VOLUME 11 □ NUMBER 1 IEEE spectrum JANUARY 1974

IEEE spectrum

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departments

the cover

We thought the painting by Daniel E. Noble, Chairman of Motorola's Science Advisory Board, particularly appropriate as an underlying theme for the special 61-page report, Technology '74, that begins on page 30. The title of Dr. Noble's painting: "Energy."

spectrum

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spectrum JANUARY VOLUME 11 NUMBER 1

Spectral lines

Energy crisis: Seeking the real alternatives

What should be the role of the technologist in communicating with the "average citizen," who knows only that fuel and electric power are in such short supply that his life style is affected? A desirable outcome that could result from a more thorough delineation of the many tradeoffs available to the U.S. and other developed countries in piloting their way to a more stable and satisfactory world energy situation is a citizenry that is "comfortable" in its knowledge that options do exist. A public that is aware of the real alternatives along with their consequences is less likely to react in ways that cause the situation to deteriorate. Such was the conclusion of a workshop of concerned engineers and scientists meeting recently on the topic of energy resources.*

But by whom and through what means can the public be brought to awareness? The mere reiteration by the popular press of superficial analyses and panic predictions may do little good, if not harm. Nor will the promise of years-away technology help.

Understandably, the public is uneasy because of its ignorance in areas such as the availability of energy reserves; the role of an open market in making energy policy decisions; economic factors that encourage or deter a business enterprise from changing its ways of doing business; and the status of alternative energy sources. But who will, or is even capable of, assuming this educational chore? As an example, the lay press, as well as some technologists, fail even to make a distinction between oil/coal *reserves* (proven sources that can be economically recovered) and *resources* (probable sources inferred from data and knowhow).

Then too, the public often becomes enraged at what appears to be just another "corporate ripoff" when it is simply not in possession of the economic facts of life. A typical comment concerns the oil companies "holding back" on the development of shale oil extraction until the price of oil from traditional sources rises to the point where shale becomes "profitable." (Such a comment, while true, is often put in such a way as to suggest that (1) the oil companies have a choice, and/or (2) running a profitable operation is antisocial.) Is it possible that the U.S. Government, as part of "Project Independence," will subsidize the production of oil from shale, or embargo the importation of low-cost oil so that the higher cost of shale oil can be passed along to the consumer? If so, it will somehow have to assure the oil companies that the rules of the game will remain fixed long enough for them to make, and recover, investments they may be induced to initiate.

In any situation short of a crisis, the public seldom favors the imposition of new restrictions by Government intervention. Perhaps the citizen senses, through a combination of intuition and awareness of history, that change, particularly that which is legislated, often foists on some segments of society unfair demands, and he fears that he may find himself among the mistreated groups. What is a mere inconvenience to most people may be a threat to his own livelihood. Thus, gas rationing, black market prices, and lowered speed limits threaten truckers, while Sunday gas bans threaten the tourist industry.

On the other hand, a situation effectively outside the control of a given country, such as the wielding of oil supplies as political weaponry, can impose, directly or otherwise, serious inequities in what may have been a reasonably open and stable market. Then it is possible that some temporary intervention is desirable to help spread the cost of economic adjustments. An obvious danger is that once helpful intervention is initiated, it may become institutionalized.

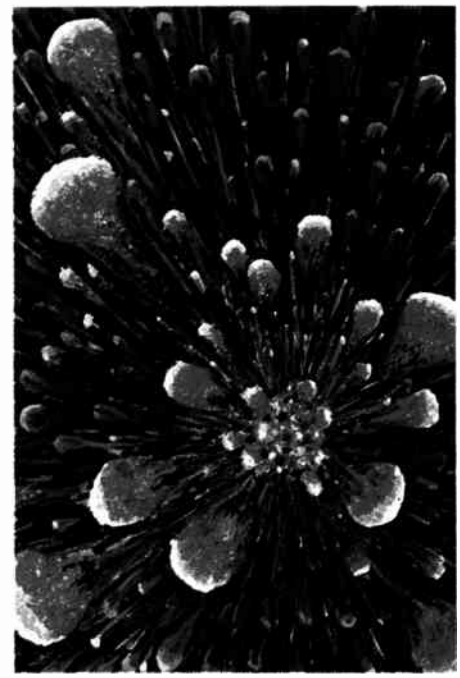
Finally, the public is frequently misled concerning the feasibility of alternatives. In time of crisis, the citizenry is told that there are not only other ways of doing things (e.g., providing energy), but better ways. Unfortunately, the time factor is too often overlooked. (How long does it take to put a nuclear plant in place, properly sited to ameliorate adverse environmental effects? Or to prove the feasibility of fast breeder reactors? Or to build the Alaskan pipeline?)

Too often the technical community itself does not make this point clear in communicating with the public. And when it does, and is then asked why such programs were not initiated years ago, too often it stammers over an answer, alluding to some obscure "they" who failed to act. In truth, no action can be or could have been taken without not only an understanding of the particular option, but a subsidizing of its development. Every technological process has its own "due season" which is paced by economics. It cannot be advanced in time (and often cannot even be put in place when needed) without subsidy. In a complex situation involving world energy policy, or even national energy policy, such subsidy must almost of necessity stem from the Government. Even a monopolistic industry—because of the uncertainties involved—is not likely to make the investment as early as it should to least disrupt service to its customers. Furthermore, subsidy, for better or worse, carries with it a degree of *de facto* control.

Donald Christiansen, Editor

*"Technology and social institutions," an Engineering Foundation Conference," May 20-25, 1973.

Special report



Technology '74

The experts analyze the immediate past to help define significant hard/software trends for the year ahead. Solid-state and computer technology pervade many of the most significant new electrical/electronic developments.

Where does one start? So much happened during the year just past in both the electrical and electronics arts that to rank order the developments by "significance" is a virtual impossibility. Nevertheless, with the invaluable aid of literally hundreds of members of IEEE Groups and Societies, as well as inputs from other industry experts, the staff of *Spectrum* has assembled this report on hardware and software developments and trends. The emphasis is on existing products and equipment, and near-term new equipment, as opposed to blue-sky projections.

The report is divided into 12 technical sections, covering subjects from computers to cybernetics, and concludes with a discussion of the social implications of technology. Occasionally it ranges into speculation about hardware that has not yet been proven feasible, but these instances are clearly spelled out. Because certain hardware (or software) items may be mentioned in more than one section, we have used a marginal indexing scheme to help locate them.

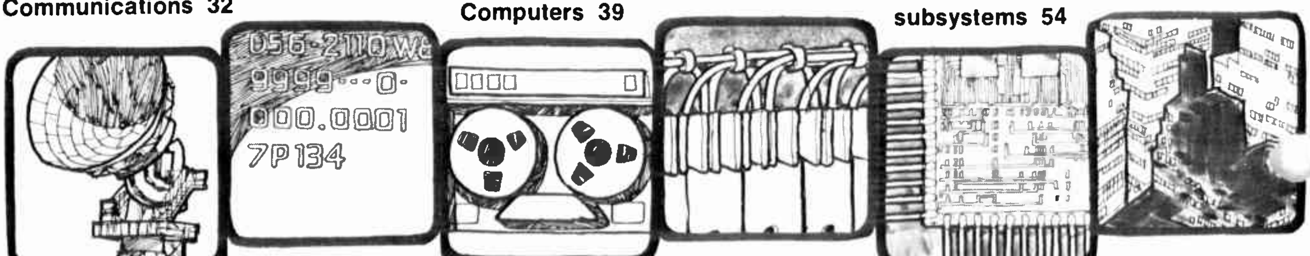
The single device technology that cuts across almost all application areas is, of course, solid state, while, in the case of systems, it is computer technology that dominates, with communications running a close second.

A good example of the pervasiveness of semiconductor and computer technology is seen in large-scale integrated microprocessors, which have arrived on the shelves of semiconductor makers at attractive prices. Coupled to companion semiconductor memories, they become microcomputers for instrumentation and production processing.

New supercomputers went into operation during 1973, including one at the Rome Air Development Center (and the famed ILLIAC IV became partially operational). The cost of computer terminals has dropped significantly—particularly for the "intelligent" terminals. And small flexible plastic discs have been developed for low-cost random access storage for minicomputers.

The growth of computer networks and allied data communications equipment is underscored by an increase of expenditures of nearly 28 percent during the past year. The Advanced Research Project Agency (ARPA) network alone now includes 36 sites and 40 computers nationwide. Its operation is

Donald Christiansen Editor



based on "packet" switching (messages are divided into short segments called packets). Similar systems are under development elsewhere, including Japan. The first nationwide commercial network designed specifically for digital data transmission is Canada's "Dataroute" system; a similar system for the U.S. is scheduled to go into service this year.

Meanwhile, in regard to general communications, the technology is moving toward ever-higher frequencies to make more efficient use of the limited spectrum. Both better spectrum management and improvements in hardware are aimed to help solve this problem. At Hughes Aircraft, a 60-GHz spacecraft communications system, containing two significant new types of upconverters, has been built. For voice communications, PCM has come into its own (new facilities are being added at the rate of 16 000 channel-kilometers per day).

The computer, too, more than anything else, has contributed to advances in automation of industrial systems. Programmable controllers are estimated to have increased in usage more than a dozenfold over the past two years. Last year, Digital Equipment Corp. introduced one having single-unit-expandable inputs and outputs (to 512 and 256, respectively) and modular construction. Modicon's new Model 184 monitors parameters such as tool life and running time. FX Systems developed a reprogrammable-ROM-type programmer.

In the numerically controlled machine tool field, computerized NC, as opposed to hard-wired (direct) NC, is growing rapidly. And, finally, solid state has firmly taken hold in power utilization and control, in the form of thyristors. Notable new applications of thyristor-based control systems are in cement plants and glass manufacturing, as well as for regenerative braking of rapid-transit equipment. Use of automatic test and checkout increased, particularly in the automotive industry for tasks such as emission analysis and carburetor testing.

In the device area itself, developments and applications in both large and small displays abound. In integrated circuits, new device isolation techniques are under development that will shrink IC size and increase switching speeds. Radiation-hardened CMOS devices have been built that provide an order of magnitude increase in resistance to ionizing radiation. In the linear IC area, progress is evident in the inevitable evolution to the fabrication of television sets using a mere handful of IC packages. Among the building-block components, monolithic D/A converters are now available that have 10-bit resolution, and an instrument maker has built a nonlinear amplifier with an 80-volt swing and a slew rate of 1.7 V/ns.

Highlights of recent developments in other electrical/electronics areas include:

☐ Prototypes of cryogenic cables, for underground applications, are under test, and the use of gas-insulated conductors enables switching stations to be assembled on a fraction of the land previously needed.

☐ Sophisticated telemetry and supervisory control systems for power dispatching, load prediction, and plant protection are being installed.

☐ BART, soon to reach San Francisco via tunnel, is already moving as many as 70 000 passengers daily.

☐ The U.S. Department of Transportation is testing high-speed tracked air-cushion vehicles on a 5-km test track.

☐ Toronto is developing a Maglev personalized rapid transit (PRT) system.

☐ M.I.T.'s Lincoln Laboratory is probing a variety of discrete-address beacon systems (DABS) to provide ground controllers with aircraft position and identity information. Future systems are intended to communicate advisories and commands to aircraft automatically without controller involvement.

☐ Power systems for unmanned spacecraft are undergoing improvements to cut weight and increase efficiency.

☐ Microwave ICs are helping reduce size and cost of satellite ground stations.

☐ Competition looms for consumer attention between video disc recorders and video tape recorders.

☐ General-purpose microcomputers are replacing hard-wired controllers for industrial uses.

☐ Oscilloscope writing speeds have reached 400 cm/μs and bandwidths, 1 GHz.

☐ Minicomputer power and signal acquisition capability are joined in new instruments.

☐ Ultrasound techniques are being exploited in new diagnostic instruments as those for cardiac examination and abdominal cancer detection.

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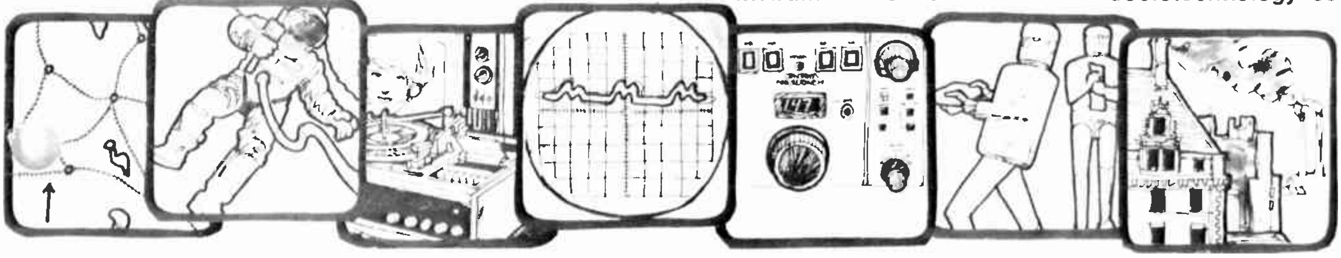


Communications and microwaves

A good spectrum stretcher is hard to find. Reaching toward light frequencies seems a good alternative

94-GHz paramp

Ever-increasing demands for transmission bandwidth are pressing communications technology towards light-frequencies. The aim is to enlarge the strained information-carrying capacity of atmosphere-borne communications and, equally vital, to increase the number and capacity of earth-bound channels.

Today, a half dozen Federal agencies are struggling valiantly to find more efficient ways to apportion use of precious spectrum space. Proposed measures include new, more nearly optimal strategies for frequency assignments and a satellite system to monitor spectrum use.

IMPATT oscillators

Even as these centralized plans are forming, communications engineers throughout the world are working to provide the new technology needed to supply the transmission bandwidth needs of the future.

100–200-GHz oscillators

Entering the 100-GHz region

Microwave technology, armed with new low-cost semi-conductor devices, is moving rapidly into millimeter-wave communications, approaching the near-infrared region of the electromagnetic spectrum.

During the past few years the art of solid-state microwave component fabrication has matured rapidly. Acceptance of these components by communications equipment designers and manufacturers has been widespread, a development that is especially significant in light of this industry's conservative preference for proven technology.

Requirements for improved cost-performance, for high-speed data transmission, and for more effective satellite channels have urged the development of new millimeter-wave systems.

60-GHz system

Solid-state technology made a number of significant advances in the millimeter wave field during the past year. Among the most important of these is a 60-GHz spacecraft communications system built by Hughes Aircraft (Malibu and El Segundo, California).

X-band circuits

The most highly developed component for this system is a low-noise V-band mixer and L-band IF preamplifier for the receiver front end. The single-sideband noise figure for the entire front-end averages less than 8.4 dB over a 500-MHz bandwidth.

Two types of upconverters, developed for the Hughes system, represent significant advances. One uses a silicon Schottky-barrier varistor to deliver more than 3 mW of power over a 600-MHz band; the other uses a silicon p-n junction varactor to deliver more than 20 mW over the same bandwidth. Both outputs are sufficient to drive directly a travelling wave transmitter tube.

A parametric amplifier, capable of low-noise operation at 94 GHz, was developed this year at LNR Communications (Farmingdale, N.Y.) built around a varactor with a 600-GHz cutoff frequency. The operation of this paramp is several times higher in frequency than that of previously available units and noise temperatures of less than 1000°K have been obtained.

Millimeter wave sources for frequencies above 100 GHz are important as pump sources for such paramps and also as local oscillators for mixer circuits. IMPATT diode oscillators for the 100–170-GHz range have been developed at Hughes Aircraft. Continuous output power of the devices is 120 mW at 130 GHz and 70 mW at 140 GHz.

At Bell Telephone Labs (Holmdel, N.J.), a family of hybrid integrated circuits has been developed for operation in the 100–200-GHz range. These circuits are first modeled and optimized at a low frequency (1–3 GHz), and then are scaled down in size for operation at the higher frequencies.

Solid state for microwave power

The bulk of the world's existing microwave radio relay transmission plant consists of point-to-point links, and the most common type of equipment used in long-haul high-capacity routes is the heterodyne repeater. These repeaters downconvert the received signal to an intermediate frequency (IF), then amplify and reconvert without ever demodulating the signals.

At present, travelling-wave tubes are used as output power amplifiers in most of these repeaters, but solid-state amplifiers are already competitive in performance and cost. At RCA (Princeton, N.J.), for example, device designers have produced gallium arsenide field-effect transistors (GaAs FETs) that deliver 0.63 watt at 6 GHz with 3 dB gain.

Improved low-noise FET amplifiers are becoming available for use at X-band frequencies near 10 GHz. Wide-band amplifiers developed at Hewlett-Packard Co. (Palo Alto, Calif.) have exhibited gains of 8.5 dB over a band of 8–12 GHz, and noise figures as low as 3 dB have been achieved.

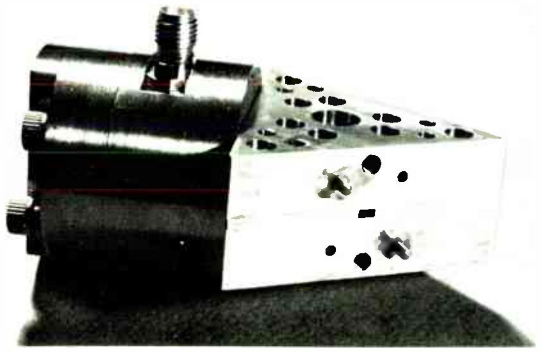
At Raytheon Corp. (Waltham, Mass.), GaAs IMPATT devices have produced 4–5 watts of X-band power with efficiencies approaching 30 percent. This is very significant since it is a power increase of two to three times over past efforts.

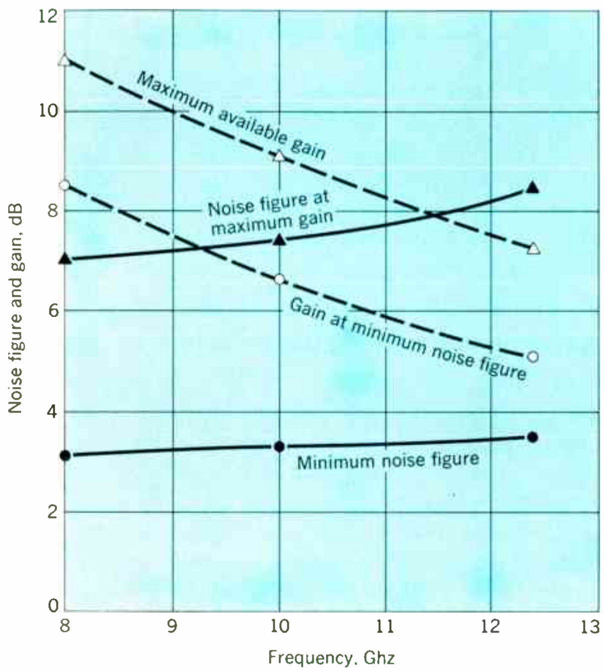
Other major recent trends in more conventional microwave systems include use of digital modulation techniques and design of equipment to supply broader transmission bandwidths.

Narrow beams for efficient transmission

Antennas, like microwave systems and components, are meeting the requirements of the crowded spec-

Howard Falk Associate Editor





trum with new and more sophisticated designs.

Communication satellites, sitting high above the earth, are in a position to cause widespread interference with earthbound communications. One way of minimizing this interference is to use narrow multibeam antenna patterns to trunk information between cities and countries. Some progress in using focal region optical methods to produce switchable high-gain beams has been made.

Small, linear bilateral antennas with short-backfire have been produced at the Air Force Cambridge Research Laboratories (AFCRL) with gains of 10–25 dB. There have been substantial improvements in side lobe reduction and in the impedance and pattern bandwidth characteristics for these cost-saving antennas, used in VHF satellite ground stations and in higher-frequency satellite-to-satellite communications.

short-backfire units

Higher gain antennas help considerably in reducing the radiation interference among users of the congested radio spectrum. Sidelobe reduction has been a recognized help in meeting this problem, and more recently, deep nulls in the antenna patterns have been used to blank out interfering sources, and relieve intentional or unintentional jamming. Such nulls can now be steered by self-adapting systems to reduce or eliminate unwanted signals from unpredicted sources. This development is based on antenna synthesis that generates and guarantees nulls at some angles with minimum deterioration of antenna gain in the desired directions. Recent progress in these antennas includes phased-array designs with minimum losses in gain or pattern shape and also wire antenna designs. Similar capabilities are being sought for reflector and lens antennas.

null steering

Phased arrays meet new needs

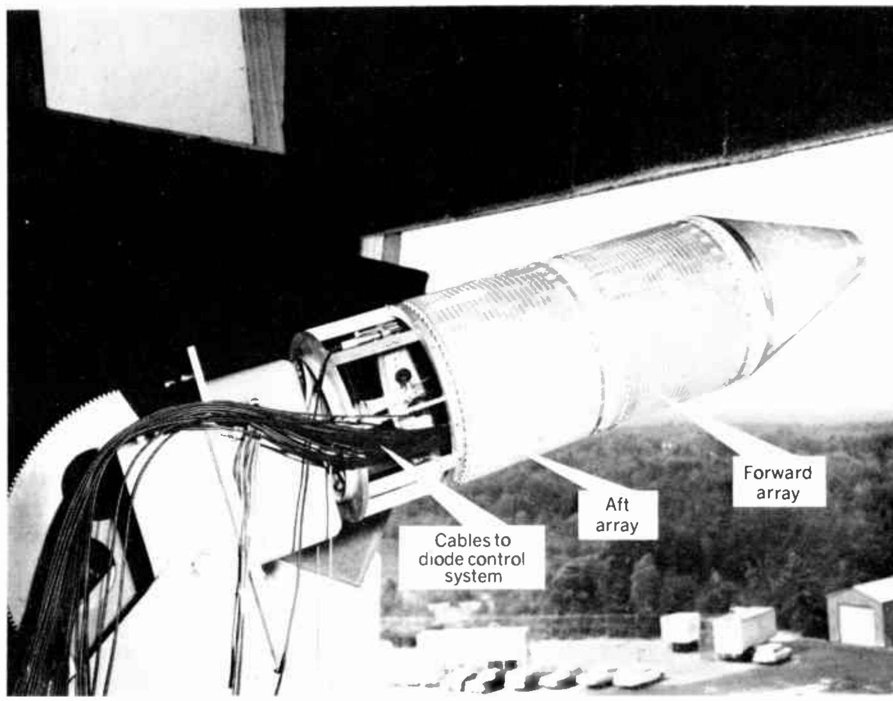
Dramatic progress in phased arrays has moved these versatile antennas into significant new applications. Phased arrays are multielement antennas, and a great variety of different characteristics can be obtained by varying the shape, size, and spacing of the elements as well as the sequence in which they are activated or scanned.

