramatically influence the design and performance of communication systems, components and test equipment.

Such giant organizations as Bell Telephone Laboratories, General Telephone and Electronics and International Telephone and Telegraph are currently investing millions of dollars in research and development on fiber-optic, voice and digital-data communications systems. In fact, testing of experimental optical telephone communications will begin this spring and summer.

Why fiber optics over conventional copper-wire systems? For one thing, they are lighter, have broader bandwidth capabilities, are smaller for the equivalent information handling capability. And they are potentially much cheaper. Besides, fiber-optic systems are practically immune to electromagnetic and radio-frequency interference.

In almost every fiber-optic link under development, solid-state light sources are used to generate the fast pulses used to transmit the data. The most promising source to date appears to be light-emitting laser diodes fabricated using a double-heterostructure aluminum gallium arsenide material. One problem that still needs to be solved is how to maintain the light-emitting efficiency of solid-state-laser light sources. Work is under way to extend the usable lifetime of these devices from about 10,000 hours today to over 100,000 hours—a period needed to make fiber-optic communication links a reality.

In addition to fiber-optic activity, more and more microprocessors are finding their way into telephone and data-network systems. These tiny chips are being used in such applications as network controllers, diagnostic tools, digital filters, store-and-forward-devices, and front-end processors.

A μP-based message-switching system has recently been installed by the New York City Police Dept. And microprocessors are also being actively considered by the military for use in such applications as back-pack radios, field-data terminals, mobile-switching centers, portable satellite communication terminals and mobile relay links.

The dynamic growth of communications in recent years has also focused attention on a key system-component element—the packaged microwave oscillator. The search for a greater spectrum capacity in long-haul telephone and data links, and the spread of land mobile radio has brought demands for tighter specs on these packaged oscillators. These demands are being met by the development and production of a variety of microwave integrated-circuit designs that have improved performance.

The increasing demand for better performance and tighter specs in communication systems and components is putting an equal burden on manufacturers of specialized test equipment. This is particularly true in rf and microwave test gear where systems are now designed to be “smarter” and to have a greater range of operation than ever before.

For an inside look at the exciting developments in today’s fast-growing communications world, turn to the pages of this special section.

The photo depicts the several metamorphoses of glass as raw materials are transformed into optical fibers. The powdery substance at bottom is melted to make glass discs. The cylindrical blocks are formed into a rod and tube and the combination is pulled into a cladded fiber.
Telephone and data transmission via fiber optics is being pushed

Off-the-shelf fiber-optic systems now transmit and receive data at rates ranging from 1 to over 100 Mb/s. The transmission of thousands of conversations over a single beam of light has become feasible.

Like microprocessors, fiber optics is a new technology with great promise. There is a potential for data to be carried on a single hair-thin fiber at upwards of 100-Gb/s, and for optical fibers to displace wire and cable in literally thousands of data-transfer applications.

The unique advantages of fiber-optic systems are the solution to the problems of today's wire system. These advantages include:

- Substantially lighter weight and smaller size for the same or greater information-carrying capability.
- Potentially much lower system cost.
- Immunity to electromagnetic and radio-frequency interference (EMI and RFI) as well as to the electromagnetic pulses of a nuclear explosion (EMP).
- Virtual elimination of cross-talk.
- High degree of system information security.
- Lower signal attenuation than comparable copper-conductor systems.
- Broad bandwidth capabilities ranging from over 100-Mb/s for present LED-driver systems to greater than 100-Gb/s for future optical-IC systems.

Fiber-optic communications development is being pushed by a broad group of users. A major investment has been made by organizations like Bell Telephone Laboratories, General Telephone and Electronics Corp. and International Telephone and Telegraph. Companies in Canada, England, Europe and Japan are pursuing the same objectives.

Tests of optical telephone communication systems will be conducted this spring and summer by both GTE and Bell Labs.

At Bell Labs' Atlanta, GA, facility, a 2000-ft cable containing over 100 single fibers will be installed in ducts and manholes. Testing of a simulated miles-long transmission line will be effected by joining individual fibers at the cable ends.

Fibers supplied by both Western Electric and Corning will be used to evaluate digital transmission for use between switching offices in metropolitan areas.

Light pulses at rates of 1.544 Mb/s and 44.7 Mb/s will be supplied by both LEDs and solid-state lasers packaged in standardized modules.

Fiber optics carry video signals

An operational optical-communication system was installed last fall in the Command Room of the Dorset County Police in Bournemouth, England after a multiple-terminal video-display system had been disabled by a lightning surge. A 10-Mb/s PPM system was installed by ITT Standard Telecommunications Laboratories, Ltd., London, to prevent a recurrence of the outage. The fiber-optic system transfers information from the data bank of a main computer that contains criminal and other records, to video terminals on which it is displayed to supervising inspectors.

The U.S. Department of Defense is funding a number of projects. Using a 20-Mb/s system, the Army is currently investigating the use of fiber optics in medium and long-line tactical and strategic systems.

The Navy is investigating the use of fiber-optic systems both in aircraft and on board ship. For example, in an avionics interface system for the Navy A-7 Attack Aircraft, fiber-optics cables replaced the conventional wiring that transmitted data between the on-board AS91 tactical computer and its peripheral avionics. In this case, 224 ft of fiber optics weighing 1.52 lb replaced 1900 ft of copper wire weighing 30 lb. The system was delivered by IBM to the Naval Elec-
Fiber-optic communication has reached the practical stage for systems in the kilohertz to 100-Mb/s range. System advances have been aided by the development of hardware like these ITT/Cannon optical connectors.

A six-fiber optical cable, Corning's Corguide, was developed for military field use. The tiny central fibers are protected by a tough, extruded jacket, shown in cross-section. Each fiber has a max 20 dB/km loss.

tronics Laboratory Center (NELC) in San Diego.

A six-station fiber-optic telephone system is in its third year of operation aboard the Flagship U.S.S. Little Rock. The voice is digitized in a pulse-position-modulation system that was developed by NELC for the ship. The optical cables are PVC-jacketed bundles, with a maximum length of 120 ft. Of interest is the fact that MIL-spec snap-action switches, TTL-integrated circuits and power supplies have failed during this period. But the fiber-optic links—LEDs, photodetectors and cables—have performed reliably.

The Air Force has developed a 10-Mb/s multiple fiber-optic system with eight remote terminals that have optical switching between them. A second AF program is now investigating the performance of a system designed for transmission rates of higher than 100 MHz using existing technology.

Considering its potentially high performance, a fiber-optic communication system is surprisingly simple. It is comprised of the following elements:

- A fiber-optic transmission cable to carry the optical data a few feet or a few miles. The cable may be a single, hair-like fiber or it may be a small bundle of hundreds of such fibers.
- A source of visible or invisible IR radiation—a LED or a solid-state laser—that can be modulated to impress optical data on the fiber.
A special connector for a 45-mil fiber-optic bundle, by AMP, can be used as an end termination or as a center splice. Only the fittings need be changed to alter its function from an end to a center connector.

Subminiature optical-cable plugs, by Amphenol, are designed to accommodate fiber-bundle cables by Corning, Galileo, Valtec, DuPont, Poly-Optics and Pilkington. The mating receptacles hold LEDs and phototransistors.

- A photosensitive detector to capture the optical information at the receiving end of the optic cable and translate it into an electronic signal.
- Efficient optical connectors at the LED-to-cable interface, at the cable-to-detector interface, and between the interfaces of joined portions where the cables are spliced.

Optical fibers for communication systems are unique in that they transmit light efficiently by acting as optical waveguides. To achieve this performance, the lower-cost fibers are constructed of a solid core that is coated with an optical cladding. The refractive index of the cladding is less than that of the core, hence the name “stepped-index fiber.” This fiber is used in multimode transmission. That is, the radiation source (usually a LED) has a fairly broad optical bandwidth, and its energy propagates down the fiber in literally hundreds of modes.

The least lossy but highest cost fiber has no discrete cladding. Instead, the fiber is doped, during manufacture, so that the refractive index varies in a nonlinear gradient, from a maximum at the center to a minimum at the outside. This is a “graded-index” fiber.

With LEDs, the graded-index fiber is used as a multimode fiber. But with a laser (such as a neodymium-YAG) of high spectral purity the energy travels down the fiber in a single mode that gives the hundred-gigahertz bandwidth.

Both glassy and plastic fibers are commercially available for fiber-optic systems.

Typical glassy fibers range from about 2 to 5 mils in diameter. Losses range from 10 to 600 dB/km (1 km = 3280 ft). The numerical aperture (N.A.) varies from about 0.25 to 0.66. It expresses the ability of a fiber to capture or project light in a cone whose apex is centered at the fiber axis. N.A. is the sine of the maximum half-angle the fiber end is capable of accepting.

Glassy fibers are used singly or in bundles. A principle problem is concentrating the broad radiation pattern of the LED onto the small input area of a bundle or of a single fiber. This has been accomplished by the use of special LED packages containing lenses. A second lens is on the fiber.

Single fibers have own LEDs

For single fibers, LEDs have been constructed with the fibers directly attached to a tiny emitting junction. Bell Northern Research; Plessey Semiconductors, Santa Ana, CA; and RCA, Somerville, NJ, have produced variations of these devices.

Optical plastic fibers available are typically 15 mils in diameter and have losses of less than 500 dB/km. But these are used only in bundles. The N.A. is 0.53.

A variety of analog and digital fiber-optic communications equipment has reached the practical stage. With existing technology and hardware, data rates in excess of 100-MHz analog or 100-M bits of Manchester digital can be achieved, according to Kenneth C. Trumble, Air Force Avionics Laboratory, Wright Patterson Air Force Base, Dayton, OH.

Systems and hardware that have been developed under independent in-house programs or under military sponsorship are now available off the shelf from suppliers like Harris Electronic Systems Div., Melbourne, FL; Meret, Inc., Santa Monica, CA; Spectronics, Inc., Richardson, TX; American Laser Systems, Inc., Goleta, CA; Valtec Corp., West Boylston, MA; and Bell North-
A digital optical link offered by Corning uses either a 19-fiber bundle or a Corguide optical cable to carry the information. Error-free transmission of $10^{11}$ bits at clock rates of 25-Mb/s is claimed. Links up to 500-m long are available.

The key development that originally made fiber-optic systems feasible was the production of the first low-loss (20 dB/km) “doped-deposited” silica fiber—by Corning, in 1970. Before that, typical plastic and glass-fiber losses were in the area of 1000 dB/km, or more. These losses were gradually lowered by other companies that began to produce medium-loss fibers in the range of 300 to 600 dB/km.

Although Corning’s low-loss fiber was useful in laboratory studies it was too fragile for military or other field operations. This problem was overcome by Corning in a two-year collaborative effort with the Army’s Electronic Command at Ft. Monmouth, NJ. The result was development of a unique, “ruggedized” optical cable called Corguide that looks much like coaxial cable. Valtec is producing a less-rugged version of Corguide.

Corguide has six optical-fibers, each having a maximum loss of 20 dB km at the 820-nm wavelength of gallium arsenide LEDs. Each fiber is plastic coated. The six of them are twisted around a central supporting fiber. For added tensile strength, two bundles of plastic fibers are embedded in a tough, extruded outer jacket.

In May, 1975 Corguide was released for commercial sale. It is now available at $13.50/m. This price corresponds to less than 70 cents per foot per fiber channel and is competitive with high-grade coax.

Some users prefer single-fiber cables because of the lower cost. A new unjacketed multimode single-fiber with a 10-dB km loss and a 20 MHz ft cable is available from Spectronics. It consists of transmitter and receiver modules with built-in power supplies. Inputs and outputs are compatible with TTL levels.
Free-space optical communication systems are useful for transmitting data over short-range links. This terminal, by American Laser Systems, operates at megabit rates.

digital-data bandwidth is available from Corning at $1/m. The fiber is coated with a 50-μm layer of ethylene vinyl acetate to protect it during handling. The user is expected to supply his own protective outer jacket.

When high-volume applications become practical the price of these kinds of fibers is expected to drop to 10 cents or less per meter.

Other fabricators who provided fibers for current military programs are now in open competition with Corning for the commercial market. These suppliers include the Galileo Electro-Optics Corp., Sturbridge, MA, and the Valtec Corp., West Boylston, MA.

Plastic optical cables have also been developed by suppliers like DuPont and Poly-Optics, Santa Clara, CA. They are suitable for nonmilitary environments and for links of 50 m or less, according to Dr. Fred Mannis, project coordinator at DuPont, Wilmington, DE. The DuPont low-loss PFX plastic cable has an attenuation of 480 dB/km at 66 nm, the wavelength of a visible LED. The cable is both tough and low cost.

Another advantage Mannis sees is that the plastic's highest transmission is in the visible region, which makes it possible to visually monitor the operation of circuits “wired” with this cable. A prime limitation is the plastic's relatively low temperature rating (80 C), compared with the ratings of glassy fibers.

One important advantage of the plastic fibers is the ease of bundle-end preparation, which is as yet a controversial problem with users of the glassy materials.

“The effective area of a PFX bundle is 45 mils,” says Mannis. “It fits into an AMP connector designed for this cabling. No adhesive is needed. Simply clamp the connector onto the cable, cut the fiber end off with a razor blade and you have a low-loss interface termination.”

Other connector manufacturers, including Amphenol, ITT Cannon and Selectro are approaching the optical-connector problem for glassy fibers by modifying existing wire connectors that have previously met military standards.

For example, Amphenol has converted an SMA connector (see photo) to a device for the 45-mil multiple-fiber bundle used by NELC.

The fiber bundle is inserted inside the connector ferrule and secured with epoxy. Then the ends must be optically finished by grinding and

Time-division multiplexed inputs are converted, by circuits on this card, into signals that modulate six optical-data channels. These channels are a part of the fiber-optic avionics/computer interface system that replaced cabling on the Navy's A-7 attack aircraft. The optical cables weighed but 1/20th of the copper wiring.
polishing, as with other competing types of optical connectors.

The process is generally unsatisfactory, points out Allen Kasiewicz, product manager of Amphenol's RF Division, Danbury, CT, which produces the SMA-type connector, particularly if it has to be done for telephone cabling down a manhole, or in the cramped confines of an aircraft.

Techniques have been developed to scribe and break the optical fibers cleanly, producing a planar face that needs no polishing, he points out. Crimping techniques have been successfully tried.

Kasiewicz believes that both active-end and fiber-to-fiber connectors will eventually be terminated quickly and efficiently because of the development of special tools.

One key sign that fiber-optics has matured is the announcement of a series of nation-wide field-training courses to update engineers on the new technology. The courses, given by Spectronics, are slated to start in San Diego in April.

Standardization a problem

The widespread application of systems in the kilohertz to megabit range is expected to be seen within the next two or three years. But at present progress is being slowed by an old malady of developing technologies—the lack of component and hardware standardization. Fortunately, standardized designs are being produced, by both in-house and military efforts, on the following system elements:

- Fiber-optic cables and their terminations.
- Cable-to-cable, cable-to-LED and cable-to-detector connectors.
- Radiation sources including LEDs and solid-state lasers.
- Radiation detectors.
- Optical routing elements such as multiport couplers and switches.
- Modular packages for LEDs, lasers and photosensors and their driving or amplifying electronics.

Standardization is a prime objective of the Tri-Service Fiber Optic Coordinating Structure, a joint effort of the Army, Navy and Air Force. The three services seek to avoid the vast proliferation of types, sizes, shapes and ratings that has plagued wire technology.

Special standards committees are now in operation. One committee, under the sponsorship of the Society of Automotive Engineers, is responsible for the development of airborne optical-system standards. Another committee, monitored by the Electronic Industries Association, is to generate standards for ground-based equipment.

Other standardization efforts are under way. At NELC contracts for the development of hybrid modular optical-transmitter and optical-receiver packages have been awarded. These modules will have digital electrical interfaces compatible with standard TTL logic at rates up to 20-M baud. They will be packaged for panel mounting.

The transmitter module will contain a Texas Instruments LED and the electronic circuits to convert the TTL input to LED drive current. The receiver will contain a silicon p-i-n diode, plus amplifiers, bias-voltage converter, and TTL outputs capable of driving 10 standard TTL loads.

The modules will be qualified to MIL-E-5400P Class II, for airborne environments and will also meet the requirements of MIL-E-16400G for fixed-station and shipboard use.

The optical-interface connectors for the LED driver and photodiode sensor will mate directly with standard cable connectors already developed for the standard 45-mil fiber-optic bundle.

Future modules planned by NELC include a video-baseband transmitter-and-receiver family for circuit board mounting, and a family of transceiver modules for full duplex operation on a single fiber-optic channel.

Developments in fiber-optic technology have overshadowed parallel efforts in commercially available optical communication systems using free-space as the transmission medium. A number of operational systems have been produced for free-space analog and data communications for outdoor and indoor environments in simplex or duplex short-haul transmission links.

These free-space systems use LEDs and solid-state and helium-neon lasers. Companies producing these systems include: American Laser Systems; Computer Transmission Corp., El Segundo, CA; Meret, Inc.; and International Laser Systems, Inc., Orlando, FL. ■
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Improvements continue in digital and analog communications devices

For the past decade, many of the advances in communications circuits and components have been made in the digital area. However, important analog circuit and device developments have also occurred. Improvements are being made in bandwidth, power output and efficiency.

For example, the efficiencies of high-frequency bulk-effect devices such as Gunn and Impatt diodes have been doubled in many cases when the silicon was replaced with gallium arsenide or indium phosphide. GaAs field-effect transistors that operate at microwave frequencies are starting to appear on the designer's workbench; so are the amplifier modules containing them.

In the digital area, ICs are finding wide application in all types of communications equipment. Manufacturers have now incorporated microprocessors into public-service frequency-scanning receivers, digital frequency synthesizers into citizens-band transceivers and solid-state switches into equipment for telephone signal switching.

Other significant developments of circuits and devices in the communications area include:
- Monolithic circuits for the telecommunications industry, including companding circuits that reduce channel bandwidths and ease transmission requirements; electronic telephone-dialing circuits to replace the mechanical dial with keyboards; tone-generating circuits for multifrequency dialing.
- Solid-state crossbar switches that can handle signal-routing requirements for telephone exchanges.
- Impatt diodes that still provide useful power at operating frequencies of up to 170 GHz.
- GaAs FET amplifiers capable of delivering 2.2 W at frequencies of over 8 GHz.

- Specialized ICs for such consumer-oriented equipment as television receivers and citizens-band transceivers.
- Specialized data-communications ICs, including single-chip modems, multiplexers and peripheral interface circuits.
- Devices such as power transmitting tubes and specialized receiving tubes for the radio and TV broadcast industry.

Communicate we must

The art of communicating takes on many forms, but the telephone is surely one of the most common. Once the signal leaves the telephone in electrical form, there are many electronic transformations performed upon it. Telephone companies also manipulate basic signals, such as the dial tone and the tones used for touch dialing in many of the newer telephone exchanges.

As an alternative to the mechanical dial, General Instrument Corp. of Hicksville, NY, offers several ICs that combine to simulate the push-button tone telephone. The AY-5-9100 accepts pushbutton keyboard inputs and converts the contact closures into rotary dial pulses that, with the aid of a relay, can dial the desired number. The chip can also store the entered number for as long as power is applied to the circuit. Upon the press of a button it can redial the entire number—up to 20 digits.

To complement the dialer circuit there are the AY-5-9200 repertory dialer memory that can store up to 10 telephone numbers of 22 digits each, and the AY-5-9500, a clock circuit that generates the necessary timing signals for the 9100 and 9200.

For those areas with tone signalling, GI has the AY-3-9400, a dual-tone multifrequency generator in a 14-pin DIP, which can supply all necessary tones for dialing. Motorola Semiconductor, Austin, TX, offers a similar tone generator—the MC14410.

Several other companies have digital dialer chips

Dave Bursky
Associate Editor
A companding d/a converter, when used as part of an a/d converter, logarithmically weights each bit to com-
press a signal. Antilog weighting expands the signal. The unit is made by Precision Monolithics, Inc.

available for the designer—LSI Computer Systems in Plainview, NY; Motorola Semiconductor; and the Collins Div. of Rockwell International in Newport Beach, CA. None of these circuits perform identically, so match the best one to your application.

Once past the telephone, the signals go through a maze of switching gear, amplifiers, conversion equipment and relay stations to get to their destination. Much work has been done in the past few years on solid-state switches to route signals.

Solid-state switches offer tremendous advantages over the older, but proven, relay switches. For instance, there are no parts to wear. They have faster switching times and require less operating power. And they are much more compact than relay crosspoint switches.

Still, they are not ideal. Solid-state switches continue to suffer isolation problems—that is,

Channel translating equipment, such as this made by Standard Elektrik Lorenz, a wholly owned subsidiary of ITT in Stuttgart, West Germany, is widely used in the telecommunications industry for frequency-division multiplexing of telephone signals.
crosstalk between adjacent semiconductors on a chip must be kept low. The best results to date—about 60 dB of isolation—have been obtained by the use of dielectric isolation between devices on a chip. This method is expensive and is still keeping the solid-state crosspoint switches on the drawing boards.

Array sizes, limited by the number of pins available on the package, are not too large; the most commonly available size is only $4 \times 4 \times 2$. But arrays can be stacked to make larger switching systems.

Motorola currently has the MC3416—a dual $4 \times 4$ monolithic crosspoint switch that uses SCRs to do the signal switching. OFF and ON resistances of the switch crosspoints are 100 MΩ and 6 Ω, respectively. Switching times of the SCRs are a low 1 μs.

Other companies, such as Signetics in Sunnyvale, CA, and, of course, different divisions of Bell Telephone are also doing heavy research in solid-state signal switching. The work Signetics is doing revolves about the company's DMOS field-effect transistor process.

**Compressing the signals eases transmission**

Once the signals are routed, the next process to be performed is the packing of the signals onto telephone lines, which are noisy. To get the best performance in the presence of noise, emphasis and de-emphasis networks are used. To do the signal manipulation, companies like SGS-ATES in Milan, Italy, Precision Monolithics, Santa Clara, CA, and Signetics are all working on monolithic companding circuits that will compress analog signals on the transmitting end of the line and expand the signals on the receiving end.

The Signetics circuit compresses a 2-dB-input-level change into a 1-dB change for transmission; the circuit's expander half changes the 1-dB signal back to 2 dB on the receiving end. The compandor is designed to operate from a 6-to-18-V supply and has only 0.5% distortion at a 0-dBm input level.

SGS-ATES has developed an expandor circuit that can double the dynamic range of an audio signal. When coupled with a complementary compression circuit on the transmitting side, the compandors are supposed to improve tremendously the quality of audio transmission.

The digital method used by PMI, on the other hand, compresses the signal logarithmically into an eight-bit data word on the transmitting end and on the receiving end takes the antilog of the digital signal and converts it back into analog form. This method provides a 72-dB dynamic accuracy with only eight bits of data. Accuracies of 0.01% near the low-voltage regions are possible.

The multitone signal frequencies generated by the tone keyboards (pads) of telephones can be used for more than just dialing a number. Just connect an array of circuits, such as made by Beckman Instruments of Fullerton, CA, and many other companies to filter the tones. Several companies offer single ICs that can generate the 12 or 16 multitone frequency pairs that are needed to dial the telephone, but to do the decoding, an array of as many as 13 hybrid circuits on the receiving end must be used to derive back the original numbers from the tones.

Not only does the telephone serve as an instrument for communicating verbal instructions, but with the additional decoding circuits the telephone serves as a miniature data-entry terminal and controller for simple digital systems. This control feature of the tone telephones is just starting to be realized by many of the manufacturers and will be a growing market in data-entry, se-
curity, and control applications.

The major drawback with the tone control is that complex decoding circuitry is needed. A complete array of circuits to decode the 16 tones can cost between $100 and $150 in large quantities. Work is being done to shrink the size of the circuits needed.

Motorola Semiconductors in Phoenix, AZ, expects to have part of the answer to the simplified decoding problem with its series of three ICs—the MC8522, 8523 and 8524. In large quantities these circuits are expected to cost about $40, total, and contain all the circuitry necessary to decode the multifrequency tones.

Transmission frequencies on the increase

To transmit information from one point to another you have a choice of three major types of relay systems: the old microwave relay links, earth-station-to-satellite communication links and the fiber-optic "wired" links.

New semiconductors and tubes for these important communications links are appearing in ever-increasing numbers. Most of the development work, though, is aimed at the earth-station and fiber-optic links. Fiber-optic links are the most exotic, with information carried on a beam of light in a glass fiber (see p. 42).

Solid-state light sources are used in almost every link to generate the fast pulses used to transmit data. Light-emitting laser diodes fabricated using a double-heterostructure aluminum gallium arsenide material grown by liquid-phase epitaxy have shown much promise as the light source for optical communication links. These diodes provide radiances as high as 100 watts steradian-centimeter$^2$ for a drive current of only 150 milliamps.

Most solid-state laser light sources have had problems in maintaining their light-emitting efficiency. Lifetimes of about 10,000 hours are commonly available, but for many applications these aren't long enough. Usable lifetimes of over 100,000 hours are needed to make fiber-optic communication links a reality.

On the receiving end of the filter-optic link are solid-state photodetectors such as avalanche and p-i-n photodiodes. These devices are readily available from many manufacturers.

Rf semiconductor developments span a range that generates frequencies as high as 170 GHz with usable signal levels. The first microwave semiconductors were built from silicon and had efficiencies of up to about 15%. With the development of GaAs material technology several years ago, efficiencies for many microwave devices have improved to over 30%.

Along with the improvements came some problems. GaAs is a difficult material to manufacture and handle, thus making the final devices hard to produce uniformly. Aging of the semiconductors also tended to change the device parameters, and thus the circuit characteristics of whatever the devices were built into. The parameter change is most critical for devices, such as FETs, that must be biased for operation.

Avantek, in Santa Clara, CA, claims to have solved much of the aging problem with a process that surface passivates the FET chip with a coating of silicon nitride.

Whether a diode or transistor is used in an amplifier or an oscillator, power gain is an important factor in device use. Amplifier modules with small-signal gains of 63 dB are possible at frequencies as high as 13.525 GHz with bandwidths of 250 MHz.

As digital control takes over more and more of the communications gear, electronic tuning
methods are becoming an increasingly essential part of any system. Work being done by Thomson CSF has produced electronically tunable Gunn-oscillator circuits that have a tuning range of 6.4 GHz, centered around 14 to 15 GHz.

Most electronically tunable oscillators use varactor diodes to change the tank capacitances and thus the frequency. Electronic tuning isn’t all roses, though. Obtaining varactor diodes with high Qs to prevent circuit loading requires careful device and circuit design to make the most of the available Q. Hewlett-Packard in Palo Alto, CA, has recently announced a process that promises to double the available Q from varactor diodes—thus bringing Qs of 13,000 and higher to the designer’s workbench.

Gunn and Impatt diodes are also under constant improvement. They are, though, two-terminal devices and therefore difficult to bias and control. Three-terminal microwave devices, until several years ago, were not commercially available. Today, you have a choice of either bipolar or field-effect transistors to provide power gains at frequencies of up to 17 GHz. Hughes Corp., Malibu, CA, has developed a 17-GHz GaAs FET using ion implantation. Noise figures for the device are 2.7 dB at 8 GHz and 5 dB at 17 GHz, with associated gains of 9 and 4.6 dB, respectively. Japanese companies, including Fujitsu and Nippon Electric are also in the forefront of FET development research and have recently announced products. GaAs FETs offer the best gain-bandwidth products of any solid-state microwave amplifying device.

Tubes—devices rarely in the spotlight today—used in communications equipment are not all being phased out. There are many applications where solid-state signal sources cannot meet the power-output requirements. Travelling-wave tubes are still undergoing active redesign to boost efficiency and reduce size. Power outputs of TWTs can reach well over 100 W at frequencies of over 10 GHz.

To boost the tube efficiency, manufacturers are considering the use of multiple collectors within the tube to capture more of the emitted electrons. However, additional collectors add to the circuit designer’s problem because complex biasing networks must be included to provide optimum graded potentials.

The radio and television broadcast industries are also improving the efficiency of their transmitters by upgrading them with improved tubes. Most communications transmitters are completely solid-state up to the final output stage. But the final stage, which delivers 25 or 50 kW, still uses tubes.

RCA Electro-Optics and Devices in Lancaster, PA, has just introduced what it claims to be the industry’s largest air-cooled tetrode, with a power output of 55 kW at vhf-TV frequencies. The tube offers cost savings to many stations because it eliminates the need for two 25-kW tubes and a power combiner. This makes possible a single-tube final stage for circular polarization transmitters. The tube has an efficiency of 75% and a gain of 17 dB.

Consumer communications leans on digital

Many of the communications developments of the data-processing industry have found their way into consumer communications gear. The citizens-band transceiver, for instance, has incorporated digital circuits to make it lighter and more efficient.

Some of the latest innovations include the use of a microprocessor to control the scanning and frequency-selection capabilities of a public-service-frequency receiver made by Tennelec of Oak Ridge, TN. The receiver uses a PPS-42, 4-bit microprocessor to search out frequencies, digitally generate them, store them in memory and recall
them at your convenience. FM frequencies in the 30 to 50 MHz, 150 to 170 MHz or 450 to 470-MHz bands are covered and any of 4096 possible frequencies in each band can be selected. The scanner costs under $400.

There has recently been some discussion by the FCC and CB transceiver manufacturers of doubling the channel allocation from the present 23. If crystals were used in every transceiver to generate all the possible channel frequencies, the price and size of the units would probably jump to an unmanageable amount for the average consumer. Many companies are thus looking at the possibility of using a single crystal and some form of digital-synthesizer IC to generate all the transmit and receive frequencies.

Hughes, Newport Beach, CA; Nitron in Cupertino, CA; Fairchild in Mountain View, CA; National Semiconductor in Santa Clara, CA, Nippon Electric and Motorola are all introducing specialized ICs that will cut the parts count and generate up to 1023 possible channels. The Hughes HCTR0320 synthesizer, originally developed for the U.S. Army's Manpack radio, has been modified for CB applications. On the chip is a divide-by-N counter, an adder, a three-digit BCD register, a seven-bit binary register and a phase frequency detector. All that's needed is an external voltage-controlled oscillator—and the crystal—to make a complete frequency synthesizer.

Discrete devices for consumer communications equipment are also undergoing close manufacturer scrutiny. The main object of the study is to lower the manufacturing cost of the final product by lowering the cost of the internal components. The power transistors used to deliver an rf signal to the CB antenna are finding themselves housed in plastic packages, as opposed to the metal cases used several years ago. Panasonic and many other companies have pioneered low-cost, reliable plastic transistors.