After a decade of struggle to eliminate "blind spots" on wide-angle scanning arrays, there are acceptable specialized solutions, and attention has shifted to new problems such as broadband solutions for phased-array radars. Rather dramatic progress has taken place in the use of waveguide radiators loaded

[1] For the 94-GHz parametric amplifier assembly shown at the top of the page, electro-forming and split-block machining techniques were used to achieve needed tight-coupling joints.

[2] Low-noise figures have been obtained for FET amplifiers at X-band frequencies, as shown in the graph above.

[3] High-gain, low-cost antennas for satellite ground stations like the one shown at the left, now use short-backfire linear, bilateral designs.



[4] Flush-mounted phased-array antennas, now used in missile work, are being adapted for aircraft communications.

to increase bandwidth, with dielectric coverings to control blind spots during wide-angle scanning.

limited-scan arrays

Demand for "limited scan" capabilities has led to arrays—produced at AFCRL—that perform with high gain and precise pointing in a limited angular sector for applications like glide path control of aircraft, and satellite scanning of the earth. The major drawback of phased-array technology has always been the cost of the elements and their phase shifters. By using large aperture horns and controlling the odd modes in the horns, the grating lobes—which are the nemesis of arrays with widely spaced elements—can now be controlled to preserve gain, and maintain low sidelobes over many beamwidths of array scan. This novel approach could make phased arrays very cost competitive for limited scan services.

polarization control

Phased arrays, with flexible (arbitrary) control of polarization, are finding application in the fields of interference reduction and in military electronic warfare. Recent work has demonstrated the electronic control of polarization with only two or three parameters for a planar array of several hundred elements.

▸▸▸ spread-F effects

Flush-mounted phased arrays have become serious candidates for use in aircraft communications, particularly for air-to-satellite work. Clever choice of element parameters and dielectric layer covering have produced designs in which antenna gain can be maintained over a hemispheric sector.

active car antennas

Important antenna advances, in addition to phased-array developments include the development of compact, active antennas designed for automobile radios. There have been important gains too—based on advances in wire-antenna theory—in the performance of log-periodic antennas for radar applications.

As for the future, current work in phased arrays and in comformally shaped arrays may lead to digitally controlled antennas. Here we can envision microwave integrated circuits combined with digital integrated circuits to solve antenna feed problems.

Modeling and heating the ionosphere

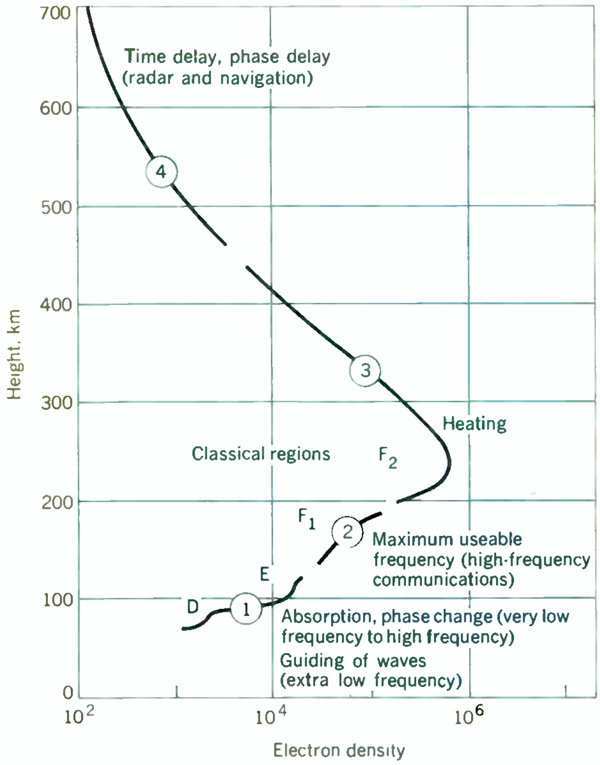
The years 1972–1974 will likely be known in radiowave propagation history as the heyday of ionospheric models. Empirical, statistical, and morphological models, as well as those that embody basic propagation theory, have synthesized, integrated, organized, and placed into usable form the material supplied by rocket experiments, satellite measurements, and ground observations. Although model studies are still in their infancy, system designers now have numerical and predictive tools for such applications as high-frequency propagation, over-the-horizon detection systems, and evaluation of error in radar systems. Added detail, such as irregularities which produce scintillations at microwaves over the magnetic equator, the trough of low electron density at auroral latitudes, and the polar behavior pattern, are now being inserted into these models to make them more accurate and useful.

Spectacular success in controlling nature has been achieved by using high-power transmitters to heat the ionosphere. At Boulder, Colo., 2 MW of 5–10-MHz power was used to create spread effects in the F-layer (200–600-km altitude), so that pulse returns were received from altitudes ranging from 250–375 km. At Arecibo, a high-powered 40-MHz transmitter raised the temperature of the E-layer (100–200 km) by tens of degrees.

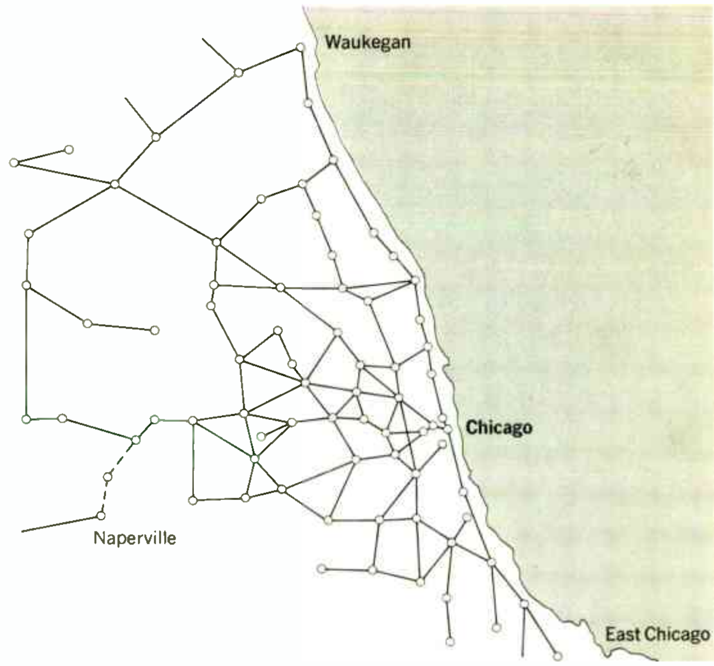
Telephone transmission developments

In our gigantic, interconnected telephone systems there is a growing need for plentiful, low-cost, broadband transmission facilities, to keep pace with expanding telephone use. While coaxial cables and millimeter-wave pipes are being developed to meet these needs, hopes for dramatic improvements now center on the use of fiber optics technology.

What is envisioned is transmission of modulated light through glass fibers about 0.01 inch in diameter.



[5] Ionosphere models allow forecasting of propagation conditions. This curve describes the mid-latitude daytime profile of electron density.



[6] In U.S. metropolitan areas, the network of PCM digital voice channels is extensive. Shown here are the T_1 digital lines linking central telephone office facilities in the Chicago area. The density of this network is typical of that in urban areas throughout the U.S.

Fibers have recently been produced having an attenuation of less than 20 dB per kilometer. Such optical fibers are much smaller than pairs of wire or coaxial cables, and thousands could be packed into a small diameter sheath. Furthermore, the transmission bandwidth of the fibers is almost unlimited so they seem the ideal transmission medium for providing broadband circuits within a city. If digital transmission techniques are used, the signals will not be impaired with distance, making very wide-band long-distance transmission feasible.

Some idea of the potential of such optical systems can be gleaned from the present growth of wire-based digital lines.

optical fibers

Surprising PCM

Recent growth in digital facilities for telephone voice-transmission has gone far beyond what anyone in the field thought possible only a few years ago. Pulse-code modulation (PCM) facilities are now widespread, not only in telephone cable transmission, but over coaxial and microwave links as well.

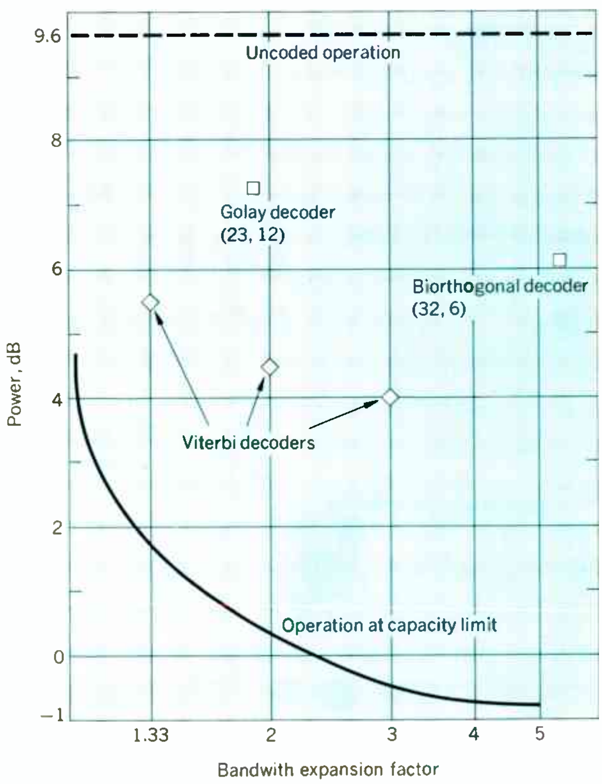
PCM

Use of frequency-division multiplexing and other analog techniques is decreasing while PCM continues to come into ever wider use. During the past decade, over a million PCM digital voice channels have been placed in Bell System service in the U.S., and new facilities are being added at a rate of about 16 000 channel km per day.

Adaptive delta modulation, an alternative to PCM, is finding application in telephone systems in Japan and the Netherlands, as well as in local loop telephone transmission in the U.S.

delta modulation

[7] Convolutional techniques have provided a substantial improvement in the power-reduction capability of coding equipment. Convolutional equipment has been commercially available since about 1965, the more recent Viterbi types have been finding their main application in space and satellite communications.



With increasing use of PCM channels, like the T_1 digital line with a capacity of 1.544 Mb/s, new equipment for PCM has been developed.

microwave multiplexing

For example, a PCM scheme is now being used by GTE Lenkurt (San Carlos, Calif.) to make microwave channel use more efficient for telephone transmission. This system allows transmission of two standard T1, 1544-Mb/s bit streams over a single 3.5-MHz microwave channel.

The quiet evolution

loop electronics

Alongside the dramatic developments in transmission technology, there has been a quiet evolution in the telephone loop plant that may well change the face of this huge part of the telephone industry.

For the first time, low-cost integrated circuit technology is making it possible to place economically sophisticated electronic multiplexer systems in many locations where they can help to provide transmission between the customer and his central office.

Until very recently, the cost of electronics equipment prohibited its placement except in the toll plant where it could be shared by many customers. The new move to use of electronics in the loop plant means an overall saving in copper, significant because copper is a rapidly dwindling natural resource, and a large portion of the yearly U.S. consumption is in the telephone loop plant. Loop electronics also means a more sophisticated telephone plant, where test functions and administrative and bookkeeping chores will more and more be turned over to minicomputers or microprocessors.

CCD arrays

By the way, electronics does not necessarily mean digital electronics, for the availability of integrated arrays of charge-coupled devices (CCDs) may soon make feasible an analog time-compression-multiplex (TCM) communication system. These CCD arrays are analog shift registers which can simultaneously sample and store the level of an analog signal, since the charge stored in the devices is proportional to the signal voltage levels. If many baseband telephone channels are sampled, these samples can be read out of the CCD registers at a fast rate and multiplexed so that all samples occupy the same sampling-time interval. The composite transmitted signal is essentially analog with a bandwidth ideally equal to that of a single sideband FDM system. However, terminal equipment for generating and detecting the TCM signal is essentially digital. Such a system therefore takes advantage of the best qualities of both a digital and an analog system—namely, the cheap digital terminal and the cheap analog transmission medium—and may have wide applicability in loop transmission applications.

Convolutional coding arrives

▸▸▸ Viterbi encoders

Coding techniques offer a practical method of expanding the usefulness of available bandwidth resources, for, with coding, desired digital or analog information can be communicated with an effective expanded bandwidth that allows lower transmission power.

Convolutional coding, using the Viterbi encoding algorithm, has achieved a reduction of 5.6 dB in transmission power requirements for error rates of one in 10^5 bits, with a bandwidth expansion of 3 to 1.

Improved feedback decoders for convolutional codes have also become available recently. These offer simplicity of implementation and adaptability for burst-error correction through use of internal inter-leaving. Using inexpensive read-only memories (ROMs), much more elaborate, and hence somewhat more powerful, feedback decision logic functions have been implemented in place of previous threshold logic.

During 1973, experimental video compression systems operated satisfactorily using only one bit per picture element. This means that relatively high-quality digital television can now be transmitted in the same bandwidth as conventional TV.

Information for this article came from many sources. Key contributors include: Harold Sobol, IEEE Microwave Theory and Techniques Society; Carl Sletten, President, IEEE Antennas and Propagation Society; and Ralph Wyndrum, IEEE Communications Society.

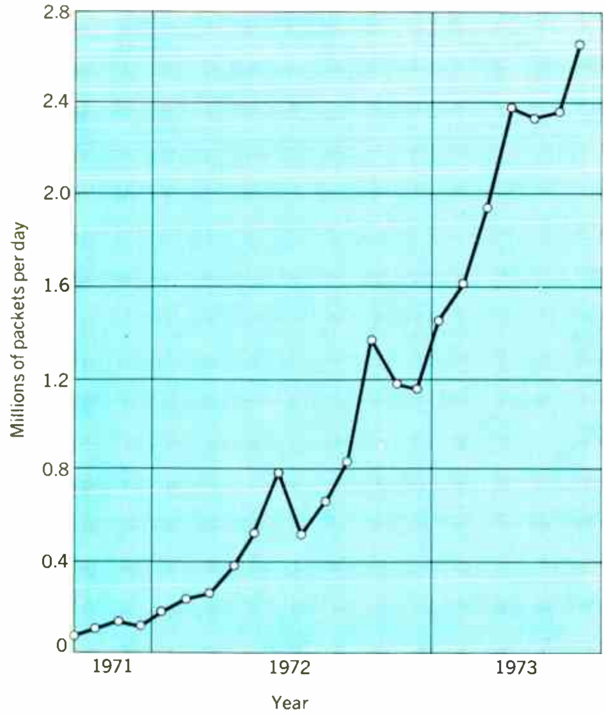
Data communications

"I'm all digital," said one computer to the other. "So'm I," the other replied, "Let's trade packets!"

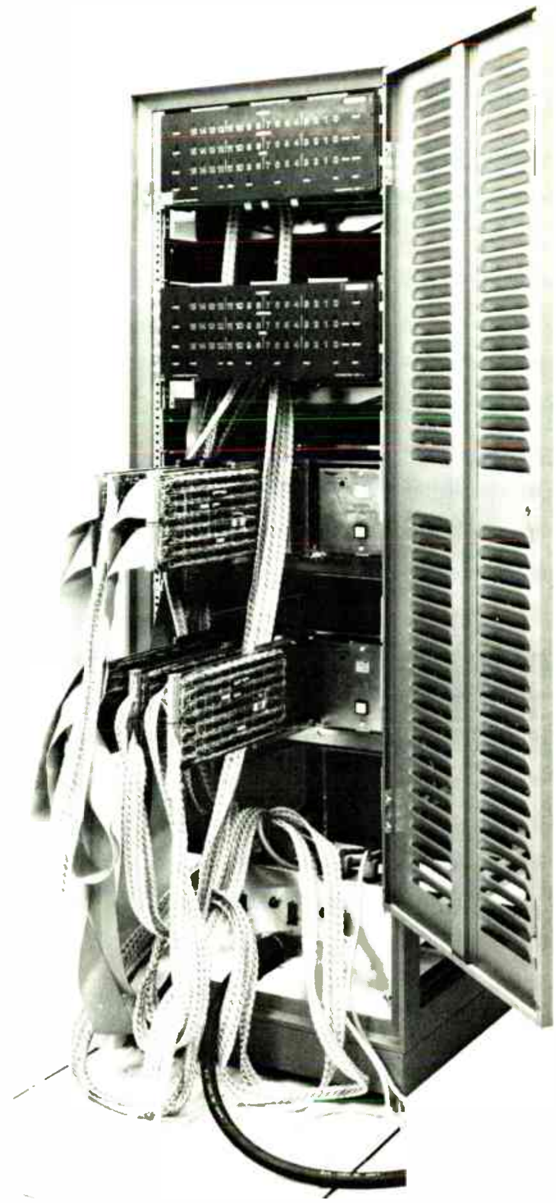
Millions of computer terminals are expected to dot the U.S. landscape during the next few years, and they will tie into tens of thousands of interconnected computers in hundreds of different commercial, industrial, Government, and educational networks. The needed links between widely dispersed equipment will be provided by data communications facilities.

Between 1972 and 1973, U.S. data communications expenditures have grown 27.5 percent to a total of about $1.45 billion; they are believed to be headed towards a total of about $70 billion by 1980. And similar growth is taking place in Canada, Japan, and many European countries.

Howard Falk Associate Editor



[1] **The rapid growth of the Advanced Research Project Agency (ARPA) network continues to accelerate with no end yet in sight. Shown here is the average daily traffic between ARPA nodes.**



[2] **Packet communications will be speeded by this Interface Message Processor (IMP) designed for operation with 1.3-Mb/s links.**

Data transmission over existing telephone links is getting faster and more efficient, and special digital links, specifically designed for data transmission, are coming into widespread use. But the most exciting recent development has been the appearance of a growing variety of practical, operating computer networks—the forerunners of future networks.

Packet switching, the networking key

Perhaps the most significant of these is the Advanced Research Project Agency (ARPA) network. Begun as a research project in 1968, the ARPA network now includes 36 sites (nodes), with about 40 different computers—actually 19 different *types* of computers—linked by nationwide communications.

The key ARPA network concept is packet switching. Data messages are divided into short segments or packets, each containing about 100 characters. Every packet carries its own identification and destination address. As packets arrive at a network node, they are routed along a path that minimizes transmission delay. The packets are handled by special minicomputers called Interface Message Processor (IMPs) or Terminal Interface Processors (TIPs). Each computer in the network is connected to one of these interface processors (terminals can be directly connected to TIPs) which perform all necessary communication tasks including formating, handshaking, and error control. Since all these functions are performed rapidly and automatically, the entire process of sending a complete error-free message from source to destination in the ARPA network takes only a fraction of a second over the 50-kb/s leased lines that form the communication links between ARPA nodes.

The ARPA network allows the unique capabilities of a computer in Santa Barbara to be shared by another computer in Cleveland or Boston. Other networks like Tymnet, Infonet, Cybernet, and the GE Information Services Network connect remote terminals to a central computer. There are also many operating inquiry networks, like the airlines' reservation systems, and the National Association of Security Dealer's systems for automatic quotation (NASDAQ), in which terminals enter and retrieve information from a central data store.

◀◀◀ *interface message processors*

Helter-skelter development

The tremendous proliferation of computer networks has been happening so fast that growth is rapidly outstripping the available technology. There has been so much pressure to bring new networks rapidly into operation, that little time or energy has been devoted to consolidate or refine design techniques. Instead, much of the work has been done with seat-of-the-pants methods.

software

Communications software provides a prime example of this helter-skelter development. Almost all communications is becoming computerized—even if it doesn't involve data. For example, ordinary telephone calls are routed through computer-type electronic switching systems. Despite the fact that software has been found to be one of the biggest bottlenecks in computer communications, operating systems with standardized communications features are still lacking, and higher-level languages specifically designed for communications have not yet been widely and successfully applied.

▶▶▶ *Dataroute*

▶▶▶ *Bell DDS*

Hardware progress has been more tangible. For example, specialized minicomputers used as network communications processors, have been rapidly developing. The latest version of the IMP, designed for the ARPA network by Bolt Beranek and Newman, Inc., can accommodate as many as 20 "host" computers, and permits direct connection of communications links operating at about 1.3 Mb/s.

Traditional computer manufacturers are now placing greater emphasis on computer communications. In 1973, for the first time, IBM made a lower-cost programmable communications processor available. The IBM 3704/5 remote communications controller can be used to concentrate low-speed, remotely generated data for high-speed transmission; it can also serve as the communications front end for a central or remote computer.

synchronous data link control language

During 1974, IBM is expected to introduce a synchronous data link control (SDLC) language which will make full-duplex line control widely available. The result should be more flexible, efficient use of a wide variety of communications links.

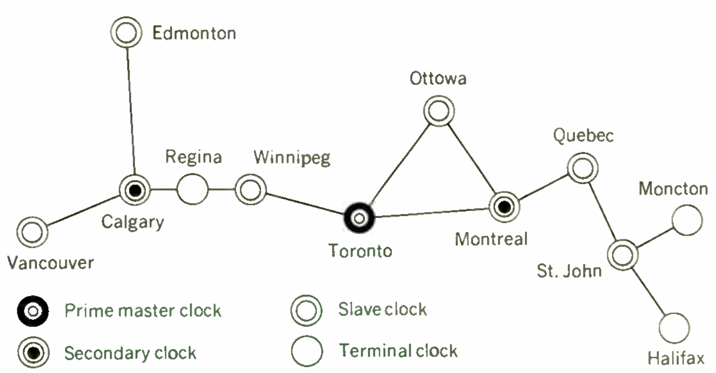
Needed: more data links

With the rapid growth of computer communications has come increased awareness of the limited ability of the existing telephone network, and tariff structures, to serve data transmission needs. Direct distance dialing telephone facilities, for example, now take several seconds to make a cross-country connection, but a typical data message is transmitted in a fraction of a second. Worse yet, telephone tariffs are still based on a minimum 3-minute billing unit, completely inappropriate for data.

Dataroute, recently put into service by the Trans Canada Telephone System, is the first nationwide, commercially available communications system designed specifically for digital data.

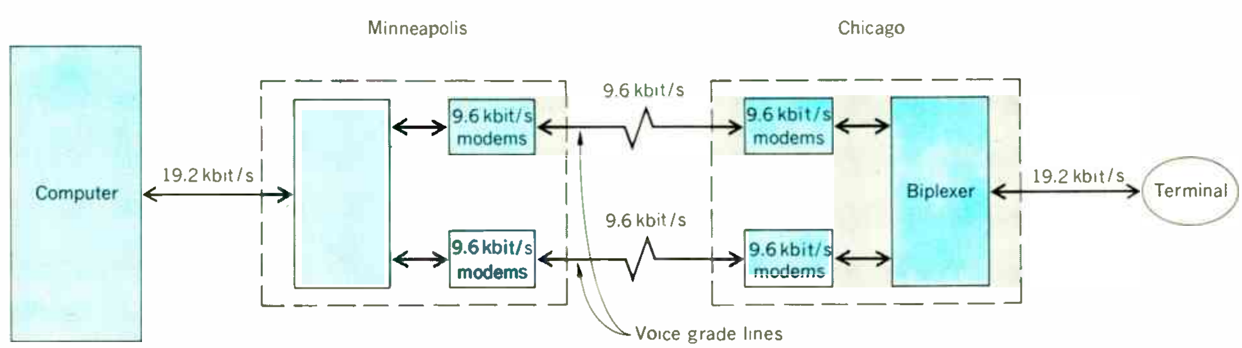
Planned by the Bell System for introduction in 1974 is a similar U.S. Digital Data System. By more complete use of existing microwave transmission facilities—using a technique called "data under voice" —and by using existing local digital lines Bell plans to avoid large new capital investments. The Bell System could therefore be in a position to offer users very attractive data communications tariffs. Japan, and many European countries have specific plans for installing nationwide data transmission systems in the near future.

In addition, the advent of special service common carriers have given U.S. users the brand new option of obtaining communication lines from sources outside the telephone systems. By the end of 1973, a host of carriers like MCI Telecommunications, Inc., and Western Union were supplying customers with both



[3] Canada's Dataroute stretches across the entire continent. The network already includes six added nodes not shown in this diagram, and continues to grow at the rate of about one node per month. A hierarchy of clocks maintains network synchronization even if individual links are broken.

[4] A biplexer unit in Chicago accepts data from a remote job entry terminal at 19.2 kb/s and splits the data into two 9.6-kb/S streams. At the receiving end in Minneapolis, a second biplexer recombines the two streams to feed the data to a computer.



voice and data communications links.

Two companies, Telenet and Packet Communications, have filed for FCC permission to make ARPA-style packet-switched services available—with features such as improved error control, the ability to easily interface many different computers and terminals, and with tariffs based only on number of packets, independent of distance—while Datran and the MCI Data Network plan to offer direct digital transmission services.

Satellite-based telecommunications channels are scheduled to become available to users in late 1974. These promise price reductions for very long distance transmissions, but they will also pose new problems. For example, satellite line-control software will have to cope with one-way propagation delays of 400–600 ms.

Data on the voice network

Despite the boisterous growth of new facilities supplying all-digital transmission, most current needs for data communications are still met by voice-bandwidth facilities developed for telephone service. For effective transmission over such facilities, digital pulses must be converted to a modulated-wave format that fits the voice-transmission band, and they must then be recovered at the receiving end. This signal-conversion process is usually carried out by devices called modems (modulator–demodulators). Since 1960, when commercial data communications over telephone lines began, modem speeds up to 2400 b/s have been available.

It is a somewhat easier task to send data over private, permanently connected lines, than to venture out into the wider, noisier world of the direct-dial telephone network. For some time, it has been possible to send digital signals at 9600 b/s over private-line voice band channels, but not until very recently have modem speeds of 4800 b/s been attained for direct-dial network use.

Higher speeds for the dial network

◀◀◀ *packet services*

A major problem in transmitting data over telephone lines at speeds above 2400 b/s has been delay distortion—which causes signals to smear and overlap. Automatic equalizer circuits are now used to compensate for such distortion, but these circuits require a "training" period of about 50 ms, before model transmission can begin.

◀◀◀ *modems*

During the past year, several modems capable of 4800-b/s operation over the dialed network have become available—all with training times of 50 ms or less. Bell System's version, called the 208B, has a 50 ms training time and uses an eight-phase modulation scheme. A similar modem, the International Communications Corp. model 4700/48 uses a vestigial sideband modulation technique and has a 40 ms training time. A third unit, the Codex 4800 dial modem, also has a 40 ms training time, but uses a scheme called quadrature amplitude modulation.

Merging bit streams

As discussed in another article in this issue, the general task of multiplexing—merging many low-speed bit streams into one higher-speed line—is receiving considerable attention. Many new pieces of multiplexing equipment, such as statistical multiplexers, are appearing on the market and, as these grow more complex, the boundary between the multiplexer and the communication processor is fading.

multiplexers

To push data transmission to 19.2 kb/s over ordinary leased-lines, Codex Corp. has a clever technique that uses two voice-grade channels simultaneously. Their 296 Biplexer unit splits the original data into two 9600-b/s streams. Each of these is transmitted and received using conventional 9600-b/s modems. At the receiving end, a second 296 biplexer recombines the two streams into a single 19.2-kb/s stream.

Special thanks to Ray Pickholtz and Adam Lender of the IEEE Communications Society for supplying information for this article.

Computer hardware/software

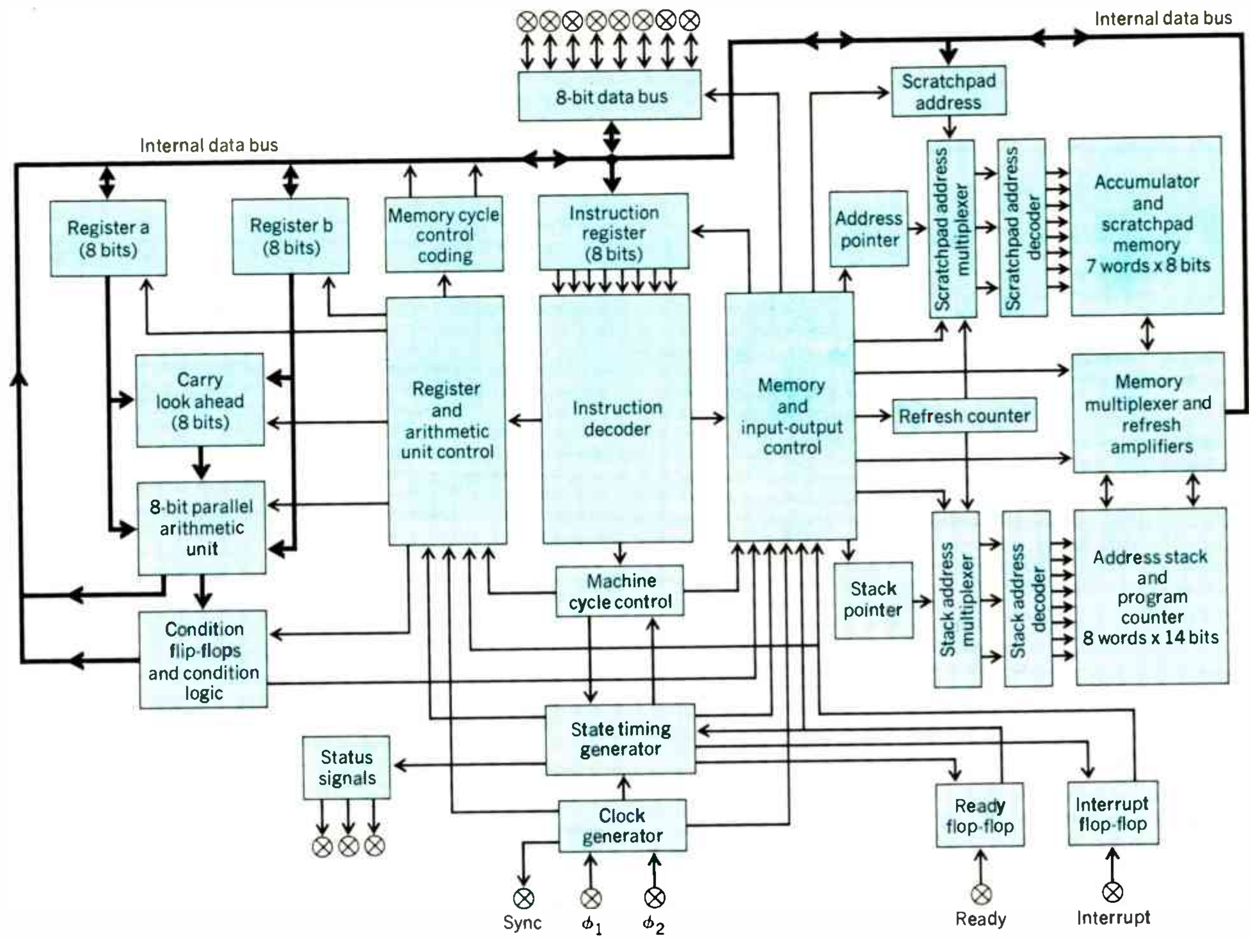
Hardware: microprocessors and memories marry
Software: modular programs and "kernels" arrive

Howard Falk Associate Editor

The great new fact in computer technology is that we now have large-scale integrated microprocessors. Major semiconductor manufacturers are beginning to supply off-the-shelf microprocessors, and sixteen-bit units with 2- to 3-μs instruction times are now available in chip form for about $150.

Make no mistake, these are full-fledged processors—"micro" refers to physical size and cost, not to computational capability. Their instruction repertoire is as rich and powerful as that of the computers of the early 1960s.

Led by Intel Corp. (Santa Clara, Calif.) several manufacturers are now producing microprocessors. Intel has both a 4-bit and an 8-bit processor, the latter comes in an 18-pin circuit package less than one inch long, containing a single MOS chip. The smaller processor is an outgrowth of a printing calculator de-



[1] All this or one chip. Intel's complete 8-bit microprocessor fits in a standard 18-pin circuit package-size 0.915 inch × 0.25 inch.

velopment program, while the larger one evolved from an intelligent terminal application.

micro-processor chips

Other manufacturers, like National Semiconductor (Santa Clara, Calif.) have taken a modular approach to microprocessors. In the National processors, 4-bit register and arithmetic unit (RALU) chips are assembled to create 8-bit, 16-bit, or larger configurations.

Microcomputers in the marketplace

Mated with high-density semiconductor memory packages, these microprocessors become full-fledged microcomputers, potentially capable of taking over many traditional computer tasks—and of moving computer use into entirely new areas.

For several years, minicomputers—low-cost systems made up of assemblies of integrated circuits—have been available to users who cannot afford full-sized computers and their application has been breaking new ground in computer use. Now, with the advent of microcomputers, a flood of new applications is sweeping into every aspect of daily life.

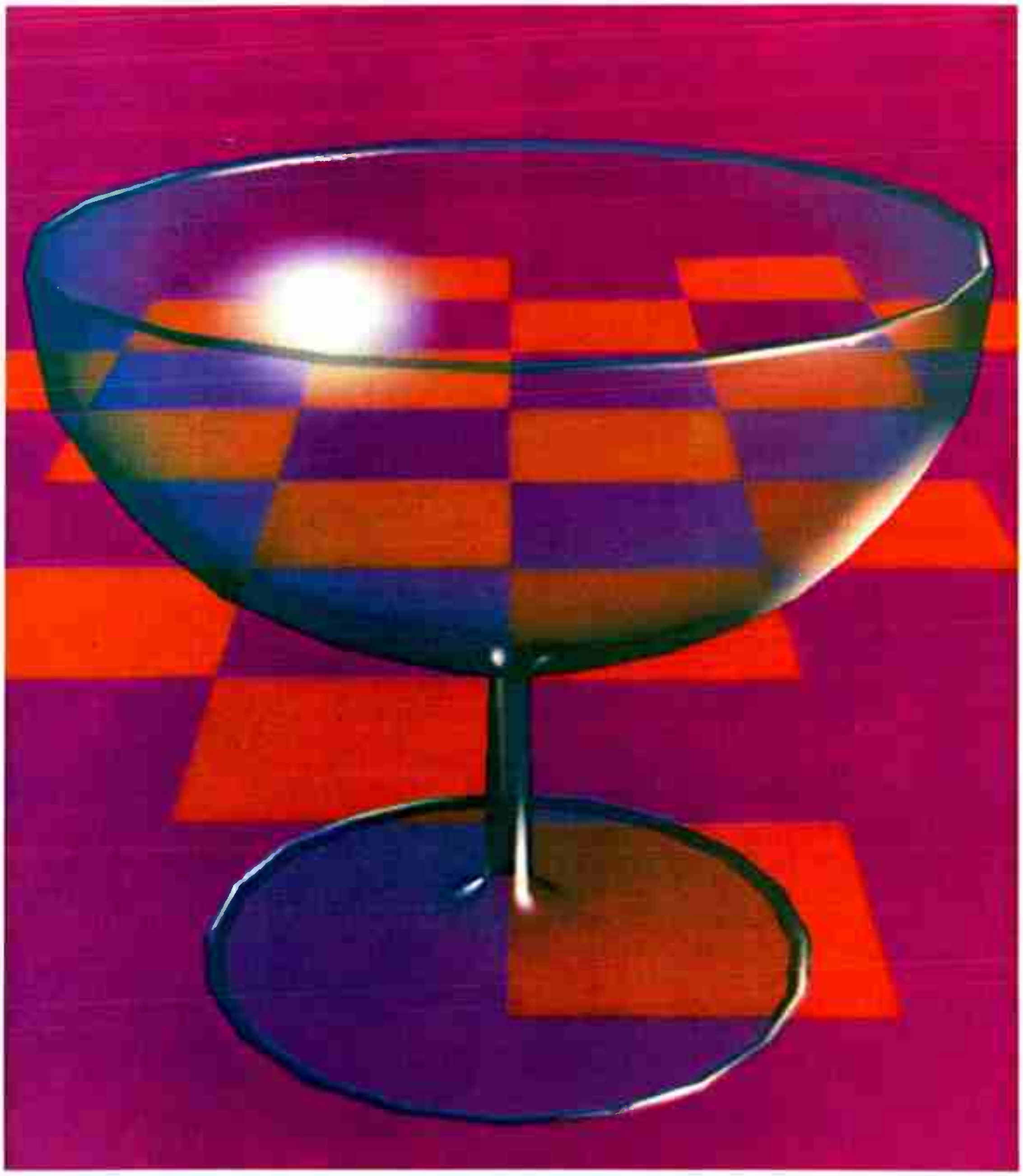
▸▸▸ *cross assemblers*

We are all familiar with small special-purpose computers in the form of hand-held electronic calculators, but it is less well-known that GM, Chrysler, and Ford have all had negotiations with semiconductor manufacturers, looking forward to the near-future use of an on-board microcomputer in every car that comes off the assembly line. Much more easily than their larger, more-expensive predecessors, microcomputers will find their place in homes and offices. Virtually every form of service that is repeatable can potentially be aided by mini- and microcomputers, which can be used even by the smallest of businesses.

Micro- and minicomputers promise also to revolutionize instrumentation, and are expected to quickly find use on production lines and in processing plants as well as in medical electronics, transportation, and energy conversion applications.

Design problems still ahead

These are indeed exciting prospects, but between the present state of the microcomputer art and its widest future application, there remain some significant problems to be solved. First, these machines lack applications software. Microprocessor manufacturers now supply cross-assembler programs that are executed on any computer capable of handling the Fortran language. These cross-assemblers generate code which can be loaded into and executed by the microcomputer. There are even a few simulator programs by which the microcomputer code routines can be debugged on a larger machine, but these tools are still limited in power and will have to be extended and sharpened to meet the oncoming tide of applica-



More realistic computer graphics

Shaded computer graphics in color are here, and soon they will be animated. The images shown above were photographed directly—untouched—from a CRT display screen. Graphic displays with shaded surfaces, color, visual texture, transparency, and similar sophisticated effects are now becoming available. Black and white shaded displays with moving images have already been produced, and it is expected that moving color displays of the sort shown here will also be produced—having rates of about 10 frames per second—within a few months. This technology has received much recent attention, with some of the best work being done at the Computer Science Department of the University of Utah. Such displays are important because they provide a basis for man-machine graphical communication at a level that line-drawings cannot convey. Applications to design of tools, parts, and structures as well as to the visual arts seem likely. In fields such as flight simulation, real-time moving images are already having a profound effect.

The realistic shading and highlighting in the images shown above are results of the most recent improvements in these techniques, developed by Phong Bui-Tong, now Assistant Professor of Computer Sciences at Stanford University.

Images such as these are modeled geometrically in a computer memory. This model may be changed dynamically as part of a simulation or design procedure. Illumination and viewing geometries are then used along with the dynamic model to drive real time, digital, hidden surface and shading hardware which produces video signals for a moving color display.

[2] This floor-full of equipment is the Illiac IV supercomputer, recently installed at NASA's Ames Research Center. The giant machine not only services local computation needs, but is connected—via the ARPA network—to many computers and terminals in other locations.

[3] Radical improvements in hardware are sharply dropping the costs of computer apparatus, but programming, planning, and operations' costs continue to grow.

[4] Intelligent cash registers with built-in microcomputers are finding widespread application in retail trade. This supermarket register contains a microprocessor with both core, and read-only MOS memories.

tions for these tiny machines.

A second problem area, probably more acute, is to interface microprocessors with other processors, with input-output devices, and with shared memory facilities. In general, there seems to have been too little attention given to systems use of microprocessors. For example, it is not clear how present-day microcomputers will share an interconnection bus or communicate with peripheral devices. These interface problems can, however, be rapidly solved, and the solutions may open new possibilities for hierarchical, distributed computer equipment configurations.

Third, low-speed is a serious limitation of microprocessor applications. Even electronic calculator design is hindered by the multimicrosecond cycle times of MOS logic—almost too slow to satisfactorily compute elementary functions like sine and tangent. However, during this coming year we can look forward to the appearance of several microprocessors with cycle times of 1 μs or less. As multiprocessor interconnection problems are solved, speed is likely to be less of a problem.

MOS memories break the cost barrier

To complement the microprocessor, semiconductor technology has produced low-cost memory circuits—the high-capacity MOS memory, bipolar high-speed memory, and even higher-performance memories using Schottky-diode clamped transistors.

The recent, key breakthrough has been in cost and yield of MOS devices for memories, and this is a culmination of several years of processing experience. As a result, 1973 has been the year in which the threshold of practical application for semiconductor memories was reached in many application areas.

MOS memory chips

A 4-kb MOS read-only memory chip now sells for about $20 in quantity. With continued price declines of 20 percent a year expected, the time seems very near when cores will be replaced by integrated circuit chips on a wholesale basis.

Standardized 2- and 4-kb MOS memory chips have recently become available from at least a half-dozen suppliers, so equipment manufacturers now have multiple sources of supply.

Toward distributed systems

Low-cost, compact memory technologies, together with newly available microprocessors are fueling an evolution in computer system design. According to Jack Shemer, Technical Editor of *Computer* magazine, the trend is towards distribution of computer functions so that incoming problems are divided into their constituent parts and a separate portion of the computer's capabilities is dedicated to solving each of those parts. Thus, separate processors within the computer would handle functions like main memory management, file processing, unit record input-output, and arithmetic processing.

Such distributed architectures are by no means a new idea, but with a mature MOS large-scale integration technology at hand, use of many processors in each computer will probably become commonplace.

Several companies are now developing machines in which a large central memory is shared by a number of separate processors.

Supercomputers in action

Side by side with revolutionary microcomputer developments, long, patient computer development efforts have also been paying off.

Three new supercomputers went into operation in 1973. The ILLIAC IV began limited operations at NASA's Ames Research center, and a Texas Instrument ASC computer was delivered to the Anti-Ballistic Missile Defense Agency installation in Huntsville, Ala., while a second ASC machine went operational in Europe. Still another supercomputer, the Goodyear Aerospace STARAN became fully operational in 1973, at Rome Air Development Center, N.Y.

Powerful as these machines are, further progress is needed in hardware for highspeed operation of parallel memories and switching of parallel data streams. According to David Kuck of the Computer Sciences Department, University of Illinois, present difficulties in programming parallel computations would be greatly relieved by such hardware improvements. In the near future we can expect to see even more-powerful supercomputers, combining pipeline hardware with the ability to handle tens of thousands of bits in parallel. With the advent of low-cost microprocessors, machines containing 8000 or more processors seem feasible.