Since the power devices in CB sets usually serve a dual function (both power output and audio amplifier) they must work under a wide range of bias and operating conditions.

CB transceivers are not the only growing personal communications market. The 900-MHz industrial-communications market has opened a new range of circuit design problems and device requirements. High-frequency power transistors that can deliver several watts at 900 MHz are needed, as well as specialized filtering circuits.

Hybrid power amplifiers and gold-metallized transistors are just some of the devices that the portable communications requirements are spawning. Modularized circuits are almost an absolute requirement for high-frequency transceivers because parts placement can actually affect the performance of the radio. Beam-led discrete devices help in the critical circuit designs since they practically eliminate the package inductances and capacitances. Since there are no bulky packages to mount, the finished circuit is smaller.

Digital communications: a growing need

With the advent of low-cost data-processing equipment, the need for these devices to communicate with one another has grown into a major product area. Microprocessor-based equipment, for instance, uses many different types of digital communications circuits to transmit and receive data. Data links built using both modems and serial data transmitters are used when these digital computers talk over long distances.

Much work is being done to simplify the communications circuits. Motorola has introduced monolithic ICs that serve as modem, bit-rate generator and serial-data transmitter. The MC14412 single chip modem offers a simple solution for telephone-line data links, and the MC14411 bit-rate generator offers the multifrequency timing outputs needed to control the modem transmission rates.

Universal synchronous and asynchronous receiver/transmitters are also part of the digital communications scene, with at least one of these devices incorporated into almost every digital machine. These devices, commonly called UARTs, accept parallel data from computer busses and transform the data into serial form (synchronous or asynchronous, as the case may be) for transmission on a two-wire or telephone data link. ■■
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3. Is continuous tuning along with phase lock best for my test procedure?
4. Do I need a separate, low RFI counter?
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Microprocessors help to communicate by voice and bit stream

Throughout the fields of telephony, data networking and satellite and military communications, companies are designing equipment with μPs in them. Chips serve as network controllers, diagnostic tools, digital filters, store and forward devices, front-end processors, tariff computers and more.

Most applications are being handled by MOS μPs, but a few use bipolar bit-slice processors instead.

μPs find use in telephony

Telephony was one of the first areas of communication to feel the influence of the μP. Among the initial products to reach the market were the BCS-50 Private Automatic Branch Exchange (PABX) from Chestel Corp., Chester, CT, and the Transaction Telephone from AT&T, Shreveport, LA.

Chestel’s PABX system, which uses time-division multiplexing, employs a single 8008 μP from Intel, Santa Clara, CA. The 8-bit, PMOS μP searches for data during time slots. It checks on terminals for on-hook, off-hook or other status, sets up conference calls, keeps track of over-all system status and gives instructions to the terminals. The features or restrictions for each terminal are stored in PROMs.

A μP-controlled accessory—the SMDAS Message Accounting System—is also being built for the BCS-50.

The SMDAS plugs in and keeps track of any traffic on the system. It uses an M6800 μP from Motorola Semiconductor, Phoenix, AZ.

The Transaction I and Transaction II telephones from AT&T incorporate a PPS-4 μP from Rockwell International, Anaheim, CA. The main functions are credit card authorization, check verification and other electronic funds transfer functions. The μP is used to store information and release it at the appropriate time on a coded signal. Multitone or rotary telephone sets can be programmed by a plastic dial-up card.

The μP also provides character checking and sets up the required line protocol. The set can be used either for direct dialing or in branch exchanges.

“Soon the μP will be used for almost every function available in telephony—and used more efficiently,” says Martin Fletcher, vice president of ComQuest Corp., Palo Alto, CA. “Even now, more sophisticated use of the devices is being designed into 2-way concentrators, central office switching equipment, PABX, tariff rate computers, paging equipment for multiterminals, message accounting systems, message switchers and scramblers.”

Since 10 to 50 μs per instruction is all the speed necessary for most of these applications, he says, NMOS μPs of the type now available will be able to handle them.

Diagnosing telephony

What happens when something goes wrong in a switching system? Lynch Communications, Reno, NV, says diagnosing problems in its B280 electronic subscriber switching system was a tedious task. Now, it has designed a μP-based instrument, the B280 Maintenance Monitor. Using an Intel 8008 μP the unit is plugged into the switching system to monitor 128 points. If a fault occurs, the μP analyzes the problem and isolates it down to PC-board level.

“Newer switching systems will use internal μPs to perform fault diagnosis as a routine function,” says Lynch’s Alan Hutcheson. He also expects the next generation of switching systems and line concentrators to all use μPs. The concentrators use space-division switching to concentrate many lines onto a smaller number of trunk lines.

David N. Kaye
Senior Western Editor
In these systems, the \( \mu \)P will handle faults, take traffic data and control the switching.

Microprocessors are being designed into a variety of central office switching equipment. The \( \mu \)P may eventually monitor traffic, handle memory control, perform line scanning to determine the proper routing for best economy, maintain internal control and accounting and handle interoffice tones.

Rolm Corp., Cupertino, CA, and AT&T recently introduced minicomputer-controlled PABXs. Although initial products in this field may be controlled by minicomputers or custom LSI circuits, ultimately the \( \mu \)P is expected to win out as the dominant PABX control element.

**PABX goes digital**

Once the PABX is digitally controlled it can readily handle a variety of digital transmissions as well as voice. Once the exchange is made programmable, the lines it controls can accept data in a variety of line protocols and speeds. The exchange can then translate the protocols as required and transmit the data in the most economical manner. It can even provide error checking and correction, or scrambling for secure communications. All features that were once hardwired can be duplicated through software.

**Microprocessors in digital networks**

Microprocessors are on the verge of finding wide use in various parts of digital data-communication networks. The first important product in this field is the Model 6000 Intelligent Network Processor from Codex, Newton, MA, a multiprocessing network processor. It uses an Intel 3000 bipolar \( \mu \)P as a controller for up to eight Motorola M6800s.

The 6000 handles network management, can support a throughput of 50 to 60-kb/s, does error checking, handles up to 252 terminal ports, does automatic channel assignment, dynamic network reconfiguration, data compression, system diagnostics and handles intermixed data rates and protocols.

Terminals can be intermixed with synchronous data rates of up to 9600 b/s and asynchronous data rates of up to 1200 b/s.

"In the communication environment, an eight-processor mainframe has approximately the processing power of two middle-sized minicomputers of the Digital Equipment PDP-11/40 class," according to John Pugh of Codex.

A rather sophisticated network processor, "an automatic terminal controller," is under development at the Multigraphics Div. of Addressograph-Multigraph Corp. It will be a node controller for one part of a larger data communications network. The heart of the system is a microcomputer based on the Intel 8080A.

Most of the terminals in the system will transmit either 300 or 1200-baud data, according to M. Glen Looney, manager of systems and software development. The terminal controller will be connected to a large number of terminals where it will handle polling, message transmission and retransmission, diagnostic testing, buffering, error checking (with automatic retransmission) and line protocol. The data out of the terminal controller will then go to a host controller for communication back to the main computer. The system should be available for delivery around midyear, Looney says. He expects main applications will be in point-of-sale and electronic-funds-transfer systems.

A \( \mu \)P-based message-switching system has recently been installed by the New York City Police Dept. Up to 4 National Semiconductor IMP-16 \( \mu \)Ps and a 32 x 16-k National 2102 semiconductor memory are used to handle synchronous and asynchronous data from up to 16 lines. One IMP-16 writes asynchronous data into the memory while the other reads synchronous data from memory. The other pair of processors perform the same function.

The devices also calculate cyclic redundancy
check numbers for the data. The \( \mu \)Ps serve to convert asynchronous data from inquiring terminals to synchronous data, which is fed to a host minicomputer. They then reverse the process to feed data back to the terminals.

Built by Action Communications of Dallas, TX, the system is marketed under the name Telecontroller.

A front-end processing function is also being performed by an Intel 8080A in an Energy Saver system. Developed by Systems Technology Corp., Detroit, MI, it manages the power usage in one or more buildings. A host minicomputer is used in the system. The \( \mu \)P front-end uses a proprietary protocol with error detection and correction for transmission of data over a twisted pair or modem. “We can also send control signals to other \( \mu \)Ps in different locations. The result is a distributed computing system,” says William Buyers, president.

The Systems Technology equipment is one of many using an 8080A-based microcomputer designed by Process Computer Systems of Flint, MI.

“It is useful for data communications applications because our I O structure is very flexible,” according to Arthur Harmal of PCS. “All I O is treated as memory locations. We can handle up to 40-kbaid in an asynchronous manner and can do cyclic redundancy code or BCH error checking at that speed.”

PCS offers the computer in either an 8-bit or 16-bit version. The I O is organized in a 16-bit manner by splitting up 16-bit words and treating them 8 bits at a time.

Another PCS customer is Interautomation, Mississauga, Canada. They are using the PCS \( \mu \)C to make a digital multiplexer for industrial control applications. It can handle both analog (4 to 20 mA) and digital inputs and outputs and can deal with up to 1000 total inputs and outputs.

Into the modem

Microprocessors in the view of many do not offer any advantage over conventional circuitry for low-speed modems. But they can be very useful for controlling high-speed programmable modems. Another possible use for \( \mu \)Ps is for digital filtering and adaptive equalization in high-speed modems. In time they will also be able to handle UART functions through software instead of hardware.

Processing a satellite

“We are expecting to get an order of magnitude improvement in reliability, size and power consumption when we use \( \mu \)Ps in our systems,” says Richard Cooperman of Comsat Laboratories, Clarksburg, MD.

“We are now looking at the use of a \( \mu \)P on board the satellite for an attitude control application,” he says. Funded by INTELSAT, the attitude controller needs a flexible I O structure to handle a large number of sensors. Since speed is not a concern the firm will probably use either an NMOS or CMOS \( \mu \)P. A 12 or 16-bit processor is optimum.

Comsat is also looking at a \( \mu \)P as an on-board power system controller.

For earth-station applications Comsat has built \( \mu \)P-based hardware for adjusting the polarization of the beams in a dual-polarization transmission system. The Intel 8080 \( \mu \)P optimizes the quadrature angle of the two polarized beams. It has this equipment currently operating in the laboratory.

Using \( \mu \)Ps for telemetry encoding, random logic replacement for improved reliability, and distributed processing of satellite data are currently under study at such companies as Hughes Aircraft, El Segundo, CA; TRW Systems, Redondo Beach, CA; and Lockheed Missiles and Space, Sunnyvale, CA.

Securing the data

Security of voice and data transmissions is a primary concern of the military. In each of the services a number of classified programs are underway to explore the use of \( \mu \)Ps in secure communications systems.

The Transaction II Telephone from AT&T is a \( \mu \)P-based credit-authorization and check-verification device. It uses its Rockwell PPS-4 \( \mu \)P for storage, forwarding, line protocol set-up, and error checking.
The Telecontroller from Action Communications uses up to four IMP-16 μPs from National Semiconductor to translate asynchronous data from remote terminals into synchronous data that is fed to a host minicomputer. The IMP-16s also retranslate the data and distribute it back to the terminals from the mini.

One of the most widely accepted methods of obtaining a secure communications link, spread-spectrum communications, increases the frequency spectrum of the transmitted signal so the signal is hidden far below the background noise. The received signal is correlated with signal-compression circuitry at the receiver. The information, which is often coded before being spread, must also be decoded at the receiver.

Two primary methods of frequency spreading are used. The first is called frequency hopping. Here the carrier is rapidly changed so that only a small portion of the coded signal is contained on any single channel. The more frequencies (channels) used, the less information that can be detected if a single channel is received by the enemy.

Direct sequencing is the second technique. Here, the desired signal is blended with a known pseudo-noise code. The resulting combined data stream is transmitted using an rf bandwidth far larger than the information bandwidth. The message being transmitted resembles the background noise level and is thus hidden. At the receiving end, a μP-based correlator strips the message from the pseudo-noise code and, if necessary, decodes it.

These techniques are being looked at for back-pack radios, field data terminals, mobile message-switching centers, portable satellite communication terminals, mobile relay links and a variety of other applications.

Soon μPs may also find their way into the communication and navigation systems of remote pilotless vehicles and cruise missiles.

What of office products?

There are now a great many office products that communicate. Examples are word processing systems and facsimile equipment.

Companies such as Xerox, IBM and 3M are known to be actively developing μP-based office products, but none of them will comment on the subject.

One of the most promising areas for using μPs is facsimile. Rapifax of Santa Clara, CA, may be the farthest along with this technology. According to Norman Peterson, executive vice president: "μPs might have a place in both control and imagery aspects of facsimile."

Xerox and 3M are rumored to be nearing the product stage with μP-based facsimile systems of their own. ■
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Rf and microwave test equipment getting more automatic and smarter

In rf communications, measurements that once took 15 to 20 minutes and required elaborate calculations can now be performed almost automatically.

Rf and microwave test equipment is now being designed to be "smarter" and have a greater range of operation than ever before. In addition, remote programming and readout capabilities are being included.

In frequency synthesizers, spectral purity has increased, frequency range extended, and provision included for remote, computer-controlled operation.

In power meters, bandwidth and dynamic range have been stretched and standing-wave ratio (SWR) decreased.

Frequency counters are being pushed to measure higher frequencies, and network analyzers appear in the background seemingly capable of doing anything.

A new breed of frequency synthesizers

Engines who recall working with signal generators—where frequency, signal amplitude, and modulation level all had to be set by cranking knobs manually while carefully eyeing an array of monitoring meters—will appreciate the new breed of frequency synthesizer now available.

Current models range from very versatile remotely-programmable synthesizers capable of generating a wide spectrum of frequencies, to units designed for testing specific items—citizens-band radios, for example. The newest models have not only become more versatile but have acquired "smartness" as well thanks to the capabilities of the ubiquitous microprocessor.

John Minck of Hewlett-Packard, Palo Alto, CA, suggests a note of caution, however, for those planning to use synthesizers.

"No matter how attractive synthesized signal generators look from the standpoint of programmability, stability, or even price, the user would be well advised to carefully match his tests to the specs," Minck cautions.

For example, in testing receivers for spurious response, the engineer must be careful that the synthesizer itself does not emit significant levels of nonharmonic spurious signals. For such signals, a level even 70 dB down (from the main signal) may be too high.

Frequency synthesizers, rather than the more conventional cavity or LC-tuned signal generators, are generally used where signals must not only be programmed and set, but have high resolution and long-term stability.

A considerable increase in versatility is becoming available through the use of the IEEE 488 standard interface. This is an instrument-interconnection system that allows controls to be set and data to be taken automatically—all under the control of a minicomputer or a calculator.

The Fluke Model 6010A from John Fluke Co., Mountlake Terrace, WA, is reported to be the first commercial frequency synthesizer to include a microprocessor. The µP gives the 6010A the ability to store and recall data programmed by the operator. Up to ten items of information, including frequency, modulation, and attenuation settings can be stored and recalled at the push of a button.

By means of a front-panel keyboard similar to that of a standard pocket calculator, the operator can select both the frequency (in the range 10 Hz to 11 MHz with 0.1-Hz resolution) and the desired output voltage from 0.25 mV to 5 V.

In addition to its ability to remember, the 6010A demonstrates its "smartness" in other ways. Whenever the synthesizer is turned on, it automatically starts out at minimum output, to ensure that whatever is being tested won't be accidentally damaged.

And should the operator try to program the unit to provide output conditions that are impossible for the machine, the ever-watchful micro-

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Samuel Derman
Associate Editor
The accuracy of this device is 3 parts in 10⁶ per year. The tight control of frequency, coupled with the μP-based memory, enables the 6010A to be used for repetitive testing. Moreover if automatic operation is desired, the microprocessor permits interfacing of the 6010A to an external system through byte-serial, bit-parallel interfacing. Other interface options are also available.

A frequency synthesizer that extends the frequency range up to 500 MHz is the 1062 from GenRad Co., Concord, MA (formerly General Radio). This signal source features especially high spectral purity and stability, making it possible to up-convert or multiply the output signal into the microwave-frequency bands.

Nonharmonics are down more than 80 dB below the signal, with harmonics down more than 25 dB. Residual phase noise is —100 dB at 10-Hz offset from the carrier.

In keeping with the trend toward automatic or remote operation, the levelled output signal of the 1062 may be varied (from —7 dBm to +13 dBm) either by an externally applied dc signal or by manual front-panel control.

Even more significant, the signal frequency may be programmed remotely via standard 8-4-2-1 binary-coded-decimal (BCD) signals. Switching speed—from one frequency to the next—is an extremely fast 50-μs. This allows, for example, the scanning of 100 points (in a digitally swept system) in 50 milliseconds, with 400 μs of dwell time allowed for each measurement.

As a further indication of the trend toward remote-programming capability, the basic models of the 1062 now come without front-panel controls, although they are available as a standard option.

Hewlett-Packard offers a new laboratory synthesizer, the 8672A. This unit, called a synthesized-signal generator, offers highly stable, very-low-noise signals covering the 2-to-18-GHz range, with provision for internal FM or AM.

Frequency resolution of the 8672A is 1 kHz in the frequency range 2 to 6.2 GHz, 2 kHz in the interval 6.2 to 12.4 GHz, and 3 kHz for frequencies above 12.4 GHz.

Spurious signals, excluding power-line related noise, are 60 dB or more below the carrier level at 18 GHz and more than 70 dB below at 6 GHz. Single-sideband phase noise in a 1-Hz bandwidth typically exceeds 78 dB below carrier (dBc) 1 kHz away from a 6-GHz carrier signal. At 110
kHz from the carrier, the noise is less than 109
dBe.

All front-panel controls of the 8672A are re-
modally programmable, and the unit is compatible
with the Hewlett-Packard Interface Bus System.

The 8671A, a similar, lower-cost synthesizer
covering 2 to 6.2 GHz range, is also available.
It does not provide a calibrated output, however.

For lower frequencies, HP’s 8660 (10 kHz to
2600 MHz) still remains a broad-capability syn-
thesizer that features AM, FM, and phase
modulation.

A new, specialized frequency synthesizer called
the Receiver Test Set Model 980 is available from LogiMetrics Inc., Plainview, NY.

The synthesizer provides a fully levelled output
capable of being switched to any of the pres-
tant 23 citizens-band (CB) channels (fre-
quency range 26.995 to 27.255 MHz), with pro-
vision for up to 64 channels as requirements
increase. These additional channels are available
via a programmable read-only memory (PROM)
and can be connected by the user once the FCC
assigns frequencies for these channels.

The 980 is designed for maximum simplicity
so that a less-skilled production person, rather
than a technician, can use it.

The 980 is designed to test transceivers. Should
the user inadvertently connect the transmitter
portion of the transceiver to the synthesizer out-
pin the expensive attenuator would be damaged.
The 980 protects against this occurrence for
transmitter power levels up to 5 W.

Frequency coverage from 0.1 to 26.5 GHz
(using appropriate plug-ins) is provided by
Model 1250 frequency synthesizer introduced last
June by Watkins-Johnson Co., Palo Alto, CA.

This is a phase-locked fundamental-oscillator
synthesizer that offers low single-sideband noise
and low nonharmonic spurious noise.

Frequency counters are becoming smarter

Universal frequency counters measure a num-
ber of parameters in addition to frequency. These
include period, time, and the ratio between two
input frequencies. Nonuniversal types are re-
stricted mainly to frequency measurements.

Frequency counters have come a long way
since their first appearance over two decades ago.
During this time they have evolved from ma-
chines that could measure only up to 10 MHz, to
today’s versions, which offer standard capabilities
up to 24 GHz with sensitivities down to 20 and
30 dBm.

In keeping with current trends in rf and
microwave test instruments, many of the latest
counters are also provided with interface capa-
ibilities for remote programming and remote
readout. This provision also permits computer
counters and readout.

“Smartness,” in the form of internal micro-
processor control, also enables some models to
perform a number of difficult timing measure-
ments almost automatically; rise time determina-
tion is an example. Robert Metzler of Tektronix,
Beaverton, OR, points out, however, that while
microprocessors can make things easier for the
operator and can provide savings in power, cost
and design time, they do not actually advance the
range of operation of frequency counters. That
is, they can’t provide a higher frequency-meas-
urement capability or greater sensitivity.

Some recently-introduced models are the fol-
lowing:

A frequency counter offering the highest dy-
namic range (60 dB for frequencies up to 10
GHz) and one of the highest frequency-counting
capabilities (24 GHz) is Systron-Donner’s Model
6054B, introduced just last month, (Systron-
Donner Corp., Concord, CA).

This unit measures frequencies as low as 20
Hz, and provides sensitivities of -30 dBm for
frequencies up to 10 GHz, -25 dBm from 10 to
18 GHz and -20 dBm from 18 to 24 GHz.

Other features of the 6054B include an 11-
digit display, a single input connector (50 n) for
the entire frequency range, selectable resolution
from 1 Hz to 1 MHz, high FM tolerance, and in-
put overload protection up to 1 W.

For automatic or computer-controlled opera-
tion, an optional feature allows complete pro-
gramming of all front-panel controls except the
main power switch. Also, all information on the
front panel, such as control settings and digital readout, can be accessed in parallel 8-4-2-1 BCD format via a rear-panel connector.

Dana Laboratories' (Irvine, CA) Series 9000
universal counter timer features μP control for
such measurements as pulse width and rise and
fall times, and has keyboard-pushbutton function controls. It measures frequencies in the range from near dc to 100 MHz.

Four different interfacing options allow a var-
iety of arrangements for remote, computer-
controlled operation.

The Dana 9000 provides all the capabilities of
a timer, counter, reciprocal counter, and calcula-
tor. An example of how the μP controls the opera-
tion of complex measurements is as follows:

Determination of pulse rise and fall times—
measurements that usually require skill and good
eyesight (for scope measurement)—can now be
accomplished with a single keyboard command,
using the 9000.

To make a rise-time measurement, the micro-
processor scans the pulse to determine the appro-
 priate voltage range. The microprocessor then
measures the peak amplitude, computes the 10%
and 90% voltage levels (the traditional values for
computing rise time), and makes the measure-
ment, all in less than 1 s.

The 9000 provides both high resolution and
high accuracy for low and high-frequency mea-
surements—a near-impossible feat for conven-
tional counters.

The counter's sensitivity is as follows: 25 mV
for frequencies to 1 MHz, 50 mV to 50 MHz, and
100 mV to 100 MHz. For the 9035, sensitivity
is 15 mV. All voltages are rms.

Full 9-digit resolution is reported for this
counter for any frequency from near dc to 100
MHz. Higher frequency counting is possible with
the 9035, which uses a prescaler (basically a
divider) to extend the frequency to 512 MHz.

For remote operation, this unit provides the
following interface capabilities:

- Connection via the general-purpose interface
  bus.
- High-speed computer interface with parallel-
  bit format for maximum data-transfer rate.
- Serial ASCII-system interface for direct
  hookup to a keyboard printer (teletypewriter for
  example). The terminal can be used in turn as an
  I/O device for entering data to a remote com-
  puter.
- Parallel BCD output. TTL-compatible out-
  puts are provided.

The Series 700 digital universal counters mar-
keted by Newport Laboratories, Santa Ana, CA,
can directly measure up to 100 MHz; up to 1 GHz
can be counted with a prescaler. A BCD output
allows remote readout as well as remote control
of all counter functions.

The sensitivity for direct measurements is 50
mV for frequencies up to 100 MHz. A unique
feature of the 700 is that programmable read-
only memories (PROMs) rather than conven-
tional wafer switches are used for changing the
time base.

A frequency counter aimed especially for the
communications industry is the Tektronix Model
DC502. It covers the frequency range 10 Hz to
550 MHz.

This unit is one of a series of 30 compact
plug-in test and measurement instruments de-
digned to be used individually or in combina-
tions to suit the user's special needs.

A 100-ps resolution universal counter, the
DC505A, is also available as part of this series.
It covers the frequency range to 225 MHz on both
input channels.

Network analyzers sweep up to 1.3 GHz

Network analyzers in their present form made
their appearance on the instrument market only
about ten years ago. But in that short time they
have established a secure position for themselves
as an essential piece of test gear for rapidly
measuring the transmission and reflection param-
eters of a variety of electrical networks and
components.

Not so long ago amplitude and phase character-
istics were determined by making difficult point-
by-point measurements using either cumbersome,
manually-adjusted high-frequency bridges, or
more recently, the RX meter. Network analyzers
now perform all these measurements almost instan-
tly by sweeping through an entire frequency
range and presenting the amplitude and phase
information graphically.

Current models can sweep through frequencies
up to hundreds of MHz, and in one case (the
HP8505A), up to 1.3 GHz.

The genealogy of these analyzers, short as it is,
already shows a trend toward more extensive
frequency coverage, greater dynamic range, and
a wider use of digital techniques. This last attri-
bute implies capability for remote computer-con-
trolled operation.

In November, 1975 Hewlett-Packard introduced
its 8505A network analyzer ("Analyzer Brings
New Power to Network-Behavior Measurement," ED No. 23, Nov. 8, 1975, p. 113). By doing so,
they extended the capability for automatic swept-
frequency measurement of network characteris-
tics into frequency ranges higher than ever be-
fore—to 1.3 GHz.

Providing a continuous 100 dB of displayed
dynamic range, this device presents a CRT plot, in either polar or cartesian form, of many signal parameters. These include transmission, reflection, group delay, deviation from linear phase, and S-parameters of active devices.

Every function on the 8505A is digitized—even those functions that would normally be analog controlled. For example, the sweep limits have an analog "feel" but are actually digital encoders. Because the functions are all digital, the 8505A analyzer can be controlled by a calculator or computer via a standard interface bus.

One version of this analyzer, the 8507A, comes configured with a programmable calculator, the HP 9830A, that provides the network analyzer with a number of unique capabilities.

If the analyzer is put into "learn mode" the operator can set all the controls in the normal fashion. These settings are memorized by the calculator, and at any time in the future can be reset to these positions by a remote signal.

Or, the analyzer can be set to correct for the normal transmission errors unavoidably encountered in high-frequency measurements. Signal losses or mismatch caused by the interconnecting rf hardware are measured by the analyzer and stored in memory. These errors are then subtracted from the measured parameters of the device being tested.

A printer and an optional plotter are available with this system to provide hard-copy readout.

General Radio's entry into the field is its Model 1710 rf-network analyzer. This unit covers a frequency range extending from 400 kHz to 500 MHz, has a dynamic range of 115 dB (with switching), and resolution capability to 0.005 dB.

Even though the 1710 provides complete control over all measurement parameters it is human-engineered to provide maximum simplicity of operation. It is capable of making a variety of measurements, including admittance, impedance, group delay, amplifier gain, and filter attenuation.

The 1710 solves a special problem of growing importance today, that of measuring the passband of devices (such as crystal or surface-wave filters) that have very narrow bandwidths. Such testing requires signals that have great stability and spectral purity. But the sweep frequency generator used in network analyzers usually cannot provide the low-noise qualities necessary for such accurate measurements.

Instead of frequency sweeping through the passband of interest, the GR 1062 frequency synthesizer (together with the companion 1062-P1 tracking synthesizer) traverses, point by point, the passband of interest. The result is a measurement similar to that provided by a network analyzer but with the frequency, precision, and stability of a synthesizer, and none of the noise limitations of a sweep.

By adding a General Radio 1167 frequency programmer, the operator can perform this measurement nearly automatically. Through a pushbutton keyboard, he simply sets the frequency limits and the increments. The synthesizer then automatically sequences through the desired range of frequencies.

Another network analyzer currently available in the American market is the Rohde and Schwarz (Fairfield, NJ) Sweep Diagraph ZWD. This unit, which measures the signal reflection and transmission characteristics for both active and pas-

The 1710 GenRad (formerly General Radio) Network Analyzer measures a variety of parameters of active and passive networks.

(continued on page 70)
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HP DVMs—the right decision
Sweep width can be varied by an external dc voltage, and the output-signal level very precisely remote-controlled by a separate programmable attenuator, the Rohde and Schwarz DPVP.

**Power meters are more versatile**

Power meters, long considered to be one of the simpler pieces of rf and microwave test equipment, have also been affected by the currents of change.

Power meters today cover a greater dynamic range and a broader frequency spectrum, than did their predecessors, and provide a better match in the form of lower SWR. In addition, many units offer digital readout and a capability for remote programming and readout.

One of the greatest problems in using power meters is the measurement uncertainty caused by the imperfect match (SWR) between the signal source and the power-meter detector. This uncertainty or error can often be as much as ten times greater than the instrumentation error (meter movement error etc.), so much of this has gone into SWR improvement. One note of caution: spec sheets often give the instrumentation error and the input SWR in two separate places on the sheet.

The Boonton 42B series of rf microwatt-meters (power meters) embodies many of these new features (Boonton Electronics Corp., Parsippany, NJ).

The 42B meters can measure power down to a minuscule 1 nW (−60 dBm). The upper limit is 10 mW (+10 dBm) for a total dynamic range of 70 dB. A 300 mW overload tolerance is also provided.

As in most power meters, the detector head is a separate unit that electrically connects with the main body. For the 42C three power heads are available, all with a low-frequency limit of 200 kHz, and with the high frequency extending up to 18 GHz. Model 42B offers a conventional analog-meter readout and the 42BD provides a digital readout.

SWR is less than 1.12 for frequencies up to 4 GHz, 1.18 from 4 to 12.4 GHz, and 1.28 from 12.4 to 18 GHz.

Other features of the 42BD include:
- Solid-state switches that activate each power range. These allow the meter to be ranged manually, automatically, locally, or remotely.
- Computer-controlled test systems, printers and comparators that can be interfaced by using the power-meter BCD output.

Zero drift of these power meters is reported to be less than 1 nW per hour, thus reducing the necessity for frequent zero adjust, one of the perennial headaches of early units. Above 1 µW no zero adjust is necessary.

Frequency coverage from a low 100 kHz up to 18 GHz with a 50-dB dynamic range is offered by the HP 435A (analog readout), and 436A (digital readout).

An assortment of sensor heads is available to allow measuring from a low of 3 µW full scale up to 3 W full scale. The newest power head, Model 8484A, pushes the power-measuring limit even lower, to 100 pW (−70 dBm). The highest power is −20 dBm, giving a total dynamic range of 50 dB.

A significant feature of the new head, the 8484A, is its use of low-barrier Schottky-diode technology to achieve low SWR without loss of detector sensitivity. The SWR is 1.3 at 18 GHz and 1.2 from 30 MHz to 10 GHz.