Software kernels to handle input–output

In mini- and microcomputers, in parallel computation and computer networking, hardware developments have been breathtakingly fast. Unfortunately, in each of these cases, the full application of hardware advances still awaits more slowly-developing software innovations.

One key development is that input–output (I/O) interface problems for mini- and microcomputers are, in part, now being solved by software I/O handlers written as standard program kernels. With these, the user doesn't have to be concerned about writing his own software for much of his peripheral equipment. Some initial progress in software operating systems to manage minicomputers (similar to systems long-available for larger machines) is a second important recent development. Development of the standardized higher-level languages that now seem a necessity for many industrial and service applications of minicomputers is also making progress, but slowly.

In the computer communications area, specialized operating systems and higher-level languages have not yet made their appearance. As for supercomputers, software for parallel computation is still in its infancy.

To enter: fill the blanks

The past year has seen the cost of computer terminals drop dramatically, particularly those "intelligent" terminals that possess some degree of computer processing power—usually in microcomputer form.

Terminals such as those supplied by Four Phase Systems (Cupertino, Calif.) allow easy input of data, from their original source into the computer, without the need for punched cards. People using these key data-entry terminals are cued by terminal-generated requests for needed information. In effect, the terminal provides a questionnaire form, with blanks to be filled in by the user.

ILLIAC IV

Intelligent terminals are being widely used for data entry, but they are also capable of word processing, including text editing. With built-in processors and ample low-cost memory, such terminals are finding increased application to automated typing as well as to input preparation for information retrieval and computer-controlled typesetting.

Universal Product Code

Use of intelligent cash registers at retail points of sale has become widespread, and the food industry has adopted a Universal Product Code that allows optical scanning of color-bar coded information at the supermarket checkout counter.

Disks, floppy and dense

Floppy disks, about the size of 45-rpm records but made of flexible plastic, have brought large, random-access storage within the price range needed for mini-computer systems. Since the disks are interchangeable and easily transported they open the way for more-powerful, free-standing terminals and systems.

Floppy disk equipment capable of storing 2 million bits, and operating at 250-kHz bit-serial rates now sells at under $800 in quantity lots. Even compared to lower-cost tape cassette storage, the floppy disk's random access times—less than one half of a second—make them a very attractive choice for a wide variety of systems and peripherals.

One limitation on floppy disks is their useful life: after about 10 000 accesses at any given location, physical contact with the read-write heads tend to wear out the disk surface. Noncontact floppy disk equipment is appearing, but this added feature is expensive.

I/O handlers

More conventional disks like the IBM 3330, with 200 tracks per in carrying 4000 b/inch—a recording density twice as great as previously available—have prompted a widespread movement away from tape files and toward bigger, faster disc-based on-line data bases in large computer systems.

Printing without impact

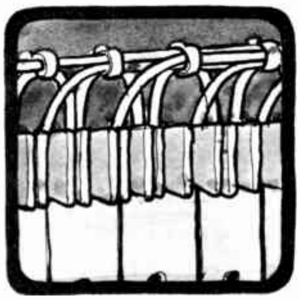
electrophotographic printers

Development of hard-copy output equipment, priced to match the needs of a broad variety of computer users, continued during 1973. Several different types of nonimpact printers recently became available including the Xerox 1200, which uses electrophotographic imaging techniques to produce 132-character lines at 4000 lines per minute. Other noncontact printers use ink-spitting jets, electrostatic operation of closely-packed wire ends, and thermal outputs from thick-film arrays.

intelligent terminals

The general trend in output devices appears to be a resurgence of electronic, or light-beam scanning techniques using single, or multiple beams to generate patterns of dots and thus form characters or graphical elements.

Many individuals and organizations contributed information for this article. The efforts of Robert A. Short, Editor of the *IEEE Transactions on Computers;* Jack Shemer, Technical Editor of *Computer* magazine; and True Seaborn, Editor of *Computer* magazine were especially helpful.



Industrial electronics

"Computers and solid state are in... Computers and solid state are in... Computers and solid state..."

automation

Automation was the key to progress for industrial systems during 1973, with the second-generation controller emerging as the most exciting system and the thyristor the all-pervasive device.

One of the major reasons for the general acceptance of automated techniques has been their wider applicability at decreasing cost—which has led in turn to increased sales volumes for automatic systems. The computer—one of the primary components of automation—has contributed to this decreasing cost with a whopping cost-reduction factor of 10^{-2} over a span of 23 years. In a period when manufacturers and processors are faced with demands for better quality and higher reliability, the increased use of computers to monitor and control industrial operations has been wholly justified.

program-mable controllers

Yesterday's tolerances of such parameters as dimension, weight, consistency, temperature, and speed are just not realistic given today's rigid specifications and competitive atmosphere.

The computer has done more than contribute to lower costs and better products, however. Its capability of interfacing with the entire industrial environment gives it a flexibility unknown to most technologies. Not only is the computer used for such obvious functions as production control, product assembly, and material transfer, but for inspection, testing, scheduling, warehousing, resource allocation, and management information systems (MIS). Computer use in MIS becomes doubly effective and profitable once part of the control process rather than a separate system.

The trend toward automation can be seen no more clearly than in the *machine tool industry*. According to a long-range study by Chase Econometrics, a subsidiary of the Chase Manhattan Bank, today's predominating emphasis on automated machine tools indicates "that automatic factories will be in widespread use by 1980." Based on existing tool data, an analysis of over 150 companies, and an evaluation of all new equipment, Chase's econometric forecasting shows that computer control of every operation from machining and handling to scheduling and ordering can only lead to greater speed, increased quality control, and lower costs.

It should be understood that the computer is only the upper level of an identifiable pattern in the development of automation, each step of which has brought the state of the art further along toward greater reliability, faster speed, and a higher degree of control. As the increasing use of automation demands more levels in the hierarchy of control and control systems, the need for more sophisticated control methods such as parallel processing and hierarchical arrays should become more pronounced.

Marce Eleccion Staff Writer

Industrial control

1973 was a year of increasing automation in the area of industrial control. Although conventional relay panels had already given way to more efficient solid-state modules in many control applications, in 1973 such dedicated logic systems were themselves being replaced by the programmable logic controller (also called programmable controllers, PCs), which offered the user an easily programmed, reliable system capable of direct interface with high-power input/output devices (see Fig. 1). Basically a simple specialized form of minicomputer with the arithmetic functions omitted (aside from basic add and subtract circuits to execute fundamental programs), the programmable controller's primary appeal to the industrial user is that he is not required to learn a computer language as he would for more sophisticated computer-based controllers.

Originally spawned by a General Motors decision to equip their engineers and technicians with a small, reliable, and easily programmed and maintained machine-tool controller that would be cost-competitive with relay and solid-state panels, the programmable controller made its greatest initial impact on the metal-working and automotive industry. According to Jackson & Associates of Columbus, Ohio, the largest segment of growth in controller use will be in the chemical, metals, petroleum, and electric power industries, in that order. Others agree that this priority listing is correct for minicomputer control, but insist that the major areas of controller use are metal working, welding and fabrication, discrete manufacturing, petroleum and chemical, and power, in decreasing order.

Since 1970, over 2000 programmable controllers have been installed to perform a variety of industrial functions, with market projections indicating that 3000 will be operational by the beginning of 1974. Considering that in January 1972 only 200 installations existed throughout the U.S., this constitutes an amazing two-year rise of 1400 percent. In 1972, controller sales were estimated at $12 million, a figure expected to exceed $20 million for all of 1973 and represent a five-fold increase by 1976.

Second-generation controllers

Several new second-generation programmable controllers were introduced in 1973. At Digital Equipment Corp. (DEC), Maynard, Mass., two models—the Industrial 14/30 and Industrial 14/35—starting at a basic price of $3600 (minimum I/O modules and no programming panel) began being delivered in November. Not only have timers, counters, shift registers, and retentive memory elements been included within the basic unit, but a new read/write core memory of 4096–8192 words provides added flexibility. [Users who prefer read/write memories are usually attracted by the ease of reprogramming, while read-only memory (ROM) and programmable read-only memory (PROM) users prefer a program that is hard-wired and foolproof.] DEC's Industrial series also have the capability of adding input and output points one at a time, a significant feature, since most programmable controllers expand by adding modules of from 8 to 32 inputs and outputs.

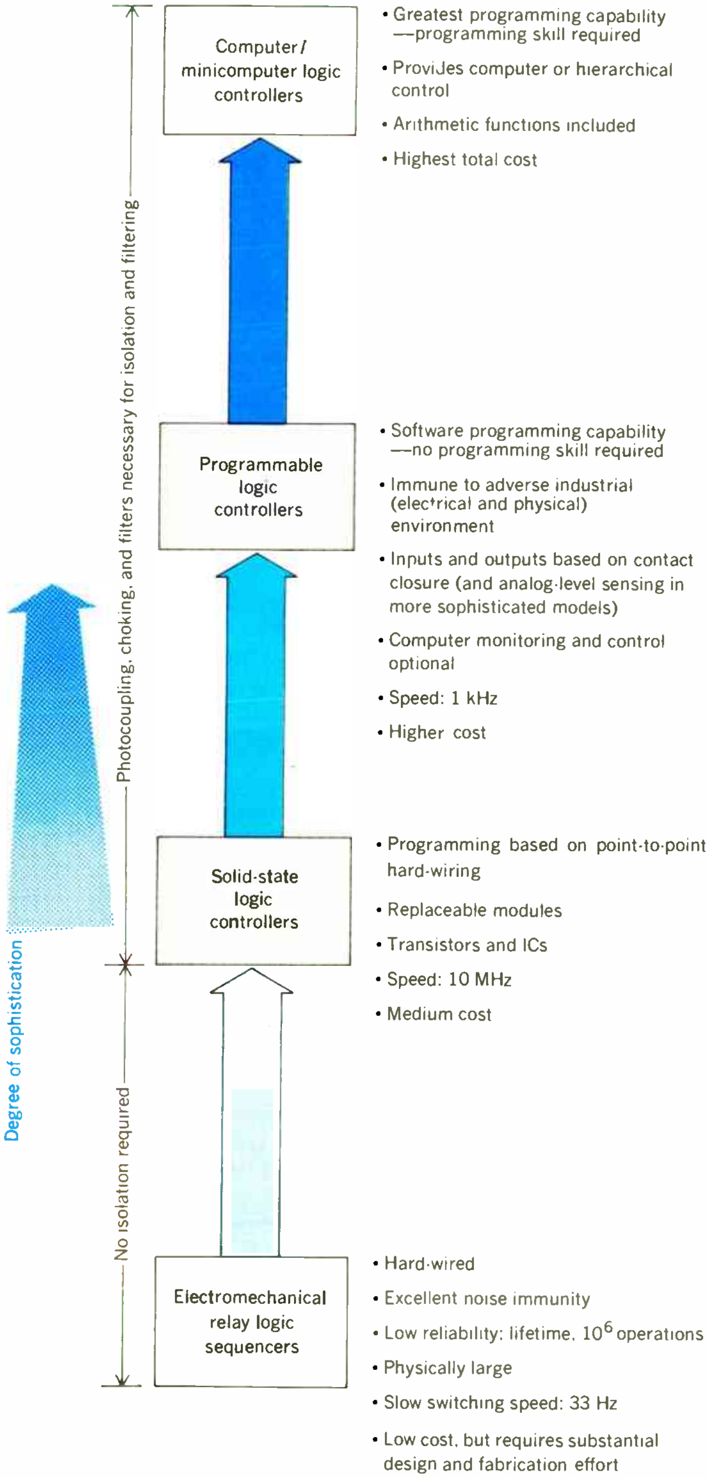
Also introduced in the fall of 1973 was DEC's VT14 ($5990), a separate programming terminal or panel that displays all control circuits on a CRT screen, either for checking before entry into the controller memory or for problem spotting of an already entered circuit. After plugging the VT14 into the controller to be programmed, the control engineer simply enters the system schematic in terms of relay ladder diagrams one output at a time and observes each contact connection on the CRT, which provides a visual matrix of up to 80 contacts and branch points. Both the controller memory and punched tape can serve as storage for ladder diagrams. To troubleshoot, the user recalls an existing circuit from the controller memory and observes the control display. Since relays that carry current appear brighter on the CRT, a contact that is supposed to conduct and doesn't can be spotted immediately.

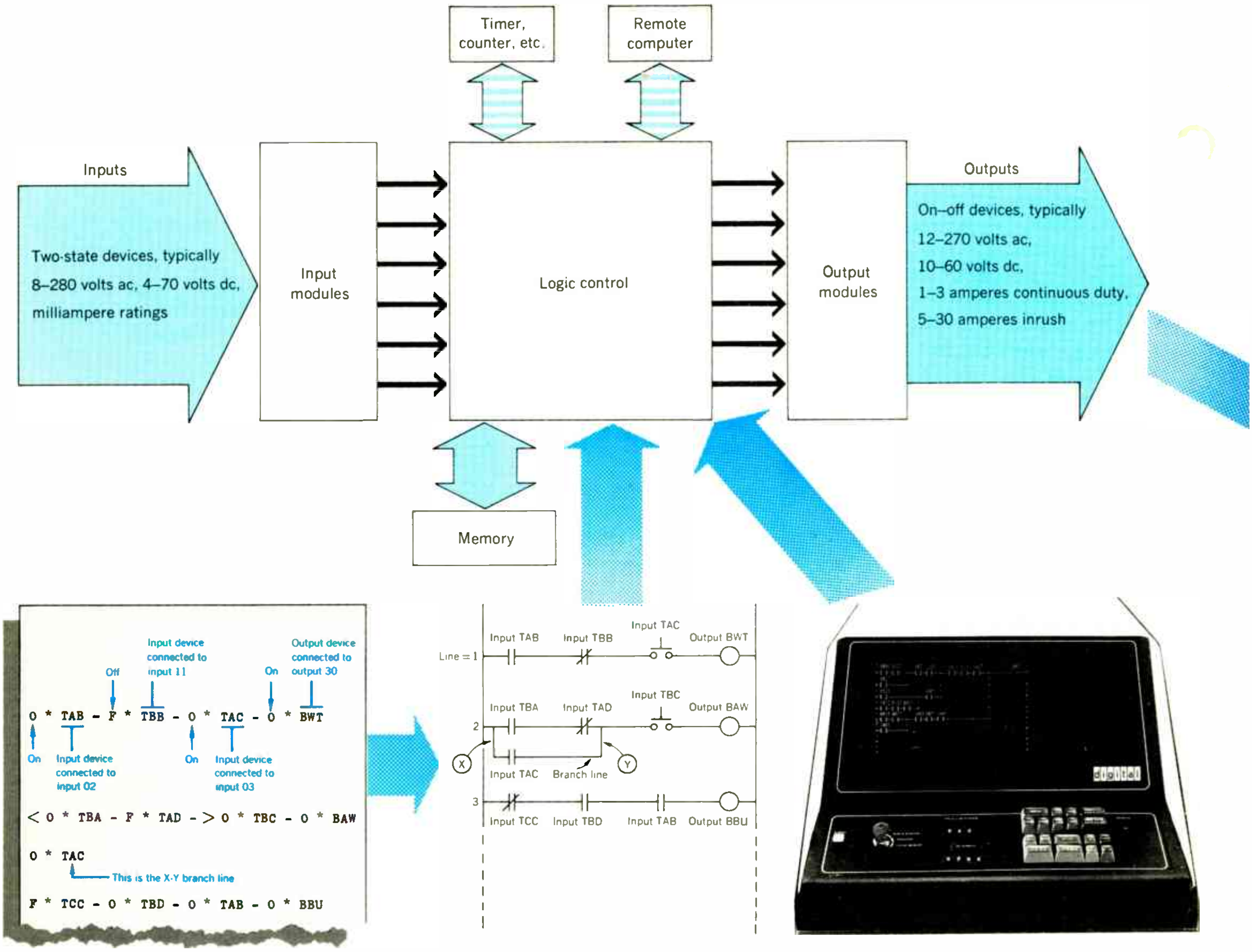
At Modicon Corp., Andover, Mass., the Model 184 programmable controller was introduced in April 1973 with a read–write core memory capacity of 1000, 2000, 3000, and 4000 words (a key-lock memory-protect system prevents accidental alteration or loss of program due to power loss), status lights for each input and output circuit, a remote control that allows input/output equipment to be located up to 600 meters from the controller, and increased diagnostic capability in the form of operations-oriented status lights. Perhaps the most unique feature of the 184 is its capability of monitoring such production parameters as running time, tool life, machine degradation, and down time when used with Modicon's separate programmable printer. The first of its kind on the market, Modicon's printer has a memory of 1000 prestored messages and is priced at approximately $3000. A General Electric programming panel (PC-45), used to program, monitor, and debug the 184, costs $4000; the 184 itself starts at $3460.

Other programmable controllers that appeared in 1973 include the Allen-Bradley Systems Division (Highland Heights, Ohio) Bulletin 1750 PMC with a 1000 9-bit word, read–write core memory (successor to the old PDQ II controller) for $1250, and Reliance Electric Company's (Cleveland, Ohio) AutoMate 32 (a smaller version of their AutoMate 33) for $2000, which provides for up to 191 relay points rather than the 512 total inputs and outputs of the older AutoMate 33.

At FX Systems Corporation, Saugerties, N.Y., two new controllers—the PMT-10160 and SP series—were introduced in October. In the PMT (precision multipoint timer) model, a single unit with up to 160 timed outputs may be cascaded with three other units for as many as 640 controlled time intervals (320 "windows") for timing, sequencing,

[1] Before deciding what type of control system to buy, an industrial user must carefully evaluate such parameters as cost, reliability, ease of implementation, and degree of sophistication to suit his needs.





monitoring, or controlling events and devices over varying and numerous (10 000) time intervals. The SP (sequence programmer) series model is a time- and sequence-based machine that replaces drum, crossbar, matrix, and stepping switch programs (15, 30, and 60 outputs) at greatly increased reliability and capacity and lower cost per function.

front-panel programming

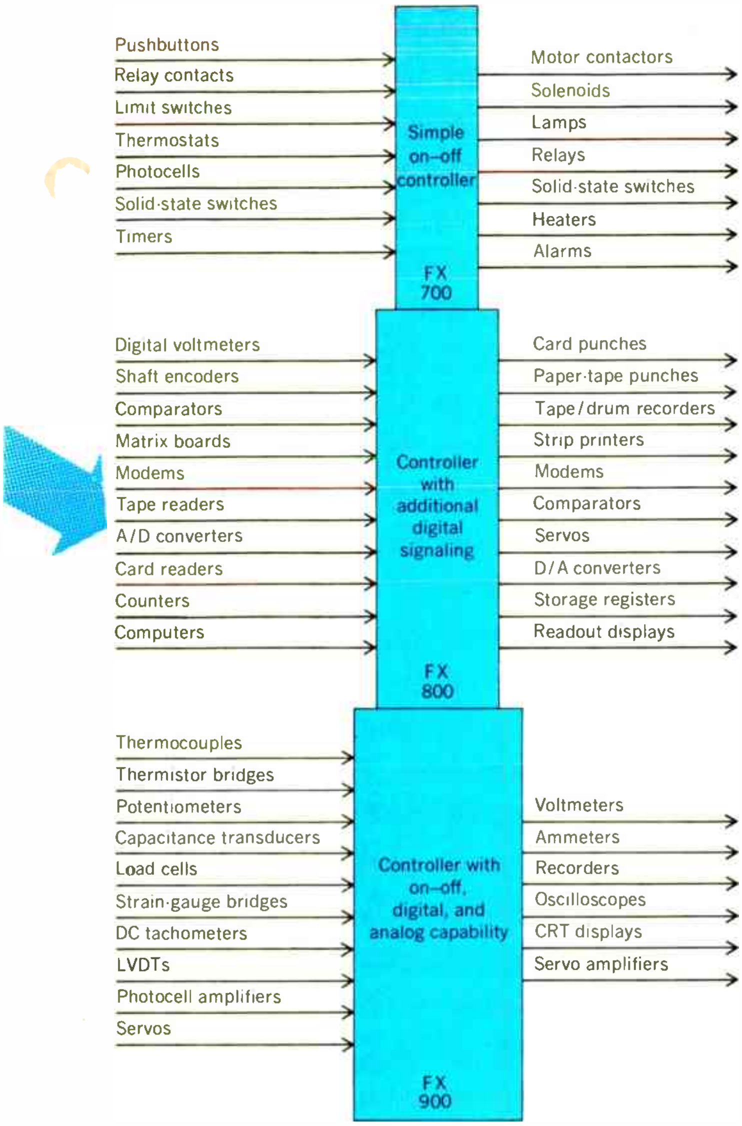
Perhaps the most appealing aspect of the easily loaded FX controllers is that the programming functions—simple thumbwheel switches and pushbuttons—have been placed directly on the front panel of the unit, thus eliminating the need for leasing or buying expensive programming terminals. These units also employ the jargon of conventional electromechanical drum programmers and relays to simplify the control programming. In addition, manual override, fault signalling, and immediate program access via a front panel display are provided. Prices for the PMT and SP systems begin at about $2400 and $2350, respectively.

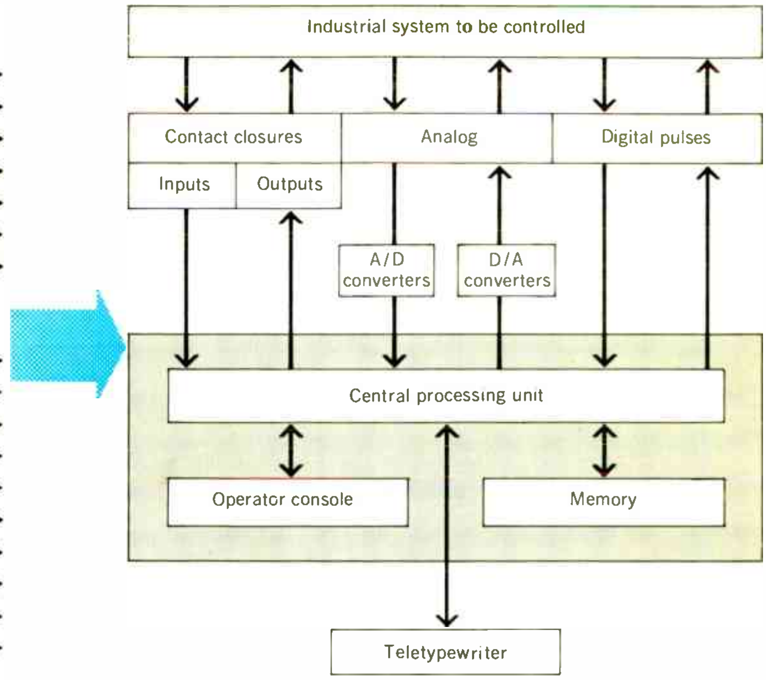
A good indication of the types of controller systems that are presently available and the costs that may be encountered to set them up may be obtained from Table I. It should be noted that the base price of a system usually includes the central processor, power supply, a minimum number of input-output channels, and limited memory; price ranges for a practical control system are usually much higher. (Not all systems in Table I were introduced in 1973.)

Low-cost controllers

Aside from the fact that programmable controllers are becoming easier to operate and smaller (e.g., the FX Systems PMT and SP models are 19 x 16 x 7 inches), they are also falling drastically in price—enough to establish a separate line on a cost-function chart (see Fig. 2).

One such controller is the Struthers-Dunn (Bettendorf, Iowa) S-D77, which is 12 x 7 x 16 inches and costs less than $1500. Equipped with 20 inputs, 12 outputs, 32 internal storage (scratch-pad) locations, and four timers, the S-D77 has a multiple-slaving capability that enables several units to communicate directly with one another, thus allowing for distributive control functions for such applica-



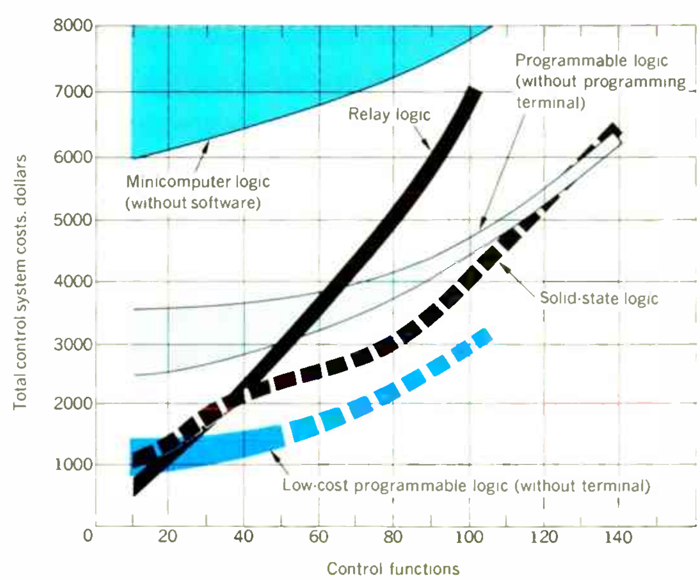


Ease of implementation at low cost is the main feature of programmable controllers. Instructions are loaded by three different methods: relay-ladder (far left, bottom) or symbolic-logic statements typed on teletype-punched paper tape (as in the Allen-Bradley PDQ-II, DEC PDP-14, and FX Systems Mark series), programming terminals (middle left, bottom), by far the predominant programming mode, and front-panel thumbwheel/pushbutton controls located on the controller itself (such as FX Systems' new PMT and SP units). Essentially a highly specialized minicomputer, the basic programmable controller (far left, top) can be expanded from a simple on–off system to include digital and even analog control functions, as in the FX Systems 700, 800, and 900 Mark series shown at the left. Highly sophisticated "industrial" controllers approach the complexity and versatility of minicomputer systems (above).

tions as transfer lines and printing presses. One unique feature of the S-D77 is the use of COS/MOS logic, which not only has low power requirements but is relatively immune to noise. To program the S-D77, the memory boards (256 to 1024 12-bit words, ROM) must be removed from the controller and placed in a portable programming terminal, where the program is entered by simple pushbutton procedures. Light erasable, the S-D77 can be reprogrammed to suit different control applications.

The advantage of having the ability to reprogram rugged ROMS has not escaped controller manufacturers, and at least one company is now offering a reprogrammable ROM as a substitute for its standard ROM. Announced by FX Systems in October 1973, a new series of EAROM (electrically alterable read-only memory) programmable controllers has now entered the market, extending the capability of FX Systems' low-cost MC series of PROM controllers ($845 with 16 I/O). Called the MC-A, this new EAROM controller offers ROM or EAROM for the same price and can be reprogrammed to fit the needs of a particular application

[2] Costs on this controller comparison chart are based on overall estimates, including hardware, panel wiring, etc., but not programming terminals (used with programmable controllers) or computer software.



Automating the automotive industry

It's a practical certainty that today's quality-controlled, mass-production automotive industry could not survive its highly competitive market environment without intense application of automated manufacturing and testing methods. Such systems provide no end to increased productivity, improved quality control, and reduced labor costs.

At present, systems that have been designed and installed for use by the automotive industry include those for

- End-of-line emission analysis
- Carburetor testing
- Evaporative emission canister automated production
- Machine tool control
- Electrical wiring harness testing
- Fuel injection prototype testing
- Engine testing
- Production MIS broadcasting (factory data collection)
- End-of-line quality control inspection
- Crash testing

The experience of such companies as General Automation, Inc., Anaheim, Calif., a leading manufacturer of minicomputers and computer systems for science, business, industry, communications, and data processing, serves to illustrate the inroads that automation has already made. Based on General Automation's System 18/30 supervisory computer, the SPC-12 and SPC-16 minicomputers and automation interface minicontrollers, many users in the auto industry are not only able to automate production lines, but implement quality control and product testing as well (see illustration).

In *safety testing*, an SPC-12 collects data through specially designed high-speed analog scanners in burst modes for storage and future analysis by a central computer.

In *engine testing*, SPC-12s are being used to measure RPM, torque, temperature, pressures, and other variables related to engine operation, as well as for fuel and lubricant testing, signature analysis, and other performance study applications.

In *fuel injection research*, 18/30 systems test pilot-model injection assemblies, monitoring pressure, flow, and temperature of key variables associated with the pilot device.

In *carburetor systems*, SPC-12 systems test and adjust auto carburetors on multiple test stands, measuring pressure and flow, calculating design parameters, and logging reject data for factory management.

In *wire-harness testing*, quality control is assured by a functional check of all wiring on a vehicle production line by an SPC-12, with correct system operation and fault location displayed on an indicator panel, and rework action defined by printout data.

In a *management information system* (MIS), data is obtained from machines and work systems throughout a factory floor to give management a comprehensive view of snop efficiency and material flow by way of an SPC-16 computer.

In *fuel evaporation canister production*, an SPC-12 controls assembly and testing, indexing the rotary assembly stand, checking completed operations and tool positioning.

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by using a portable programming panel (MCP-10) that requires no programming experience. (On the other hand, once programmed [using panels to burn diode paths to produce ROMS], PROMS are no longer programmable and must suffice for one control need only. At $30 a chip, this can become a costly method of building a control apparatus.)

The analog controller

▶▶▶ *direct numerical control*

The standard programmable controller is a ruggedly simple Boolean-logic computer that is designed strictly for on–off sequential operations. There are, however, a whole group of more sophisticated programmable *industrial* controllers that differ from standard controllers in that they are able to process analog signals, provide hard-copy readout and CRT displays, and, in general, interface with most minicomputer peripherals. In fact, these systems give such good control capability, at a price much lower than general-purpose minicomputer systems, that a major U.S. corporation has opted for such a system (FX Systems' Mark II) to control two of the world's largest electric furnaces.

▶▶▶ *computer numerical control*

Equipped with A/D/A interface PC card modules, high-level inputs and outputs, an add-on memory with a possible capacity of 32 000 words, and a unique priority-interrupt module that protects against power failure and program interruption, the Mark II systems will interface and control an entire industrial process—conveyors, weighing and batch feeds, skip cars, moving belts, and hoppers.

In short, the state of the art for controllers is leading toward two distinct areas—one represented by a vast, hitherto inaccessible but diversified majority of users in need of inexpensive controllers with limited application, the other represented by sophisticated users who need more peripherals, memory, and arithmetic capability but cannot afford minicomputer pricing and knowhow.

Progress in numerical control

Of the "subindustries" that exist in the automatic *machine tool* field—numerical control (NC), direct numerical control (DNC), and computerized numerical control (CNC)—CNC, introduced in 1972, is expected to be one of the fastest growing automation markets in the near future.

In 1973, events helped to extend the spread of automation methods developed in the United States. Given approval by the U.S. Department of Commerce to export three CNC systems to the U.S.S.R., General Automation, Inc., sold SPC-16/40 CNC systems to Messer Griesheim, a West German flame-cutter manufacturer, who in turn supplied the Russians. In addition, the world's first commercially available "true" computer-controlled lathe was unveiled in September 1973. Essentially a marriage of General Automation's Adapt-A-Path CNC system to an American Tool Co. (Cincinnati, Ohio) Hustler lathe, the combined system differs from standard minicomputer systems that front-load a standard hardwired controller.

Offering programming advantages comparable to those of DNC systems, CNC is cheaper, more reliable, and more suitable to present machine tool capabilities than DNC. In addition, since a CNC system typically controls 1–4 machine tools as opposed to 10–15 for DNC systems, a malfunction can be much more costly for DNC than for CNC. Hence, CNC systems helped increase overall machine tool sales by over 25 percent for all of 1973.

Nevertheless, NC systems are still anticipated making final quality-control checks, and providing data to the shift foreman on reject rates.

In *emission analysis systems,* SPC-16 systems are now on-line performing both end-of-line and HEW Certification emission test cycles. Analyzer operation is fully controlled, thus eliminating the need for full-time operators.

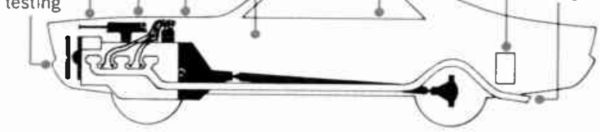
. . . and more

Supplementing General Automation's automation control product line are three numerical control systems that use an SPC-16 minicomputer to perform 95 percent of all machine tool functions currently needed, including drilling, stamping, routing, winding, milling, and lathing. Called Adapt-A-Path, these systems feature point-to-point (at a basic price of $6000), continuous-path ($9975), and three-dimensional ($30,000) contouring tasks, resulting in cost savings of over 40 percent, and—at one West Coast moldmaking firm—improving productivity by over 700 percent.

Recognition of the advantages of automation is not restricted to the United States alone. In 1973, Subaru of America and Fuji Heavy Industries, Ltd., Japan, importer and manufacturer of the Subaru car, installed an SPC 16/30 to monitor exhaust emissions at the Subaru Emission Laboratory, Huntington Beach, Calif.

The future

According to Raymond J. Noorda, General Automation executive vice president, the total market for numerical control systems—including hard-wired devices—exceeds $70 million annually, of which computer-based systems represent 10 percent. If he is correct, the total available market for numerical control systems will be $125 million by 1975, with computer-based systems representing more than 25 percent—no small share of what appears to be one of the most viable markets around!



Modern automatic control and testing is the basis of today's competitive automobile industry.

to hold their own for the next eight years. Programmed and directed by coded punched-paper-tape instructions, hard-wired NC logic units—despite the stiff opposition from computerized systems—have been restored to life by relatively new low-price versions that have afforded manufacturers with basic equipment automation at reasonable costs.

Introduced in 1970, DNC systems offer computerized control in the form of temporarily stored machine programs that are much faster and of higher quality than NC programming, which requires repunching of new paper tape for each new operation. Because machine tool users lacked both the expertise and confidence in dealing with large computerized systems, however, sales performance of DNC systems has been disappointing and is said to have contributed to the depressed level of machine tool sales during the early 1970s. It is forecast that sales of DNC systems—especially with the introduction of less-expensive minicomputers—will rise to large numbers by 1976.

Manufacturing technology

In its race to produce competitive high-quality products—now estimated at over $23 billion a year—the electronics industry made significant improvements in automating production during 1973.

In manufacturing alone, the assembly of printed-circuit (PC) boards—practically the bread and butter of the industry—has been greatly enhanced by automation, with axial-lead components now being inserted at the rate of 7000 per hour, ICs at 3000 an hour, and equipment shortly available that will be able to insert transistors, disc capacitors, and even assemble parts onto PC boards. Although semiconductor manufacturing is being forced to improve productivity to satisfy an exploding market, special emphasis is being made in improving yield in wafer fabrication—in fact, computers are now being used to monitor and control furnaces to increase wafer yield.

One area of great concern to the manufacturer is testing. With testing costs ranging from 5 to 30 percent of manufacturing cost, *automatic test* *testing*

At General Motors' Rochester Products Division, an IBM System 7 supervisory computer transfers data into an IBM 370/145 for hierarchical control of as many as 31 carburetor-flow test stands, each of which is controlled by a General Automation SPC-16 minicomputer.

equipment that is easily programmed is being sought to increase production speeds and lower costs. With the new varieties of equipment such as that described in this article now appearing, manufacturers are now more than ever concerned with the throughput and cost of such equipment.

modeling

The use of *modeling* is finding increasing application in process design, preanalysis of machinery characteristics, and improving cost effectiveness. In the glass industry, the modeling of parts is being given serious consideration, and in the steel, mining, and cement industries modeling is extensively used not only to control processes but to determine the cause of excessive machinery wear and vibration in order to "design" these problems away.

▶▶▶ *thyristors*

Another technology that found wide application in 1973—with even more expected in 1974—is the combining of digital techniques with the control of drives themselves. Most of the *float glass process* drives in the glass manufacturing industry use digital methods to control the thyristor manipulated drives for the very high accuracies needed in continuous manufacture of float-process plate glass.

In just a few years, the float glass process—virtually precipitating a technological revolution—has lowered costs so markedly that the flat glass manufacturing industry now uses it for over half of its production.

Solid-state technology

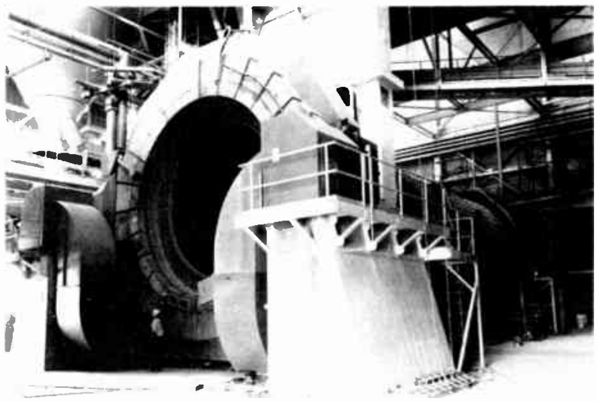
One of the most dynamic areas to emerge in industrial electronics during 1973 has been the application of solid-state devices—especially the *thyristor*—and systems to power utilization and control. Not only has integrated circuitry made possible the development of complex control functions compatible with large power converters, but more sophisticated large-area thyristors were developed to keep pace with the technology.

Specifically, 1973 has seen all major U.S. manufacturers offer practical families of 50-mm diameter thyristors (the record thyristor size was 100 mm). While the art has developed to the extent that the industry expects new devices to have a spectrum of ratings that trade voltage capability for current capacity within a given pellet size and design, at the same time these devices have compatible dynamic properties (e.g., dv/dt and di/dt) that are a direct result of highly developed gate structures and fabrication techniques.

Since 40-mm devices employing amplifying gates have now become widely available, logical areas of exploitation include high-frequency/high-power *induction heating*, which is universally applied throughout semiconductor materials processing.

One new power integrator and controller for induction heating that was conspicuous during 1973

[3] The first application in North America of a thyristor-driven, very-low-speed, hi-torque, adjustable-frequency, synchronous motor driving a wrap-around gearless aerofall ball mill. Located at the St. Lawrence Cement Company mill in Clarkson, Ont., Canada, the 8750-hp, 1900-volt unit is totally enclosed and features an air-to-water heat exchanger.



Control applications from space

Some of the modern control techniques that originally found application only in the most sophisticated systems of the billion-dollar space program are beginning to be used more and more in industrial systems. Of the several factors contributing to this trend, success of pilot programs and the continuing reduction in price and size of computers make implementation of some of the more complex strategies more feasible.

One of the first modern control techniques to be practiced was the *optimal linear regulator*, which is the solution to the problem of a linear plant with a quadratic performance index. Similar to classic techniques and easily implemented, this promising control method is presently being used by engineers at Babcock & Wilcox (Lynchburg, Va.) to design controls for advanced nuclear steam generators to be used for marine and utility power generation.

Pole-placement techniques are also being studied and an experimental project is now in progress to apply this method to a pool reactor. A microcomputer will be used to implement the resulting control law.

Also finding application is the *optimal linear tracking solution*, which requires the on-line solution of a vector differential equation for the feed-forward control—not an impossibility with present-day computer capability. This method shows promise in controlling generating station power, which must vary to meet the demands relayed by a central dispatcher. What the dispatcher now does is command not only the new power level, but the time history to be followed in driving to this new level.

In applying computer power to modern estimation and observation techniques, *Kalman filtering* has been used to estimate inaccessible states of a nuclear reactor steam generating system. Such estimates are required both for monitoring and feedback control, although problem-dependent approximations may be necessary to permit real-time estimation. Along with filtering techniques, an observer may be used if noise levels are low. Babcock & Wilcox has used *Luenberger observer theory* as the basis for a new reactimeter design used to determine nuclear reactivity through an indirect measurement.

Babcock & Wilcox has also used *adaptive-type control strategy* to automate the welding process. After establishing empirical relationships between variables measured during welding and weld quality, control variables are then manipulated in such a way as to drive the measurable variables to the values yielding a high quality weld.

because of the high power levels obtained was developed by Park-Ohio Industries' Tocco Division, Cleveland, Ohio. Called an energy controller, the device integrates a kilowatt signal with time and displays the value as a percentage of kilowatt seconds. Pre-set to a desired energy value, the controller will interrupt the power circuit when that value is reached. Hence a part that is induction heated can be rejected if it is over or under power level conditions; actual energy in kilowatts is digitally displayed during operation.

In the area of power *generation*, Hydro-Québec of Canada (IREQ) has already demonstrated the theoretical possibility of applying direct light-fired thyristors to HVDC (high-voltage dc) valves for rectification; neodymium lasers would be used.

1973 turned out to be a year of significant firsts for power utilization and control systems.

cyclo-converters

As an example, in the summer, the St. Lawrence Cement Co. put a cement grinding mill into operation, supplied by an adjustable-frequency thyristor *cycloconverter* and driven by an 8750-hp synchronous motor at 14.5 r/min. The synchronous motor receives energy from the cycloconverter—or frequency changer—of slightly under 5 Hz at top speed. The first such installation in North America, the technological breakthrough involves not only the large horsepower made possible by thyristors, but the complete replacement of the traditional high-constant-speed driving motor and large gear reducing unit by a single motor mounted directly on the grinding mill itself (see Fig. 3), thus eliminating the gear and various flexible couplings between the conventional higher speed motor and the mill. Seventeen cycloconverter units were installed or ordered in Europe by the end of 1973.

Optical isolation

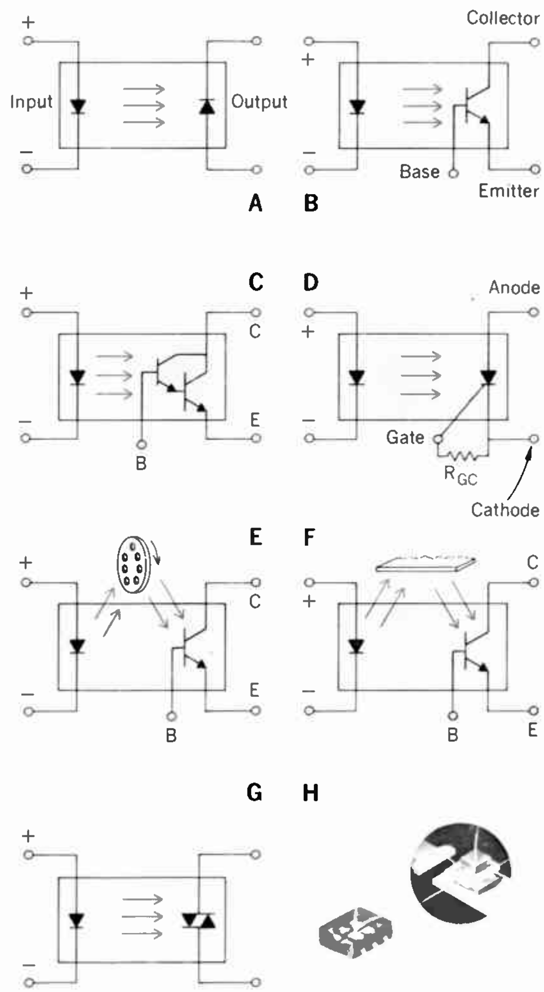
With today's trend toward highly sophisticated computer control and solid-state circuitry, more and more attention is being given to disrupting ambient and line voltages, signals, and inductances than ever before. Whereas stray surges were disregarded in systems designed around electromechanical relay banks, where undesirable tripping of contacts was highly improbable, modern control systems must be designed for isolation and filtering by such techniques as photocoupling, choking, and filters.