The 436A power meter offers features such as:
- Automatic sensor recognition. This recognizes which particular one of the 8480 series of power sensors is connected, and scales the reading accordingly.
- Automatic zero sensor. This permits zeroing the device by pushing a button.
- An analog peaking indicator. This tells the operator whether a reading is increasing or decreasing, a piece of information which is not easily discernible from a rapidly changing digital readout.
- Instrument accuracy of ±0.5%.
- Provision for digital output and for remote, automatic programming of the mode, power range, and zero functions.

Engineers of an earlier generation who may feel somewhat overwhelmed by the onslaught of today’s ultra-sophisticated test equipment can take heart. Not all the older equipment has been put out to pasture.

One of the very early warhorses of test gear, the Bird Model 43 Thruline Wattmeter from Bird Electronics Corp., Cleveland, OH, conceived in the 1950s, not only is still being used, it is still being manufactured and actively sold. Bird Electronic Corp. reports that the 76,000th unit recently left the production line.

One of the reasons for this instrument’s enduring popularity is that it is self-contained (no batteries, no line voltage). It uses microwatts of energy from the transmission it measures.

The 43, which weighs 3 lb, is an insertion instrument for measuring rf power flow. It measures both forward and reflected CW power in coaxial transmission lines. Maximum frequency measurable with appropriate plug-in units, is 2.3 GHz.

Bird Electronics also manufactures the 4371 high-power digital rf power meter. This insertion meter measures net power flow under any load conditions from 25 to 520 MHz and from 1 W to an astronomical 1 kW. The lowest indication on this meter is 1 mW.
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In addition, we've further simplified control signals. And you get the single-chip benefits of simpler assembly and less design time, plus an expanded instruction set.

All this on top of other things you liked about the 1801. Especially its COSMAC architecture, simple yet powerful. Plus its easy learning and programming.

COSMAC architecture lowers memory costs

The big advantage is 1-byte instructions: less to store, less to fetch — which means less memory to buy. Simple subroutine calls can take just one byte.
Instructions need no addresses because the 16 internal general purpose registers act as pointers. You can point these registers at data areas or program areas. They can also be used to store data directly, reducing the need for RAM. One register even acts as a built-in DMA address generator—an RCA first.

RCA offers ROMs and RAMs as standard support. But if you have reason to use memories from other manufacturers, you can use almost any industry standard in x1, x4 or x8 configurations.

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- A/D Converter

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- COSMAC Development System with 1802 Emulator (CDP18S004) for easy breadboarding and resident software development. Includes chassis, power supply, simple control functions, CPU, RAM, byte I/O, terminal interface, utility routines, plus the capability of editing, assembling and debugging software programs.
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Spectrum squeeze eased by solid-state microwave oscillator advances

Spurred by the explosive growth of communications in recent years, packaged microwave oscillators are moving to high-frequency bands and higher power levels.

Increased traffic over long-haul telephone and data links has lead to insufficient spectrum capacity. Further, the spread of mobile land communications has brought demands for tighter specs on these packaged oscillators. These demands are now being met by development and production of microwave integrated-circuit (MIC) designs.

To extract the maximum capacity out of systems, users are abandoning lower-frequency 4-GHz bands for bands in the 12-GHz area. Ultimately, 18-GHz bands are a real possibility.

Cavity tuning the oscillators

Solid-state microwave oscillators use transistors or bulk-effect diodes, such as the Gunn and Impatt devices, for signal-generating elements. For narrow-band, low-noise communication applications these oscillators are tuned by microwave cavities having relatively high Qs of 400 to 700 or more. The higher the Q, the narrower the bandwidth.

To obtain high stability the microwave rf output of the cavity is phase-locked to a selected harmonic of a crystal oscillator that is operating in the region of 100 MHz. The harmonic is obtained by multiplying and filtering the crystal output. The oscillator's output frequency is shifted within its microwave band by changing the crystal and by mechanically retuning the cavity.

For broadband operations where it may be desired to shift the oscillator output over a range of 30% to 200% of its basic microwave frequency, cavities with low Qs, of about 10 to 100, are used in the oscillator. In this case the oscillator can be electrically tuned using varactor diodes.

The broad-band oscillator may also be crystal stabilized. Or it may be purely varactor controlled to achieve modulation bandwidths of hundreds of megahertz with slew rates approaching a gigahertz in nanoseconds.

The performance of packaged communication-system oscillators is being continually improved, but at the cost of increased complexity. For example, a phase-locked-loop oscillator operating in the 12-GHz region and using a transistor oscillator and multipliers, typically contains 400 to 500

Small, light and rugged packaged oscillators that can survive a launch environment and outer space are used in communications satellites like this RCA Satcom.

Jim McDermott
Eastern Editor
The oscillator has been developed to the level of a subsystem that has been substantially refined with the addition of the phase-locked loop and a number of protection and control features.

For example, because the varactor is a square-law device, varactor voltage-tuned oscillators are highly nonlinear in respect to change of frequency with applied voltage. In terms of oscillator frequency change it approximates a fourth-law device.

To linearize a varactor sweep, an amplifier with a variable-gain curve that is the reciprocal of the nonlinear variation is added to the package. To compensate for low-input sweep-control voltages from a customer’s equipment, an additional IC amplifier may be integrated into the assembly.

To prevent output frequency from changing with supply-voltage variations, a regulator is incorporated. To limit frequency changes due to rf-load variations, an isolator is designed into the package. To compensate for frequency drift due to ambient temperature changes, a heater and temperature controller are normally included also.

Some of these features are offered as options by oscillator manufacturers. Watkins-Johnson, Palo Alto, CA, offers hybrid heaters and sweep-linearizer assemblies as add-ons to its line of solid-state VCOs.

Upper frequency limits raised

Improvements in pushing back the upper frequency limits at which transistors produce useful microwave-oscillator power outputs is a continuing effort. Three years ago the upper frequency limit for transistor fundamental oscillators and frequency-doubled transistor configurations was about 4 GHz, says Bruce Malcolm, chief microwave engineer at Texscan, Indianapolis, IN.

Today, through the use of improved microwave transistor technology, higher-frequency devices have pushed the range upward to 8 GHz. Transistor fundamental oscillators are now built up to 6 GHz with wide-bandwidth tuning and an output of 0.5-W cw which, Malcolm points out, is a significant increase.

Up to 12 GHz of useful power can be obtained using push-push transistors. The bases are fed in push-pull and the collector outputs are tied together. This produces second harmonic energy.

With a full-wave multiplier that energy can be further doubled to the 12-GHz limit. The outputs of the push-push arrangement can also be directly multiplied by step-recovery diodes to produce signals at up to 22 GHz.

GaAs FETs have the potential for making oscillators with less noise than there is with bipolar devices, but at present the cost is inhibiting their use in practical oscillator assemblies.

In the 8 to 12-MHz region it is possible to buy transistor, Gunn or Impatt-device oscillators. Transistor oscillators are generally more frequency-stable than are the bulk devices, but bulk oscillators use only a single active element and are both lower in cost and smaller in size.

Gunn oscillators popular

Gunn oscillators are the workhorses of the bulk-device microwave-oscillator field. They compete directly with transistor fundamental oscillators of up to 8 GHz; above that the Gunn oscillators predominate for fundamental-signal generation.

The highest power presently available from a single Gunn-diode oscillator at X band is about

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This parametric-amplifier pump oscillator produces 100 mW from 50 to 60 GHz. The oscillator, by Microwave Associates, is used for communication-satellite receivers.

A Gunn diode generates power in the X-band, 10.525 GHz cw oscillator shown. Developed for use as a local oscillator in a receiver, it can be tuned over ±25 MHz.
Packaged oscillators are designed in a variety of shapes, often to fit a customer's configuration. These Texscan oscillators include built-in test-equipment (BITE) units.

0.5 W. But the power barrier has been upped by combining several diodes in the same oscillator so that their outputs add in phase, according to Ken Kawakami, staff engineer at Addington Laboratories, Sunnyvale, CA, and holder of patents on this technique.

Multiple-Gunn-diode oscillators that will produce 3 or 4 W in the 8 to 12.4 and the 12.4 to 18-GHz bands are now available from suppliers like Varian and Litton, both in Palo Alto, CA. Litton, for example, produces high-powered L-band oscillators using multiple diodes in a high-Q cavity package.

Impatt oscillators traditionally have higher outputs than the Gunn units, but the Impatts tend to be substantially noisier than Gunns using equivalent rf circuits. Impatts have produced useful power at up to 100 GHz, but such devices are not available commercially.

Probably the greatest breakthrough in practical GaAs Impatt devices has been the development, at Raytheon Solid State Products, Waltham, MA, of high-powered, Read-profile Impatt diodes.

"These Read diodes produce about 4 W at X band compared with 1 W for conventional, flat-profile Impatts and 0.1 W for Gunn devices," says Jerry Simpson of Raytheon.

"We're producing saleable Read diodes with 15% efficiency at 2-W output and 20% efficiency at 4-W output in the region of 1.5 GHz."

These Read diodes have only been applied by Raytheon within the last year in both packaged oscillators and amplifiers. The Read devices are currently used in a new injection-locked, packaged oscillator that has an output of 4 W cw or pulsed, in the 6 to 8-GHz band. Components of the Raytheon oscillator include a fixed-tuned Impatt-diode oscillator, a p-i-n diode switch and two high-efficiency Read-diode amplifier stages.

A thin-film hybrid microwave oscillator is hermetically sealed in a TO-8 can. The oscillator, by Avantek, is compatible with 50-Ω stripline.

Development of the GaAs Read diodes, originally a Raytheon in-house project, has been also supported by Wright Patterson Air Force Base, Dayton, OH, and the U.S. Army Electronics Command, Ft. Monmouth, NJ.

Gunn oscillators are pump sources

Gunn-effect oscillators are being used as pump sources in parametric amplifiers for low-noise front ends in satellite-communication receivers.

"These Gunn oscillators are mechanically tuned," says Jim Bybokas of Varian. "The pump oscillators produce up to 100 mW and operate in the 40, 50 and 60-GHz regions."

But quality-control specialist Paul Koskos at Comsat Laboratories, Clarksburg, MD, is looking for new pump sources operating at frequencies as high as 150 GHz for future communications satellite ground-station receivers.

"The capacity of our present Intelsat down-link at 4 GHz is being strained and to get relief we plan to go upward to 12, 20 and 30 GHz in future satellite-system designs," Koskos says.

"This means that although a pump source now operates at 45 GHz for the 4-GHz down-link, its frequency will have to be raised substantially for future higher frequencies. For Intelsat V, which is now in the proposal stage, we are looking at 12 and 14-GHz transponders."

An important area of Gunn-diode-oscillator applications is in varactor-tuned local oscillators for
point-to-point communication-system receivers. These oscillators are typically tunable over the 10.7 to 11.7-GHz band, according to Varian's Bybokas. Provisions for automatic frequency control are designed in.

For the output stages of telecommunications point-to-point transmitters, 1-W Gunn packages are used in the X and kU bands as injection-locked oscillators.

**Advance in oscillator packaging**

The most significant development in microwave oscillator packaging that occurred in the last few years is the development and production of hybrid MICs. Manufacturers like Avantek in Santa Clara, CA, Watkins-Johnson, and Trak Microwave, Tampa, FL, are drastically shrinking the size of the oscillator packages while still providing improved performance by using added circuitry tucked onto the hybrid substrates.

An example of the advantages offered by MIC technology is found in Avantek's VTO 8000 series varactor-tuned oscillators, which are hermetically sealed in TO-8 cans (see photo). Eight of them provide total coverage of the 0.6 to 6.6-GHz range.

These oscillators employ Avantek's own silicon bipolar transistors, bonded to gold-metallized pads on high-dielectric substrates to eliminate parasitic reactance and thermal resistance. The varactor chips are bonded in similar fashion.

The Avantek oscillators use a negative-resistance transistor network coupled to a thin-film microstrip resonator. The oscillator output is compatible with a 50-Ohm microstrip, and consequently has eliminated conventional connectors.

Power required is 15 V at 50 mA. The rf output ranges from 20 mW in the 0.6 to 1-GHz band, to 5 mW in the 5.8 to 6.6-GHz band.

A varactor-tuned oscillator and integral buffer amplifier, also produced by Avantek, is packaged in a hermetic dual-in-line can. The internal buffering serves, essentially, to make the source immune to the frequency pulling that results from a variation in load over the tuning range.

Four units in this VTD series are required to cover the range of 2 to 6.1 GHz. They all produce 20 mW of rf power.

These VTD units have a small thermal mass. Consequently, the effects of ambient-temperature variations on frequency can be minimized by providing a small heater to keep the case temperature at its design value of 80°C. The VTD packages operate from a 12-V supply at a 125-mA current drain.

Varactor-tuned oscillators suffer, in general, from some drawbacks. One is the nonlinearity of the frequency change with varactor-voltage variations. This, however, can be substantially compensated for by the use of linearizer-amplifier circuits.

A second limitation is post-tuning drift, which shows up as an undesirable frequency shift some time after a step-change in the tuning voltage has been applied. The shift is due to the heat-transfer lags across the thermal impedance of the varactor junction and its package.

Yttrium-iron-garnet (YIG) spheres are excellent as magnetic tuning elements for applications requiring high linearity, low noise, and low frequency drift with temperature change. Both transistor and GaAs-Gunn-diode oscillators are available with YIG tuning.

The change in frequency of these YIG oscillators is directly proportional to the current applied and is stated as MHz mA. Linearity of the YIG sweep across an octave band is generally on the order of 0.1 or 0.2% or better. Because the YIG oscillator is a high-Q device, it is less noisy than its varactor-tuned counterpart. This lower noise is desirable in communications receivers.

YIG-tuned oscillators are generally applied in the 0.5 to 8-GHz range for both the military and commercial user. A typical application might be as a local oscillator in a sophisticated superheterodyne receiver, for accurate frequency tracking of the oscillator and a YIG-tuned preselector.

From 8 GHz upwards, Gunn diodes, rather than transistors, are used in YIG oscillators. For example, standard GaAs-diode oscillators from Watkins-Johnson cover the following ranges: 6 to 8; 8 to 12.4; 12.4 to 18.8; and 18 to 26. Higher ranges require special design.

Because most YIG-device users prefer to supply a tuning voltage rather than a current, voltage-to-current converters are specified to provide the necessary tuning amperage.

To provide for output-frequency modulation an FM or tickler coil—as contrasted to the primary tuning coil—can also be supplied in a YIG-oscillator design. The tickler provides a second tuning input that can vary the output frequency slightly, but at a much faster rate than can be done with the main tuning coil. • •
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Electronic Design 8, April 12, 1976
CIRCLE NUMBER 34
Harold Wheeler: An innovator in the world of communications

Holidays have always been important times for Harold Alden Wheeler. It was during his first summer vacation from college that he invented a neutralizing circuit that took the squeals out of radio broadcast receivers and made them easier to tune. That was in 1923.

During the 1925 Christmas holidays he designed the automatic volume control (AVC) circuit that eliminated the need for a third dial on home receivers as well as constant, irritating adjustments.

Wheeler’s AVC removed a serious defect in radio receivers which gave a boost to the already growing interest in home radio, provided rich royalties to Hazeltine Corp. from 1932 to 1941 (when the Supreme Court declared the patent invalid) and established Harold Wheeler as a major innovator in the world of electronic communications.

The AVC or more general automatic gain control, circuit is still used in all AM-radio and television receivers. Since designing the AVC, Wheeler has acquired approximately 180 US patents, and at 73 he is still actively solving problems, both engineering and management, as chairman of the board of Hazeltine Corp. in Greenlawn, NY.

Simultaneous invention

Wheeler wasn’t the only one to conceive the neutralizing circuit that was to become known as the Neutrodyne. Professor Alan Hazeltine of the Stevens Institute of Technology had come up with the same idea shortly before Wheeler did, though neither had been aware of the other’s work.

“By tremendous coincidence,” Wheeler recalls from his Spartan office at Hazeltine, “I met the professor. He invited me to visit his laboratory and in about 15 minutes we discovered we were working on the same thing. He was ahead of me in design-

John F. Mason
Associate Editor
ing the circuit, but I had actually built one.”

Was he disappointed to find that Hazeltine had already designed it? “No, I think I was just glad to find someone else who could talk the same language, and I believe he felt the same. He immediately asked me to work summers in his laboratory. My salary, plus a small share of the royalties for the Neutrodyne, put my sisters and me through school. And, of course, I stayed on with the company after graduation.” (Hazeltine incorporated the company in 1924.)

Wheeler points to a copy of the original Neutrodyne receiver, which is displayed on a table at one end of the room. The long black console looks impressive with its three large dials. “Hazeltine was just beginning to build the Neutrodyne when I went to work for him,” Wheeler says. “It was the first radio-broadcast receiver ever designed on paper; all the others were done by ‘cut-and-try’—by witchcraft.

“The Neutrodyne captured the market from RCA in 1923, superseding the Armstrong regenerative receiver, which was the historic introduction to sensitive receivers.” The Armstrong was being built by RCA, General Electric and Westinghouse.

Simple solutions to complicated problems

As with all of Wheeler’s inventions, the development of the Neutrodyne circuit came as the result of solving a practical problem. “I owe whatever success I might have had to finding problems that have simple solutions,” Wheeler says. “That is literally true, and I learned that from Hazeltine.”

Hazeltine may have emphasized the point, but it also emerged independently as a result of Wheeler’s inherent curiosity, his strong desire to solve problems, and his need to communicate the solutions in simple terms.

“I have functioned on two levels,” Wheeler explains. “I’ve solved engineering problems, such as the Neutrodyne circuit and the AVC circuit. Both were obvious, practical needs. But my greatest contributions have been as a theorist and mathematician; it’s for these that I’m actually best known.”

Wheeler says he still meets people who say: “Oh yes, I remember your paper on ‘paired echoes’”—a paper he wrote in the late thirties. “Its title has very little headline appeal, I’m afraid: ‘The interpretation of amplitude and phase distortion in terms of paired echoes.’

“I wrote it in the early days of television when certain circuits were poorly understood. The problem of paired echoes had been a very elusive topic until I reduced it to simple terms.

“I’ve enjoyed both levels of innovation,” he adds, “but probably the more satisfying is the theoretical.”

The practical problem that led to the Neutrodyne circuit was one inherent in vacuum tubes, Wheeler explains. “The capacitive coupling between grid and plate caused a feedback, which made it difficult to make a stable amplifier for radio frequencies as well as high audio frequencies. The solution was a circuit that would neutralize the coupling. And the result was the first stable high-frequency amplifier operating at broadcast-band frequencies.”

The automatic volume control was another practical solution to a troublesome problem. With existing receivers, the volume fluctuated drastically when the station was changed and whenever a station’s signal faded.

“In the summer of 1925 I saw the need for some kind of automatic volume control,” Wheeler recalls. “You already needed two hands to dial a station, and I just couldn’t see asking people to use a third to control volume.”

Other engineers were beginning to think about AVC, Wheeler says, “but they didn’t go about it the right way. Their circuits were too complicated.”

Wheeler—after a number of trials—used a single triode electron tube connected as a diode to detect the signal and develop the bias voltage needed to control the amplification.

The detector’s function was to rectify the modulated carrier signal, to separate the ac-modulation component for further amplification at audio frequency, and to separate the dc-rectified carrier component for use as a bias voltage in controlling the preceding rf amplification.

The diode circuit performed the first function with both high efficiency and linearity, neither of which was common in the detectors then in use. Because of the linearity, the dc component was dependent only on the steady carrier and not on the full, fluctuating modulation—a result not obtained in earlier proposals for AVC.

“As with many improvements, such as air conditioning, a lot of people couldn’t see any immediate need for it, even chief engineers,” Wheeler remembers. “But in 1929, Hazeltine needed a new source of revenue; the Neutrodyne was obsolete due to technical developments. Philco’s radio business was flourishing and needed a new product. They got our lab to design their sets—one of them with AVC. This was the Philco 95. It came out in 1929 and captured the market—not as dramatically as the Neutrodyne had six years before, but its royalties supplied the company a good income till World War II.”

Wheeler’s original superheterodyne receiver, using diode linear detection and automatic volume control, is on display in his office on a table near the Neutrodyne.

(continued on page 82)
With characteristic frankness Wheeler admits that his education was not remarkable. In fact, he wonders how his life might have been different if he had gone to MIT instead of George Washington University and Johns Hopkins. Wheeler received a BS in physics in the engineering school at George Washington and did graduate work in physics at Johns Hopkins.

“I don’t know,” he says in answer to his own question. “But I suspect that I might have had less time for early creative work with the more rigorous engineering course I would probably have become involved in at MIT.”

Wheeler never wasted opportunities anywhere.

Born in Mitchell, SD, in 1908, he had read nearly every book that interested him in the public library by the time he and his family moved to Washington, DC.

“I went to high school in Washington. Washington was just emerging from a ‘hick town’ to being a city. But I was not very well advised in some areas in which I should have been prepared, such as Latin. I’m sorry I wasn’t.”

“But life was much simpler in those days,” he points out. “Less demanding. Seven scholarships were given to the high school graduating class for George Washington University and I won one of them. A few days later I dropped by and

These notes and drawings in Harold Wheeler’s engineering notebook led to the invention of automatic volume control.
registered. There was no line, no trouble getting in. And I lived 30 minutes away."

Four years later, after graduating with a BS in physics in the engineering school, Wheeler went to Johns Hopkins, "the nearest good graduate school."

"I had several definite advantages going for me," Wheeler reflects: "I was an early bloomer. At 13 I knew I wanted to be a consulting engineer. I had early exposure to engineering—my father got me a job in the Bureau of Standards Radio Laboratory my first and second summers after high school, which was a tremendous opportunity; I saw things I'd never have seen otherwise. And my father gave me encouragement throughout my schooling and early career days."

The need to innovate

"In 1946 I decided there were some things I wanted to do that I didn't have the freedom to do in a big company, so I left Hazeltine and formed one of my own, Wheeler Laboratories. You can't imagine how easy it is to make decisions when you don't have stockholders to worry about. My objective was to provide manufacturers with specialized engineering services ranging from consultation to advanced development and experimental models.

"But if you think I really had a definite plan, I didn't. I only knew I wanted to do innovative work, and at that time Hazeltine had shifted from engineering to production. The laboratories prospered beyond anything I had any right to expect."

Friends at Bell Laboratories in Whippany, NJ, kept Wheeler and his group of engineers busy, subcontracting to them part of Bell's work on radar and guided missiles.

"It was government work, but we were still able to operate with more freedom than we had at Hazeltine—or could have had at Bell Labs, for that matter. We were free, working under contract, managing ourselves as we liked.

"I gave my engineers enough freedom to develop the group to its maximum. Credit to me goes only for selecting the right men and giving them freedom."

In 1959, however, Hazeltine's president made Wheeler an offer to come back with his laboratories, and Wheeler went. "Work was tapering off anyway at Bell Labs," Wheeler explains, "and military work in general was getting slack."

The golden era ends

"In 1959 the Air Force sent a memo around to contractors saying not to expect them to pay their bills promptly anymore. This was the beginning of the end of a golden era in innovative effort for defense. The end was the Robert McNamara era, which did the Defense Department more harm than we'll ever know," he says.

"The low-bid procedure is insurance against quality, reliability and innovation; it has no place in the field of high technology. "But during most of the fifties the Defense Department was a fertile field for encouraging innovation; this was right at the beginning of the guided-missile phase and the expansion of radar—starting with the Truman administration. It was the greatest period of innovation we have ever had, before or since."

The system ties your hands

Wheeler says engineers never find it easy to do creative work. "Someone's got to pay them, and it's an exception for management to be receptive to innovation."

What can a young engineer do?

"I don't know," Wheeler says. "I think one of the great opportunities today exists with Bell Laboratories. Why? It's a monopoly—a good monopoly." Wheeler pauses a moment. "This isn't to say that Bell Labs always utilizes all its engineering talent in the best way possible, but the opportunities there for innovative work are the greatest of any place in the world."

What about universities? "They're short of money. And again, the labs have more continuity, more far-sighted plans." NASA? "It came and went." FAA? "FAA covers a multitude of sins; which one shall we discuss?"

What qualities must a creative engineer possess?

"He's got to be wired up the right way. You can't attribute his creative ability to education. He's got to have an inquiring mind, deductive reasoning, and abstract reasoning.

"Of course there are all kinds of engineers: innovative and cook-book engineers, and we need both in our society."

New engineers are trained by professors who are out of date, Wheeler feels. "There was a time when a professor could grow along with the advances in society and technology. Now, he can't grow that fast. When I was born, areas of technology and people grew at about the same rate. Technology has got way beyond me now."

The solution? "I wish I knew. Electronic training devices would help. A system that calls for taking notes off a blackboard is too old."

Technology may have gone beyond Wheeler, but no more than it has other engineers. And more important, he's "wired up right." He continues to offer his expertise and invaluable experience to the world of communications and the engineering profession. ■
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Sin

When I was very young I learned, or rather, I was told, that sin was bad. My friends got the same story and, as you might suppose, we looked forward to our first taste, lest we have nothing to repent.

Whatever our feelings might have been, and they were mixed, we knew deep down that sin was bad—especially, we learned later, if discovered.

But now the world is upside down. Opposition to sin has become suitable for Sunday School lessons. But it's out of place anywhere else. We accept with amusement the proposition that a pastry is sinfully delicious. And we avoid motion pictures that feature lust and sin, only because they tend to be boring.

While objection to sin is socially accepted on week-ends, such an objection during the week is often a mark of communist leanings, or at the least, laughable naivete in the ways of the business world.

Isn't it only natural that leaders of our business community should bribe government officials? If they didn't bribe—or make illegal campaign contributions—they might lose business to an unsophisticated competitor. And losing business would be a disservice to stockholders. Should not business leaders bribe—or pay "commissions" to—representatives of other governments so that they can get more business and provide jobs for American engineers? Aren't government officials (paid with our tax dollars) perfectly justified—on the grounds of protecting the reputation of individuals—in withholding the names of Lockheed officials whose activities include corruption of others?

Further, Lockheed employs many engineers. And if Lockheed's management feels it must bribe to get business, and get taxpayer-backed loans to stay in business, then these actions must be proper and wise. For Lockheed's management must surely be wise or it couldn't command high salaries.

I was almost shocked the other day when I learned that Hewlett-Packard had discovered some minor cases of bribery within its company and promptly discharged the offenders. "Don't they know anything about business?" I asked myself, "That's un-American."

Then I realized that the ancient moral edict might perhaps be outdated. Maybe it should be modernized to read: "Thou shalt not sin—except in the interests of business."

George Rostky
Editor-in-Chief
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Use optical fibers for long-range data communications. They provide interference-free operation and better performance than coaxial cables. Here are some fiber basics.

Consider fiber optics for the design of your next long-distance communications system. Fiber-optic links offer performance that coaxial cables can't match, and don't have the failings of wire systems. Presently available coaxial cables for, say, a 102 Mbit/s system have losses that run as high as 33 dB/km. In contrast, a multimode, graded-index fiber has a loss of only 4 dB/km.

Even though fiber-optic cables may cost more initially, repeater-spacing distances can be increased by more than five times, or, in short runs, can be eliminated. (Suggested repeater spacing is about 2 km for coaxial cable.) In addition to the reduced repeater cost, cable sizes are smaller (diameters are usually less than 0.5 in. for optical cables), crosstalk is almost negligible (isolation is usually better than 60 dB) and there is no interference from nearby electromagnetic or radio-frequency fields.

Before you start to design a fiber-optic system, though, let's look at the different types of cable, their specs, and the different transmitting and detecting devices. The performance limit for a long-distance system is, of course, set by both the characteristics of the transmission medium and the signal format. System costs and required performance are the two factors most often traded off.

Let's look at fiber-optic performance

In a fiber-optic system, there are many general specifications that you should consider:

- Source optical power (expressed in milliwatts or dBm). It represents the total amount of optical power emitted by the light source used.
- Spectral width (expressed in Angstroms). This depicts the wavelengths of the light emitted by the source.
- Coupling loss (expressed in decibels). It tells how much power in the fiber-optic link is lost at such discrete junctions as the one between the light source and the cable end.

![Diagram of fiber-optic cables](image)

1. The three major types of fiber-optic cables include the step-index multimode (left), the step-index single mode (middle) and the graded-index multimode (right). The step-index single-mode fiber has the highest efficiency.

- Cable loss (expressed in decibels/kilometer). This represents a distributed loss due to scattering and attenuation within the cable.
- Cable dispersion (expressed in nanoseconds/kilometer, the reciprocal of this spec is a rough estimate of the maximum frequency transmitted over a specified length). It defines how much the transmitted pulse broadens (widens) as the signal propagates in the fiber, and is a combination of multimode, waveguide and material-dispersion effects.
- Receiver sensitivity (expressed in dBm). This tells how much optical power the photodetectors must receive to achieve a specified baseband performance, such as a specified bit-error rate or signal-to-noise ratio.

There are currently three major types of optical fibers in use: step-index multimode, step-index single-mode and graded-index multimode (Fig. 1). The step-index and graded-index multimode fibers are the least expensive, and presently the most widely used. Aside from cost considerations, the choice of fiber type depends on band-
width needed, pulse format and transmission distance.
For long-distance applications at a high data rate, the most important fiber parameters include loss (attenuation), numerical aperture (NA) and dispersion. The loss of a cable reduces the optical power that the detector receives. NA defines the light gathering property of the fiber and can be expressed as

$$\text{NA} = \arcsin \theta,$$

where \( \theta \) is the light-gathering acceptance half angle, and the dispersion defines how the transmitted pulses will widen between repeaters and thus create intersymbol interference.

**Know the fiber problems**

Light can be attenuated in fiber-optic cable by any of three major factors—absorption, scattering and cabling. Absorption is caused by such cable impurities as transition-metal ions and hydroxyl radicals. Material scattering stems from impurities in the fiber core material. The dominant scattering loss in good fibers varies in proportion to the \( \lambda^{-4} \) (wavelength\(^{-4} \)). Cabling attenuation is also caused by radiation from microbends in the material itself.

Scattering attenuation depends on the composition of the fiber material. The lowest loss is available from fused \( \text{SiO}_2 \) (glass); loss increases for materials with higher refractive indices. Highest quality cables are available with attenuations of only 1 or 2 dB/km for a transmission wavelength of 0.82 \( \mu \text{m} \).

The fiber's NA determines the maximum angle from the fiber axis at which light rays can enter the fiber and be transmitted through it. The NA primarily affects the coupling efficiency and the pulse dispersion. The larger the aperture, the greater the coupling efficiency—and, unfortunately, the wider the pulse dispersion too. For low-loss fibers, the NA can be as high as 0.3.