Especially severe is the industrial environment, and for this reason such systems as programmable controllers are not only optically isolated but encased in heavy steel cabinets. Thus, it is particularly welcome when a company provides cabinet structures that can survive a rugged environment.

An example of the type of optical-isolation devices that were introduced in late 1973 can be had from such companies as General Electric Semiconductor Products Department and the Monsanto Commercial Products Company.

At the General Electric Company, Syracuse, N.Y., three new high-isolation-voltage photon-coupled isolators of up to 3500-volt peak isolation voltages and 100 percent current transfer ratios were announced in November. Fabricated from GaAs LEDs optically coupled to silicon phototransistors in dual-in-line packages, the 4N35/36/37 series utilize GE's glass isolation process of precise alignment and controlled spacing between LED and detector to optimize photon coupling and minimize the inverse relationship of isolation voltage and current transfer ratio. Retail price of the 4N35 is $1.85 in 1000-lot quantities (see Fig. H, this box).

At Monsanto, Palo Alto, Calif., the MCT10 was introduced in October and designed to match the size of the largest chip capacitor presently used in hybrid work. Compatible with hybrid circuits using reflow soldering and with TTL logic without additional interface circuitry, the MCT10 features 1500-volt isolation and a typical dc transfer ratio of 80 percent; nonsaturated rise time is 3 μs, with a corresponding fall time of 16 μs. Aimed at such applications as digital logic coupling, triac control, line receivers, and control and monitoring circuitry, the MCT10 is perfectly suited to isolate voltage transients, floating grounds, and logic signals, and eliminate groundloop feedthrough. OEM price is $3.15 for orders of 1000 or more.

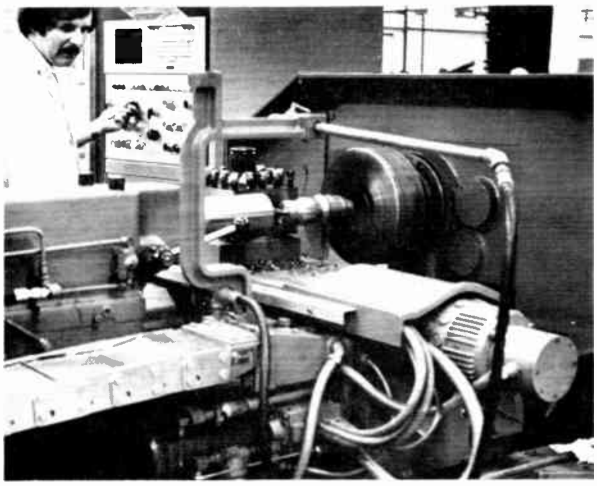


The numerous photocouplers offered today are based on neon-lamp, tungsten-lamp, or LED (shown here) inputs, and a variety of outputs, including photodiodes (A), phototransistors (B), Darlington amplifiers (C), and photo SCRs (D). Variations such as photocoupled encoding (E) and reflective photocouplers (F) provide important control functions. AC or bidirectional control is obtained triac or diac configurations (G); a typical device (from General Electric) is shown in H.

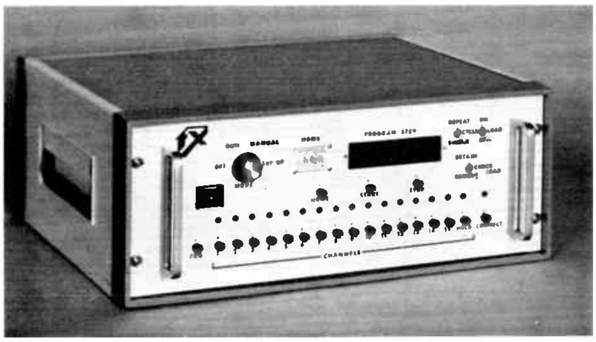
I. Some programmable controllers on the market

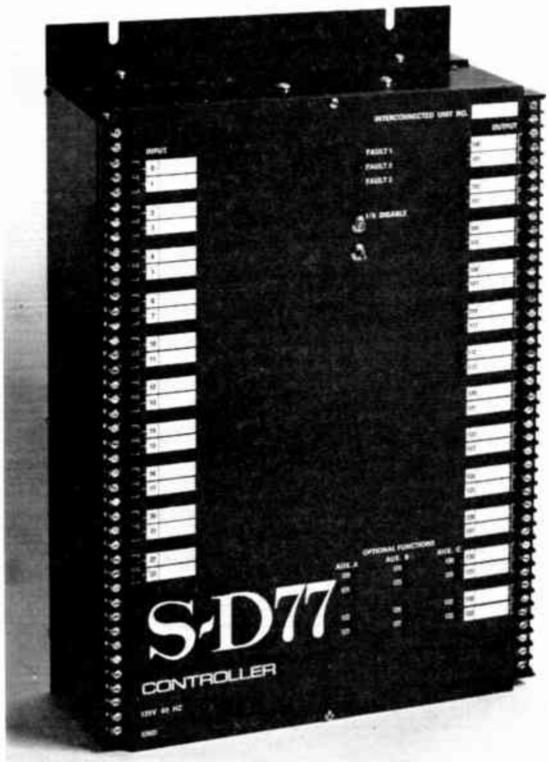
Company	Model	Price*	I/O Capacity
Advance Technology & Testing, Wilson Engineering, Livonia, Mich.	Series 500	$2000 ($3–30k)	I: 8–unlimited O: 8–unlimited
Allen Bradley Co., Systems Division, Highland Heights, Ohio	Bulletin 1750 PMC	$1250 ($4.7–20k)	I: 4–24 O: 4–62
	Bulletin 1760 PDQ-II	$3900 ($6.8–23k)	I: 16–442 O: 16–250
Datrak Corp., South Windsor, Conn.	Neuron 800	$2220 ($6.7–18.6k)	I: 8–512 O: 8–512
Digital Equipment Corp., Maynard, Mass.	Industrial 14/30	$3600 ($7–16k)	I: 1–256 O: 1–128
	Industrial 14/35	$4800 ($8–17k)	I: 1–512 O: 1–256
Eagle Signal, Gulf & Western Industries, Davenport, Iowa	Controlpac 600	$2418 ($6.4–23k)	I: 16–512 O: 16–512
Entrekin Computers, Cutler-Hammer Inc., Fenton, Mich.	Type GF Mini-controller	$6440 ($8.7–13.5k)	I: 16–256 O: 16–128
Entron Controls Inc., Glen Ellyn, Ill.	En-210	$1350 ($1.35–8k)	I: 16–unlimited O: 1–unlimited
FX Systems Corp., Saugerties, N.Y.	MC-A-16	$845 (NA)	I: 8–32 O: 8–32
	PMT-10160	$2400 ($2.4–3.5k)	I: 1–160 O: 1–160
	SP series	$2350 ($2.35–3.5k)	I: 9–72 O: 9–72
	Mark I/II	$3755 ($7.7–17.8k)	I: 8–512 O: 8–512
General Electric Co., Bloomington, Ill.	Logitrol	$5180 ($7.5–16.5k)	I: 16–1023 O: 8–1024
Industrial Solid State Controls Inc., York, Pa.	IPC-400	— ($8–16k)	I: 16–1000 O: 16–1000
Modicon Corp., Andover, Mass.	184	$3460 ($6.8–18.4k)	I: 16–512 O: 16–512
Reliance Electric Co., Cleveland, Ohio	AutoMate 32	$2000 ($8k)	I: 1–191 O: 1–191
Rybett Controls Inc., El Segundo, Calif.	I-100	$525 ($1.7k)	I: 36 fixed O: 2–20
	I-200	$663 ($1.8–5k)	I: 10–180 O: 4–36
Sperry-Vickers, Umac Division, Burlington, Vt.	AP 1000	$1800 ($3.8–8.7k)	I: 16–512 O: 8–256
Square D Co., Industrial Control Division, Milwaukee, Wis.	Sycom	$2500 (7.5–18k)	I: 16–2048 O: 16–2048
Struthers-Dunn Inc., Systems Division, Bettendorf, Iowa	VIP	$2264 ($6.7–19k)	I: 16–512 O: 16–512
	S-D77	<$1500 (<$2500)	I: 20–32 O: 12–24
Westinghouse Electric Corp., Pittsburgh, Pa.	QB-11	$750 ($5–15k)	I: 6–120 O: 4–80
Worcester Controls Corp., West Boylston, Mass.	SC	$950 (NA)	I: 4–28 O: 2–26

*Prices in parentheses reflect costs of small ($\approx$40 outputs) to large ($\approx$150 outputs) applications.



The world's first "true" computer-controlled lathe, this American Tool Hustler (above) uses a General Automation Adapt-A-Path CNC control system for direct control of its 137-cm turning center; more than 90 percent of the conventional magnetics used for control interface have been replaced by solid-state devices. Other CNC systems now provide automatic interchangeability and operation of as many as 30 machine tools. The two programmable controllers below (FX Systems' SP unit and Struthers-Dunn's S-D77) show how compact these systems can really be—the SP is 19-in wide, the S-D77, 12-in wide.





Making the draftsman obsolete?

Draftsmen, watch out—the IBM Thomas J. Watson Research Center (Yorktown Heights, N.Y.) has developed an electronic drawing experimental system that converts rough sketches into finished drawings in one fifth the time required by conventional methods.

Consisting of a TV screen, electronic tablet and pen, paper keyboard, and IBM 1800 data acquisition and control system, the technique can also be used in filing and updating maps, engineering drawings, and other types of graphic material. It works this way: after the designer randomly places his rough sketch and paper keyboard anywhere on the tablet to suit his work habits, he traces his design and indicates all dimensions, circles, labels, broken and dotted lines, etc., by touching the appropriate computer-function area on the keyboard with the pen. When a view of the results is desired, a "display" function on the keyboard is touched and the transformed finished sketch appears on the screen. If a paper copy of the completed drawing is needed, all that is required is a touch on the "finished drawing" function box, and *voila*, the drawing appears.

The designer needn't chuckle too . however, for it looks as if some of his basic functions will be preempted as well. McDonnell Douglas Corp., St. Louis, Mo., has built an automatic drafting machine that not only generates three-dimensional geometries, but uses CAD software to integrate specified parameters into basic designs.

Also installed in 1973 was a thyristor cycloconverter for the testing of large turbine generators. Ranging to 20 000 hp at top speed, this equipment maintained adjustable drive speeds by application of adjustable frequencies through thyristors to the secondaries of wound rotor drive motors.

At the Dundee Cement Company, Dundee, Mich., two 500-hp adjustable frequency induced draft fan drives were recently installed to meet newer dust emission standards. At smaller horsepowers, adjustable-frequency PWM (pulse-width modulation) systems are sharing a larger portion of the variable-speed-drives market previously dominated by thyristor-controlled direct-current drive systems.

Another example of solid-state intrusion into the industrial controls area is seen in the application of thyristors to provide *soft starts* for long conveyor belts for materials handling. Although several of these systems went into service in 1973, the challenge to ac drives is expected to increase in 1974.

glass processing

In the electric furnace area, the glass industry is undergoing a major upheaval in the process of *melting glass*. Not only are such systems ecologically acceptable, but thermal efficiencies of up to 80 percent can be obtained in large furnaces, as compared to melting efficiencies of 25–30 percent for commercial fuel-fired glass processes. In the wake of the current fuel crisis, even the relative high cost of electric heating does not seem unreasonable.

During 1973, several thyristor-controlled glass-melting furnaces were described, one with a 4300-kW power supply and another with a total connected capacity of over 10 000 kVA. The latter system was so highly proprietary that no further information could be obtained.

arc furnaces

Arc furnaces also received attention last year, with the first switched shunt reactor using thyristors for *metal melting* placed into service late in the year. This process involves switching a 25 MVAR, 13.8-kV reactor one-half by one-half cycle. The installation was to compensate for the voltage flicker problem inherent in electric melting of scrap by arc furnaces at Nucor Steel, Norfolk, Nebr. Other even larger systems are being installed elsewhere.

transportation

Under a Federal grant, an advanced pulse-width modulated inverter ac propulsion system was demonstrated in 1973 on the Cleveland Transit System. With obvious benefits of such a system including acceleration, high performance, and low maintenance—all inherent in solid-state control—a principal feature is its capacity for full-power regenerative braking, which has been shown to consistently recoup over 36 percent of the input energy. Such a system is a direct response to the energy crisis and yields savings in power costs.

Perhaps the most valuable and least obvious benefit of regenerative braking is the significant reduction in tunnel heating. The cost of alternate methods such as tunnel ventilation is substantially higher by comparison. While regenerative braking has been utilized in the past and on dc systems, this is the first full-scale revenue-service application.

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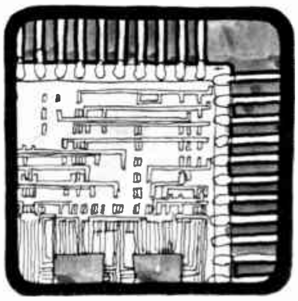


Circuit/system building blocks

Recent new devices are faster, and cheaper, and provide a higher function density

The growth of consumer electronics, especially in hand-held calculators, electronic watches, and the burgeoning automotive market has spurred development of low-cost, low-power displays. The leading contenders at this time are light-emitting diodes, liquid crystals, and plasma displays. Also, undergoing serious development are potential substitutes for the cathode ray tube in large displays and in television. The strong interest in this new field, coupled with rapid strides being made in developing new display techniques and lowering production costs, makes display technology one of the most dynamic areas of electronics.

Progress in integrated circuits continues unabated. Much of the recent work in the digital area is centered around developing new computer memories (now that semiconductor storage is becoming established), with the lion's share of attention focused on methods of building larger and faster memory chips. Also significant are attempts at reducing the cost of bipolar circuits and increasing the speed of MOS.

Linear IC development has been accelerated by the consumer electronics boom in much the same way as displays. Recent progress suggests that the TV set built from a handful of ICs is just a few years off and that before the end of the decade, the average automobile will contain many linear (and also digital) ICs in fuel injection, antiskid braking, and other safety and pollution control systems. The use of linear ICs is also growing rapidly in instrumentation, control systems, and communications equipment.

Another newcomer with great potential is the charge-coupled device, which may someday replace TV camera tubes and other image sensors. It is also taking aim at the mass memory market.

Other areas undergoing extensive development are superconductivity, hybrid ICs, active filters, magnetic materials, and computer-aided design.

Displays: A wide-open race

The increasing use of specialized computer terminals in laboratories, classrooms, industrial plants, military and aerospace systems, hospitals, and countless other applications has opened a vast new market for displays of all types. This, coupled with the phenomenal growth of calculators, the insatiable demand for color TV, and the anticipated use of displays in automobiles has made display technology one of the most dynamic areas.

▸▸▸ plasma discharge displays

Gerald Lapidus Associate Editor

The main contenders for leadership in the numeric display field are dc excited gas discharge displays, liquid crystals, and light-emitting diodes (LEDs). Gas discharge displays offer good appearance, can be quite large, exhibit a broad range of colors, and have proven reliability. An important disadvantage of today's gas discharge devices is that they are not directly compatible with MOS ICs. LEDs offer good appearance and have the closest compatibility with ICs, but are limited in size. Liquid crystals require the lowest power (an extremely important factor in watches and portable calculators), but have the poorest appearance and reliability. Many observers believe that the competition between the three technologies will continue unabated, but that LEDs may be edged out of competition for large size or multicharacter (greater than 10) displays.

Pressure for new displays comes from users of both large and small displays. In large displays, most commonly served by the cathode ray tube, attempts are underway to develop a display having all of the versatility of the crt—that is, cheaper, smaller, consumes less power, and operates at a lower voltage.

A prime contributor to such pressures has been the progress of integrated circuits, which have made rapid gains in these areas, causing displays to stand out as major contributors to cost, bulk, and power consumption.

In applications for small displays, such as hand-held calculators and electronic watches, display costs, readability, and power requirements have become leading factors in selection of one type of display over another. Still other requirements may be addressability, linearity, intrinsic memory, and flat packaging.

As might be expected, much of the work in displays—especially for small devices requiring readout only of numeric or alphanumeric characters—is related to developing easily integrated, planar structures that can be readily batch-fabricated, as is the case with integrated circuits. Among the technologies undergoing this type of development are liquid crystals, plasma panels, light-emitting diodes, thin-film electroluminescent devices, electrophoretic displays, and projection light valves.

Substantial work continues in plasma discharge displays to reduce costs, improve contrast, and to make these displays directly compatible with MOS ICs. Burroughs plans to introduce an MOS-compatible "Panaplex" display in 12–18 months, with which it will attempt to put plasma devices squarely in competition with LEDs and liquid crystals for the hand-held calculator market.

Plasma displays also are undergoing development as possible replacements for the crt, especially in the long-awaited flat, color picture tube for television. The phosphors of such these tubes are excited by photoexcitation from ultraviolet photons, generated in the discharge. Another approach is for the phosphors to be excited directly from low-energy discharge electrons. A major hurdle yet to be overcome is inadequate brightness. There also is a limit on the number of lines that can be scanned in a given frame. Present devices produce 280 lines.

Displays may be classified into two categories: light-emitting and light-controlling. An example of a light-controller is a liquid crystal display, in which characters are read out by changing the reflection characteristics of the material and readability is determined by the amount of incident light.

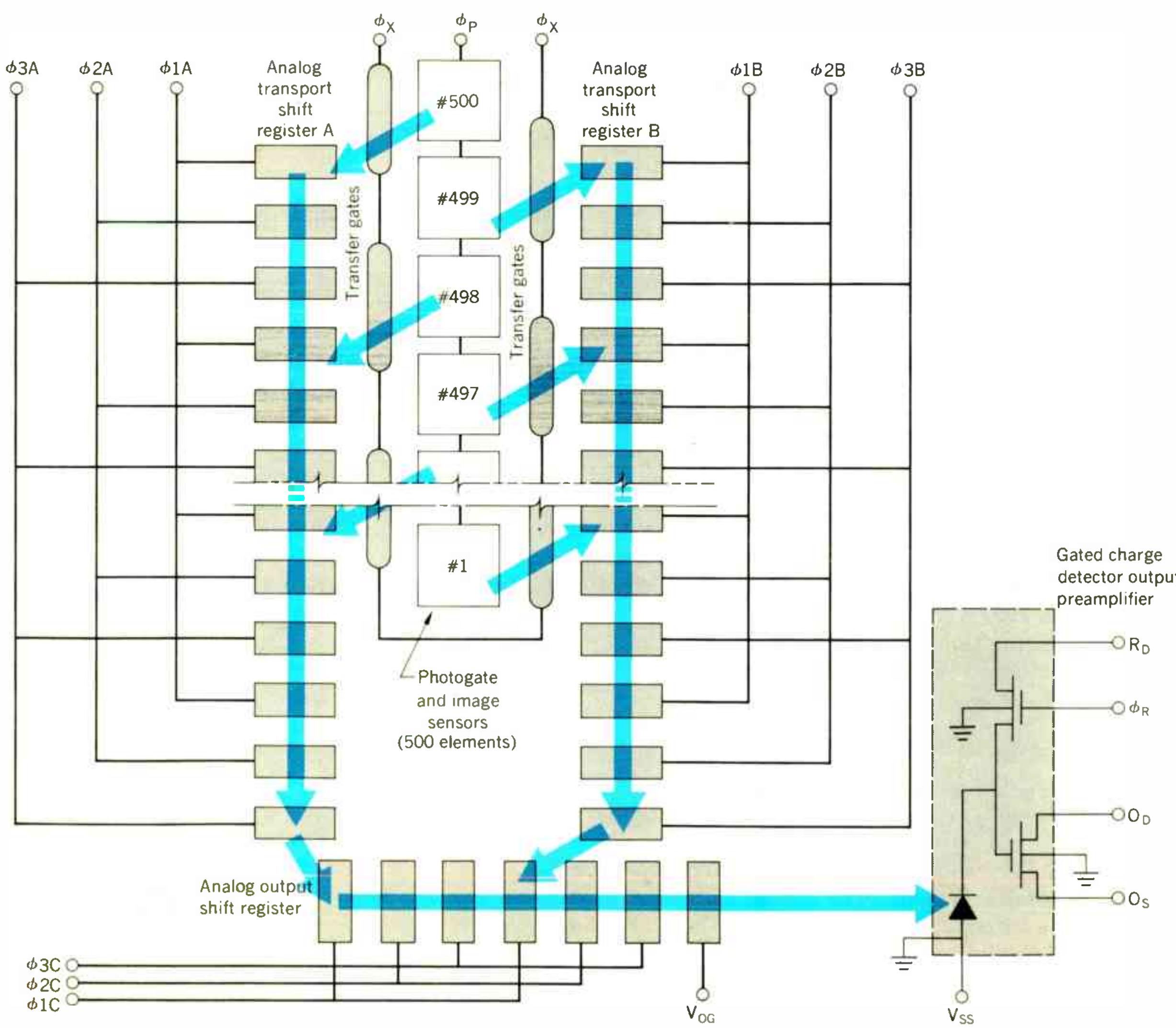
light-emitting diodes

Light-emitting diodes (LEDs) have been one of the most successful of the new display technologies, having found broad acceptance in numeric displays for calculators, watches, and instrumentation. The commercial strength of these devices is based on their brightness, low price, and low power consumption. The largest commercially available devices are 1½ inches for readouts built with discrete diodes and ¾ inch for integrated devices. Individual lamps are limited in size to 0.2 inch and magnifiers are used to increase the apparent size. The original red LEDs have been joined by green (late in 1972) and yellow (early in 1973).

liquid crystals

Liquid crystal displays thus far are the only light controllers to achieve a measure of commercial acceptance. To some extent, this is due to their modest drive requirements, which have attracted more development activity to these devices than other light-controlling displays. Among the other matrix addressed light-controlling devices that have been demonstrated are electrochromic devices using thin

The first commercial CCD. Fairchild's 1 × 500 linear image sensor contains 500 photosensitive elements that collect light striking the device. Individual charge packets, proportional to the amount of light at each photoelement are then transferred to one of the 250-element, three-phase, charge-coupled shift registers at either side of the photo gate. Alternate charge packets are simultaneously shifted to the left and right shift registers. The packets are then transferred vertically through the shift registers to a two-element horizontal selection register, which interleaves alternate packets from the left and right vertical registers, to restore the proper sequence of image elements. These elements are next applied to an output gate, which in turn feeds the image signal an NMOS preamp.



films of transition metal compounds, colloidal dipole suspensions, and electrophoretic suspensions.