Pulse dispersion stems from three main sources—material, waveguide and multimode. Since the effect of dispersion is to widen the transmitted pulses, it limits the maximum repeater spacing for a fixed data rate.

In single-mode fibers, only material and waveguide effects are present and the total dispersion is mainly controlled by the material properties. The material dispersion depends on the light source's spectral width and emission wavelength.

When the core is large compared with the wavelength, the number of modes increases as the square of the diameter. The spread of an impulse over a distance can be related to the time-arrival difference between the various modes. The delay spread for multimode step-index fibers vs NA, plotted in Fig. 2, shows almost a three-order-of-magnitude difference for different types of

**2. Profiled-index optical fibers** offer a thousandfold performance advantage over step-index fibers. Of course, you'll pay for the decreased delay in the higher cost of the graded fibers.

**3. For the same amount of drive current,** an injection-laser diode can deliver more light power to a fiber than a LED. This is because the light from the laser is totally coherent and thus passes through the cable easier.
fibers, depending upon the aperture.

Multimode dispersion in graded-index fibers is governed by the shape of the index profile. In general, compared with step indexes, profiling reduces the spread of group velocities for the various propagating modes. As can be seen on the graph of Fig. 2, the profiled index materials have a much lower pulse spread.

Ideally, in a perfect multimode fiber structure, the various modes propagate independently. However, structural imperfections such as direction change, refractive-index variations and diameter fluctuations cause mode coupling. This coupling, in turn, causes guided modes to be radiated out of the fiber—especially the higher-order modes near the critical angle. Thus higher modes are attenuated faster and the multimode delay characteristics are rarely encountered in profiled cables.

In addition to high-order mode attenuation, mode coupling reduces the spread in group velocities because modes coupled to each other tend to have a common mean velocity of propagation. If the coupling is equal between modes, the pulse spread will increase in proportion to \((L_w)^{1/2}\), where \(L_w\) is the length at which mode coupling reaches equilibrium. \(L\) will probably be greater than 1 km for low-loss fibers, and \(L\) is the total length of the fiber.

Select the light sources carefully

When you design a fiber-optic system, you must take into account the light source used in the transmitter. Source requirements depend upon the specific application and must usually be custom selected. The main characteristics you should consider during selection include brightness, size, output spectrum, efficiency, life, modulation rate and cost.

The three primary sources available to designers are gallium arsenide LEDs, GaAs injection lasers and Neodymium: Yttrium-Aluminum-Garnet (Nd:YAG) lasers. Presently, much research work is being done on AlGaAs, and it is expected that these devices will fill many of the fiber applications.

Both LEDs and injection lasers use the basic GaAs diode structure and the wavelength of the radiated light depends on the device material and the dopant. The typical emitted radiance of LEDs currently available can be as high as 100 W·cm⁻²-steradian (unit of solid angle) for a drive current of 150 mA and an emission area of \(2 \times 10^{-5}\) cm². The half-power spectral width of these diodes is typically 350 to 400 Å, and their quantum efficiency about 3 percent.

Coupling efficiency for these diodes is very poor with fibers because of the diode's larger incoherent solid-angle emission. Power launched vs NA is much better if you use a coherent light source such as a laser (Fig. 3). LEDs can be easily modulated by directly varying the injected current. Modulation rates of over 100 Mbit/s are possible.

Life expectancies are presently the only limiting factor in LED usage. Current lifetimes of several thousand hours are not sufficient for many applications. Improvements are starting to

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5. P-i-n and avalanche photodiodes are the two most often used detectors in fiber-optic data links. The p-i-n diodes are lower in cost than APDs, but are slightly noiser and slower.
appear and lifetimes of over 100,000 hours will be available shortly. And diode costs should follow the typical price patterns of most other semiconductors—decreasing as the product matures.

Semiconductor injection lasers are well suited for optical-fiber transmitters. Low-current continuous operation at room temperatures has been achieved and is a necessity for reliable source operation. Specially designed devices like the double-heterostructure device shown in Fig. 4 permit the light-output region to be matched to the fiber-core diameter.

For a single transverse-mode laser, the output wavelengths range from 0.7 to 0.9 μm, for optimum device design. Injection lasers can also be easily modulated by controlling the input current. However, in current-modulated injection lasers a phenomenon similar to resonance is caused by the phase relationship between the photon and electron densities, and may excite damped oscillation. This leads to a relatively flat frequency-dependent modulation efficiency, out to some frequency where severe peaking may occur. Typical peaking frequencies range from tenths of a gigahertz to several gigahertz. Modulation rates of up to 2 Gbit/s are possible, though.

The power coupling from a semiconductor laser to an optical fiber depends on the fiber geometry and also on the geometry of the laser-emitting area. Pulse modulation of injection lasers can offer some advantages over current modulation. For example, higher peak optical powers can be obtained and the laser lifetime can be increased. If the laser is pulse modulated without any forward bias, however, a prepumping time is required before lasing action will begin.

In the past, the reliability of injection lasers has been poor, but improved theoretical knowledge and material control have boosted reliability so that devices will soon be available that have a mean-time-between-failure of 100,000 hours.

The Nd:YAG laser offers several advantages over both the LED and injection-laser light sources in transmission systems:
- Its emission wavelength of 1.06 μm coincides with one of the low-loss regions of silica fibers.
- Its longer wavelength also means less scattering loss since scattering is a function of λ^-4.
- Its emission spectral width is narrower than that of injection lasers which, in turn, means less material dispersion.
- Its output is a single-mode, single-frequency light beam and easy to handle.
- Its LED pumping source has a long life; therefore, the over-all life expectancy of the unit is long.

Recently, an experimental unit delivered an output of 52 mW in TEM₀₀ modes at an operating temperature of 269 K when pumped by an array of AlGaAs diodes. Short lengths of fused-silica fibers with Nd-doped cores have been operated as end-pumped lasers and hence, provide extremely high coupling efficiency.

However, Nd:YAG lasers can't be directly modulated at megahertz rates; an optical modulator is therefore a necessary companion for communications applications. The cost of the Nd:YAG laser is higher than the LED or injection sources, but the higher efficiencies will eventually compensate for the difference.

**Match the photodetector to the application**

Once the light signal reaches the end of the cable it must be strong enough to cause a reaction in the detector. A typical optical receiver consists of a photodetector, a front-end amplifier, an equalizer, a filter and demodulation circuitry.

For most fiber applications, the detector is usually a p-i-n or avalanche photodiode. Unlike

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6. This simple graph can help determine the necessary repeater spacing in a fiber optic link. You must specify the bit transmission rate, the fiber type and the light source to determine the spacing.
conventional electrical signals, optical signals have an inherent noise that is signal dependent. To calculate performance, the unique characteristics of optical signals and optical detectors must be taken into account.

In a receiver, there are several noise sources that can be modeled as parallel current sources at the receiver input. The five primary noise sources include quantum noise, background noise (including dark current), surface leakage-current noise, beat noise and amplifier noise.

For applications that use PCM (pulse-code modulation) and have high bit rates and a good detector, the total noise may be closely approximated by the sum of the quantum noise and the amplifier noise. Fig. 5 shows the required average power at the receiver input for a bit-error rate of $1 \times 10^{-6}$. With a p-i-n detector, the bipolar-integrating front-end has a response that is about 3 dB better than a resistively-loaded front end.

![Diagram of a typical PCM receiving system](image)

7. A typical PCM receiving system uses either p-i-n or avalanche detectors, some amplifiers and a high-speed comparator to restore the original signal. The data can then be retransmitted or converted into analog form.

The bipolar transistor also becomes superior to a FET amplifier for data rates of 30-Mbit/s and higher with an avalanche detector. When used in amplifiers, avalanche diodes are more sensitive than p-i-n devices used similarly.

There are a wide variety of modulation techniques for digital-data transmission. Since each has a different power requirement and reliability level, choosing the modulation method is critical.

Once all the system components are selected, they must be put together into a workable system. Depending upon the end-to-end system length, repeaters may be necessary to restore the pulse width and boost signal strength. To determine the repeater spacing, first specify the system bit rate and calculate the repeater spacing by using the maximum acceptable dispersion value or loss.

There are some tradeoffs, though, that should be considered. For instance, if the repeater spacing is limited by multimode dispersion, the NA of the fiber may be reduced, which can increase cable losses even though it increases the possible repeater spacing. If material dispersion limits repeater spacing, reduce the spectral width of the source to boost performance. Or use a better grade of fiber.

If the repeater spacing is loss-limited, the NA spacing—and hence the coupled power—can be increased, which cuts dispersion in multimode fibers. Several tradeoffs are shown in Fig. 6. A typical PCM receiver, shown in block diagram form in Fig. 7, uses standard circuitry to recover the transmitted signal.

The incoming signal can be detected using an avalanche or p-i-n detector, and an amplifier in the front-end. If signal integration occurs as a result of input capacitance, an equalizer must be used to restore the pulse shape. Additional wide-band amplifiers can increase the signal even more. A filter following the amplifier limits the noise and then the prepared signal feeds a high-speed comparator that feeds a D flip-flop. A timing-recovery circuit accepts the comparator's output and provides clock signals to the D flip-flop to retimed the incoming signal. The regenerated PCM can then either be converted into analog form or reconverted into light form as done in a repeater. ■

References

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<th>TYPE</th>
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<th>$V_{CBO}$</th>
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<th>$V_{CE (sat)}$</th>
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Design transistor oscillators with either bipolar or field-effect devices, using admittance data from spec sheets. Here are some circuits and design equations.

By using transistor admittance parameters, you can design bipolar or field-effect transistor oscillators that provide stable, accurate frequencies. Colpitts, Clapp, Hartley, tuned-collector (drain) and tuned-base (gate) oscillators have similar design procedures, once you know the circuit basics and the equations.\footnote{1,2,3,4,5}

Whether you use bipolar transistors or FETs in the high frequency oscillators, data sheets never give you enough information about the hybrid parameters. In most circuit-design courses you are taught how to use the parameters, but they usually are measured at 1 kHz and not the 1 or 10 MHz you really might need.

And most designs are approximate, since only the real part of the complex hybrid terms is used; the influence of the imaginary part (reactive factors) is neglected.

Admittance parameters, though, are given in most transistor handbooks and are specified at high frequencies with both real and imaginary components.

The basic oscillator design

The simplest feedback oscillator circuit uses a transistor and has feedback elements arranged in a \( \pi \) network (Fig. 1). The elements \( Z_1, Z_2, \) and \( Z_3 \) are impedances, and there is also a mutual coupling between elements \( Z_{1L} \) and \( Z_{1n} \). The basic equation that determines the frequency of oscillation,

\[
f = 1 / (2\pi \sqrt{LC})
\]

dates to well before electronic communications became a reality.

If you replace the transistor with its common-emitter equivalent circuit and the feedback impedances with their corresponding admittances, you get the circuit in Fig. 2. Here the internal feedback of the transistor is considered negligible, and its output admittance, \( y_{out} \), is included in the admittance of \( y_{2e} \), where \( y_{2e} = y_{2c} + y_{out} \).

You can use the modulus of the forward trans-
3. The bipolar (a) and the FET (b) Colpitts oscillators use center-tapped capacitors in the tank circuit to determine the frequency of oscillation.

\[ -A (y_{1c} + y_{1e} - 2y_{M}) \] \[ = 1 \] \[ (3) \]

where \( A = y_{1i} y_{1e} y_{3} \).

The basic circuit of the bipolar transistor oscillators (Figs. 3a, 4a, 5a, 6a, 7a) has a thermally stable operating point. Also, the resistance of the divider \( \left( \frac{R_{1}}{R_{2}} \right) \) should be much larger than \( R_{w} \). When the divider resistance is small, you can make it appear large by inserting an rf choke between the meeting point and the transistor base.\(^3\)

The FET oscillators (Figs. 3b, 4b, 5b, 6b, 7b) work either with a gate self bias or a source self bias. The gate bias of the FET is based on the rectifying effect of the gate-source junction, the starting point for oscillation (zero \( V_{GS} \)). This bias can be created by a parallel resistance (Figs. 5b and 6b) or with a series resistance (Fig. 7b). Usually the value of \( R_{g} \) is about 1 M\( \Omega \). Resistor \( R \) develops the source bias (Figs. 3b, 4b).

For the load impedance of the oscillator, \( R_{L} \), to have a negligible effect on the parameters, \( R_{L} \), should be much greater than \( R_{w} \) or \( R_{w} \). When the oscillator is used as a power source, change \( R_{w} \) or \( R_{w} \) with their equivalent resistances \( R_{w}/R_{L} \) or \( R_{w}/R_{L} \). By making this substitution in the equation that gives the starting conditions for oscillation you avoid any loading problems.

The Colpitts oscillator

The basic Colpitts oscillator circuit (Fig. 3a) has admittances in the feedback network that can be represented by equations

\[ y_{1i} = y_{2i} = 0 \quad y_{M} = \infty \]
\[ y_{1e} = j\omega C_{1} \quad y_{2e} = j\omega C_{2} + j\omega C_{M} + 1/R_{w} \]
\[ y_{1s} = 1/R_{i} + j\omega C_{1} \quad y_{3} = 1/(r + j\omega L) \]

To obtain the frequency of oscillation, set the imaginary part of Eq. 3 equal to zero and solve it after substituting in the component values:

\[ f = \frac{1}{2 \pi} \sqrt{1/LC} + (A + B) r/L + AB \] \[ (4) \]

where

\[ 1/C = [1/(C_{1} + C_{s})] + [1/(C_{2} + C_{M})] \] \[ (5) \]
\[ A = [(C_{1} + C_{s}) R_{i}] \] and \[ B = [(C_{2} + C_{M}) R_{w}] \] \[ (6) \]

If the inductance has a low resistance, \( r \), and \( L << (C_{1} + C_{s} + C_{2} + C_{M}) R_{r} R_{w} \), the frequency of oscillation is given by Eq. 1.

Choose \( C_{1} \gg C_{s} \) and \( C_{2} \gg C_{M} \) so that the influence of the transistor input and output capacitances of the frequency is negligible.

The real part of Eq. 3 represents the starting condition of oscillation:

\[ |y_{1s}| \geq A \left( C_{2} + C_{M} \right) + B \left( C_{1} + C_{s} \right) \]
\[ + \left( C_{1} + C_{s} + C_{2} + C_{M} \right) r/L \] \[ (7) \]

The bipolar transistor has \( R_{w} \gg R_{i} \), and if the loss resistance, \( r \), is small, the starting condition simplifies to

\[ |y_{1s}| \geq \left[ \left( C_{2} + C_{M} \right)/(C_{1} + C_{s}) \right] R_{i} \] \[ (8) \]

The FET Colpitts oscillator circuit (Fig. 3b) uses the same equations established for the bipolar Colpitts oscillator. Just replace the \( Y \) parameters of the bipolar device with the \( Y \) parameters of the FET.

The FET has \( R_{i} \gg R_{w} \), and when
L << (C₁ + C₁s + C₂ + C₉)R₁R₉, the frequency of oscillation is given by
\[ f = \frac{1}{2\pi} \sqrt{\frac{1}{L} + \left(\frac{1}{C₁ + C₁s} + \frac{1}{C₂ + C₉}\right) \frac{r}{R₉}} \]  
where C can be found from Eq. 5 when FET parameters are used. If the loss resistance, r, is small the frequency of oscillation is determined by Eq. 1.

The influence of C₁s and C₉ on the frequency of oscillation becomes negligible if
\[ C₁ >> C₁s \text{ and } C₂ >> C₉. \]

The starting condition for oscillation is as given in Eq. 7, except that FET parameters are used. When r is small and \( R₁s >> R₉ \), this reduces to
\[ |y_{pe}| \geq \left(\frac{1}{C₂ + C₉}\right) \frac{r}{R₉} \]

The frequency of oscillation for this circuit is not influenced too much by the transistor input capacitance, because C₁ is much larger than it is for the bipolar Colpitts circuit.

The Clapp oscillator

A variant of the Colpitts oscillator, the Clapp, has better frequency stability (Fig. 4a). Thus the admittance, \( y_0 \), of the feedback network is
\[ y_0 = \left[ r + j(\omega L - 1/\omega C₁) \right] - 1 \]
The frequency of oscillation can now be found:
\[ f = \frac{1}{2\pi} \left\{ 1 + \left[ \frac{1}{(1/L)} + \frac{A + B}{(r/L)} \right] \frac{1}{\omega L} \right\} \frac{1}{\omega C₁} \]
where A and B are as defined in Eq. 9.

When r is small and \( LC << (C₁ + C₁s) \), the formula for frequency of oscillation simplifies to Eq. 1.

If the value of C₁ is much smaller than the values of C₁ and C₂, the frequency of oscillation is not influenced by C₁s and C₉. It becomes equal to the resonant frequency of series circuit LC₁ and is determined by Eq. 1.

The starting condition for oscillation is given by
\[ |y_{pe}| \leq \left(\frac{A}{C₂ + C₉}\right) + \frac{B(C₁ + C₁s)}{C₂ + C₉} \frac{r}{LC₁} \]
where A and B are as defined in Eq. 13.

This simplifies to the same form as that in Eq. 8, if the assumptions in Eq. 7 are used.

The FET Clapp oscillator circuit (Fig. 4b) takes into account that \( R₁s >> R₉ \). If \( LC << (C₁ + C₁s) \), the frequency of oscillation is determined by
\[ f = \frac{1}{2\pi} \sqrt{\frac{1}{L} + \frac{r}{LC₁}} \]
where B is defined in Eq. 6.

As with the Colpitts oscillator, if r is small the frequency of oscillation is given by Eq. 1.

When the value of C₂ is much less than C₁ and C₉, the frequency of oscillation is determined by LC₁, substituted into Eq. 1.

The starting condition for oscillation is given by Eq. 13, with the equivalent FET parameters substituted. Again, if you make the same simplifications, the equation reduces to Eq. 10.

The Hartley oscillator

The admittances of the feedback network in the Hartley oscillator circuit (Fig. 5a) can be represented by
\[ y_{1c} = y_{ωc} = 0 \]
\[ y_{1t} = (r₁ + jωL₁)^{-1} \]
\[ y_{2t} = (r₂ + jωL₂)^{-1} \]
\[ y_{3} = (jωM)^{-1} \]

The coupling coefficient between L₁ and L₂ is given by
\[ K = M(L₁L₂)^{-1} \]

If the coil is built on a ferrite core, K can be considered equal to unity. You can also assume that \( R₁s >> R₉ \), so that the frequency of oscillation becomes
\[ f = \frac{1}{2\pi} \left\{ \left[ 1 + \frac{r₁}{R₁s} \right] \frac{1}{LC₁ + L₁C₉} \right\} \frac{1}{\omega L}_c \]
where
\[ L = L₁ + L₂ + 2M \]

The resonant frequency of the parallel circuits L₁C₁ and L₂C₉ affects the frequency of oscillation. If the value of C is much larger than C₁ and C₉, and the inductor loss resistances r₁ and r₂ are small, the frequency of oscillation is rep-
are given by the equations
\[ y_{t,0} = 0 \quad y_{s,0} = 0 \]
\[ y_{t,1} = (j\omega L_1)^{-1} \quad y_{s,1} = (r_s + j\omega L_2)^{-1} \]
\[ y_{t,2} = (j\omega M)^{-1} \quad y_{s,2} = (r_s + j\omega L_2)^{-1} \]
\[ y_{t,c} = R_{t,0}^{-1} + j\omega (C_1 + C_{oT}) \]

When the coupling coefficient, \( K \), equals 1 and \( L_r/L_2 = \gamma^2/R_1^2 = \gamma^2 \) and \( R_m >> R_{t,0} \), the frequency of oscillation can be found from
\[ f = \left( 1/2\pi \right) \left\{ \left[ 1 + r_s/R_{t,0} \right] \cdots \times \left[ L_2 C + L_r r_s (C_1 + C_{oT})/R_{t,0} \right] \right\}^{1/2} \]

where
\[ C = C_1 + C_{oT} + C_{oT}/\gamma^2 \]

\[ C_{oT}/\gamma^2 \] represents the reflected capacitance from the base circuit. When \( r_s \) is small and
\[ C_r >> C_{oT} + C_{oT}/\gamma^2 \]

the frequency of oscillation becomes equal to the resonance frequency of the parallel circuit \( L_2 C_r \), which can then be found from Eq. 1.

The following equation gives the starting condition:
\[ |y_{t,c}| \geq M/(L_1 R_{t,0}) \]

You can make assumptions comparable to those in Eqs. 7 to reduce Eq. 24 to
\[ |y_{t,c}| \geq M/(L_1 R_{t,0}) \]

For the coupling coefficient equal to 1, you can rewrite the equation as:
\[ |y_{t,c}| \geq 1/\gamma R_{t,0} \]

The tuned-drain oscillator circuit (Fig. 6b) takes into account that \( R_{t,0} >> R_{t,0} \). Thus the frequency of oscillation is
\[ f = \left( 1/2\pi \right) \sqrt{(1 + r_s/R_{t,0})/(L_1 C + L_2 r_s C_{oT}/R_{t,0})} \]

When \( r_s \) is small and \( C \) is defined by Eqs. 22 and 23, the frequency can be found from Eq. 1.

The starting condition is the same as that used for the tuned-collector oscillator (Eq. 24) and can be simplified to
\[ |y_{t,c}| \geq M/\gamma R_{t,0} \]

Thus for \( n \) greater than 1, the frequency of oscillation will hardly be influenced by the transistor input capacitance.

The tuned-base (gate) oscillator

The admittances in the feedback network of the tuned-base oscillator circuit (Fig. 7a) are given by these expressions:
\[ y_{t,1} = (r_s + j\omega L_1)^{-1} \quad y_{s,1} = (j\omega L_2)^{-1} \]
\[ y_{t,2} = j\omega C_1 \quad y_{s,2} = y_{s,0} = 0 \]
\[ y_{t,0} = j\omega M \]

If the coupling coefficient is unity and we replace \( L_1/L_2 = \gamma^2 \) then the frequency of oscillation is given by
\[ f = \left( 1/2\pi \right) \left\{ \left[ 1 + r_s/R_{t,0} \right] \cdots \times \left[ L_2 C + L_r r_s (C_1 + C_{oT})/R_{t,0} \right] \right\}^{1/2} \]

where
\[ C = C_1 + C_{oT} + C_{oT}/\gamma^2 \]

Similar assumption as those that follow Eq. 22 can be made for this equation, and the fre-
quency of oscillation becomes equal to the resonant frequency of parallel circuit $L, C$, and can be found from Eq. 1.

The following equation gives the starting condition for oscillation:

$$|y_f| = M/L, R_{os} + L, M R_{gs} + r_t (C_t + C_{gs}) - M + L, r_t/M R_{gs} R_{os}. \quad (31)$$

If $r_t$ is small and $R_{os} >> R_{gs}$,

$$|y_f| = L_t/(M R_{gs}). \quad (32)$$

If the coupling coefficient equals unity the equation simplifies to

$$|y_f| = n/R_{gs}. \quad (33)$$

In the tuned-gate oscillator circuit (Fig. 7b) you can assume $R_{gs} >> R_{os}$. The frequency of oscillation then becomes

$$f = 1/2\pi \sqrt{L_t C_t + L_t r_t (C_t + C_{gs})/R_{os}} \quad (34)$$

where $C$ is the same as in the tuned-base oscillator, except for substitution of FET parameters. When $r_t$ is small and

$$C_t >> C_{gs} + C_{os}/n$$

the frequency of oscillation can be found from Eq. 1. The starting condition for oscillation of the tuned-gate circuit has the same form as that for the tuned-base oscillator, except for FET parameter substitutions.

Since $R_{gs} >> R_{os}$, $r_t$ is small and the coupling coefficient is unity, this equation simplifies to

$$|y_f| = 1/n R_{os}. \quad (35)$$

Designing the oscillator

To design an oscillator, select the type and the active element. Assume, for example, that you have a Colpitts oscillator that uses a FET. If you arbitrarily select a FET—in this case a 2N3330—and a frequency of oscillation of 1 MHz along with a supply voltage of 9 V, you need only the FET data sheet.

From the data sheet, you can extract the following: $P_{o max} = 300$ mW, $y_{fs} = 1.5$ mhos at an $I_D$ of 2 mA, $C_{fs} = 20$ pF and $g_m = 1. R_{os} = 40$ $\mu$hos. Now assume a value for the inductance—say, $L = 100$ $\mu$H. If you rearrange the basic formula for frequency of oscillation (Eq. 1), the total value of $C$ is found to be

$$C = 1/(6.28 \times 10^4)^2 (100) (10^4) = 254 \mu F$$

To satisfy the starting condition for oscillation —taking into account the distributed static characteristics of the transistor—you can assume

$$|y_f| = 2C/C_{os}. \quad (36)$$

$$1/C = 1/C_1 + 1/C_2$$

Solving these equations for $C_1$ or $C_2$, you get

$$C_1 = [2 + |y_f| R_{os}]/|y_f| R_{os} = 270 \mu F$$

and

$$C_2 = [2 + |y_f| R_{os}]/2 = 5000 \mu F$$

The circuit of Fig. 8 shows the FET Colpitts oscillator with the calculated values. Ten FETs of the same type number were used to determine experimentally the spread of oscillation frequencies. The spread ranged from 1.0011 to 1.0029 MHz. And the oscillator output at the drain was measured to be 6 V. ■

References:

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Electronic Design 8. April 12, 1976

CIRCLE NUMBER 43
Select mixer frequencies painlessly. With a simple, graphical method, you can sidestep long trial-and-error sessions and determine bandwidth, too.

If you've ever become bogged down in the calculation of mixer frequencies, you'll appreciate a simple, graphical selection technique that avoids the voluminous printouts of computer-aided iterations and trial solutions.

With this procedure, you can visually select the appropriate mixer frequencies to meet your spurious requirements. Only those spurs whose levels exceed the given spec are plotted on the chart. As an added benefit, you can map the output bandwidth onto the spur chart as a function of the bandwidths of the two input signals. The region thus described is an irregular hexagon with sides defined by the relative bandwidths and ratios of the mixing tones.

This definition of the locus of output frequencies mapped on the spur-chart plane lets you select mixer frequencies rapidly and lends further usefulness to the chart. (The spur chart has been available since 1966 but has not been widely used because of a poor understanding of bandwidth effects.)

Derivation of equations

Typical spurs of high and low-level mixers are shown in Figs. 1 to 4. The ordinate is the frequency ratio $f_1/f_2$, and the abscissa is the percentage bandwidth with respect to the desired output frequency, $f_o$, where $f_o = f_1 + f_2$ for the sum charts, and $f_o = f_2 - f_1$ for the difference charts ($f_2 > f_1$).

To derive the equations that generate the graphs, note that the spurs, or cross-modulation products, have the general form

$$P = M f_1 + N f_o,$$  
where $M$ and $N$ are positive or negative integers. The frequency ratio, $n = f_1/f_o$, is always less than 1. Percentage separation is given by:

$$S = \frac{P - f_o}{f_o} \times 100$$  

or

$$P = \frac{f_o S + f_o}{100}.$$  

Eq. 1 and 2 can be rewritten for the case $f_o = f_1 + f_2$:

$$f_o = \frac{P - M f_1}{N - M}.$$  

Then the frequency ratio, $n$, can be expressed, with use of Eq. 4, as

$$n = \frac{f_1}{f_2} = \frac{f_1 - f_2}{f_2} = \frac{N f_o - P}{P - M f_1}.$$  

Eq. 4 and 5 are both undefined for the case $N = M$. To simplify calculations, such spurs are deleted from this computation. It can be shown, however, that the $N = M$ spur lines are vertical and appear on the summing mixer chart at $S = (N - 1) \times 100$. Similarly, the analysis of difference mixing does not consider spurs where $N = -M$. These, too, are vertical lines on the chart, with $S = (N - 1) \times 100$.

Now, with use of Eq. 3, Eq. 5 becomes

$$n = \frac{- S + 100 (N - 1)}{S - 100 (M - 1)}.$$  

This equation relates $n$, the frequency ratio, to $S$, the percentage separation, for $f_o = f_1 + f_2$ and is used to plot the sum charts.

Similarly, for $f_o = f_2 - f_1$, Eq. 1 can be rewritten

$$f_2 = \frac{P + M f_o}{N + M}.$$  

Again, the frequency ratio, $n$, can be expressed, with use of Eq. 7, as

$$n = \frac{f_1}{f_2} = \frac{f_1 - f_2}{f_2} = \frac{P - N f_o}{P + M f_o}.$$  

Now, using Eq. 3, we see that Eq. 8 becomes

$$n = \frac{S + 100 (1 - N)}{S + 100 (1 + M)}.$$  

Eq. 9 relates $n$ and $S$ for $f_o = f_2 - f_1$, and is used to plot the difference charts.

Calculator does the plotting

A program written for the HP 9810 calculator uses Eqs. 6 and 9 to plot spurs for any $M$ and $N$. If all the spurs to the seventh order are plotted, the graphs are seen to be identical to those in reference 1. However, many of the spurs that are plotted with this procedure are very small in

M. Y. Huang, Section Head, R. L. Buskirk, Member of the Technical Staff and D. E. Carlile, Member of the Technical Staff, Communications Satellite Transponder Dept., TRW Systems Group, One Space Park, Redondo Beach, CA 90278.
1-4. Harmonic spurs of mixers can be charted as a function of output bandwidth for differences (1 to 3) and sums (4). Note that about the same spurs appear in both low and high-level mixers (1 and 2). When signal drive is decreased in the high-level mixer, however, the spurs are reduced (3).
5. Filter output-band mapping is demonstrated with a section of the summing-mixer spur chart. Harmonics are easily located relative to the output bandwidth.

6. Output spectrum for pre-filtering (top) and post-filtering (bottom) shows that filtering reduces the out-of-band spurs but not the in-band harmonics.

7. Upconversion of two frequency bands: frequencies \( f_1 \) and \( f_2 \) lie at the center of each of the respective bands. Output band appears at right.

8. The upconverted output of Fig. 7 appears on the spur-chart plane distributed about the \( f_1/f_2 \) point. Incremental effects of frequency changes are easily spotted.
9. Calculator program plots the hexagonal locus of points resulting from variations in the values of \( f_1 \) and \( f_2 \). The dimensions of the hexagon vary with the ratio of the input bandwidths: For zero bandwidth, the hexagon becomes a quadrangle. The hexagon can be plotted onto the spur chart with an HP 9810 calculator.