Until recently, most liquid crystal displays have operated by dynamic scattering, in which scattering is induced by ionic flow in a thin film of moderate-resistivity nematic liquid crystal. The requirement for current flow had led to some concern over lifetime, although evidence is mounting that carefully prepared, hermetically sealed cells can have adequate lifetime especially with ac operation.

A dynamic-scattering reflective liquid crystal display is usually backed with a reflecting mirror. This means that the angle of the observer relative to the display and the source of ambient light is critical if good contrast is to be obtained.

Not as much glamor, but continuing progress

Significant progress in materials has produced new products and improvements in existing devices. Among the material areas making important gains are permanent magnets, recording media, silicon steels, and microwave ferrites.

Recent work in cobalt-rare earth permanent magnets has resulted in Co_5R magnets having an energy product greater than that of any previously known substance and having resistance to a demagnetizing field a full order of magnitude greater than the best Alnico alloys. The Co_5R magnets, announced about 1966, were first used in traveling wave tubes (about 1970) to reduce their size and weight significantly. More recently, they have gone into wrist watches in place of the very expensive CoPt.

A number of new products have been made possible only through the use of this new material. They include: a bearingless tachometer generator, a miniaturized torque motor for aircraft instrument display, a strap-down gyro, a gimbaled gyro, and a four-pole permanent magnet generator for jet engine ignition.

Improvements in conventional tape and disk digital magnetic recording systems for computer applications are continuing, due in large part to gains in tape quality, head quality, and mechanical design and fabrication of drives. The magnetic material on the tape or disk is still essentially gamma-Fe_2O_3, unchanged, except for its quality, since the early 1950s. During 1973, new high-performance disk recording systems and tape recording systems were announced, based on a significant improvement in linear density, on a new coding scheme, and on improved error correction capabilities.

Digital ICs: faster, denser, and cheaper

Recent work in the two major digital IC technologies, bipolar and MOS, has been aimed at widening and second-sourcing product lines, as well as improving on shortcomings.

In bipolar circuits, the emphasis is on developing smaller devices to improve performance and to increase integration levels. Two of the processes being developed to meet these goals are Isoplanar II and OXIM (oxide-isolated monolithic technology). An important objective of these and other processes has been to reduce isolation areas to shrink transistor sizes. Another goal is to minimize collector-to-substrate capacitances for greater speed.

Isoplanar process

The original Isoplanar technology eliminated space between the base and the isolation layer. Isoplanar II also eliminates space between emitter ends and the edge of the base. One circuit built with Isoplanar II is a dual ECL gate made by Fairchild Camera and Instruments, which sports a subnanosecond propagation delay. Even more important than its speed is that the inherently reduced parasitics of Isoplanar II structure achieve a propagation delay as low as 650 ps with standard ECL power supply voltages and logic levels.

OXIM process

The OXIM structure is part of an evolution of bipolar processes that began with the standard buried collector (SBC) structure in which isolation is achieved with a diffused P-type guard ring. The next rung in the evolutionary ladder was the collector diffusion isolation (CDI) structure in which the collector contact diffusion surrounds the active transistor to achieve collector contact and isolation in the same operation. This structure is smaller than the SBC. However, parasitic capacitances are not reduced in the same ratio as the area, because of high capacitance between the collector contact and the extrinsic base diffusion.

In the OXIM process, isolation is achieved by selectively oxidizing the region around the transistor using silicon nitride as an oxidation mask. This technique produces a transistor that is slightly smaller than the CDI transistor and yet has substantially smaller parasitic capacitances. The reduction in capacitances can be as much as a factor of 10 in some cases.

NMOS

An important trend in MOS has been the transition from P-channel devices to N-channel. This is due to the better operating characteristics obtainable with NMOS because the mobility of electrons in these devices is higher than holes. The reason NMOS development is only now reaching maturity is that there was the problem of sensitivity of N-channel devices to positively charged mobile contaminants. However, processing improvements have alleviated this difficulty.

Other advantages of NMOS over PMOS are compatibility with TTL inputs, power can be obtained from a single +5-volt supply, and for comparable speeds NMOS requires less silicon area than PMOS. Proponents of NMOS also claim that it has the best speed–power performance of all single channel LSI technologies.

▸▸▸ silicon-on-sapphire

Silicon-on-sapphire (SOS) technology applied to MOS circuits is seen as a way in which MOS circuits may become competitive with the speed of bipolar. In these devices, sapphire is substituted for conventional bulk silicon substrates. This drastically reduces the parasitic capacitance of the drain-to-substrate diodes and that of the metal over silicon wiring found in conventional bulk silicon devices. The only significant capacitance is due to the active channel of the driven MOS device. The internal array time constant approaches that of bipolar devices, which may be as low as a fraction of a nanosecond. The major problem with SOS is substrate cost—$20–$30 compared to $2–$4 for conventional MOS.

Still another participant in the MOS race is

CMOS, for complementary symmetry MOS, (also commonly called COSMOS). This type of circuit brings to ICs, the advantages of complementary symmetry circuit configurations that originated with discrete devices, which include low power, quiescent operation, fast propagation delay, high noise immunity, large fanout, well defined 1 and 0 levels, and operation from a single power supply. However, to achieve symmetry the circuits must be built with matched P and N channel devices, which makes the device designer's job more difficult.

Comparing NMOS and PMOS memory technologies, we find that the biggest advantage of CMOS is low power dissipation. A *static* CMOS cell requires one percent of the total power of an analagous *dynamic* NMOS device. CMOS also operates over a wider power supply range, starting at about the N+P threshold voltages and going up to the maximum voltage. NMOS, however, has the edge in lower cost and greater packing density.

However, in logic arrays, a *dynamic* PMOS or NMOS array can have power dissipation almost as low as dynamic CMOS. But *static* PMOS or NMOS has much higher dissipation than static CMOS.

One aspect of MOS development that has received a large measure of attention is combining CMOS and SOS. Such a device could not only equal, but exceed the speed of bipolar devices, with switching rates of 300 MHz possible.

Semiconductor components are sensitive to both the displacement effects created by neutron bombardment and the ionizing effects of gamma radiation. Studies on MOSFETS show them to be relatively immune to displacement effects. However, they are severely degraded by ionizing radiation, which causes changes in surface states. Large threshold voltage shifts result from radiation damage.

Recent advances in the radiation hardening of MOS devices and circuits center around the use of ion implantation techniques for accurately controlled impurity doping of bipolar P and N regions, and for the controlled introduction of traps in oxides leading to a reduced susceptibility to ionizing radiation.

Linear ICs spurred by new markets

The pace of linear (analog) IC technology has traditionally lagged behind that of digital technology because of the tighter performance requirements of linears. Much of the effort in linears is aimed at accommodating more circuit functions on a chip, to reduce the cost per function to the user. Another important trend is the recent combination of bipolar and MOS circuits on the same substrate to enhance further the degree of integration.

An example of how increasing integration has gobbled-up discrete circuit functions is in the television receiver, long a holdout from solid-state technology. Although the sets being manufactured today have just completed the evolution from tubes to solid-state components, the receivers built a few years from now will have almost all circuits on a few IC chips. Thus, a single IF system chip, such as one recently developed by Plessey Semiconductors might contain the video IF amplifier, a synchronous detector, video amplifier with noise inversion, and gated AGC functions. The Plessey design also contains a limiting amplifier and quadrature detector that can be used as a sound detector or AFC generator.

One of the biggest potential markets for linear ICs is the automotive field. With electronic fuel injection, antiskid braking, collision-avoidance radar, vehicular diagnostic systems, and other electronic devices in the offing, automotive manufacturers are faced with the question of whether to build these devices with standard ICs or to develop customized circuits. The standard devices offer the advantages of a short development cycle and more predictable yields than do custom devices. However, standard ICs are not usually designed to operate from a power supply which may vary from 4 to 24 volts. Nor are they designed to handle the environmental rigors of the engine compartment. Therefore, the long term answer may lie in custom ICs for the automobile.

An important element of the design of these new circuits is preventing the substantial voltage transients found in automotive electrical systems from disrupting circuit operation and possibly even de-

◄◄◄ CMOS

MOS-bipolar

consumer ICs

◄◄◄ radiation hardening

Computer-aided design going commercial

Computer-aided design (CAD) is turning away merely from the generation of new theoretical results by expanding towards the application of existing techniques to practical problems.

The need for practical implementation is especially acute in MOS/LSI, which is the first area to be completely dependent on computer-aided circuit simulation. As a result, there is strong interest in FET modeling.

A continuing problem in the application of computer aids to the design of practical circuits is adapting the aids to fit the real world. As pointed out by Stephen W. Director and Barry J. Karafin, guest editors of the November, 1973 special issue on computer aided design of the *IEEE Transactions on Circuit Theory:* The design of practical circuits often requires a *guru* —a CAD expert who can make changes in the CAD programs, link the right ones together, and make the necessary simplifying assumptions. They cite, for example, a common occurrence in which optimization and sensitivity packages require that the designer specify a figure of merit for his circuit. But often, he does not have solid requirements of any kind. Even when a performance function is established, it might be more complicated than a single transfer function, involving gain-bandwidth products, distortion performance, noise performance, pulse shape, degradation, etc. Therefore, it is often an art where experience of a given design may not be transferable.

However, despite the difficulties, much successful work continues. Notable among recent progress is CAD applied to nonlinear circuits.

stroying ICs. Negative transients in particular can cause electrons to be injected into the substrate, thereby activating a parasitic lateral PNP transistor, which can seriously degrade performance. In addition, high frequency voltages are especially troublesome in bipolar circuits, due to the wide bandwidths of these devices.

Some common linear building blocks

Among the basic building block circuits used throughout the electronic industry are amplifiers, A/D converters, D/A converters, and multipliers.

/D and D/A

All of these product areas are continuing to receive a great deal of attention. Monolithic D/A converters are now available with 10-bit monolithic resolution. An inherent problem in designing such high-accuracy converters is one that has always plagued linear IC designers, that of producing precisely matched components. Although IC processing techniques have for a long time produced well-matched components (which sometimes outperform their discrete counterparts) the need for 10-bit precision nevertheless presented a great challenge. Engineers at Signetics Corp. have obtained sufficient accuracy and matching through the use of ion-implanted resistors, combined with standard bipolar processing methods. Therefore, the converter can be manufactured on the same process line as high-volume products, with only a small amount of additional handling. Another approach to building a 10-bit D/A converter was taken by Precision Monolithics, Inc., by refining diffused resistor matching techniques.

amplifiers

Amplifier frequency characteristics continue to be pushed far and wide. Some examples are a monolithic amplifier built by Tektronix that is capable of an 80-volt swing and 1.7-V/ns slew rate. The amplifier was designed to drive capacitive loads such as electrostatic deflection systems. A totem pole circuit arrangement is combined with active feedback to produce the large voltage swing without excessive power consumption. The amplifier is fabricated with standard IC techniques.

An amplifier with a uniform bandwidth from dc to 1 GHz has been developed at Philips Research Labs. This wide bandwidth was obtained by a number of sophisticated processing techniques including microwave transistor diffusions, double-layer interconnections, beam leads, air isolation, and microstriplines on ceramic substrates. The circuit itself is otherwise conventional.

In the power area, long a deficiency of IC technology, a 15-watt monolithic operational amplifier has been designed at the University of California (Berkeley), based on a new transistor structure that includes emitter degeneration transistors as part of the emitter structure.

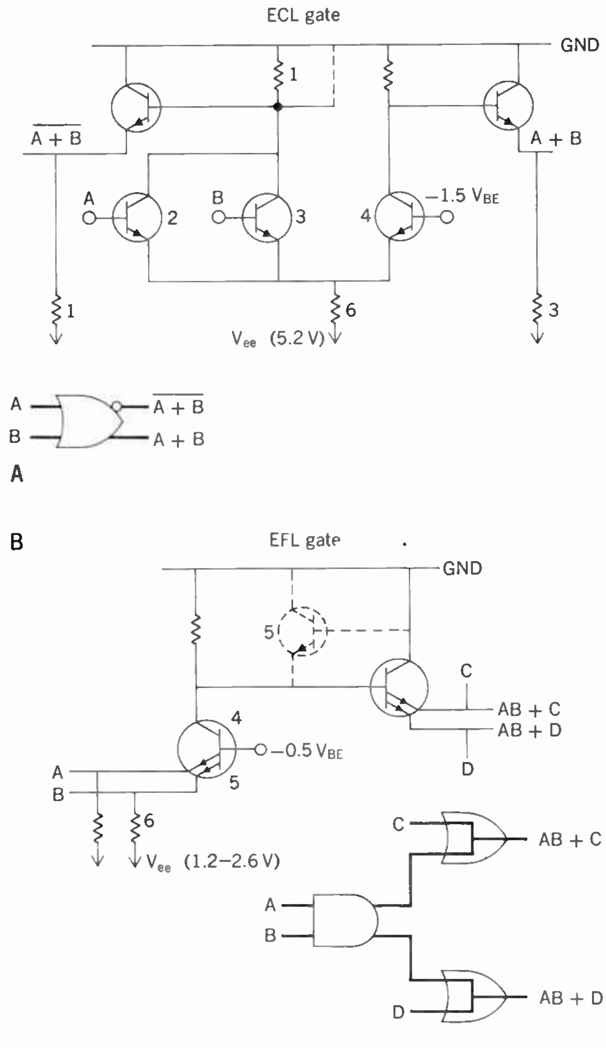
active filters

Increasing use is being made of RC active filters in linear ICs. The low cost and small size of these filters now have made them competitive with discrete, passive filters. Previously, voice frequency amplifiers containing RC active filters were built with discrete amplifiers, resistors, and capacitors, with component selection requiring time-consuming testing of components from normal production runs. Monolithic circuits eliminate much of this effort and so today, tantalum, thin-film RC networks can be precisely built with batch fabrication methods. Important factors in this development have been refinements in photolithographic processes and in the selection of materials for circuit elements and interconnections. Also contributing is the ability to combine the silicon amplifiers with the thin-film RC networks.

Charge transfer devices enter the market

Charge transfer devices, consisting of charge-coupled devices (CCDs) and bucket brigade devices (BBDs) were announced four and five years ago, respectively, and the first commercial CCD devices

Emitter function logic (EFL) is a new form of LSI that is said by its proponents to combine the performance advantages of emitter coupled logic (ECL) with the compactness of multiemitter structures. The simplified gate design has been found to reduce propagation delay, power dissipation, and the number of logic levels required. The differences between ECL gates and EFL gates are indicated by the numbered labels.



1. Eliminated inversion
2. Replaced OR function
3. Eliminated second follower
4. Bias shift-input clamp
5. AND function plus clamp diode
6. V_{ee} decrease

were introduced last year. The basic function of these devices is to transfer a quantity of charge from one part of the circuit to a neighboring element. The uses arising out of this mechanism are collecting charge from photosensors, delay lines, filters, and serial memories.

In 1973, Fairchild Semiconductor introduced the first commercial image sensors: a 500-element, linear, self-scanned device and a 100 × 100 array. The linear sensor can provide a single line of a TV picture at a time, while the area device views an entire picture simultaneously. The array has been built into a miniature TV camera about the size of a package of cigarettes.

CCD image sensors offer the advantages of smaller size and lower power requirements than vacuum tube image sensors. The array operates from a 20-volt power supply, compared to about 2000 volts for typical vacuum tube sensors. Nominal power consumption is 50 mW.

Memories undergoing technology shift

Magnetic core memories are beginning to lose ground to semiconductor storage, with many new computers featuring semiconductor memories. At present, core memories are still competitive in cost at the system level, but semiconductor prices are continuing to drop much more rapidly than core. Semiconductors are also surpassing core memories in speed. However, cores are far from being obsolete and they still account for the largest share of the memory market.

Core makers are lowering production costs by automating production, by mounting more cores on a plane, and by greater integration of supporting circuits. Performance improvements are coming from the use of smaller cores and new stringing arrangements such as 2.5D or 2D organization. Other attempts at improvement are based on storing more than one bit per core using multiple flux levels. Improved core uniformity may help this to come about.

Projections for 1973 were that cores took 69 percent of the mainframe market, down 10 percent from the previous year. Two areas in which semiconductor memory technology has had limited success are in noise immunity and volatility, both strongpoints for magnetic core technology and plated wire. Plated wire, with an estimated 4 percent of the field is seen as finding continuing use in military and some industrial control systems, where its superior noise immunity relative to other read–write memories is unmatched.

MOS and bipolar ICs are vying for the lead in the semiconductor storage competition, with MOS capturing the low cost, but slower applications and bipolar hitting the faster systems. MOS leads in the number of bits that can be stored in a single chip, with 4-kb devices in production and 8-kb units still in the laboratory. MOS access times are below 300 ns and costs per bit are well below 1 cent.

Bipolar RAMs (random access memories) have been developed in 1-kb sizes, with access times under 50-ns (for ECL) and bit costs approaching 5 cents (for TTL).

◀◀◀ *charge-coupled devices*

Work continues in read-only memories (ROMs), with selectively erasable ROMs being the focus of attention. MNOS (metal nitride semiconductor—not to be confused with the aforementioned NMOS) are entering production and may someday evolve into a nonvolatile form of read–write memory, providing the write voltage can be reduced and speed increased. The level of integration of ROM chips is 16 kb in MOS and 10 kb in bipolar.

Among the memory technologies being primed for the future are magnetic bubbles and charge transport devices, both serial. These memories are expected to meet needs for medium-speed, low-cost mass storage devices, whose functions are being performed by magnetic tapes and disks. Magnetic bubbles are moving towards production, now having reached the stage where operating prototypes are being described in detail and fabrication capabilities are being scaled up from singular experiments towards laboratory run capabilities. The most significant new developments include single mask fabrication methods and the demonstration of amorphous bubble materials which do not require single-crystal substrates.

◀◀◀ *magnetic cores*

Charge-coupled devices offer extremely high circuit densities, possibly exceeding the density of the 1D MOS cell by a factor of four. A 4-kb device has been developed by Bell-Northern Research of Canada and its 8-kb successor is well along.

Hybrid ICs benefiting from monolithic advances

Hybrid integrated circuits (HICs) have benefited by, rather than suffered from, rapid advances made in monolithic silicon integrated circuits. Monolithic IC developments such as sealed junctions, beam leads, and flip chips having expanded rather than limited the capabilities of HICs. Forecasts for the total dollar volume of HIC production indicate a 20-percent growth in 1974 to $690 million.

digital HICs

Digital circuits are the most volatile portion of the HIC business. The HIC technology and package design is dominated by the scale of integration and type of terminations used on monolithic ICs. Today, the typical digital HIC is a multichip package containing up to about ten small ICs. Some designs have 50 or more ICs which makes the interconnection technology used in the HIC extremely important. Either multilayer thick films or plated beam thin-film crossovers are being used on the ceramic substrates which support the ICs. As the sizes of ICs increase, the same electronic function can be achieved with fewer chips per package which will simplify the HIC interconnection problem. (On the other hand, it will still be possible to have a large number of ICs and provide more functions per HIC package.) The optimum HIC design in this situation involves many tradeoffs which are sensitive to the cost of assembling and testing. Diagnostic testing and repair procedures are becoming more important considerations as the complexity of the package grows.

◀◀◀ *IC memories*

analog HICs

In analog circuits, HICs provide high-quality, passive elements which are not available in silicon. Both thick and thin films are used to provide integrated arrays of resistors which can be readily

> **Tomorrow's solid-state headlines**
> For a preview of what's going to be unveiled at the 1974 International Solid-State Circuits Conference next month, see the article beginning on p. 98.

adjusted to provide the proper circuit function. For frequencies up to 1 MHz, thin films are also used to provide as much as 0.05 μf of capacitance.

Film technologies provides unique capabilities for microwave HICs in the form of microstrip wiring and precision lumped element geometries. Both thick and thin films are used for frequencies up to about 1 GHz. The thin-film capability extends up to about 30 GHz because of the precise patterns obtained by photolithographic pattern generation techniques.

What changes in HIC technology will 1974 bring? One of the most important and controversial points which remains to be resolved is the best method of connecting an IC to the film circuitry of the HIC. The dominant method used today is conventional wire bonding. Flip chips and beam leads offer considerable assembly cost savings to the HIC manufacturer, but unfortunately these devices are still not readily available. A recent survey conducted by Raytheon indicates that, although the present use of beam leads is relatively small, it is the preferred configuration of HIC manufacturers.

Another controversial point which will receive a lot of attention is the acceptability of plastic encapsulation as an alternative to the hermetically sealing of HIC packages. As the reliability and understanding of materials used to encapsulate HICs improves, there should be fewer applications where hermetisity is considered necessary.

It is doubtful that the question of choosing between thick- and thin-film technologies will be resolved any further this year than it has been in the past. Thick film has dominated the HIC market because it requires less capital investment and is often a lower cost process. Thin film, however, offers smaller size and higher packaging densities which may become increasingly important. Also, thin film presently has the unique capability of integrated capacitors for analog circuits and a higher frequency range for microwave applications. As the HIC technology matures, there will be an increasing emphasis on standardization of HIC package designs and of the form of the ICs used in those packages.