**How to use the charts**

To accomplish such a mapping, consider first the simple case of mixing two fixed frequencies. Given the two input frequencies and an output frequency range, you can plot a line for the function of percentage separation vs \( f_1/f_2 \). (The value of \( f_1/f_2 \) corresponds to the ratio of signals producing the selected output tone \( f_1 + f_2 \) or \( f_2 - f_1 \).) The end points of the line can be called \(-BW\) and \(+BW\) and are calculated from Eq. 2:

\[
+BW = \frac{f_{BW} - f_o}{f_o} \times 100, \quad (10)
\]

\[
-BW = \frac{f_{BW} - f_o}{f_o} \times 100 \quad (11)
\]

where \( f_{BW} \) is the upper edge of the output filter passband, \( f_{ BW } \) is the lower edge, and \( f_o \) is the desired instantaneous output frequency.

The points along this straight line correspond to frequencies within the filter passband. The curves for various orders of harmonic spurs are displayed similarly—that is, each point on the line corresponds to a frequency. (This frequency is determined by the specific values of \( f_1 \) and \( f_2 \), thus defining a specific point on the ordinate.)

The use of these graphic definitions can best be explained with an example. A small portion of the summing-mixer spur chart may look as shown in Fig. 5. Let \( f_1 = 20 \, \text{MHz} \) and \( f_2 = 150 \, \text{MHz} \). (This will quickly prove to be a poor frequency assignment.) Then \( f_1/f_2 = 0.133 \). Also, define the output filter bandwidth to span 125 to 175 MHz. The spur chart indicates that for this \( f_1/f_2 \) value, the filter bandwidth extends from 3% above \( f_o \) to 26% below \( f_o \). The chart also shows the \( f_2, 7f_1, \), and \( f_2 - f_1 \) spurs intersecting the filter line. These points indicate in-band harmonics, as can be verified numerically.

Plots of the output spectrum (prefiltering and postfiltering) for this example are shown in Fig. 6. The in-band spurs—those intersecting the filter
10. **Calculator program** for the circuit in (a) maps a "hexagonal" perimeter when \( f_1 \) and \( f_2 \) vary in infinitesimal steps (b).

11. **Design example:** Figures generated by five different bandwidths show the advantage of a small bw at \( f_1 \).

12. **Other trends are shown** by various frequency assignments. Shown are the benefits of a smaller bw for \( f_1 \).

Locus approximates a hexagon

Again, a decrease in \( f_2 \) causes the reverse to occur. Now for each value of \( f_1 \), you can also vary \( f_1 \); this results in a region bordered by a hexagon. Because of the normalization by the
local value of $f_\text{m}$, the sides of the hexagon are not straight lines but hyperbolic arcs. However, the curvature is very slight, and for all practical purposes, the sides can be thought of as straight lines.

Another program for the HP 9810 calculator plots the hexagon on the spur chart (Fig. 9). Fig. 10 shows an example generated by this program. To help illustrate the earlier discussion, the mapping of the output bandwidth for each set of $f_i$ and $f_s$ values is also superimposed ($f_i = 16, 17, 18, \cdots 24$; $f_s = 30, 39, 48, 57$). If you change $f_i$ and $f_s$ in infinitesimal steps, rather than the 1 and 9-MHz steps of the example, you end up with a region whose perimeter is defined by the hexagon shown.

An example outlines the use of this program as a design tool. For a proposed output bandwidth spanning 800 to 880 MHz, choose input frequencies between, say, 220 and 620 MHz to give a favorable $f_i/f_s$ value on the summing-mixer spur chart. Fig. 11 is a plot of the areas (through which spur lines cannot be tolerated) for five different bandwidth assignments for $f_i$ and $f_s$. This graph clearly shows several important features.

As mentioned previously, the dimensions of the hexagon change with the ratio of input bandwidths. In the two cases of zero bandwidth, the hexagon degenerates to a quadrangle. The total horizontal excursion of the figures remains constant for a constant percentage output bandwidth. Thus, for a given acceptable harmonic output level and absolute output bandwidth, a minimum center frequency for the output signal is defined for either sum or difference mixing.

Furthermore areas free of spurs for various ranges of $f_i/f_s$ indicate suitable ratios of the input signals. Minimum $f_i/f_s$ ranges are obtained when the lower input signal is given the smaller bandwidth. (This is also a favorable condition for realizable filters in a network of mixers.) In some applications the shape of the hexagon may be important in the elimination of spurs. Again, this can be adjusted with the ratio of the absolute bandwidths of the input signals.

Exact relations between frequency assignment parameters have not been established. But Figs. 12 through 14 provide examples of the trends. These confirm what intuition suggests. The smallest region is of general interest when you map the output bandwidth on the spur chart.

Fig. 11 shows that it is preferable to have wider bandwidths with the higher mixing frequency than vice versa. Figs. 12 and 13 show that a smaller percentage output bandwidth is superior. Fig. 14 suggests that you should choose low $f_i/f_s$ ratios, but this suggestion is tempered by the actual bandwidths and the spurs that appear, as shown in Figs. 1 to 4. Graphs for difference mixers exhibit similar trends.

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Teletypewriter printouts for minicomputers, data loggers and alarm monitors are frequently short and infrequent; thus, to save wear, the teletypewriter unit should be switched on only during data reception. If a computer-operated relay is available, of course it’s simplest merely to use it; however, it is often not available.

The circuit in Fig. 1 senses when data are available, turns the teletypewriter on and keeps it on until data arrival ceases for 100 s. Since the teletypewriter motor requires 300 ms to reach full speed, the first three characters in each data block must be in nonprinting codes.

The circuit is coupled to the teletypewriter’s data-input with an optical coupler connected in series with the teletypewriter’s code coil. The teletypewriter is turned on and off by a relay contact in series with the power to the teletypewriter’s Line/Off/Local switch, with the switch set to the Line position.

The code coil is continuously energized when data are not being received; with no data, LED, Q, and Q, are on. However, the first bit in a data block de-energizes the code coil, and LED, Q, and Q, turn off. Since triac Q, turns off together with Q, relay K, drops out and closes the teletypewriter power circuit via a normally closed contact on K,. The on-off action of the incoming data, and consequently of Q,, keeps C, in a discharged state, which prevents the unijunction transistor, Q,, from firing and turning on Q,. Consequently, the teletypewriter remains switched on.

When data reception ends, Q, remains off; C, charges through R, and R, and after about 100 s fires Q, to energize K, and open the power circuit.

Capacitor C, provides an initial surge current to help fire Q,. After Q, turns on, D, keeps the voltage on C, low to prevent Q, from oscillating. The 100-s delay in turning off the teletypewriter eliminates unnecessary starts and stops.

J. R. Saltvold, Reactor Analysis Branch, Atomic Energy of Canada Ltd., Pinawa, Manitoba, Canada, ROE 1LO.

CIRCLE NO. 311

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A digital high/low-pass filter features voltage-adjustable cut-off points

You can build a high-pass and low-pass filter circuit for TTL signals without inductors or the need for complicated circuit networks. Inputs below a selected frequency appear at a low-pass output and those above at a separate high-pass output (Fig. 1). The cut-off frequencies are adjustable over a wide range and controlled by only a level. This allows for easy remote operation.

The basic frequency discriminator element is IC₁, an SN-54161 asynchronous counter. The input TTL signal feeds into the counter's clock input, which is enabled only when the clear is HIGH. If during this enable period the input frequency can generate 16 or more leading edges, the counter delivers a carry output that is inverted by G¹ and used to reset the R-S flip-flop, G₂ and G₃. The G₃/G₂ flip-flop is set by any pulse to G₁ from the Q₄/Q₁, voltage-controlled free-running multivibrator output. The G₄/G₅ flip-flop outputs control gates G₆ and G₇ to provide a smooth decision criterion and to separate the low and high-pass outputs.

Because of the asynchronous operation of the counter, a possible one-count ambiguity in 16 counts results in a frequency indeterminacy, or "knee," equal to about 6% of the set frequency. For 100 kHz, this would be ±3 kHz. The knee could be made smaller by use of a counter with more stages.

The multivibrator output has a fixed-period portion, and the period of the other portion is voltage controlled by the current-source circuit of Q₁ and Q₂. The variable portion is wider and its width, PW, varies linearly with the current supplied from the voltage-controlled current-source. As V₁ is raised, the current to the base of Q₁ increases, C₁ charges at a more rapid rate and time interval PW becomes narrower. The counter is enabled during the PW intervals; thus the pass frequencies are inversely proportional to PW.

The filter's cut-off, or trip, points and ambiguity range can be expressed by the relationship

\[
\frac{1}{15} \text{PW} \leq f_{\text{trip}} \leq \frac{1}{16} \text{PW},
\]

where

\[
\text{PW} = K \frac{C_1}{I_{R2}}.
\]

Constant K has been experimentally determined to be approximately 3.6, and since

\[
I_{R2} = \frac{V_{cc} - V_{in}}{R},
\]

then

\[
V_{cc} - V_{in} \leq f_{\text{trip}} \leq \frac{V_{cc} - V_{in}}{16(3.6)C_1R}.
\]

For the circuit values shown in Fig. 1 the trip points are adjustable over 25 to 120 kHz.

Michael F. Black, Advanced Engineering Branch, M/S 295, Texas Instruments Inc., 13500 N. Central Expressway, Dallas, TX 75222.

CIRCLE NO. 312

1. The variable period of the Q₁/Q₂ one-shot controls the trip point of this low and high-pass digital filter.

---

Electronic Design 8, April 12, 1976
Memories are made of this.

The Harris family of GENERIC PROMs

Once you know about the Harris family of GENERIC PROMs, stand-alone PROM designs are easy to forget. That's because the diverse requirements for density, modularity and performance within a system can be completely satisfied by our one GENERIC family.

As a result, there are many advantages of the Harris GENERIC PROMs to keep in mind. Like compatible DC electrical specifications and common programming requirements.

Fast programming speed (guaranteed 1 ms per bit max.) Equivalent I/O characteristics for easy upgrading. Fast access time, guaranteed to meet worst case N° sequencing over temperature and voltage. And improved testability.

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So remember, if you want PROMs with common programming requirements, low system costs, and the highest performance, get the Harris family of GENERIC PROMs. It'll give you plenty of great memories.

<table>
<thead>
<tr>
<th>Device #</th>
<th>No of Bits</th>
<th>Organization</th>
<th>No of Pns</th>
<th>Max Access Time*</th>
<th>Price 100 up</th>
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<tbody>
<tr>
<td>HM 7602</td>
<td>256</td>
<td>32x8</td>
<td>16</td>
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<tr>
<td>HM 7610</td>
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<tr>
<td>HM 7620</td>
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<td>HM 7643</td>
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<td>1024x4</td>
<td>18</td>
<td>70ns 85ns</td>
<td>$19.95 $39.95</td>
</tr>
</tbody>
</table>

* Access time guaranteed over full temperature and voltage range. Industrial (TA = 0°C to 70°C, VCC ± 5%) Military (TA = 55°C to 125°C, VCC ± 10%)

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CIRCLE NUMBER 51
Digital circuit detects frequency-modulated signals

A digital circuit can be used to demodulate frequency-modulated (FM) signals (Fig. 1). First, a sinusoidal FM input signal, \( f_\text{c} \pm \Delta f_\text{m} \), is converted to a square wave by a comparator. The output of the comparator is then divided into two digital signals. One signal goes directly to an Exclusive-OR circuit; the other is sampled by a clock and entered serially into a shift register.

The frequency of the clock, \( f_\text{s} \), must be sufficiently high to preserve faithfully the zero crossings of the square wave. The shift register provides a fixed delay, which is the equivalent of a phase shift proportional to frequency. The length of the shift register must equal \( f_\text{s} \cdot 4f_\text{c} \) so that the center frequency, \( f_\text{c} \), receives a phase shift of 90 degrees. If \( f_\text{s} = 40f_\text{c} \), only 10 register stages are needed.

Frequencies higher than \( f_\text{c} \) receive phase shifts greater than 90 degrees; frequencies lower, receive less.

The shift-register output is combined with the direct signal in the Exclusive-OR circuit to obtain an output whose average value is proportional to the input frequency. This signal is then low-pass filtered to remove the high-frequency carrier components. If the input frequency is FM, the filter's output reproduces the modulating signal, \( f_\text{m} \).

Fig. 2 shows typical waveforms at the inputs and output of the Exclusive-OR circuit for frequencies \( f = f_\text{c} \), \( f > f_\text{c} \), and \( f < f_\text{c} \).


CIRCLE No. 313

SEND US YOUR IDEAS FOR DESIGN. You may win a grand total of $1050 (cash)! Here's how. Submit your IFD describing a new or important circuit or design technique, the clever use of a new component or test equipment, packaging tips, cost-saving ideas to our Ideas for Design editor. Ideas can only be considered for publication if they are submitted exclusively to ELECTRONIC DESIGN. You will receive $20 for each published idea, $30 more if it is voted best of issue by our readers. The best-of-issue winners become eligible for the idea of the Year award of $1000.

IFD Winner of December 6, 1975

Roy A. McCarthy, Production Engineer, GYYR Div., Odetics, Inc., 1845 S. Manchester Ave., Anaheim, CA 92802. His idea “Microvolt Probe Traces PC Current Paths to Help Locate Those Defective ICs” has been voted the Most Valuable of Issue Award.

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Supplied in standard 16” lengths, series 97-520 is ideal for metal cabinets and electronic enclosures where variations exist in the space to be shielded, and where high shielding effectiveness must be maintained in narrow spaces, even with frequent opening and closing of the cabinet.

Select the exact series that fits your application best. Write today for a complete catalog, list of finishes available, and our latest Independent Shielding Evaluation Report. Address: Dept. ED-68.

Series 97-500*—the original ¾” wide Sticky Fingers. For greatest possible shielding and where space permits. Also available: Series 97-505—90° configuration of Series 97-500, same shielding effectiveness.

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*For under $1200*

**FROM 1 MHz TO 960 MHz IN ONE SWEEPER**

**WB-713 SPECIFICATIONS**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Details</th>
</tr>
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<tbody>
<tr>
<td>Frequency Range — Band I</td>
<td>1 to 500 MHz</td>
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<tr>
<td>Band II</td>
<td>450 to 960 MHz</td>
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<tr>
<td>Sweep Width — Bands I and II</td>
<td>0.1 to 500 MHz</td>
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<tr>
<td>Output</td>
<td>+10 dBm</td>
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<tr>
<td>Flatness</td>
<td>± 0.25 dB</td>
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<tr>
<td>Distortion — Band I</td>
<td>- 35 dB</td>
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<tr>
<td>Band II</td>
<td>- 30 dB</td>
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<tr>
<td>Residual FM</td>
<td>Less than 10 kHz</td>
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<tr>
<td>Sweep Rate</td>
<td>0.01 to 100 Hz variable</td>
</tr>
<tr>
<td>Linearity</td>
<td>1%</td>
</tr>
<tr>
<td>Markers</td>
<td>Provisions for up to 7 plug-in harmonic or single frequency markers.</td>
</tr>
<tr>
<td></td>
<td>Marker Tilt Control</td>
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<tr>
<td></td>
<td>Marker Clip Control</td>
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<tr>
<td></td>
<td>Marker Width Control from 20 kHz to 300 kHz</td>
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<tr>
<td>Weight</td>
<td>15 lbs.</td>
</tr>
<tr>
<td>Size</td>
<td>9&quot; x 4 3/16&quot; x 12 5/8&quot;</td>
</tr>
</tbody>
</table>

Texscan has sweep generators covering from Audio to 2350 MHz. Please contact your local Texscan representative for a demonstration.

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**CIRCLE NUMBER 53**
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CIRCLE NUMBER 55
Impedance converters buffer signals without loading


Got a signal you want to amplify and afraid of loading it down? Fret no more—Siliconix has just introduced a single-chip JFET impedance-converting preamplifier with internal biasing. It can buffer high-impedance signals without loading the minimum input resistance of 200 MΩ (typically 50 Ω).

There are two versions of the impedance converter available—the T100 and T300. Both are four-terminal units housed in TO-72 packages, or they are available as chips. The T100 unit is a micropower preamp that draws a minimum drain current of 10 μA and a maximum of 50 μA. The T300 requires from 70 to 350 μA.

Both converters have an operating supply-voltage range of 1.3 to 30 V and can handle input signals (with respect to ground) that span 2 to 2 V. Total harmonic distortion for either preamp is typically 1%. Input capacitance for the units is typically 3 pF and is guaranteed to be 4 pF, max. Output capacitances are typically 4.4 pF and are guaranteed to be 6 pF, max.

Aside from the supply current differences, the T100 has an output resistance that can be between 1.5 kΩ, minimum and 3.5 kΩ, maximum. It also has a maximum broadband output noise of 4 μV. The T100 has a voltage gain of 0.4, minimum, and 0.6 typical.

The T300 offers an output resistance that ranges from 500 Ω, minimum, to 1300 Ω, maximum, and has a broadband output-noise voltage of 2 μV, maximum. It has a voltage gain of 0.3, minimum, and 0.45, typical.

The maximum forward gate current for the impedance converters is 1 mA and the total unit dissipation at 25°C is 180 mW. For operation at higher temperatures the preamps must be derated by 3 mW/°C. The units have an operating range of -25 to +85°C.

Comparable circuits can be built with discrete components but a larger package would then be required. The total cost would be more than double that of the T100 or T300. With discrete-component versions such as the Model 320 from Eltec (Daytona Beach, FL), though, you can get different input bias levels, output resistances and transistor types.

Prices for the Siliconix preamps start at $2.95 for the T300 and 67¢ for the T100, both in 100-up quantities and TO-72 packages. Delivery is from stock.

Schmitt trigger combines with flip-flop

RCA, Solid State Div., Route 202, Somerville, NJ 08876. (201) 722-3200. 95¢ to $1.10 (100).

A programmable Schmitt trigger with an internal flip-flop to assure positive switching, the CA3098 provides a precision level-detector hysteresis switch with a dual input for performing over/under or high/low control functions. It can be operated with either a single power supply—16-V max—or dual supply—±8-V max. It can directly control currents up to 150 mA, and operates with microwatt standby power dissipation when the current to be controlled is less than 30 mA.

3-state transceiver extends busses

Motorola, P.O. Box 20924, Phoenix, AZ 85036. (602) 244-3251. $2.95 to $3.95 (100).

A Schottky-TTL quad transceiver extends the data-bus capacity of systems using the M6800 processor or other comparable MOS microprocessors. Each M6880/MC-8T26 contains four 48-mA inverting drivers and four 20-mA inverting receivers. Both drivers and receivers are short-circuit protected and feature three-state capability.

IC simplifies data comm systems

Etude et Fabrication de Circuits Intégrés Speciaux, 17, Avenue des Martyrs, 28 Grenoble, France.

A universal biphase receiver/transmitter (UBRT) offers baseband modulation and demodulation, half and full-duplex modes and rates up to 75,000 bits per sec. The UBRT is compatible with Intel's 8080 interface module, and it can be programmed to have 8 to 64 synchronization bits in transmission and 4 to 32 bits in reception. The MOS chip comes in a 28-pin package and uses 5 and —12-V supplies. In 1000 quantities, the the UBRT costs 110 French Francs.
We have your High-Rel Hybrids!

INTEGRATED CIRCUITS

S-TTL octal buffers dissipate 80 mW

National Semiconductor, 2900 Semiconductor Dr., Santa Clara, CA 95051. (408) 732-5000. $1.35 (100); stock.

Four three-state octal buffer ICs, employing low-power Schottky-TTL, have a typical power consumption of less than 80 mW and typical propagation delay of less than 14 ns. Each device in the new DM81LS95 through 98 series provides eight two-input buffers in a single package. The DM81LS95 and 97 present True data at their outputs, while the DM81LS96 and 98 invert the data.

Hi-fi audio IC supplies 20 W

SGS-ATES Semiconductor Corp., 435 Newtonville Ave., Newtonville, MA 02160. (617) 969-1610. $5.20 (100); stock.

A monolithic audio IC that provides hi-fi performance, the TDA2020 supplies 20 W of rms output power into a 4-Ω load with less than 1% THD over the frequency range of 40 Hz to 15 kHz. The output power with an 8-Ω load is 16.5 W under the same conditions. With 10 W of output power into an 8-Ω load the distortion is typically between 0.1 to 0.2% over the 40-Hz-to-15-kHz frequency range. The device incorporates a proprietary overload-protection scheme that automatically limits the peak dissipated power so as to keep the working point of the output transistors within their safe operating area. The device also incorporates a conventional thermal shutdown system.
16-pin 4-k RAM has 200-ns access

Mostek Corp., 1215 W. Crosby Rd., Carrollton, TX 75006. $24.20 (100); stock.

The company's latest 4-k bit RAM entry features 200-ns access time and 10% tolerance on all supplies. Packaged in a 16-pin DIP, the new MK 4027 features Schottky-TTL compatibility, and allows memory-system performance to match that of 160 ns, 22-pin 4-k's; the MK 4027 eliminates the 40-ns delay of a 12-V clock driver. Other features include low-capacitance inputs and output, on-chip address and data registers, two methods of chip selection, simplified refresh operation (RAS only) and gated-CAS to compensate for system-timing skews in the column-address timing. Also the MK 4027 offers page-mode operation with page access of 135 ns. Active power for the MK 4027 is under 470 mW with standby power under 27 mW.

CIRCLE NO. 308

Quad analog gate turns on fast

Teledyne Crystalonics, 147 Sherman St., Cambridge, MA 02140. (617) 491-1670.

The CAG-49 high-speed four-channel analog gate has a turn-on time of 20 ns and ON resistance of typically 35 Ω. The CAG-49 costs about half the price of four switches purchased independently. In quantities of 100 to 999, the quad analog gate costs $62. Delivery is from stock.

CIRCLE NO. 309

This is an echo chamber?

Yes, and much more! It is the first N-channel Bucket Brigade Device designed with the audio engineer in mind. The SAD-1024 Serial Analog Delay will provide reverberation, echo, tremolo, vibrato and chorus effects in electronic organs and musical instruments. It will equalize speaker systems in an auditorium, or can be used in speech compression or voice scrambling systems. The SAD-1024, which contains two independent sections of 512 analog storage elements will accomplish all of these with a signal-to-noise ratio in excess of 75 dB. The two sections may be used independently or they may be connected in sequence to provide 1024 clock periods of delay. The delay provided by the device can be continuously varied by the clock rate from less than one millisecond to more than one second.

Other performance characteristics include:
Signal bandwidth from 0 to 200 KHz, less than 1% total harmonic distortion, 0 dB insertion loss, and less than 5 mW power requirements from a single 15V power supply.

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CIRCLE NUMBER 57
INTEGRATED CIRCUITS

Chroma demodulator simplifies color TVs

RCA, Solid State Div., Route 202, Somerville, NJ 08876. (201) 722-3200. $2.95 (100).

A linear IC for color-TV receivers—called the CA3137E and designed to function compatibly with the company's CA3126Q color processor—contains chrominance demodulators with three color-difference outputs, a dynamic "flesh-correction" circuit, a hue control, and a saturation control. Only a few external components are required to complete the circuit, and no tuning adjustments are necessary.

CIRCLE NO. 310

12-bit DACs have long-term stability

Analogic, Audubon Rd., Wakefield, MA 01880. (617) 246-0300. $39 to $42 (100); stock to 30 days.

Two 12-bit d/a converters—the internally referenced MN563 and the externally referenced MN562 series—are guaranteed not to have an error exceeding a fraction of an LSB over a six-month period. They have maximum relative accuracy ranges from $\pm 0.006\%$ to $\pm 0.012\%$ FSR. Gain and differential linearity tempcos are less than 3 ppm$/^\circ\text{C}$ for the MN562 series, and less than 10 ppm$/^\circ\text{C}$ for the MN563 series. Monotonicity is guaranteed over the operating temperature range of 0 to 70 $^\circ\text{C}$, $-25$ to 85 $^\circ\text{C}$, or $-55$ to 125 $^\circ\text{C}$, depending on the model. Settling time to 1/2 an LSB is 1.2 $\mu$s with the MN563 series, and 1.5 $\mu$s with the MN562 series. Both series have a current output of 0 to $-2$ mA, or $\pm 1$ mA, and programmable output voltage ranges of $\pm 2.5$ through $\pm 10$ V.

CIRCLE NO. 321

13-bit a/d converter costs only $25

Analog Devices, Route 1 Industrial Park, P.O. Box 280, Norwood, MA 02062. (617) 329-4700.

The AD7550 a/d converter combines 13-bit accuracy and 1-ppm$/^\circ\text{C}$ offset and gain tempcos with a price tag of $25 in hundreds. The AD7550 contains an amplifier, comparator, clock, and digital logic on its 118 x 125-mil chip, and it requires only an external resistor and capacitor, for integration, and a reference supply, for ratiometric operation. The chip draws a maximum of 2 mA and converts at the typical rate of 40 conversions per second with a 1-MHz clock. The clock input (up to 1 MHz) can be driven externally or self-generated through an external capacitor. Also, the three-state output of the AD7550 allows it to be directly interfaced with the 8-bit bus line of $\mu$Ps through the use of the ADC's "high byte enable" (5 MSBs), "low byte enable" (8 LSBs) and "status enable" lines.

CIRCLE NO. 320

5-V regulator outputs 3 A

Silicon General, 7382 Bolsa Ave., Westminster, CA 92683. (714) 892-5531. $9.35 to $12.50; stock.

A three-terminal 3-A, 5-V regulator, supplied in a hermetic TO-3 package, provides current limiting, power limiting and thermal shutdown protection. No external components are required. The 5-V output level is preset internally. Minimum input voltage is 7.5 V and typical output impedance is 0.01 $\Omega$. Power dissipation is 30 W. Worst-case regulation is $\pm 100$ mV for combined effects of input voltage, load, temperature and power dissipation.

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California Eastern Labs, One Edwards Court, Burlingame, CA 94010. (415) 342-7744. From $3 (100-up); stock.

The “Micro-X” package line of microwave transistors includes npn and pnp silicon devices that have fT’s of up to 9 GHz. All transistors use high-reliability gold, titanium, platinum-silicide metallization techniques. Typical of the devices is the NE02135, with an fT of 5 GHz and a noise figure of 216 dB at 2 GHz. The transistor operates at currents of 50 mA for low-distortion applications. Other available units include the NE-57835 with an fT of 7 GHz and the NE88935, a pnp transistor with an fT of 3.5 GHz.

Solid-state noise source comes in TO-18 package

Micronetics, Inc., 36 Oak St., Norwood, MA 07648. (201) 767-1320. $20 to $40 (1 to 99); stock.

A solid-state noise-source in a TO-18 transistor package has a current-limiting resistor built-in for optimum output performance. The source is hermetically sealed to satisfy the environmental requirements of MIL-S-19500 over the operating range of -55 to +125 C. For a limited time only, units will be available from stock at prices ranging from $20 to $40, in quantities from 1 to 99. Introductory evaluation units will also be available at 1/2 price (C.O.D. only) with a minimum three-unit order in any mix. This offer expires September 30, 1976.

LED lamps come with midget flange bases

Dialight, 203 Harrison Pl., Brooklyn, NY 11237. (212) 497-7600. From $0.79 (1000-up); 2 to 3 wks.

The 521 series of LED lamps is interchangeable with filament lamps that have midget flange bases. These T-1 3/4 lamps are available in red, green and yellow with a variety of lens styles. The lamps have luminous intensity of 2 mcd at 20 mA, typical (the green and yellow are at 10 mA). Maximum ratings for the red lamp include: forward dc current of 50 mA, reverse voltage of 3 V, power dissipation of 100 mW and a storage and operating temperature range of -40 to 100 C.

POWER MINI’S FOR LOGIC OR OP AMPS

Terminal strip input/output connections on these miniature power modules eliminate the need for sockets or soldering. They mount in an area only 3.5” x 2.5”. Ratings: 5 volt models to 2.5 amps, ±15 volts to .5 amps. Other models from 1 to 75 volts, all with 3-day shipment guaranteed.

Supplies that fit in thin spaces

Measuring only 1.68” high, Acopian narrow profile power supplies fit where many others cannot. Available in a wide range of ratings from 1 to 150 volts, to 4 amps. Regulation to ±0.005%. Tracking dual output models for op amps also available. Guaranteed 3-day shipment.

CIRCLE NO. 323
CIRCLE NO. 324
CIRCLE NO. 325
CIRCLE NUMBER 60
CIRCLE NUMBER 61

136

Electronic Design 8, April 12, 1976
Limiter diodes protect over 0.1-to-20-GHz range

Alpha Industries, 20 Sylvan Rd., Woburn, MA 01801. (617) 935-3150. From $6 to $8 (1 to 9); stock to 30 days.

The CLA series of limiter diodes can handle incident pulses of up to 4 kW peak power. Their leakage power is as low as 10 mW. The Models CLA3131, CLA3132, and CLA3133 series are p-i-n silicon chips that provide passive protection from 100 MHz to beyond 20 GHz. The diodes have a peak input power range, max, at 1 µs of 50 to 66 dBm, a peak output leakage power range of 22 to 44 dBm, an insertion loss of 0.1 dB and a recovery time of 10 to 50 ns.

Numeric LED displays have up to 9 segments


Watch and instrument designers may now choose different character styles for their 4-digit LED displays. The R7H-12W-4 displays use hybrid construction to eliminate the thick magnifying lens required by earlier devices. The displays are available with a range of segment configurations from the 3.5-digit 12-hour display to the complex 8 and 9-segment, 4-digit units required for day-of-the-week presentations. All displays are available with optional continuous bar or evenly spaced dot segments. Custom-tailored digit fonts, insignia and logos are also possible. Each display is encapsulated for mechanical and environmental protection and is internally connected for common-cathode, multiplexed operation. Mounting can be either with conductive epoxy or reflow solder. R7H-12W-4 1000-piece prices range from $4.75 to $5.00.

Stackable LEDs come in red, green and yellow

AEG-Telefunken, 570 Sylvan Ave., Englewood Cliffs, NJ 07632. (201) 568-8570. From $0.27 (1000-up); 4 to 6 wks.

The V 146 P, V 147 P and V 148 P long-life red, green and yellow LEDs are encapsulated in a flat plastic package. The package permits stacking so that compact visual displays can be made. All three devices have an 80° viewing angle between half luminous intensity points. The luminous intensity of the red, green and yellow units at 20 mA is 1.6, 2 and 3 mcd, respectively.
Tunnel diodes available for most applications

Custom Components, P.O. Box 334, Lebanon, NJ 08833. (201) 236-2128. From $9; stock to 2 wks.

Tunnel diodes, supplied in accordance with MIL-S-19500 requirements, are suitable for use in low-noise amplifiers to 25 GHz, high sensitivity detectors, with a TSS to –60 dBm, and switching circuits to 30 ps. Diode types are available with virtually any parameter combinations needed by the circuit designer.

CIRCLE NO. 329

Varactor tuning diode designed for Ka band

Microwave Associates, South Ave., Burlington, MA 01803. (617) 272-3000. From $34; stock.

The MA-46600 series of GaAs tuning varactors can be used for both broad and narrowband tuning through Ka-band. The varactors have Qs greater than 4000. Standard capacitance matching is ±10% but closer matching is available on request. All diode types are available in a wide selection of ceramic packages as well as in chip form. The series is available in three minimum breakdown voltage ranges: 30, 45 and 60 V.

CIRCLE NO. 330

Power transistors handle currents of up to 100 A

Solitron, 1177 Blue Heron Blvd., Riviera Beach, FL 33404. (305) 848-4311. From $25 (100-amp); 3 wks.

High-current industrial power transistors in the 2N5250 family handle currents of up to 100 A. Typical specs of the 100 A, TO-3 cases (Model SDT-96301-2-3) include 60 to 140 V, V_CEO; an 80 to 160 V, V_CBO; a 120-A max collector current; and an h_FE of 10 min at 70 A and 5 V. A 70-A TO-3 unit, the SDT-96304-5-6, has a V_CEO of 200 to 300 V, V_CBO of 225 to 325 V and an h_FE of 8 to 40 at 40 A and 10 V. All transistors are also available in TO-63 and TO-68 cases.

CIRCLE NO. 331

LED-photocell pairs have up to 1500-V isolation


Two LED-photoconductive cell opto-isolators, the CLM-8500 HV and CLM-8600, have decay times of 40 ms. The CLM-8500 is designed for line voltage operation, and its photocell output is rated for 400- V peak ac. The isolator has 1500-V peak isolation capability, a maximum output resistance of 5 kΩ when I_s is 16 mA, and a dark resistance of 10 MΩ. The CLM-8600 has a 500-V-ac peak output rating and a 2-kΩ output resistance at an I_s of the 16 mA. Input-to-output isolation is 2500-V peak.

CIRCLE NO. 332

Microwave transistors operate at 4 GHz


Repeatability of transistor parameters is guaranteed for the Models 35868E and 35868L microwave transistors. These transistors are npn bipolar devices optimized for low noise and high gain at 4 GHz. Minimum-guaranteed tuned gain for both units is 8 dB at 4 GHz. In addition to the tuned-gain guarantee, the Model 35868L also has a guaranteed low noise spec of 4.5 dB at 4 GHz and 7-dB minimum associated gain. Both devices meet environmental requirements of MIL-S-19500 and the test requirements of MIL-STD-750/883.
Opening new frontiers with electro optics

Solid state laser breakthrough: CW output at room temperature
You get at least 5 mW of continuous lasing in a solid state package. RCA's new AlGaAs CW injection lasers have a rise time of less than 1 ns — allowing modulation rates beyond 100 MHz. This plus small source size (13x2 μm typical) and 820 nm wavelength make the C30130 and C30127 well suited to optical communications, facsimile, fiber-optic transmission, document reading, flying spot scanning. RCA also offers complete solid state systems (C30125 and C30131), which include a regulated DC power supply and a thermal stabilization network.

New PMT looks for oil at temperatures as high as 150°C.
To help geophysicists in their search for oil and minerals, RCA has produced new, long-life photomultipliers designed for repeated cycling at temperatures up to 150°C (302°F). They're being operated at depths as far down as 20,000 feet. These tubes can take the heat because of a special bialkali (NaKsb) photocathode. The 1" dia. C3016G for gross counting systems meets MIL-STD-810B. Larger sizes 1½, 1⅛ and 2" for differential counting systems.

RCA lowers the bloom in S-I camera tubes. New SI target the key.
RCA has developed a new target that limits charge leakage between diodes. The result: bloom is dramatically reduced to provide more picture information in the presence of bright highlights. You can get low-bloom plug-in replacement versions of the popular 1" 4532 S-I vidicon series and 4804 silicon intensifier target (SIT) camera tubes.

Low-cost IR emitting diodes from RCA: 940 & 1060 nm types.
When you think IR for fire and smoke detection, auto ignition, sorting, counting or reading - think RCA. Our mass-produced, off-the-shelf diodes have high power outputs (see table) and can replace many types you may be using. Other GaAs emitters have outputs from 1.1 to 3 mW at 940 nm, 20 to 50 mA drive. Packages to suit your needs. And our 1060 nm InGaAs emitter has typical rise time of less than 10 ns with a minimum continuous output of 100 μW, making it an excellent simulator for Nd: YAG systems.

If electro optics can solve your problem, remember: EO and RCA are practically synonymous. No one offers a broader product spectrum. Or more success in meeting special needs. Call on us for design help or product information. RCA Electro Optics, Lancaster, PA 17604. Phone 717-397-7661.
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That's the day 25,000 "delegates" will gather for the opening of ELECTRO/76, the new IEEE international electronics convention in Bicentennial Boston.

Just about everything new and significant in electronics will be there - more than 500 hands-on product and systems demonstrations; more than 130 hours of solid, useful professional programming.

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Everything at ELECTRO/76 is up-front and in-person. More than 300 leadership companies presenting the newest high-technology hardware, from microprocessors to "smart" instruments, and from raw materials to complete systems. ELECTRO/76 is the biggest all-electronics event in the eastern United States in many years.

All exhibit space in Hynes Auditorium has been sold out for months, and world-wide electronics industry attention is clearly focused on beautiful, springtime Boston.

Programming by Objective
35 half-day professional program sessions have been selected and refined from more than 100 proposals, by a committee of leaders in electronics technology.

This program is designed for immediate impact - direct usefulness to professionals in their job assignments with strong emphasis on new-technology applications.

All sessions will be held in ballrooms of the Sheraton-Boston Hotel, immediately adjacent to the Hynes Auditorium exposition halls.

A single low registration fee gives you all four days of ELECTRO/76 - 500 exhibits, strong sessions, and a fine technical film program. All this, and Bicentennial Boston, too!

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ELECTRO/76 is a brand-new, all-industry activity. It combines the best of the Nerem and IEEE Show traditions - and adds much more.

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Registration for ELECTRO/76 - for all of it - is just $6 for IEEE members, $9 for non-members. You'll find that's a very modest price to pay for the dozens of new ideas you'll discover for yourself. Make your plans now to join the leaders in Boston - and take home some great ideas!

Electro76
The IEEE Convention in Bicentennial Boston May 11-14
Hynes Auditorium and the Sheraton-Boston

For further information: ELECTRO/76 31 Channing Street, Newton, Massachusetts 02158 (617)527-6944

CIRCLE NUMBER 66
Mini connectors have from 1 to 100 contacts

Microtech Inc., The Park Square Bldg., 777 Henderson Blvd., Folcroft, PA 19032. (215) 532-3388. From $0.45; stock.

Miniature and microminiature co-axial, 4, 7 and 12-contact connectors are available along with a 1 x 1 in. 100-contact matrix board. The boards are designed so that they can be cut in rows and columns of any configuration from 100-contacts down to a single contact. The units are constructed of gold plated brass bodies and contacts with FEP Teflon inserts. Co-axial and special multiconductor cables are designed specifically for the connectors to give optimum miniaturization. The dielectrics and jackets are also made from Teflon.

CIRCLE NO. 337

Epoxy casting compound is self-extinguishing

Hightemp Resins, 225 Greenwich Ave., Stamford, CT 06902. (203) 325-4124. See text.

Hightemp 5600, a general-purpose, low-cost epoxy-casting compound, is self-extinguishing. A 1-lb. amount of the resin, when cured at room temperature, will set overnight to a strong, tack-free solid with an exotherm peak below 100 F. Other features of Hightemp 5600 include: a cost of $0.95/lb in 50 gal. lots, a viscosity of less than 3500 cps, a pot life of 2 to 3 h; a shrinkage of less than 0.1% and a water absorption of only 0.1%. The epoxy is normally white and is claimed to have good thermal conductivity.

CIRCLE NO. 338

Wrapped-wire panels speed μP breadboarding

Mupac Corp., 646 Summer St., Brockton, MA 02402. (617) 588-6110. $57 (10-up); stock.

Wrapped-wire panels have a variety of different size sockets for breadboarding systems using μPs, LSI circuits, semiconductor memories and other ICs. Panels mount on a predrilled frame. A 108-pin connector may be mated with standard box-type connectors and flat-ribbon or twisted-pair cable assemblies to connect to peripheral devices.

CIRCLE NO. 339

Card and file systems hold up to 2106 ICs

Teradyne Components, 900 Lawrence St., Lowell, MA 01852. (617) 454-9195. For 10-up lots: From $40 (cards), $125 (files); 1 to 2 wks.

The module library, a wrapped-wire interconnection system, is available in many different configurations. The library consists of two basic units: the module interconnect file and the pluggable module cards. The files come in single and double row configurations. Each configuration is available in two heights and two connector spacings. The modules cards are available in various etched configurations to hold 14- and 16-pin DIP ICs, various MSI and LSI packages and discrete components. Packaging densities range from 264 to 2106 ICs per file.

CIRCLE NO. 340
The Universal Counter.

Everything you’re likely to need. The HP 5328A.

Here’s a counter so versatile, it can really be called universal. You get high accuracy, operating ease and a low price tag of just $1300* It’s modular so you can buy the capability you need. Not more. Not less. Start with the basic 8-digit instrument with 100 MHz frequency range and 100 ns single shot T.I. resolution. You also get period, 10 ps time interval averaging, ratio, scaling and totalizing. Then you can add more: 512 MHz with 9 digits and 15 mv sensitivity; time base aging <5 x 10^18/day; and 10 ns single shot time interval with improved averaging. But look what else you get:

**UNIQUE TRIGGER LIGHTS**

Tell you what’s happening. They’re on when the input is greater than trigger level and vice versa. And they blink when the input channel is triggering from 0 to 100 MHz. Standard.

**UNIQUE BUILT-IN DVM**

Gives an instant accurate digital display of trigger levels. Or use this option to measure external voltages 10 µV to 1100V auto-ranged, integrating, full floating, high common-mode rejection with switchable input filter. Optional.

**HIGH SPEED MARKERS**

Show just what your counter is doing with your input waveform. Use the markers on the second channel of your scope to see where the counter is triggering. Really useful thanks to the 5328As 100 MHz ECL outputs. Standard.

**EASY SYSTEMS INTERFACE**

With the HP Interface Bus simplifies integration of the counter into a system. You get this programmability plus standard format data output with a single connector. Optional.

**ARMED MEASUREMENTS**

Solve difficult dynamic measurement problems. The counter goes to work when your command tells it to. Ideal for burst frequency or sweep generator linearity measurements. Standard.

These are just a few things, of course. There are many more thoughtful engineering innovations that combine to give you everything you’re likely to need in a general purpose, medium-priced counter for a long time to come. We talk about them in our 12 page booklet. Write for one or ask your nearby HP field engineer for a copy. We want you to find why we call this universal counter universal.

*Domestic US Price only.
for at 60 Asynchronous
And, start/stop.
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cable
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and
three
electrical
conductors
is
$30/meter.

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PACKAGING & MATERIALS

Metal foil shields enclosed areas

Emerson & Cuming, Inc., Canton, MA 02021. (617) 828-3300. $3:
WP-3SS, $2.25: WP-3CU, $1.75:
WP-2AL, per ft² (10 ft²-up), stock.

Eccoshield WP materials are specially developed metal foils used to make rf-shielded areas. The foils are stapled or bonded to the walls, ceiling and floor of an enclosed space. The material is used in conjunction with the firm's line of adhesive-backed metal-foil tapes, conductive adhesives, surface coatings and caulking compounds to produce enclosures that have an insertion loss in excess of 80 dB over the range of 200 kHz to 35 GHz. Three types of WP material are available. In decreasing order of cost and effectiveness they are Eccoshield WP-3SS, a stainless-steel foil; WP-3CU, a copper foil; and WP-2AL an aluminum foil.

CIRCLE NO. 341

Fiber optic cable comes with many options

Rank Precision Ind., 411 E. Jarvis Ave., Des Plaines, IL 60018. (312) 297-7720. See text; stock to 30 days.
A multi-core fiber optic communications cable is available in various combinations of optical and electrical channels. Designated "Fibroflex 400X," the cable uses a multi-core fiber optic communications cable that contains 96 fibers jacketed in PVC. It has an operating temperature range of -40 to 105 C (-40 to 221 F). The cable attenuation is less than 400 dB/km at a wavelength of 800 nm. Typical price for a cable with 16 optical conductors and three electrical conductors is $30/meter.

CIRCLE NO. 342

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our quiet one

Our low noise, punched tape I/O desktop unit, is designed to satisfy numerical control, graphic arts, data communications and computer peripheral applications.

It accommodates oiled paper, dry paper, metallized mylar, sandwich paper/mylar/paper and polyester...5, 6, 7 or 8-level tapes. And, it's TTL/DTL compatible.

Asynchronous punching at up to 60 characters per second.
Photoelectric reading at up to 150 characters per second,
start/stop. Synchronous reading at up to 250 characters per second.
Via a highly reliable stepping motor tape transport. At OEM prices.

For full details, write or call us.

SWEDA INTERNATIONAL
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CIRCLE NO. 69

A WIDEBAND AMPLIFIER
WITH WIDEBAND FEATURES

It's IFI's Model 5100. Exclusive features include automatic remote leveling and remote level control. Also prominent in its wide performance spectrum: auto pulse and auto limit to confine amplifier current to safe levels in pulsed operation...Operates into any load from open to short...Frequency range, 10 KHz to 250 MHz...Peak RF input, 1 V; 40 dB gain; output, 10 W...Model 5100 was designed primarily as a preamplifier for IFI and other high power wideband amplifiers. As such, it's a direct replacement for IFI's Model 5000—with all of that unit's proven performance AND the advanced features you will find only in Model 5100. Write for technical data.

CIRCLE NO. 70

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INSTRUMENTS FOR INDUSTRY, INC.
151 TOLEDO STREET • FARMINGDALE, N.Y. 11735
516-694-1414 Cable: Electronic Hallendale, Fla. Telex: 51-43-32

CIRCLE NO. 144
Clip-on heat sink holds
TO-202 and 220 cases

Wakefield Engineering, 77 Audubon Rd., Wakefield, MA 01880. (617) 245-5900. $0.04 (lge. qty.); stock.
The Series 291 Clip-Cooler heat sink is claimed by the manufacturer to have double the heat transfer capability of competitive units. The unit has a one-piece construction and can hold TO-202, TO-220 or other plastic tab devices. The clip-on design guarantees secure fastening without chance of slipping. Clip-Coolers are available in 0.36 and 0.74-in. heights with a choice of black, gold or plain finishes.

CIRCLE NO. 343

Stampd PC boards cut costs vs etched boards

Rogers Corp., Electro Components Div., Rogers, CT 06263. (203) 774-9605. See text.
Mektron stamped circuits are claimed to offer significant cost savings for companies that purchase over $10,000 of PC boards a year. The all-mechanical production technique permits the designer almost limitless combinations of conductive and resistive foils, and substrate materials. Production-capability-limits of the process, include conductor thicknesses between 0.007 and 0.0068 in. (for copper, 0.5-to-5-oz.) and a minimum line width of 0.02 in. with a minimum spacing of 0.025 in. The die-stamped circuit minimizes the possibility of chemical contamination, making possible the use of less expensive, even semi-absorbent substrate materials. A typical 2.25 x 2 x 0.062 in., 1 oz. copper board with 79 holes costs about 15¢ in 25,000 pc lots, excluding tooling.

CIRCLE NO. 344

Enclosures molded from high impact plastic

Vero Electronics, Inc., 171 Bridge Rd., Hauppauge, NY 11787. (516) 231-0400. See text.
Instrument cases molded of ABS plastic provide high strength. They contain built-in mounting guides for vertical or horizontal mounting of printed-circuit boards. The boxes are formed in two sections with separate anodized aluminum front and rear panels for mounting of controls. The standard color is two-tone gray, but custom colors are available at no extra cost when at least 1000 units are ordered. A typical box with dimensions of 4.3 x 8.1 x 5.5 in. (Model 75-1412 K) costs $7.32 in single quantities.

CIRCLE NO. 345

MICROPROCESSOR SERIES NO. 1
OUR EASIEST-TO-USE
2650:
NOW MULTI-SOURCED.

All the 2650's you need, in stock at Signetics, authorized distributors, Advanced Memory Systems (AMS) and Philips, too.

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THINK

CIRCLE NUMBER 71
Electronic Design 8, April 12, 1976
POWER SOURCES

Supply allows control of plating process
Leighton Electronics, RD#1, Box 374, Leighton, PA 18235. (717) 386-4156. $1980; 8 wks.
Improved plating of semiconductor parts, wafers, etc., with greater control over amount deposited, porosity, adhesion and smoothness is achieved with this solid-state ac-dc power supply, the PD01. In the ac mode, the output is continuously adjustable for both the plating and deplating portion of the cycle with four independent current-regulated power supplies. Dc output is filtered so that maximum ripple is merely 25 mV at 100 mA. Any of three adjustable output ranges can be selected.

It looks like a DMM; it's a lab source
Boston Electronics, 109 Massachusetts, Lexington, MA 02173. (617) 861-8620. $199; stock.
Model 131 multisource, designed for use as a general laboratory instrument, is housed in a compact case and provides outputs of 5 V dc at 1 A and ±15 V dc at 100 mA. Optional ac and dc test signals are available for use with most analog and digital circuits. Options include test signals and higher current capability. Accessories available include dust covers, carrying cases and rack mount kits.

125-W supply measures just 1.7-in. high
Model 325 20-kHz switching power supply produces 5 V at 25 A in a unit only 1.7-in. high. The total package operates at 1.3 W per cubic inch, traceable to the high efficiency of 75%. The unit offers many innovations such as all-plug-in, functionally isolated control cards, as well as easy access to all of the power components for field repairability. It will take either 115 or 230-V input without any switching or without any changing of taps or straps. Brownout protection is included, so that line dips below 95 V still provide usable outputs.

GIVE’EM HELL.
They can take it. And come back for more. Beautifully.
You’ve spent a great deal of time and money designing your equipment to work in the field. That means unpredictable conditions, rough handling and plenty of abuse. And when your product is 200 miles from the nearest service center, it had better work.
Give it the extra protection of Zero Centurion™ carrying cases, combining the best in classic styling with rugged durability. Durability that’s been proven by people like yourself in environmental extremes around the world.
Choose from 59 standard sizes for two week delivery A.R.O., with unlimited modification capabilities. And the price is surprisingly low. Consider it low cost life insurance on your equipment.
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CALL ME, I’M INTERESTED CIRCLE #272 FOR MAIL CATALOG CIRCLE #271

Electronic Design 8, April 12, 1976
Got a printer? Here's a power source for it

Boschert Associates, 1031 E. Duane, Suite C, Sunnyvale, CA 94086. (408) 732-2441. $225 to $235 [100s].

Models OL150 and OL151 are four-output, switching power supplies designed to power daisy wheel printers and the associated logic in computer terminal applications. In addition to the voltages needed for the printer, +5 and ±15 V, a fourth output voltage is available and can be selected by the customer. These supplies have overvoltage, overcurrent and reverse-polarity protection. Currently models are available to drive the Diablo HY Type I and HY Type II (fits inside) and the Qume Q30, 45 and 55.

Send for information now!

NORTH AMERICAN PHILIPS CONTROLS CORP.

Frederick, Md. 21701 - (301) 663-5141
FOR IMMEDIATE NEED CIRCLE #73
FOR INFORMATION ONLY CIRCLE #74

Electronic Design 8, April 12, 1976

10 amps of switching in a 1"cube

Series 19 Relay. One of the most compact and reliable relays you'll ever use.

In just one cubic inch, the remarkable Series 19 relay combines the advantages of miniaturization with a capacity to handle heavy switching loads. Result: more performance in a smaller overall package. Yet the cost is low — less than $2.00 each in 100-piece quantities.

Contact arrangement is SPDT. Rating is 10 amps, 28 vdc or 115 v, 60 Hz. Available coil voltages range from 3 to 24 vdc.

Consider the Series 19 relay for low level to 10 amp switching applications such as remote control, alarm systems and similar industrial and commercial uses.

Send for information now!

NORTH AMERICAN PHILIPS CONTROLS CORP.

MPS-1; $88, MPS-2.

"MPS" Series is interchangeable with Lambda's MPU Series and is said to sell for less than half the price. The series consists of two models: MPS-1 is rated at 5 V dc at 3 A, 12 V dc at 0.6 A, and 9 to 12 V dc at 0.6 A or 5 V dc at 0.38 A. Model MPS-2 is rated at 5 V dc at 7.0 A, 12 V dc at 1 A, and 9 V dc at 1.2 A, or 5 V dc at 0.75 A. Both units are fully protected against overload and overvoltages and are mechanically interchangeable with other competitive units.

Supply aims at µPs, interchanges with others

Tele-Dynamics, 525 Virginia Dr., Fort Washington, PA 19034. (215) 643-3900. Starts at $215; stock.

The Brute series has been enhanced in performance and versatility with no change in price. The supplies are rated to 1200 W, and they can be set for either constant current or constant-voltage operation. Remote sensing and coarse- and-fine voltage adjustments cover 2-to-25 and 5-to-50 V ranges. The Brute units produce no output spikes, and their power efficiency exceeds 75%.

CIRCLE NO. 349

CIRCLE NO. 350

CIRCLE NO. 351

MICROPROCESSOR SERIES NO. 2

2650 DEVELOPMENT HARDWARE FOR ALL COST/CAPABILITY LEVELS.

Here now:
• PC1001
  Prototyping Card
• PC2000 4K
  Byte RAM Card
• DS2000 Demo
  Base with P.S.
• PC3000 Smart
  Typewriter
  Democard
  *KT9000 Prototyping Kit
  More Soon!

Clip to your letterhead. Send me the Short Form Catalog including the foregoing data sheets.

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THINK

SIGNETICS µP

CIRCLE NUMBER 75
UNBELIEVABLE!!!!!!
The Intecolor® 8001
A Complete 8 COLOR Intelligent CRT Terminal
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CIRCLE NUMBER 77

MODULES & SUBASSEMBLIES

Multiplier & log modules have wide ranges

TAU Systems, Box F, Newton, NH 03858. (603) 382-7218. $18.90 (either unit); 1 to 3 wks.

The USC 1220 transconductance multiplier has a four decade range and a response to better than
0.3%. The multiplier has a built-in FET operational stage so that the USC 1220 can be used for volt-
age or current-controlled active filters, oscillators and amplifiers. Another module, the LAM 1212
log/antilog unit, has multiple outputs which are capable of simulta-
neous log and anti-log output signals, from 500 μA to 500 pA.
The 1212 outputs are directly capable of driving the 1220 multi-
plier to obtain non linear control of linear signal voltages. Both de-
vices are housed in 1 × 1 × 0.6 in. 10-pin plastic cases.
CIRCLE NO. 352

High power amplifier delivers up to 250 W

Technical Research & Mfg., Grenier Field, RFD #3, Manchester, NH 03103. (603) 668-0120. $275 (1 to 4); 4 wks.

The AP-150 power amplifier has a fixed gain of 28 dB. It can deliver
160 W into an 8 Ω load and 250 W
into 4 Ω over a −3 dB bandwidth of 1 Hz to 60 kHz. The amplifier has a full, push-pull compliment-
ary-symmetry circuit, low distortion, (0.03% TDH at 1 kHz), high
 slew rates (25 V/μs) and peak output currents of ±14 A. The mod-
 ule, with integral isolated heat sink measures 9 × 4.8 × 2.3 in. with
cover.
CIRCLE NO. 353
Frequency synthesizer has 1-to-32-MHz range

Syntest, 169 Millham St., Marlboro, MA 01752. (617) 481-7827. $429; stock.

The SM-105 frequency synthesizer card offers a 1-to-32-MHz range. The output frequency can be set in 500-Hz steps. Direct BCD (parallel load, TTL-compatible) programming can be used. Outputs are both TTL and ECL-compatible and have logic-controlled enable lines. Spurious outputs are greater than 60 dBc. It takes 50 ms for the output to settle within 10% of a frequency step. Power requirements are 8 V at 700 mA and 24 V at 20 mA. The synthesizer is built on a 6.5 x 4.5 x 0.75 in. board and has an operating temperature range of 0 to 50 C.

8 and 10-bit DACs fit in 16-pin DIP-like case

Intech, 1220 Coleman Ave., Santa Clara, CA 95050. (408) 244-0500. For 1 to 99 units: $15 (861-8), $22 (861-10); stock.

The A-861-8 and A-861-10 d/a converters are designed to be pin-compatible to the Hybrid Systems 371 converter family. These 8 and 10-bit converters are packaged in 16-pin DIP-like cases that measure 1.3 x 0.6 x 0.3 in. The A-861-8 operates from a +15-V supply and uses 52 mW. The A-861-10 requires ±15-V supplies. Both converters have a maximum nonlinearity error of 0.5 LSB and a worst-case nonlinearity error of 0.01%.

Phase sensitive detector spans 0.01 Hz to 1 MHz

Evans Associates, P.O. Box 5055, Berkeley, CA 94705. (415) 848-6839. $175; 2 to 4 wks.

The phase-sensitive detector card, Model 4110, is intended for measuring the amplitude of phase-coherent periodic signals. It provides lock-in amplifier circuit functions from 0.01 Hz to 1 MHz. The analog output is compatible with meters, recorders, DPMs and a/d converters. Input-output sensitivity of the 4110 ranges from 10^-5 to 10^-1 V/V in decade steps. The detector is constructed on a 4.5 x 6.5 in. (11.4 x 16.5 cm) board, mating to a standard 2 x 22-pin edge connector. It requires ±15-V-dc supplies and has an on-board regulation for isolation.

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CIRCLE NO. 354

CIRCLE NO. 355

CIRCLE NO. 356
Power multicoupler handles 1 kW sources

Electronic Navigation Inc., 3000 Winton Rd. S., Rochester, NY 14623. (716) 473-6900. $295 (5 to 49); 30 days.

The Model PM1777 four-port, power multicoupler can combine or split power levels of 1 kW over a 20-to-80-MHz range. The unit operates over an ambient temperature range of −50 to +90 C. Internally, a silicone-oil bath and a high-thermal-mass heat sink conducts heat to the mounting surfaces. Insertion loss is less than 0.2 dB and the phase balance is ±1°. The amplitude balance is 0.1 dB.

Message weighting filter has 60-Hz-to-5-kHz span

Frequency Devices, 75 Locust St., Haverhill, MA 01830. (617) 374-0761. For unit quantities: $65 (581-1), $55 (581-2); stock to 4 wks.

The 581 series C-message weighting filters provide a frequency response characteristic simulating the perceived response of the human ear to telephone noise. The 581-1 provides a ±1 dB approximation to the theoretical C-message weighting function. It is intended for use where a tight tolerance is required over a full 60-Hz-to-5-kHz range. The 581-2 has a looser tolerance below 300 Hz and above 3 kHz. Both models are housed in 2 × 2 × 0.4 in. modules that require no external adjustments.

Telephone autodialler stores up to 96 numbers


The PYE TMC modular autodialler can store and access 96 different telephone numbers, each of which can be up to 21 digits long. The module has facilities for single-key dialling of prerecorded numbers; keypad dialling of any other number; and automatic recording of the last number entered via the keypad (for redialling). The module has a printed-circuit edge connector for plugging into OEM equipment and is shielded from mechanical damage by a metal cover. Any number of modules can be banked to provide the desired storage. Other circuitry on the board allows for connection of a 96-address button keypad for key dialling and programming, dial-tone pause button, double-pause inter-digit button, finish button or cancel button, on/off/record switch, in-use lamp, telephone handset, power supply and exchange line.
Temperature controller handles 3 A loads

The Series 400 millivolt control accepts all standard ISA thermocouple calibrations. The output for ac inductive or non-inductive loads is a 3 A, 120 V ac single-pole-double-throw relay. The relay has adjustable hysteresis and on-off or, optional, time proportioning circuitry. Temperature setpoint is adjustable by an integral or remote potentiometer. Calibrated scales with temperature ranges to 2000 °F or C are available. The control operates from a 120 V ac, 50/60 Hz supply. It has a frequency response of 100 kHz and a linearity of 0.1% of span.

CIRCLE NO. 360

CRT memories show 16 lines x 32 characters

Matrox Electronic Systems, P.O. Box 56, Ahuntsic St., Montreal, Que., H3L 2S0, Canada. (514) 481-6838. $243 (10-up); 4 to 8 wks.

The MTX-1632 video random-access memory can display 16 lines of 32 characters. On the input side, the VRAM looks like a 512 x 8 RAM but on the output it delivers a video signal that can directly drive a CRT monitor. The display modules need no external refresh, have a bidirectional data bus, have an access time of less than 650 ns and can drive up to 25 CRT monitors. The 4.4 x 3.9 x 0.45-in. module operates from a +5-V supply and draws 600 mA, maximum.

CIRCLE NO. 361

Low-cost a/d converter spec’d for MIL temp

Micro Networks, 324 Clark St., Worcester, MA 01606. (617) 552-5400. See text; stock.

The MN5120H 8-bit a/d converter combines a fast conversion speed of 6 μs, full military-temperature (−55 to +125 °C) operating range and low cost ($98 in quantities of 100). Operating over the full temperature range, the MN5120H is guaranteed to maintain ±2 LSB absolute accuracy (±1 LSB at 25 °C), ±0.5 LSB linearity, and to have a zero error of no more than 1 LSB. The converter consumes only 680 mW. The MN5120H series has four models: the MN5120H, with 0 to −10 V input range; MN-5121H, ±5 V; the MN5122H, ±10 V; and the MN5125H, 0 to ±10 V. Power supply requirements are ±15 V and ±5 V for all units.

CIRCLE NO. 362

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CIRCLE NUMBER 81

Electronic Design 8, April 12, 1976
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CIRCLE NO. 83

Meet the top new analyzer.

Quan-Tech introduces a high-frequency wave and spectrum analyzer with a range of 1 KHz to 1.5 MHz.

The Model 2525 is a new, high performance Wave and Spectrum Analyzer with many features including electronic sweep. This portable unit offers unequaled capabilities for accurate harmonic measurements, fourier amplitude analysis of complex signals and spectral density analysis of random signals.

CIRCLE NO. 84

MICROWAVES & LASERS

4-output multiplier uses small package

Trak Microwave, 4726 Eisenhower Blvd., Tampa, FL 33614. (813) 884-1411, $2700; 90-120 days.

The Model 3850-1610 multiplier provides outputs of 100, 300 and 500 MHz, and a 4-to-8-GHz comb line. The unit measures only 3 x 1.75 x 0.6 in. and weighs 3-1/2 oz. Powers of the respective outputs are 5, 17, 10, and -25 dBm. A 25-MHz input is required, and the multiplier operates from 15-V-dc, 200-mA supply.

CIRCLE NO. 363

Laser rangefinder measures up to 2 miles

International Laser Systems, 3404 N. Orange Blossom Trail, Orlando, FL 32804. (305) 295-4010. $25,000; 120 days.

The Model GR-5000 laser rangefinder can measure target distances up to 10,600 ft. with an accuracy of ±5 ft. Using a GaAs laser diode as the optical source, the system produces an eye-safe output in 40-ns pulses at repetition rates up to 2000 pps. Range-output indication is provided via a four-digit LED display. An internal sighting telescope enables the user to locate and track the desired target. First-pulse logic selects the first return. Transmitter beam divergence can be varied from 5 to 50 mr by adjustment of an external control. The rangefinder comes in a weather-resistant enclosure, measuring 11 x 9.5 x 16 in. and weighing 22 lb. The unit operates from a 24-V-dc source and draws about 1.1 A.

CIRCLE NO. 364
WG circulator handles 3 kW

Merrimac Industries, 41 Fairfield Pl., West Caldwell, NJ 07006. (201) 228-3890. $150; 45 days.

A high power, air-cooled waveguide junction circulator—the FCW-1528—handles more than 3 kW average power and operates over the 5.025 to 6.425 GHz frequency range. The unit specs an isolation of 20 dB, insertion loss of 0.15 dB, VSWR of 1.2:1, and cooling flow rate of 25 ft³/min. Waveguide size is WR 137 and waveguide flange is CPR 137F.

CIRCLE NO. 365

Mixer/preamp spans 1 to 18 GHz

Aertech Industries, 825 Stewart Dr., Sunnyvale, CA 94086. (408) 732-0880. $695 up; 45 to 60 days.

A series of octave-band integrated mixer/preamplifiers covers the 1- to 18-GHz frequency range with several options of i-f frequency. Conversion gain is 25 dB, and LO-to-rf isolation is 20 dB minimum. Units have an output power at 1-dB compression point of up to +20 dBm, and its SSB noise figure is 8 to 10 dB. Gain flatness is ±1 dB, and the mixer/preamp can operate from 15, 20, or 24-V-dc supply. Temperature range is –40 to 81 C.

CIRCLE NO. 366

Ion laser outputs 40 W

Spectra-Physics, 1250 W. Middlefield Rd., Mountain View, CA 94042. (415) 961-2550. $44,900 to $47,900.

An ion laser, the Model 921, offers more than twice the output power of earlier commercial models. In all-line mode operation, output is specified at 40 W for a period of one year; operation in excess of 46 W is typical. Individual lines are specified at 15 W for 514.5 nm and 14 W for 488.0 nm. All output powers are TEM₀ mode. The Model 921 laser has two high-power plasma tubes mounted in tandem in an optical resonator structure. Only two mirrors are used in the cavity for minimum optical loss.

CIRCLE NO. 367

NOW—A FAILSAFE SOLID-STATE RELAY

A unique combination of dv/dt snubber, fusible-link protection, and an overdesigned triac makes the new optically-coupled Heinemann SSRs fail-safe. Now, the worst thing that can happen to your system in the event of relay failure is the simple need to replace the relay. That's a lot better than having to reprogram your entire control sequence, isn't it?

We make our new SSRs for either zero-voltage or non-zero-voltage switching, and both types are rated for maximum ac load currents of 5A or 10A. Any control voltage from 3Vdc to 32Vdc; all models compatible with TTL, DTL, and CMOS logic.

And you have a choice of solder-pin, quick-on, and screw terminals.

Talk with Bob Kusek (609-882-4800) or write for further information.

Heinemann Electric Company, Brunswick Pike, Trenton, NJ 08602

CIRCLE NUMBER 85

Electronic Design 8, April 12, 1976

THINK signetics µP

subsidary of U.S. Philips Corporation

CIRCLE NUMBER 86

153
MICROWAVES & LASERS

YAG laser outputs
4-W in TEM₀₀ mode

Hadron, 2520 Colorado Ave., Santa Monica, CA 90404. (213) 829-3370.

A YAG laser system for industrial or laboratory use—the Model KY3—can be operated in either a cw or Q-switched mode, and achieves power outputs of up to 30-W multimode and 4-W TEM₀₀. Priced at $8920 for the cw system and $12,935 with acousto-optic Q-switch, the system consists of laser head, power supply and heat exchanger.

Yig oscillators span 7 to 19 GHz

Systron-Donner, 735 Palomar Ave., Sunnyvale, CA 94086. (408) 735-9660. $1020; stock to 45 days.

Yig-tuned Gunn-diode oscillators consist of the Model SDYX 3000, which covers the 7-to-12.4-GHz frequency range with 25 mW of output power, and the Model SDYX 3001, covering the 12.3-to-18.5-GHz band with 30 mW of output power. The oscillators hold spurious signals to 60 dBc and harmonics to 30 dBc. Residual FM is less than 10 kHz peak-to-peak. Other specs include wide tuning bandwidth of 3 kHz, narrow tuning bandwidth of 10 kHz with 2 dB/decade rolloff to 250 kHz, and linearity of 0.2%. Units measure 1.7 on each side.

Modulator features 2000-µs pulse widths

Polard Electronic Instruments, 5 Delaware Dr., Lake Success, NY 11040. (516) 328-1100. $550; 30 days.

The Model 1020A Modulator provides pulse widths from 0.2 to 2000 µs. The solid-state unit can be employed with the company’s modular microwave signal generators and signal sources in the band from 800 MHz to 21 GHz. The modulator’s output signals typically have less than 100 ns pulse rise times. Other specs include pulse rates of 10 Hz to 10 kHz, sync delay of 0.3 to 2000 µs and internal or external synchronization. The Model 1020A also provides FM and square-wave modulation. The compact unit is only 1-3/4 in. high.

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Motor claimed world’s tiniest

Seiko Instruments, Inc., 2990 W. Lomita Blvd., Torrance, CA 90505. (213) 530-3400.

Five new ultra-small motors include a two-pole stepping motor, a three-phase stepping motor and a dc brush motor. The three-phase motor is only 0.0036 in.³, which makes it one of the smallest in the world, according to Seiko. The motors are equipped with a ruby bearing as used in wristwatches. The motors can turn either clockwise or counterclockwise.

LOCK SELECTOR SWITCHES ADDED TO OILTIGHT LINE


Allen-Bradley has added cylinder-lock switches to its Bulletin 800M line of small oiltight pushbuttons. The units mount on 1-1/4-in. centers. They are NEMA Type 13, oiltight and dust-tight, when mounted in suitable enclosures. Cylinder-lock selector switches help restrict operation to authorized personnel. Two, three and four-position switches are available with a variety of locking positions and contact configurations.

PRECISION POTENTIOMETER AT SEMIPRECISION PRICE

Computer Instruments Corp., 92 Madison Ave., Hempstead, NY 11550. (516) 483-8200. $9.50 (10 up); stock.

The LCP-78 Series potentiometers provide precision potentiometer construction and performance at semiprecision prices. In all-metal 7/8-in. diameter cases, the units come with threaded bushings, or servo mounts with optional ball or bushing bearings. Other features include infinite resolution, linear or functional outputs and precious-metal multiple-fingered wipers to yield life in excess of 20-million revolutions over a wide range of environments.
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(201) 699-6640

CIRCLE NUMBER 91

COMPONENTS

Decade resistor network holds 0.05% tolerance

Caddock Electronics Inc., 3127 Chicago Ave., Riverside, CA 92507. (714) 683-5361. $4.92 (1000 up); prototypes in stock.

Series 1776 edge-mounted precision decade-resistor networks can provide improved stability and accuracy in the input-voltage divider circuits of multimeters, oscilloscopes and other range-switching laboratory instruments. The standard version includes individual resistor values of 9 MΩ, 900 kΩ and 10 kΩ—values most commonly used in scaling the input signals of laboratory instruments. Ratio tolerances between resistors are held within 0.05%. The TC of the ratios holds to less than 10 ppm over 0 to 70 C. The maximum voltage-coefficient of the ratio is less than 0.02 ppm/V; the typical value is 0.003 ppm/V.

CIRCLE NO. 374

High-temp thermistors operate ac or dc modes

Fenwal Electronics, Div. of Walter Kidde & Co., Inc., 63 Fountain St., Framingham, MA 01701. (617) 872-8841.

Ionic-conduction Hi-Temp thermistor units are designed for high-temperature measurement and control from 500 to 1000 C in either ac or dc modes. In the dc mode, the unit's resistance is 10 kΩ at 750 C; in 60-Hz ac, 6300 Ω. Typical temperature coefficient is —1% at 750 C. Special order units are available in resistance values from 3 to 12 kΩ at 750 C, with body lengths from 1/4 to 2 in.

CIRCLE NO. 375
Micromotor features ironless rotor

Portescap US, 730 Fifth Ave., New York, NY 10019. (212) 245-7716.

The new 34 L dc-micromotor series in a 34-mm case, at rated voltages, has a typical no-load speed range from 4700 to 5900 rpm and a range of stall torques to 14.8 oz-in. The torque constant is 8.1 oz-in/A and the unloaded mechanical time constant is 13 ms. The motor series uses an ironless rotor that features a low moment of inertia. Maximum operating temperature is 100 C. Linear relationships between voltage, speed and torque, as well as a low starting voltage make this series particularly suitable for servo applications.

CIRCLE NO. 376

Sealed relay provides mercury-wetted contacts

Fifth Dimension Inc., 707 Alexander Rd., Princeton, NJ 08540. (609) 452-1300. $2.50 (OEM qty); stock to 6 wks.

The LC2RE SPST relay is epoxy encapsulated and features the use of a welded LC2 switching capsule that has only one moving part. Mercury films give mercury-wetted contact performance in all mounting positions. The initial contact resistance of 0.15 Ω is kept stable to ±0.015 Ω over the relay’s lifetime of over 500-million cycles for either dry-circuit or power loads. The contacts operate and release in approximately 2.5 ms without contact bounce. Standard temperature limitations are −38 to 85 C.

CIRCLE NO. 377

Mechanical filters reject adjacent channels

Collins Radio, Rockwell International, 4311 Jamboree Rd., Newport Beach, CA 92663. (714) 833-4632. $11 (5000 up).

A new single-sideband mechanical filter, PIN 526-9877-010, for the CB market (455-kHz carrier) features stability and excellent adjacent-channel rejection, according to Collins. Disc resonators are made from specially processed Ni-Span “C,” so that the total frequency shift over the temperature range of −30 to 50 C is typically only 35 Hz at the carrier 3-dB points. Either filter end may be used as input or output, but only one end is balanced. Both ends should be terminated with 2700 ±10% Ω shunted by a capacitance of 380 ±10% pF.

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CIRCLE NO. 92

Electronic Design 8, April 12, 1976
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Flow Chart: How to travel safely and quickly from spec sheet to your µC.

1 Applications Engineers — in the field now, more coming. Specific assistance to you is available around the USA, and in Belgium, Holland, Germany, France, Sweden, Britain, Italy, etc.

2 Multi-sourced 2650 — available in any quantity from Signetics, at the unprecedented low price of $21.50. Also available from AMS and Philips, and from Signetics' authorized distributors.

3 Development Software — includes the PL µS, an extremely efficient High Level Language (compiler) that reduces programming effort and cuts development time. ANSI standard Fortran IV executes on most machines without alteration. 2650AS1000/1100 Assembler and 2650SM1000/1100 Simulator are available in both 32- and 16-bit, on GE and NCSS time-sharing.

4 Multi-sourced Support Circuits — You'll need MOS and/or Bipolar Memories, Interface and Logic. Signetics has everything for a complete system. Back up any item from other sources. Coming soon from Signetics are: Programmable Peripheral Interface and Communications Interface, A-D Converters, Synchronous Data Link Controller, 16k NMOS & Bipolar ROMs, 4k & 8k NMOS EROMs, and 8k Bipolar PROMs.
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6 TWIN With Floppy Disks — "crashproofs" your system checkout. With DOS, Resident Assembler, and Text Editor. You develop programs and circuits together in an actual system environment with TWICE (TestWare In Circuit Emulator). PROM programming, too.

7 Over 30% Faster 2650 — By the time you've proven out your μC, you'll have available a faster 2650 if you want it. Uses the same software. For still higher speeds, call Signetics Bipolar Microprocessor Marketing about our 2650 emulator using 3000 series μP.

You go from gleam-in-your-eye to proven prototype in less time for less cost, and the μC you develop is easier and cheaper to produce in quantity, when you start with the 2650. Start now by mailing the coupon.

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THINK Signetics μP
811 E. Arques Ave., Sunnyvale, Ca. 94086

CIRCLE NUMBER 94
Lighted pushbutton operates on 120 V

Micro Switch, Div. of Honeywell, 11 W. Spring St., Freeport, IL 61032. (815) 232-1122. $3.65 (1000 up).

A UL-listed commercial pushbutton added to the Series-4 lighted pushbuttons can be wired directly into 120-V circuitry without transformers or resistors. A T2 lamp with slide-base construction, rated at 120 V and 0.025 A for 5000 h, is used. A locked-in-button retainer prevents front-of-panel tampering.

Vernitech Div., Vernitron Corp., 300 Marcus Blvd., Deer Park, NY 11729. (516) 586-5100. $25 (10,000 up); stock to 4 weeks.

The OADC-023/256P/INC incremental optical-encoder kit for industrial applications features 256 pulses/revolution, a single output, an all-solid-state light assembly and modular construction. Its LED light assembly has a guaranteed life expectancy of 100,000 h. Other kit encoders are available with two channel outputs, indexing channels, up to 1000 pulses/revolution squared output and operating voltages from 5 to 15 V dc.

Centralab, 5757 N. Green Bay Ave., Milwaukee, WI 53201. (414) 228-2911. See text; stock.

Off-the-shelf DIP resistor networks are available in four popular configurations. The thick-film networks consist of 7, 8, 13 or 15 resistors in 14 or 16-pin DIPs. The networks have a ±2% resistance tolerance, 2.5-W package power rating and ±200 ppm/°C resistance tempco. Price for a typical seven resistor, 14-pin unit is $0.61 each in lots of 1000 pieces.
Front panel components should look good.

Today's market is aesthetics-conscious. An attractive front panel adds to the acceptance of your product. Front panel components, including control knobs and dials, must contribute to the overall design. Some knobs and dials simply look better than others. We think that the Rogan line illustrates superior styling details, while offering the largest selection of functional shapes and sizes available.

Obtain a copy of our catalog by contacting Rogan...

the control knob and custom dial company.

ROGAN CORPORATION

3455 Woodhead Drive, Northbrook, Illinois 60062
Phone: (312) 498-2300 • TWX: 910-686-0008

CIRCLE NUMBER 98
COMPONENTS

Bridged-T-pad trimmer operates in CATV range


A dual molded-carbon trimmer Type BT offers superior performance at frequencies of 300 MHz and higher encountered in CATV. The single-turn 0.5-in.-diameter plastic unit is designed for bridged-T-pad applications. The impedance is 75 Ω ±20% over its entire 295-degrees of rotation. The operating temperature range is −40 to 120 C.

CIRCLE NO. 382

Ultrasonic control turns appliances on/off

Mark Engineering Inc., 34 Towers St., P.O. Box 308, Hudson, MA 01749. (617) 562-7883. $18.95 (unit qty).

A wireless ultrasonic remote-control device can turn televisions, lights and appliances on and off at the squeeze of a finger. Called Whistle Switch, the receiver part of the system plugs into any 110-V outlet along with the appliance to be controlled. A hand-held transmitter is then squeezed to turn the power on or off.

CIRCLE NO. 383

Toroidal cores can cut Xformer weight by 1/3

International Commerce Aid Ltd., Horii Bldg 501, 3-5-3 Misaki-Cho, Chiyoda-ku, Tokyo 101, Japan.

Nippalloy-S core materials made from 78.5% Ni, 4% Mo and 17.5% Fe can cut toroidal transformer weight by 33-1/3%. The cores are designed for operation at frequencies above 2000 Hz. The material has a density of 8.65 g/cm³, a resistivity of 50 µΩ-cm, a Curie temperature of 400 C and a saturation induction of 8.2 kgauss.

CIRCLE NO. 384

Gas-discharge displays upper/lower decimal

Cherry Electrical Products Corp., 3600 Sunset Ave., Waukegan, IL 60085. (212) 689-7702. $6.95: display, $1.02: connector (2000 up).

The new Plasma-Lux 16-digit gas-discharge display, W16-0002, has both upper and lower decimal points and commas. The display has 0.25-in. high characters. A unitized connector, W30-1602, with bifurcated contact tabs assures positive connection to the display's PC terminals. The unit's neon-orange color provides easy visibility and the display's image can be readily filtered.

CIRCLE NO. 385

Stacked-film extended to metallized-Mylar caps

Siemens Corp., 186 Wood Ave., S., Iselin, NJ 08830. (201) 493-1000, Ext. 338. $0.11: 0.01 µF (100 up); stock.

The space efficiency afforded by stacked-film construction has been extended to a new line of metallized-Mylar capacitors, heretofore restricted to polycarbonate-film capacitors. Constant lead spacing for all capacitor values simplifies mechanical layout. Designated B32560, B32561 and B32562, the new capacitors are available in 100 or 250-V ratings. Capacity range is from 0.001 to 2.2 µF with a ±5% standard tolerance.

CIRCLE NO. 386
9 questions and 8 answers about Fairchild's microprocessor kit.

What exactly is an F8 kit?
Put simply, it's a package designed to help you get better acquainted with microprocessors in general and our F8 in particular.

What's in it?
Each kit contains a fully assembled microprocessor which includes an F8 CPU, a preprogrammed Program Storage Unit, an F8 Memory Interface Circuit, and 1k bytes of static RAM. You'll also get a wired edge connector—one end for the board, another for your TTY and three wires for power. And it all comes on a fully assembled and tested PC board.

The board is a complete microcomputer with CPU, memory, 32 I/O bits, two levels of interrupts, two programmable timers, and all the necessary control circuits. I/O signals are T'IL compatible. And have been brought out to the edge connector. Internal signals have also been brought out to connectors for possible system expansion.

Unlike most other kits there's no additional assembling. Just add power. No soldering. No wiring. Compare that with the assembly time you'll spend getting other kits up and running.

What if I don't really know all that much about microprocessors?
No problem. We've included everything you'll need. The F8 Programming Manual, the F8 Data Book, and the Fairbug program.

Will they really help me get on the air?
They sure will. The F8 Programming Manual contains all the basic programming information you need even if you've never written a program before. And, if you're already acquainted with programming, it contains some very sophisticated techniques.

Fairchild F8 microprocessor kit.
What's in it for you?
The Data Book completely characterizes the F8 parts, both internal functions and the electrical characteristics of all the pin-outs.

With the aid of these two manuals you'll be writing and running programs in a couple of hours.

And don't forget Fairbug.

What's Fairbug?
The kit's PSU has the Fairbug program on it. It's a series of user oriented subroutines to make your job as a designer a little easier. For instance, entering a program into RAM can be a difficult process. But our Fairbug handles the problem quickly and easily with a "bootstrap loader" that loads data from a terminal and stores it in RAM.

What else will Fairbug do?
The Fairbug contains 1,000 bytes of programming and the "bootstrap loader" is only a small part of it. The remaining functions allow you to communicate with virtually any terminal or TTY at speeds from 10 to 300 cps; dump memory from RAM for future loading or to create a PROM and to read from a high speed paper tape reader.

It also lets you examine and alter any register or memory location in an F8 system from a terminal. Suppose you've erred midway through your program and need to change several instructions. What can you do? Simple. Go to Fairbug, examine the bad locations, and alter them. All done at the terminal.

These are all written in subroutine format. So you can use them both as the Fairbug package, and as part of a subroutine library.

Sounds pretty impressive. What does the whole kit cost? Would you believe $185.00 for a fully assembled microcomputer?
That's a lot less than the bag of unassembled parts offered by most other manufacturers. Then add our powerful Fairbug user's program and twice as much RAM as most kits.

Where can I get a kit?
Kits are available for immediate delivery from your local authorized Fairchild distributor. Or, if you prefer, use the coupon below, and we'll process your order from the factory.

Last question. How effective will Fairchild's F8 kit be in my application?
We thought you'd never ask. That's one you'll just have to answer yourself after you've tried it, and the first step is to get the kit.
Better... ...across the board.

Our PLP-550 logic probe is internally programmed to select C-MOS, HTL, TTL/DTL logic. Stretch memory catches single, short pulses you can't see. Unique three lamp system gives you duty cycle information you'd otherwise need a scope to see. Next time out, take the Kurz-Kasch PLP-550 with you... and leave your scope back at the shop. Soon to be available are single and dual family probes in the same rugged, functionally designed package.

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Electronics Division
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Ann Arbor makes over 1000 standard RO and KSR display terminal models. Alphanumeric, Graphics. Or both.

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INTRUMENTATION

Keyboard controls precision calibrator

Digitec, 918 Woodley Rd., Dayton, OH 45408. (513) 254-6251. 3210, $1795; 3220, $1595.

Expanding its High Technology series instrumentation line, Digitec has introduced two new models in its precision calibrator family—the Model 3210 keyboard-controlled unit and the Model 3220 programmable unit. The units are designed to function as both constant-voltage and constant-current sources. Model 3210 has a keyboard that replaces conventional front-panel controls and permits operation from remote locations or by semi-automatic testing systems. Model 3220 is designed for fully automatic systems and can be programmed to accept TTL/BCD logic, or other codes. Both models provide a precise LED digital display of the output voltage to ±200 V and current to ±200 mA.

CIRCLE NO. 387

True-rms meter offers high accuracy

UFAD Corp., 700 36th St. S.E., Grand Rapids, MI 49508. (616) 241-6000. $345; stock-30 days.

True-rms 733 series voltmeters offer converter accuracies of ±0.25% and full-scale meter accuracies of ±1%. The units can convert inputs of any wave shape, including noise up to 1 MHz at rated accuracies over ranges from 3 mV to 300 V. Additional features include a crest factor of 5.5:1 and two selectable response times.

CIRCLE NO. 388

Electronic Design 8. April 12, 1976
HP displays.

Because your system deserves a bright, sharp image.

You put a lot into each OEM system: good circuit design, quality components, careful testing. But end users will judge it by the information they get from the display. They expect bright, sharp images. That's why HP's 1332A, 1333A, and 1335A CRT displays make excellent choices for all types of systems—from spectrum, network, and chemical analyzers, to automatic test systems.

Each display has a very small spot size that focuses uniformly over the complete viewing area, regardless of writing speeds or intensity level. This eliminates the need to refocus at each intensity setting and assures crisp images, even around the outer edges of the screen. Fine image detail with excellent contrast and uniformity make them particularly well suited for applications involving complex graphics, especially those with alphanumeric data.

The 1335A, a variable-persistence, storage, and non-storage display, introduces a totally new CRT design optimized exclusively for information display. It offers exceptionally good resolution over the entire 8 x 10 cm screen. And the 1335A is versatile too. Any operating mode—erase, store, write, conventional, or variable persistence—can be selected with manual front-panel controls, remote program inputs, or a combination of both. Manual controls can be inhibited entirely during remote operations. The 1335A is a welcome addition to medical and instrumentation systems.

OEMs who need a larger viewing area and a brighter image at faster scan rates like the 1332A. They appreciate its 9.6 x 11.9 cm viewing area, its superior performance, and the ease with which the 1332A, like the others, integrates into a variety of racks and cabinets.

For photographic recording of displayed data, the new 1333A offers new performance levels. Its extremely small spot size of 0.20 mm (0.008 in.) provides the exceptional quality necessary for easy and accurate photo evaluation. And its 8 x 10 cm screen allows reproduction on Polaroid film with very little optic reduction. For convenience, all frequently used controls on all of these displays have been placed on the front panel for maximum accessibility.

Which display best fits your requirements? Let your local HP field engineer help you decide. Or write for specific details. We'll help you pick a display that makes your system look as good as it actually is.

HEWLETT PACKARD

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1501 Page Mill Road, Palo Alto, California 94304

Electronic Design 8, April 12, 1976

CIRCLE NUMBER 103
MONTOLITHIC CRYSTAL FILTERS

the State of the Art

SPEAKING TO THE DEAF
Our monolithics find their way into some fascinating and unusual applications. For instance — a narrow-band FM system which allows children with severely impaired hearing to participate in normal classroom activities. One of the requirements of the system was that both the students’ receivers and the teacher’s transmitter allow unhindered movement by the wearer. Another was freedom from interference, including interference from other systems in nearby classrooms. Cost was also an important factor. One of our standard 10.7 MHz tandem monolithic crystal filters in each receiver takes care of the interference. Its size is consistent with the needs of the wearer. Its cost is consistent with educational budgets.

HAVE IT YOUR WAY
As regular readers of this column know by now, we offer the broadest line going of standard monolithic crystal filters. It may be worth mentioning that we’re just as interested in helping you with a custom monolithic as we are in showing you new ways to use our regular models. We’ve done hundreds of production “specials” from 5 to 180 MHz. May we do one for you?

What’s your production application? Talk with us about it. We may be able to help. And if your interests include teaching the deaf, we’d be happy to put you in touch with the manufacturer of this equipment.

INSTRUMENTATION

Ultrasonic units fit modular instrument line


MP203 and MR101 are part of a modular, plug-in ultrasonic system, designed to operate with Tektronix TM-500 system power modules. M-series is TTL-compatible. The MP-203 is a variable output ultrasonic pulse generator. It generates a negative spike pulse with a typical rise time of 7 ns and a peak amplitude of 230 V into 50 Ω. Repeat rate is adjustable to over 10 kHz. MR101 is a receiver-amplifier with a calibrated gain of 40 dB.

CIRCLE NO. 389

Chart recorder offers remote control

McKee-Pedersen Instruments, P.O. Box 322, Danville, CA 94526. (415) 937-3630. $695.

MP-1027-MR recorder is a general-purpose, flat-bed unit for laboratory use. The recorder features a six-speed, digital chart drive and electric pen lift. Both can be remotely controlled by contact closures. The chart drive can also be stepped by logic pulses. It is possible to slave the chart drive to the pen lift so that only one contact closure is required to drop the pen to the writing position and start the chart. A major feature is the wide range of calibrated full-scale spans: from 1 mV up to 100 V.

CIRCLE NO. 390
use pressure sensitive TEMP-R-TAPE of fiberglass for quick relief.

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Find your nearest Distributor in the Yellow Pages under “Tapes, Industrial” or in Industrial Directories or write for complete specification kit and sample offer. The Connecticut Hard Rubber Company, New Haven, Conn. 06509

CHR
an ARMCO company

CIRCLE NUMBER 106
Electronic Design 8, April 12, 1976

Speed indicator displays digitally


A new digital speed indicating system consists of a 3-1/2-digit panel meter and a precision, permanent-magnet, dc tachometer generator. Also available are 2-1/2 and 4-1/2-digit meters. The system provides a continuous updated reading of rpm and allows any reading to be displayed indefinitely, regardless of speed, through the actuation of a hold signal. Three bidirectional ranges are offered as standard: 0 to 100 rpm, 0 to 1000 rpm and 0 to 10,000 rpm. Other ranges and engineering units are also available, as are BCD outputs.

CIRCLE NO. 391

DMM/thermometer linearizes sensor inputs

Takeda-Riken, 1-32-1 Asachi-Chō, Nerima ku, Tokyo, Japan.

Model TR-2112 thermometer-multimeter measures dc V, ac V, resistance and dc and ac current in addition to temperature. The unit digitally linearizes the sensor input to cover a temperature range from -100 to +1600 °C with five kinds of thermocouples and an accuracy of ±0.3% of rdg ± 1 digit. With a CC thermocouple, resolution is 0.1 °C. As a DMM, the TR-2112 counts to 1999, with automatic ranging and resolution of 10 μV on dc V.

CIRCLE NO. 392

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A QUICK QUIZ ON MAGNETIC SHIELDS

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4. How many layers of 2044 Hypernom foil will attenuate a 4 oersted field by a factor of 10? What is "Mu" anyway?

Answers: 1. Amuneal; 2. six; spot welded, heliarc welded, drawn, spun, wrapped or hydroformed, 3. Amuneal; 4. two layers; 5. to restore the optimum magnetic shielding properties of the metal destroyed during fabrication; 6. the Greek letter denoting permeability, the ability of the shield to carry the field.

For all the answers, send for your free Magnetic Shield Source Book today.

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Continuity checker uses no return lead

X-Tronics Electronics, 15500 Trask River Rd., Tillamook, OR 97141. (503) 842-7296. $12.50 w/o batteries; stock-30 days.

This continuity checker has no ground-return lead. The circuit is completed through the hand and body of the user and the component being tested. The checker is completely portable and can be carried in a pocket. The output indication is visual.

CIRCLE NO. 393

Sig gen stretches range of scope cal unit

Tektronix, P.O. Box 500, Beaverton, OR 97077. (503) 644-0161. $1995; 10 wks.

Model SG 504 leveled sine-wave generator is said to extend the frequency range of the company's TM 500 oscilloscope calibration package far beyond that of any other on the market. The unit provides a regulated, constant-amplitude sinusoid over a 245-to-1050-MHz range. The unit indicates frequency on a high-resolution tape dial that expands each band over 28 in. It produces internally selectable amplitude reference signals of 0.05 MHz for real-time bandpass measurements, or 6 MHz for sampling.

CIRCLE NO. 394
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CIRCLE NUMBER 110

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CIRCLE NUMBER 111

Electronic Design 8. April 12. 1976

decitrak

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Optical BCD Encoder...

LED Light Source Heavy Duty Industrial Design...

BCD Output at DTL/TTL Compatible Levels High Speed... Low Torque Operation

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LITERATURE: Write for descriptive literature and your free copy of Digital Solutions to Automatic Control.

Theta

INSTRUMENT CORPORATION

Fairfield, New Jersey 07006 • 201-227-1700

CIRCLE NUMBER 112

Electronic Design 8. April 12. 1976
**DATA PROCESSING**

**Printer for calculators enhances programming**

Texas Instruments Inc., P.O. Box 5012, M/S 84, PC-100, Dallas, TX 75222. (214) 228-2011. $295 (re-tail).

The new PC-100 print cradle allows any TI hand-held programmable calculator to become a desktop printing unit. The user is able to print anything shown in the display, or to print the step-by-step execution of a program. A 2.5-in. thermal tape has room for 20 char/line with each character printed in a 5 × 7 dot matrix. The printer is fully controllable from the calculator keyboard or card program.

**Drum memory suits military users**

Datum Inc., RMS/Timing Div., 1363 S. State College Blvd., Anaheim, CA 92806. (714) 533-6333. From $25,000; 120 days.

Called the 300 Series, this ruggedized drum memory is supplied with a controller to mate with the Honeywell H316 computer. It is a fixed head-per-track unit with a capacity of up to 4.66 Mbits, a data rate of 2.5 MHz and an average access time of 17 ms. It withstands 10-G shock, 2-G vibration, 0 to 55 C and up to 90% relative humidity. A complete system consists of a controller in an ATR package that measures 10.125 in. W × 7.625 H × 15.5 in. D and the drum, which measures 13-1/4-in. dia. × 14-1/2 in. height, and has a total weight of 72 lb.

**Floppy-disc controller uses single-chip μP**

Scientific Micro System, Subsidiary of Corning Glass Works, 520 Clyde Ave., Mountain View, CA 94043. (607) 974-8147. $320 (100 up).

The SMS FD0300 is one of a series of complete IBM-compatible floppy-disc controller systems. All the controllers use single-chip bipolar microprocessors developed by SMS. The FD0300 requires less than 50 IC packages and occupies less than 100 in.² of PC board. It can interface floppy-disc drives with CRT terminals, instruments, microprocessors or other byte-oriented systems, and can interface up to four floppy-disc drives in series.

**Disc drive accesses track-to-track in 6 ms**

Orbis Systems Inc., 14251 Franklin Ave., Tustin, CA 92680. (714) 838-1491. $528 (OEM qty).

Model 76 low-cost diskette drives for OEM use are offered in standard or double-density versions with up to 5.4 million bits, a 250-kbps transfer rate and an access time of 6-ms track-to-track. A door interlock eliminates operator error and data corruption; no job restarts are required. A self-centering lotus-petal clutch gently eases the diskette into registration position. And a uniball head positioner provides zero backlash. Options include sector generator and write enable, which can expand system flexibility and performance better than IBM-3740-specification requirements.

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- AMERICAN DATA, Huntsville, Alabama
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CIRCLE NO. 113

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**CIRCLE NO. 395**

**CIRCLE NO. 396**

**CIRCLE NO. 397**

**CIRCLE NO. 398**

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Electronic Design 8, April 12, 1976
High performance you can really see.

Look to Motorola CRT modules for sharper, brighter displays.

Motorola's 12 and 15 inch CRT modules deliver! 80 sharp characters by 24 lines, with a 7x9 dot matrix display. Video response to 22MHz. Horizontal scan frequency up to 19KHz. TTL separate sync or composite video input. And all at a lower cost than you may now be paying for CRT's with lower performance.

Other screen sizes are 5, 9, 19 and 23 inches. All are optimized for data display applications. All are adaptable for U.S. or European operation. All circuitry is completely solid state. In fact, up to 99% of the module circuitry comes on easily removed printed circuit boards . . . for quick and easy maintenance.


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To find a fault fast... "QUIK-FREEZE IT!"
Drops surface temperature to -50°F. in seconds

Few things waste more time than locating an intermittent circuit component. Isolate off-again on-again resistors, capacitors, etc. by quick-freezing them during testing. Remember: MS-240 “Quik-Freeze” is not only a circuit cooler, but also a full-fledged freezer. It can drop surface temperature to -50°F. -( -45°C.) in seconds. A handy extension nozzle confines the chilling spray to the suspected component. Use MS-240 also to prevent undesirable heat transfer to delicate circuit elements during soldering or welding.

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DATA PROCESSING

Unit scrambles data for RS-232C modems
Datatek, Inc., 13740 Midway Rd.,
Dallas, TX 75240. (214) 233-1030.
$4900: half duplex; $6400: full duplex.
The DS-138 scrambles synchronous data at any rate up to 9600 baud. A method of code generation is used that will not repeat a scrambling pattern until 10^6 bits have been transmitted. The scrambler has 10^6 code settings available and the provision for visual and audible failure warnings to ensure secure operation. The unit is housed in a locked steel case that measures 5-1/4 x 17 x 16 in.

Tape-recorder system for industrial use
Emerson Electric Co., 3300 S. Standard St., Santa Ana, CA 92702. (714) 545-5581. $2295:
Model 2005 (unit qty); $70: Model 2004 (OEM qty).
The 2000 Series Tape Pac system includes a 1/2-in. computer-compatible magnetic tape that can work in industrial environments. Tape is protected from temperature and humidity variations. The standard system consists of a Model 2005 tape drive and a Model 2004 Tape Pac. The Tape Pac is plug-to-plug compatible with conventional tape drives using industry-standard tape formatters that handle phase-encoded (PE) or NRZI data. The tape drive has a bidirectional read/write speed of 25 in/s and a search/rewind speed of 240 in/s. No reel motors or associated complex servos are needed. Recording densities include 7-to-9-track NRZI at 556 and 800 bpi, or 9-track PE at 1600-bpi recording density. Also, a special recording format in serial PE can record at 3200 bpi. The data transfer rate is 40-k bytes/record at 25 in/s with a recording density of 1600 bpi.

The first, accurate digital pyrometer that measures thermocouple and RTD ranges for $165.00

Newport’s Model 268 Digital Pyrometer gives you 19 optional bipolar ranges. It can be adapted to almost any application where temperature is measured. Power and signal inputs are attached to a convenient screw terminal barrier strip, while digital signals are handled through a PCB connector.

OTHER OUTSTANDING FEATURES:
- Large 13mm (1/2 inch) LED digits
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- NMR 60dB
- CMR 120dB

Newport Laboratories, Inc.
630 E. Young St., Santa Ana, CA 92705
Call Collect: (714) 540-4666
In Netherlands, Call:
Amsterdam (20) 45-20-52

Data logger monitors processes
The Digisense 200 digital multipoint data logger can monitor up to 24 process points. The inputs can be in the form of low level analog signals from thermocouples or other transducers. The unit will digitize, and, if necessary, linearize the signals and display and print the data. The printout can also include time of day, point number, magnitude and symbol.

CIRCLE NO. 399

CIRCLE NO. 400

CIRCLE NO. 401
$250 PAPER-TAPE READER
HAS ONE MOVING PART

This paper-tape reader comes with TTL interface and has only one moving part. It reads any standard tape at 150 cps, asynchronous. Bi-directional, the unit stops on character and automatically detects taut tape and end of tape. The reader's user-furnished clock input is a positive-going pulse that advances tape at the input's negative-going edge and may also strobe the output data. Power requirements are +5 V at 200 mA and 24 V at 600 mA. Stand alone versions with parallel or serial RS 232 outputs, fanfold box and spooler are also available. Price $250 (1-99 units).

CIRCLE NUMBER 117

Penril Modems offer the OEM and End User advantages in...

CUSTOM DESIGN
Our facilities and capabilities enable us to provide both OEM and End Users with low, medium and high-speed modems tailored to meet their specific system requirements and cost objectives.

RELIABILITY
Our modems use hermetically sealed semiconductors and ceramic integrated circuits exclusively. Vibration, burn-in, and complete electrical and mechanical testing is performed on every unit prior to shipment. Perhaps these are the reasons our modems are experiencing MTBF's ranging from 35,000 hours to 200,000 hours.

DIAGNOSTICS
No special tools or equipment are required to install, operate or maintain our modems. Built-in diagnostics obviate the need for test equipment and minimize the time and labor involved in performing system fault isolation. Many of our units feature a unique telemetric test capability whereby non-technical personnel can test the entire link and isolate faults therein all from one site.

PERFORMANCE
The bit error rate probability of our modems is $1 \times 10^{-6}$ or better over leased lines or the dial network. Our units are virtually unaffected by the major line impairments affecting data transmission.

AND MUCH MUCH MORE
If you'd like to know more of what Penril modems have to offer, ask for our modem brochure, or let us know of your specific requirements.

Penril Corp. Communications Division
5520 Randolph Road • Rockville, Maryland 20852 301/881-8151

CIRCLE NUMBER 118

CIRCLE NUMBER 119

Electronic Design 8. April 12. 1976
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Our Silvercel rechargeable batteries pack the most useable power into the smallest and lightest weight modular package now commercially available. In fact, per unit of weight Silvercel delivers 3 to 4 times the energy of common rechargeable batteries and does it with flat, non-tapering discharge voltage characteristics.

Whether you are an OEM development engineer, a supplier or a battery user, we invite your inquiry. Our technical assistance and advice are yours for the asking.

Write or phone for complete information.

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Yardney Electric Corporation

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Pawcatuck, Connecticut 06261
(203) 599-1100

CIRCLE NUMBER 120

DATA PROCESSING

Erases PROMs with UV radiation


The Model 2537 erase-light module can erase any electrically programmable memory designed to be erased by UV. It uses a 2537-A source, and is equipped with interlocks to protect the user against accidental exposure. A timer provides up to 30-min of exposure in 5-min increments.

CIRCLE NO. 402

Optical lines used in severe locations

Spectronics, Inc., 830 E. Arapaho Rd., Richardson, TX 75080. (214) 234-4271. Qty. 1-9; SPX 2672, $750; 2673, $900; and 2674, $1000; 6 wks.

Three optical transmission lines, Models SPX 2672, 2673, 2674, provide communication in severe environments. They accept electrical signals at one end, and transmit, with no electrical attenuation, to the other end 150 ft away. The SPX 2672 is designed for standard TTL levels and will handle input data from dc to 100-k bits/s. The SPX 2673 handles 1-V pk-pk video signals, and the SPX 2674 handles TTL levels from dc to 10 Mbits/s. These lines are immune to EMI and other adverse atmospheric conditions, and produce no electrical noise. They also have complete isolation from input to output.

CIRCLE NO. 403

Core memory board achieves double density

Fabri-Tek Inc., 5901 S. County Rd. 18, Minneapolis, MN 55436. (612) 926-2721. $2650; single qty.

Core-memory boards with twice the capacity of the company's earlier Model 696 are now available. Each stores 32 k x 18 bits and plugs into an enclosure that has an integral power supply and is capable of holding up to eight boards. The system can be configured for a 512-k x 9-bit to 128-k x 36-bit format.

CIRCLE NO. 404

Digital recorder system uses ultra-low power


Because individual data-recording requirements can vary widely, Datel introduces the ICT series of ultra-low power, write-only incremental cassette transports and a family of compatible circuit-card modules that sequence and drive the transport stepping motor and format the tape heads. Extensive use of CMOS circuitry minimizes power drain. A building-block approach enables the engineer to customize the system he needs. The ICT-series transport can begin writing data within 20 ms from a standing start. Power is consumed only during motor stepping, and the transport and card modules remain turned off when not writing data. Forerunner of the new series is the Model ICT-WZ incremental system. It uses Philips or other certified computer-quality magnetic-tape cassette intended for CNRZ data formatting. With a bit density of 615 b/in., the transport records at 100 b/s and uses only 100 mA at 12 V dc. Word length can be user programmed to 8, 10, 12, 14 or 16 bits long, and depending on jumpering of the circuit cards, files can consist of 1, 2, 4, 8, 32, or 64 words, or an externally controlled file length. Optional circuit cards include an EOT/BOT sensor, motor drive, clock and head drive and formatter—an 8-bit, CMOS parallel input/output encoder.

CIRCLE NO. 405
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EMI AND DECOPLING
PROBLEMS...

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hermetic seal

Unique center hole (weldable)
(Actual Size)

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applications, featuring:
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Electronic Components Division
212 Durham Ave. Metuchen, N.J. 08840, (201) 548-2800

CIRCLE NUMBER 121

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CIRCLE NUMBER 123

Electonic Design 8, April 12, 1976

CIRCLE NUMBER 122

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and mechanical strength. Resists
corrosion and chemicals and will
not support a flame. Used for
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and fittings. Effective as scuff
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cables and harness ... and much
more. Sizes ½" to 4". Black only.

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CIRCLE NUMBER 122
"The majority of can
our new business be attributed to the GOLD BOOK."

"Electronic Design has done one hell of a job in getting the GOLD BOOK to the places it should be," says Richard D. Vance, President, Ad-Vance Magnetics, Inc., Rochester, Indiana. Ad-Vance describes itself as the industry's largest, oldest, most experienced independent firm exclusively manufacturing magnetic shielding. Mr. Vance continues:

"We're an old company with a new name, so not too well known in the field. Our two-page spread in the GOLD BOOK has made us much better known. The GOLD BOOK gave us opportunities to bid from firms who had never heard of us before they saw our GOLD BOOK ad. For example, just today we got to bid on 1,000 CRT magnetic shields for a midwest firm who found us in the GOLD BOOK.

"Engineers don't hesitate to tell us they saw our ad in the GOLD BOOK when they call. I do a lot of sales work in the field, and I run into the GOLD BOOK almost everywhere our magnetic shielding has an application, both in purchasing and engineering. You've done one hell of a job in getting the GOLD BOOK to the places it should be."

Ad-Vance states that over 90% of past and present magnetic shield designs have been fabricated in the Ad-Vance plant during the past 20 years. Its magnetic shielding is used off-planet in spacecraft and satellites, and worldwide in precision industrial, laboratory, military and consumer applications.

Because the GOLD BOOK goes primarily to Electronic Design's audience of specifiers, Ad-Vance gets the benefit of 78,000 engineers, engineering managers, purchasing agents and distributors throughout the U.S.A., not to mention 13,000 overseas. These are the men who are ready to talk shielding—the men who have the authority to buy.

**ELECTRONIC DESIGN'S GOLD BOOK IS WORKING ...IT'S WORKING FOR READERS...AND IT'S WORKING FOR ADVERTISERS, TOO.**
Semi measurements

Valid vs erroneous conclusions based on semiconductor parameter measurements made with a VOM is the topic of the newest Tech Tip, Westinghouse Electric, Semiconductor Div., Youngwood, PA

CIRCLE NO. 406

D/a converters

A wide range of applications possible with a universal d/a converter is covered in an application note. Precision Monolithics, Santa Clara, CA

CIRCLE NO. 407

Microwave freq counter

"Understanding Microwave Measurements" starts with a description of three common down-conversion techniques: prescale, heterodyne and transfer oscillator. Measurement speed, accuracy, dynamic range and tolerance to modulation and unwanted noise of each technique are discussed in detail in the 10-page note. Hewlett-Packard, Palo Alto, CA

CIRCLE NO. 408

Spring connectors

"How to Improve Performance of Spring Connectors," a six-page brochure, is illustrated with tables, flow diagrams and photographs. It is designed to aid the designer in selecting material, testing, and specifying requirements for springs made from high strength beryllium copper alloys. Instrument Specialties, Little Falls, NJ

CIRCLE NO. 409

Solid-state relays

"Introduction to Solid State Relays," a 16-pager, details the specifications, advantages and applications of solid-state relays for switching power in electrical equipment. A glossary of terms is included. International Rectifier, Crydom Div., El Segundo, CA

CIRCLE NO. 410

Programming pins

Individual programming of DIP sockets is possible with the company's Dipatch. For the ON position, the pins are inserted into the opposing socket contacts. For storage in the OFF position, the Dipatch is simply turned upside down and the plastic ears are inserted into the socket contacts. The device stacks on 0.1-in. centers and is 0.4 in. wide. Pins have diameters of 0.018 in. and are gold over nickel plated. Aries Electronics.

CIRCLE NO. 411

Circuit-board support

Series SCBS circuit-board support with a #8-32 thread for speedy screw fastening to a nut or receiver is available in eight spacing heights from 0.25 to 1.406 in. It has a top locking tab, which laps over the board after insertion for secure fastening in either an upright or inverted position. The support comes in UL-rated V-2 and V-0 nylon flame retardant materials. Richco Plastic.

CIRCLE NO. 412

Knurled pins

Cold formed, knurled pins with diameters as fine as 0.029 in. easily pass industry standards for pull-out torque. Knurls available include diamond, straight, diagonal, annular groove and undercut. Parts come plated or unplated to specs. Art Wire and Stamping Co.

CIRCLE NO. 413

Conductive fabrics

Electrical resistance for high-performance, electrically conductive fabrics measures 10^1 Ω. The fabrics also feature exceptional strength and inherent flame-resistant properties. For a sample, send a letterhead request to Hercules Protective Fabrics, 1107 Broadway, New York, NY 10010.

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CIRCLE NUMBER 124
Processing analog signals?
Use the Panasonic 512-stage BBD for 25.6 m/sec. delay with wide frequency range and excellent S/N ratio of 70 dB.

The Panasonic MN 3001 contains two BBDs with independent input, output and clock terminals. Uses a common power supply. Pair of output terminals allows the clock component to be cancelled.

The BBD MN 3001 gives you wide frequency response. Up to 0.3 x fcp. Clock frequency range from 10 kHz to 800 kHz. S/N ratio of 70 dB.

Use the Panasonic MN 3001 BBD for variable speech speed control in tape recorders, tremolo and vibrato effects for musical instruments, plus telephone time compression and voice scrambling. Any place you design to process analog signals.

Panasonic® just slightly ahead of our time
Keytek's new Model 424 Surge Generator/Monitor is the first commercially available, self-contained instrument for generating and measuring the peak values of classic transient pulse forms. Designed to produce waveshapes such as 8x20, 1.2x50, 10x1000, 10x50 and 0.1 to 10 kV/usec, it simultaneously measures and displays, digitally, peak applied voltages and currents. Test circuits, varistors, silicon avalanche devices, gas tubes and networks of all types. Ideal for engineering, QC and production.

Programmable Pulses — Simple to operate and extremely versatile, the Model 424 can be programmed, by means of plug-in networks, to produce a wide variety of pulse shapes, with amplitudes to 1500 volts and currents to 500 amperes.

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KeyTek
INSTRUMENT CORPORATION
220 GROVE STREET, BOX 109
WALTHAM, MASS. 02154
TEL. (617) 899-6200
CIRCLE NUMBER 128

Time-code instrumentation

Precision time-code and time-keeping instrumentation, such as time-code generators, readers, digital clocks, and complete tape-search systems, are featured in a 22-page catalog. Systron-Donner, Concord, CA

Inverter SCRs

Fast switching 450-A rms, inverter SCRs in the 250RM series are described in a six-page data sheet. The literature contains 20 graphs, four dimensional-outline drawings and a photograph. Specifications and ratings are included. International Rectifier, Semiconductor Div., El Segundo, CA

Programmable calculators

A 12-page booklet describes how, with the addition of HP's EE software packs and an X-Y plotter, the HP 9800 series of desktop programmable calculators are capable of such important tasks as the design of analog networks, simulation of logic designs, prediction of system response in the time domain, simplification of microwave circuit design and interactive modeling for transformer design. Hewlett-Packard, Palo Alto, CA

TWT amplifiers

Features and specifications of the company's medium-power TW-TAs are given in an eight-page brochure, "Commercial Traveling Wave Tube Amplifiers." Varian, Microwave Equipment Operations, Santa Clara, CA

CIRCLE NO. 417

Semiconductor devices

"The Semiconductor Problem Solver" explains in detail problems of obsolete devices, custom hybrid circuits, special and assembly, custom monolithic and testing and screening. The brochure indicates the company's solutions. Custom Devices, Fern Park, FL

CIRCLE NO. 418

Microwave products

Active microwave products such as crystal, phase locked, cavity and Gunn-diode sources are covered in a 26-page catalog. Specifications, technical data and prices are shown for each device featured. Microwave Technology, Mechanicsburg, PA

CIRCLE NO. 419

Racks

Vertical and sloped racks are described in a 20-page catalog. Optima Enclosures, Tucker, GA

CIRCLE NO. 420

Double-balanced mixer

Double-balanced MIC "drop-in" mixers are described in a two-page data sheet. Detailed outline drawings and mounting data are shown. RHG Electronics Laboratory, Deer Park, NY

CIRCLE NO. 421

Comm test equipment

A 480-page communications test equipment catalog provides a comprehensive review of the company's test equipment for telecommunications. The catalog features the equipment according to the main field of application. Letterhead requests only. Siemens Corp., Communications Equipment Div., 186 Wood Ave. S., Iselin, NJ 08830.

INQUIRE DIRECT
Switches
Covered in a 36-page brochure are 10 standard types of switches, including lever, pushbutton, push-button slide and multi-pushbutton switches as well as rocker, rotary, rotary slide, slide and toggle switches. Shigoto Industries, New York, NY

CIRCLE NO. 450

Ceramic capacitors
A 20-page ceramic capacitor catalog includes expanded and extended range capacitance values, MIL-C-20 ultra-stable capacitors and additional dielectric and voltage selections in chip capacitors. Union Carbide, Greenville, SC

CIRCLE NO. 451

Signal generator
Photos, a schematic diagram and specifications in a six-page foldout cover the Model 3000 signal generator. Wavetek Indiana, Beech Grove, IN

CIRCLE NO. 452

PC & solderless terminals
"Printed Circuit and Solderless Terminal Brochure," a two-pager, includes up-to-date drawings and over-all dimensions dealing with PC extensions, PC clips, PC "T" slugs and wrapped-wire extensions for plugging into a PC board. Standard-Grigsby, Aurora, IL

CIRCLE NO. 453

Dye outputs for lasers
An up-to-date listing of dyes used in both the DL series and Spectroscan 10 dye lasers is included in a brochure. Curves show typical outputs in both the fundamental (360 to 750 nm) and frequency doubled (260 to 360 nm) modes. Molelectron, Sunnyvale, CA

CIRCLE NO. 454

Wire terminals
The geometric and metallurgical characteristics of crimp-type terminals are described in a 12-page booklet. Application tooling from simple hand-held crimping tools to fully automatic lead-making machines is also illustrated. AMP, Harrisburg, PA

CIRCLE NO. 455

Imaging devices
Imaging devices for military, space and scientific applications are described in a 10-page catalog. An explanation of the design, operation and advantages of each tube type is given, along with the specification tables and dimensional diagrams. Westinghouse Electric, Industry & Government Tube Div., Horseheads, NY

CIRCLE NO. 456

Filter characteristics
“Phase Response Characteristics of a Butterworth Filter" provides a basic understanding of the phase vs frequency relationship of a Butterworth filter, and provides step-by-step examples for calculating gain and phase shift through a high-pass, low-pass, bandpass or band-reject filter. Krohn-Hite, Avon, MA

CIRCLE NO. 457

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CIRCLE NUMBER 127
NEW LITERATURE

Resistor networks
Thick-film resistor networks and chip resistors are described in a brochure. Basic information on specifying custom networks, examples of custom circuits and a glossary of terms is included. Dale Electronics, Columbus, NE

CIRCLE NO. 422

Microwave test programs
High reliability test programs offered by the company for its entire microwave devices product line are included in a brochure. GHZ Devices, Chelmsford, MA

CIRCLE NO. 423

Battery/charger consoles
Design features, specifications and ordering information for transistor-controlled, mag-amp charger consoles for lead-acid and nickel-cadmium batteries and gelcells are given in a two-page bulletin. LaMarche Manufacturing, Des Plaines, IL

CIRCLE NO. 424

Process instruments
General information on more than 35 key process instruments is given in a 16-page booklet. The booklet groups the instrumentation by end application. Beckman Instruments, Process Instruments Div., Fullerton, CA

CIRCLE NO. 425

Knobs
Aluminum and molded phenolic knobs are illustrated in a 24-page catalog. Alco Electronic Products, North Andover, MA

CIRCLE NO. 426

Instrumentation amps
TWT and transistor instrumentation amplifiers are covered in an eight-page brochure. The catalog includes a selection chart, specifications and outline drawings. Hughes Electron Dynamics, Torrance, CA

CIRCLE NO. 427

Power supplies
Laboratory benchtop power supplies that include single, dual and triple-output models are featured in a 48-page catalog. Included are applications, a selection guide, and electrical and mechanical specifications. Acopian, Easton, PA

CIRCLE NO. 428

Triggered spark gaps
Performance specifications and application notes on over 20 types of triggered spark gaps are contained in a 12-page brochure. EG&G, Salem, MA

CIRCLE NO. 429

Plastic ICs
Life tests and screens on plastic integrated circuits are described in "Reliability of Plastic-Encased Integrated Circuits." The major failure modes of plastic-encased ICs, the causes and preventative measures and associated screening and testing are tabulated. Sprague Electric, North Adams, MA

CIRCLE NO. 430

Solenoids
Twenty-six solenoid models are discussed and illustrated in a 62-page "Solenoid Engineering Manual." Over 200 photos, drawings, schematics and charts are provided. Deltral Controls, Milwaukee, WI

CIRCLE NO. 431

Capacitors
Four bulletins cover monolithic ceramic capacitors, high-dielectric disc ceramic capacitors, temperature-compensating ceramic disc capacitors and reduced-titinate ceramic disc capacitors. Specifications and diagrams are shown for each group. Murata, Rockmart, GA

CIRCLE NO. 432
Interdata has developed a multitasking operating system called OS/16 MT2, which optimizes the use of its 16-bit minicomputers in real-time, program development and computational applications.

CIRCLE NO. 433

United Systems has expanded the Digitec data logger line. Six new models widen the temperature measurement capabilities of the data loggers to include thermistor and platinum resistance probes with readings in °C or °F.

CIRCLE NO. 434

Signetics has announced the qualification of nine low-power Schottky IC devices, which have met Mil Spec MIL-M-38510A.

CIRCLE NO. 435

GE's Hermetic Sealed Relay Operations has announced that its half-sized crystal rf relay is now qualified to MIL-R-39016/33A. Typical rf characteristics up to 500 MHz are 1.1:1 VSWR, 36-dB crosstalk and insertion loss of 0.34 dB.

CIRCLE NO. 436

Rockland Systems has announced a new frequency range extension option to its line of 2-MHz frequency synthesizers. Option 13 extends the frequency range of the Models 5100 and 5110 to 3 MHz, with no sacrifice of resolution.

CIRCLE NO. 437

CODI has added the JANTX1N-5518B series of diodes to its list of QPL products. The unit price for the JAN1N5518B through JAN1N5528B is $3.30 (100 qty.) and $4.90 (100 qty.) for the JANTX1N5518B through JANTX1N5528B.

CIRCLE NO. 438

DAC80 was formerly $46 in single quantity (voltage output) and is now $26.50 (1-24), $24.50 (25-99) and $19.50 (100-999).

CIRCLE NO. 439

Analogic has announced a price reduction on the MP2600 12-bit binary, 3-1/2 digit BCD a/d converter. Single unit price is now $89, which is less than 60% of the previous $149 unit price.

CIRCLE NO. 440

Texas Instruments has reduced prices up to 75% of its TMS8080 µP. New pricing is $34.25 (1-24) and $21.15 (100-up).

CIRCLE NO. 441

You know our reputation in DC to DC

Wait till you see Tecnetics' new 400 Hz AC power supply

We earned a reputation with our line of DC to DC power supplies. Now, we add to it with a new 400 Hz AC power supply. Like our 28VDC power supplies, the AC model features extremely high packaging density, high efficiency and reliability. Most important, it's small, measuring in at only 4x4x2 inches and weighing 36 ounces fully encapsulated. These power supplies are designed to meet the rugged vibration, shock, humidity and altitude specs of the aerospace industry (MIL-E-5400). They also have separate, remote error-sensing terminals to compensate for voltage loss, assuring that the voltage level remains constant at the load. Write for our 26-page catalog that gives full specs and prices on these and over three hundred other power supplies.

SPECIFICATIONS

<table>
<thead>
<tr>
<th>DC to DC</th>
<th>0-400 Hz AC to DC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output Power</td>
<td>150, 100, 50 &amp; 25 watt models</td>
</tr>
<tr>
<td>Output Voltages</td>
<td>13 standard outputs from 5 to 48V</td>
</tr>
<tr>
<td>Input Voltages</td>
<td>28VDC or 48VDC</td>
</tr>
<tr>
<td>48VDC only on 150 w units</td>
<td>(Single or 3 phase)</td>
</tr>
</tbody>
</table>

REGULATION

<table>
<thead>
<tr>
<th>Line</th>
<th>Load (LL to HL) 0.3%</th>
<th>Load (NL to FL) 0.4%</th>
</tr>
</thead>
<tbody>
<tr>
<td>(LL to FL) 0.1%</td>
<td>(NL to FL) 0.5%</td>
<td></td>
</tr>
<tr>
<td>0.01%/°C</td>
<td>0.01%/°C</td>
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prices.

CIRCLE NO. 442

Price cuts up to 52% in the low-cost DAC80 line have been announced by Burr-Brown. The

ELECTRONIC DESIGN 8, April 12, 1976
Annual and interim reports can provide much more than financial-position information. They often include the first public disclosure of new products, new techniques and new directions of our vendors and customers. Further, they often contain superb analyses of segments of industry that a company serves.

Selected companies with recent reports are listed here with their main electronic products or services. For a copy, circle the indicated number.

Electronic Chemicals. Electrical insulation products.  
CIRCLE NO. 443
Sangamo Electric. Energy management products, electronic components, data instrumentation, communication products, aviation services and products, and commercial vehicle instruments.  
CIRCLE NO. 444
Cetec Corp. Computer peripherals, marine communications and navigation gear, components, plastics and microphones, AM and FM broadcast equipment, high-fidelity equipment and TV broadcast antennas.  
CIRCLE NO. 445
Cooper Industries. Hand tools, aircraft parts and services, compressor units and systems, and engines.  
CIRCLE NO. 446
Comten. Communications and message-switching computer systems.  
CIRCLE NO. 447
Spar Aerospace Products Ltd. Aerospace and military electronics, gears and transmissions, aircraft repair and overhaul.  
CIRCLE NO. 448
CIRCLE NO. 449

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To prove No. 32's capabilities, we make this unusual offer: we will send you your first gallon of No. 32 for only $8.00 including freight. Put our No. 32 through its paces. You'll find the results topnotch and your costs will be lower along with your soldering safety hazards. Also available as #3298 where faster moisture removal is required.

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C Mini-Computers
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Electronic Design 8, April 12, 1976
Design with the complete flat cable/connector system.

Assembly-cost savings are built in when you design a package with "Scotchflex" flat cable and connectors. But more important, 3M Company offers you the full reliability of a one-source system: cable plus connectors plus the inexpensive assembly aids that crimp the connections quickly and securely (with no special operator training required).

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

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*Previously announced

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