▶▶▶ *Josephson devices*

Engineers entering the superconductivity loop

Although the Josephson effect has been known since 1962, until recently there was little work done in developing equipment using Josephson junctions and the superconducting coil. And most of this work has been done by physicists. Some observers attribute the reluctance of engineers to get involved to resisting reliance on refrigeration systems, which require substantially more development before superconductivity can become a viable technology. Also, EEs generally have little background in this area. However, there is increasing interest in superconductivity, especially with the compelling need to develop new methods of power generation, energy storage, and high-speed ground transportation.

Already on the market are sensitive instruments to measure magnetic fields and gradients. Detection with simple Josephson point contacts at millimeter wavelengths has produced sensitivities equal to the best competitive devices. The possibility of the superconducting computer has been reopened by the approximately 10^{-11} second switching time of the Josephson junction.

The author wishes to acknowledge the help of Frederick Luborsky of General Electric Co., David Feldman of Bell Labs, Robert McCoskey of Harry Diamond Labs, and Thomas Maloney of Burroughs Corp.

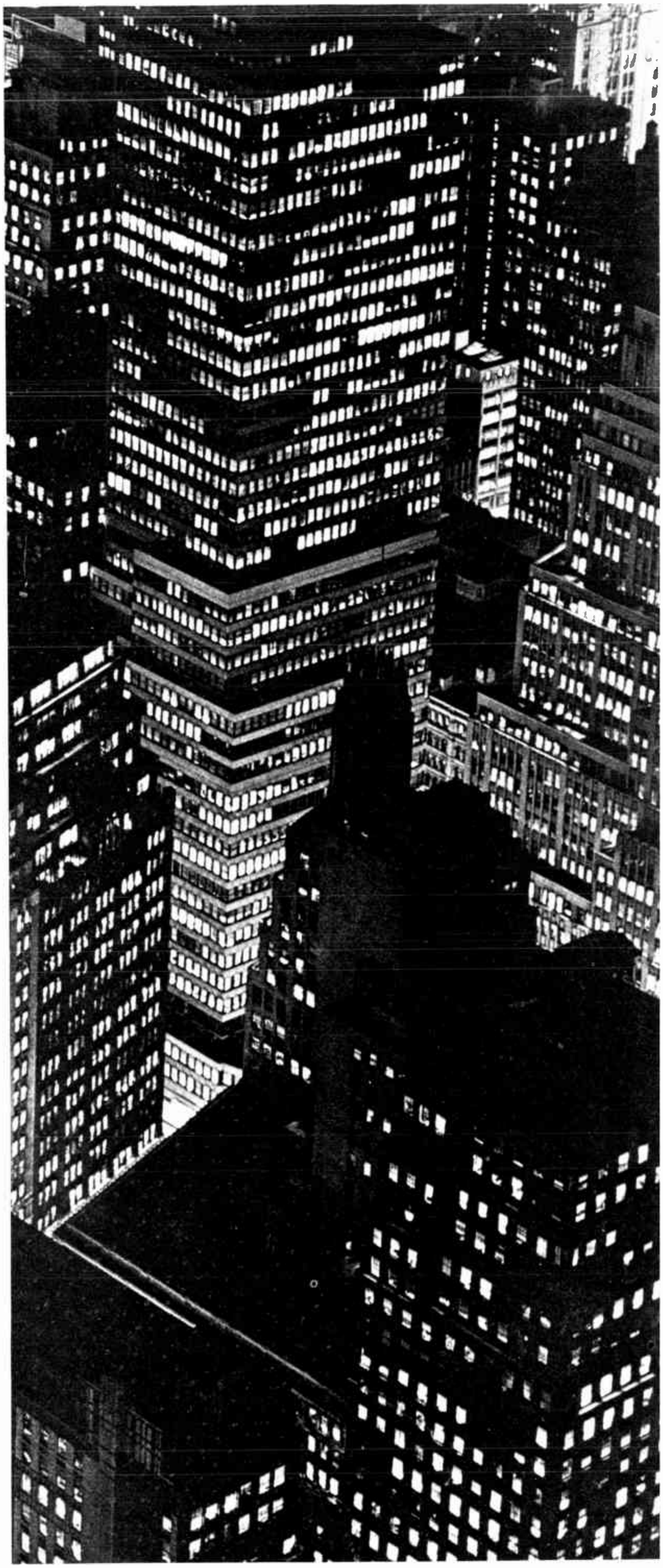
Power/energy: problems and progress

Global politics has fueled an overdue search by the industrial nations for new energy sources

At the outset of this new year, electric power engineers are still confronted by a forecast of increased electric energy requirements that, apparently, have not been modified by the tightening fuel/energy bind. In short, they envisage a doubling of the ability of the power industry to generate and deliver electric energy over the next ten years. The diminishing supplies of fossil fuels, coupled with public concern for the environment, will require massive changes in technology to meet the requirements in an acceptable fashion. And the power industry has already begun the imple-

Gordon D. Friedlander Senior Staff Writer

Life style of a profligate society. Manhattan by night is a glorious spectacle of wasted electric energy. But many of these lights will have to be turned off because of the deepening fuel-shortage emergency.



mentation of massive R&D programs to meet the known—and unknown—challenges of the rapidly changing fuel picture.

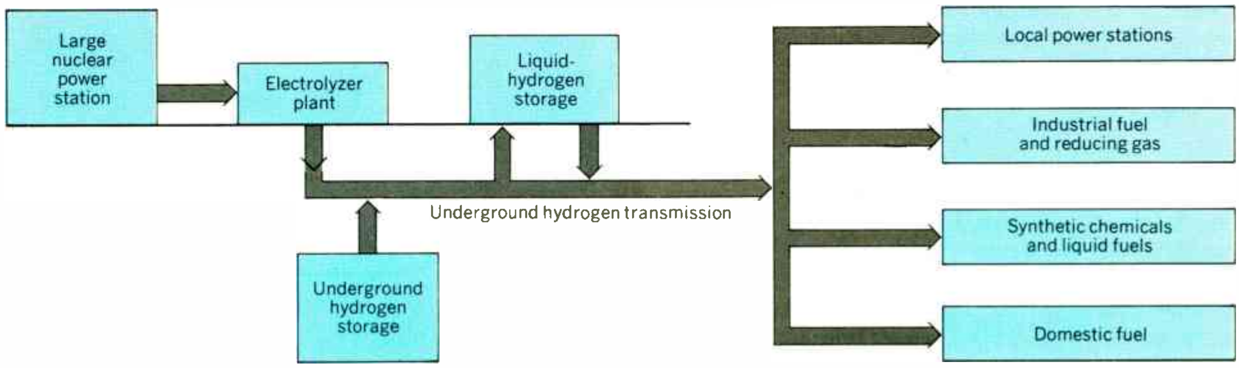
Shortages of petroleum and natural gas are focusing keen attention on finding acceptable ways to use coal reserves to meet energy needs. Research is under way and pilot plants are operating that generate clean gaseous or liquid fuels from coal (LNG, coal gasification). These new derived fuels can operate power stations and meet the desired clean air standards. There is also much interest in the potential of geothermal power, but the technological problems are still vast, and harnessing this natural power will be costly. Nevertheless, at least three geothermal plants are presently in operation (in California, Mexico, and Italy). But by 1985—or sooner—we may see a number of geothermal power plants on the line, capable of generation in the megawatt range (see "Energy: crisis and challenge," *IEEE Spectrum*, May 1973, pp. 18–27).

In the burning of all fossil fuels, considerable progress is being made in the control of stack emissions. For example: particulate matter can be removed by means of high-efficiency electrostatic precipitators; considerable work is being done on stack-gas scrubbers for the removal of sulfur oxides; and, combustion-chamber techniques are making significant reductions in the generation of nitrogen oxides.

The power industry believes that nuclear fission reactors provide clean electric energy; however, the natural uranium basic fuel supply is available in limited amounts. Although we presently have sufficient uranium ores for nuclear fission (see Table), we could be in trouble by 1990 unless an operational fast-breeder reactor (FBR) is commercially developed, or a nuclear fusion breakthrough occurs. However, the industry has already funded a major demonstration project of a FBR, with a fuel-conversion efficiency that will provide for hundreds of years of projected electric energy requirements.

Overall electric generation economy is being made by systems that store energy during off-peak periods. As one example, in an air-storage gas-turbine power station, air is compressed during off-peak hours and held in underground storage tanks. During daytime peak-load periods, the stored compressed air is used for the operation of a versatile gas turbine. Such a plant, generating about 200 MW, under a working air pressure of 25 bars, is undergoing R&D in Sweden. Operation in this mode would be about 10 hours in every 24. Another concept being actively investigated is that of superconducting inductors, with energy-storage capacities of 50 to 450 MW over a 6-hour period. Both techniques, however, require electric energy to replace the peaking energy supplied. The savings are in equipment, *not* energy.

Pumped-storage hydroelectric plants continued to be built during 1973 (and, parenthetically, Con Edison's long-delayed Cornwall Plant on the Hudson River has finally been cleared for construction) wher-



Simplified block diagram illustrating elements of the "hydrogen economy." Hydrogen would be produced as a secondary fuel by means of electrolysis in large nuclear (or even solar-power) stations. The H_2 would be transmitted by means of an underground network of pipelines, which would include facilities for storing the gas under pressure underground, or in the highly compressed liquid state above ground. The H_2 could then be distributed, as required, for use as a fuel for the production of electric, heat, or mechanical energy.

ever the water storage in the high reservoir is acceptable to the local environment.

storage batteries fuel cells

Significant research is being conducted on high-efficiency electric storage batteries (lithium-sulfur, etc.), and fuel cells to help meet peak-load demands.

In the field of electric transmission, substantial efforts and progress are being made to improve the economy of underground systems. The Edison Electric Institute, for example, is operating a major research facility at Waltz Mill, Pa., to test 500-kV cable systems. Prototypes of cryogenic cables, for underground use, operating at temperatures near absolute zero are being tested at other R&D sites. And a number of compressed-gas (SF_6, etc.) insulated conductor systems for UG transmission are now being placed in service at voltages up to 500 kV.

Research projects are under way to advance the technology of ultrahigh-voltage (UHV) alternating current (above 1000 kV). The Pacific Intertie, operating at 800-kV dc is providing the experience to determine the future applications of UHV dc transmission.

As electric power systems become ever more complex, automatic control and management systems are needed (and are continually being developed and installed) for effective load-dispatch operations. Furthermore, sophisticated telemetry and supervisory control systems are providing for overall computer system management of economic dispatching, load prediction, and power-system protection.

gas-insulated conductors

An important technological development in the use of gas-insulated conductors permits switching stations to be assembled on a small fraction of the land area previously required for such installations. The use of such stations is coming into significant commercial acceptance in 1974.

LMFBR

The United States' breeder program envisages the utilization of a liquid-metal coolant (in other countries either gas or water coolant approaches are favored). The U.S. announced plans for the construction of a demonstration LMFBR two years ago. Late in 1973, the Government awarded the reactor contract to Westinghouse Electric. The demonstration plant will generate 300 to 400 MW and is scheduled to be in operation by 1980, with follow-on full-scale commercial plants to go on the line in 1985. (A discussion of this topic will appear in the February issue of *Spectrum*.)

floating plants

The lead time for conventional land-based nuclear power plant licensing—because of the opposition of the public and environmental groups—has stretched to as much as ten years. And suitable land siting for large nuclear generating stations has become very difficult to find. One solution considered viable is the offshore nuclear power station (see "Foating reactor: 'crisis' solution?" *IEEE Spectrum*, Feb. 1973 pp. 44–51), which can be situated near power stations without competing for valuable land. At the present time, commitments for the first two offshore plants have been made by New Jersey's Public Service Electric and Gas Company. Called the "Atlantic Generating Station," the twin plants would be situated 4.5 km off the Jersey coast, approximately 19 km northeast of Atlantic City. They will be on line in 1979.

hydrogen

Hydrogen, in many ways, is the ideal fuel. It can easily be extracted from oil, coal or natural gas. And, easier still, it can be produced from the electrolysis of water by means of conventional or nuclear-energy sources. It provides a potential for relatively inexpensive underground energy transmission, of storage near load centers in tremendous amounts, and of use as a fuel with remarkably low environmental pollution effects. (When hydrogen burns, its only combustion product is water.) If energy options are restricted to the use of effectively "unlimited materials," hydrogen is, by far, the most readily synthesized fuel.

During the past year, considerable research was given over to the investigation of a possible hydrogen economy in which this element is produced from water by means of electric energy; then, it is stored in highly compressed liquid form until needed. It may then be transmitted by underground pipeline to its point of use and there burned as a fuel to produce electric, heat, or mechanical energy. For example, in one feasible scheme, power generated at a nuclear plant during off-peak hours could be used in the electrolysis of seawater (this would be particularly applicable in the offshore concept) to produce hydrogen that could be bottled under pressure and employed in conjunction with a fuel-cell program.

The transmission of electricity is expensive and re-

I. Nuclear power log—as of November 1973

State and Location	Plant	Net MW	Type/Mfr.	Utility	Operable
(Construction permits issued in 1973)					
California					
San Clemente	San Onofre 2	1140	PWR/C-E	Southern California Edison Co. (San Diego Gas and Electric Co.)	1979
San Clemente	San Onofre 3	1140	PWR/C-E	Southern California Edison Co. (San Diego Gas and Electric Co.)	1980
Illinois					
Seneca	La Salle 1	1100	BWR/GE	Commonwealth Edison Co.	1977
Seneca	La Salle 2	1100	BWR/GE	Commonwealth Edison Co.	1978
New Jersey					
Lacey Township	Forked River 1	1140	PWR/C-E	Jersey Central Power and Light Co.	1978
New York					
Shoreham	Shoreham	820	BWR-GE	Long Island Lighting Co.	1977
North Carolina					
Cowans Ford Dam	William McGuire 1	1150	PWR/W	Duke Power Co.	1976
Cowans Ford Dam	William McGuire 2	1150	PWR/W	Duke Power Co.	1977
Pennsylvania					
Berwick	Susquehanna 1	1100	BWR/GE	Pennsylvania Power & Light Co.	1979
Berwick	Susquehanna 2	1100	BWR/GE	Pennsylvania Power & Light Co.	1981
South Carolina					
Parr	Virgil C. Summer	915	PWR/W	South Carolina Electric & Gas Co.	1977
Tennessee					
Spring City	Watts Bar Dam 1	1150	PWR/W	Tennessee Valley Authority	1976
Spring City	Watts Bar Dam 2	1150	PWR/W	Tennessee Valley Authority	1977
Washington					
Richland	Hanford 2	1103	BWR/GE	Washington Public Power Supply System	1977
(1973 reactor orders)					
Arizona					
near Phoenix	ANPP 1	1300	PWR/C-E	Arizona Public Service Co. (Salt River Project, Arizona Nuclear Power Project)	1981
near Phoenix	ANPP 2	1300	PWR/C-E	Arizona Nuclear Power Project (Salt River Project, Arizona Nuclear Power Project)	
near Phoenix	ANPP 3	1300	PWR/C-E	Arizona Public Service Co. (Salt River Project, Arizona Nuclear Power Project)	1984
Connecticut					
Waterford	Millstone 3	1150	PWR/W	Northeast Utilities (The Connecticut Light and Power Co., The Hartford Electric Light Co.)	1979
Illinois					
Clinton	Clinton 1	950	BWR/GE	Illinois Power Co.	1980
Clinton	Clinton 2	950	BWR/GE	Illinois Power Co.	1982
Kansas					
Burlington	Wolf Creek	1100	PWR/W	Kansas Gas and Electric Co. (Kansas City Power & Light Co.)	1982-3
Missouri					
Fulton	Fulton 1	1100	PWR/W	Union Electric Co.	1981
Fulton	Fulton 2	1100	PWR/W	Union Electric Co.	1982-3
New York					
no site	no name	1150	PWR/W	Long Island Lighting Co.	1981
Sterling	Sterling 1	1100	PWR/W	Rochester Gas and Electric Corp.	1982-3
Oregon					
Boardman	Boardman	1260	PWR/B&W	Portland General Electric Co. (Pacific Power and Light Co.)	1980
Tennessee					
Oak Ridge	Liquid Metal Fast Breeder Reactor (LMFBR)	360	LMFBR/W	Tennessee Valley Authority (Commonwealth Edison Co.)	1980
Texas					
Wallis	Allen's Creek 1	1200	BWT/GE	Houston Lighting & Power Co.	1980
Wallis	Allen's Creek 2	1200	BWR/GE	Houston Lighting & Power Co.	1982
Bay City	Bay City 1	1250	PWR/W	Houston Lighting & Power Co. (Central Power & Light Co., City Public Service Board of San Antonio)	1980
Bay City	Bay City 2	1250	PWR/W	Houston Lighting & Power Co. (Central Power & Light Co., City Public Service Board of San Antonio)	1982
Jasper	Blue Hills 1	950	PWR/C-E	Gulf States Utilities Co.	1981
Washington					
Satsop	WPPSS 3	1200	PWR/C-E	Washington Public Power Supply System	1981

(continued on page 64)

State and Location	Plant	Net MW	Type Mfr.	Utility	Operable
Wisconsin					
Durand	Tyrone 1	1100	PWR/W	Northern States Power Co.	1981
Durand	Tyrone 2	1100	PWR/W	Northern States Power Co.	1982–3
no site	unit 1	900	PWR/W	Wisconsin Electric Power Co. (Wisconsin Power and Light Co., Wisconsin Public Service Corp., Madison Gas & Electric Co.)	1980–2
no site	unit 2	900	PWR/W	Wisconsin Electric Power Co. (Wisconsin Power and Light Co., Wisconsin Public Service Co., Madison Gas & Electric Co.)	1980–2
(No State Determined)					
	unit 1	1300	PWR/C-E	Duke Power Co.	1981
	unit 2	1300	PWR/C-E	Duke Power Co.	1982
	unit 3	1300	PWR/C-E	Duke Power Co.	1983
	unit 4	1300	PWR/C-E	Duke Power Co.	1984
	unit 5	1300	PWR/C-E	Duke Power Co.	1985
	unit 6	1300	PWR/C-E	Duke Power Co.	1986
Plants operable					
Alabama					
Decatur	Browns Ferry 1	1118	BWR/GE	Tennessee Valley Authority	1973
California					
Humboldt Bay	Humboldt Bay	68	BWR/GE	Pacific Gas & Electric Co.	1963
San Clemente	San Onofre 1	430	PWR/W	Southern California Edison Co. (San Diego Gas and Electric Co.)	1967
Connecticut					
Haddam Neck	Connecticut Yankee	575	PWR/W	Connecticut Yankee Atomic Power Co.	1967
Waterford	Millstone 1	652	BWR/GE	Northeast Utilities (The Connecticut Light and Power Co., The Hartford Electric Light Co.)	1970
Florida					
Turkey Point	Turkey Point 3	725	PWR/W	Florida Power and Light Co.	1972
Turkey Point	Turkey Point 4	725P	PWR/W	Florida Power and Light Co.	1973
Illinois					
Morris	Dresden 1	200	BWR/GE	Commonwealth Edison Co.	1959
Morris	Dresden 2	809	BWR/GE	Commonwealth Edison Co.	1970
Morris	Dresden 3	809	BWR/GE	Commonwealth Edison Co.	1971
Cordova	Quad Cities 1	809	BWR/GE	Commonwealth Edison Co. (Iowa-Illinois Gas and Electric Co.)	1972
Cordova	Quad Cities 2	809	BWR/GE	Commonwealth Edison Co. (Iowa-Illinois Gas and Electric Co.)	1972
Zion	Zion 1	1100	PWR/W	Commonwealth Edison Co.	1973
Maine					
Wiscasset	Maine Yankee	855	PWR/C-E	Maine Yankee Atomic Power Co.	1972
Massachusetts					
Rowe	Yankee	175	PWR/W	Yankee Atomic Electric Co.	1960
Plymouth	Pilgrim 1	670	BWR/GE	Boston Edison Co.	1972
Michigan					
Big Rock Point	Big Rock Point	72	BWR/GE	Consumers Power Co.	1962
South Haven	Palisades	800	PWR/C-E	Consumers Power Co.	1972
Minnesota					
Monticello	Monticello	545	BWR/GE	Northern States Power Co.	1971
Red Wing	Prairie Island 1	550	PWR/W	Northern States Power Co.	1973
Nebraska					
Fort Calhoun	Fort Calhoun	475	PWR/C-E	Omaha Public Power District	1973
New Jersey					
Toms River	Oyster Creek	640	BWR/GE	Jersey Central Power and Light Co.	1969
New York					
Buchanan	Indian Point 1	265	PWR/B&W	Consolidated Edison Co. of N.Y., Inc.	1962
Buchanan	Indian Point 2	1033	PWR/W	Consolidated Edison Co. of N.Y., Inc.	1973
Oswego	Nine Mile Point 1	620	BWR/GE	Niagara Mohawk Power Corp.	1969
Rochester	Robert E. Ginna	490	PWR/W	Rochester Gas and Electric Corp.	1969
Pennsylvania					
Shippingport	Shippingport 1	90	PWR/W	Duquesne Light Co.	1957
Peach Bottom	Peach Bottom 1	40	HTGR/GGA	Philadelphia Electric Co.	1966
Peach Bottom	Peach Bottom 2	1065	BWR/GE	Philadelphia Electric Co. (Public Service Electric & Gas Co.)	1973
South Carolina					
Hartsville	H.B. Robinson 2	700	PPWR/W	Carolina Power and Light Co.	1970
Lake Keowee	Oconee 1	874	PWR/B&W	Duke Power Co.	1973
Lake Keowee	Oconee 2	874	PWR/B&W	Duke Power Co.	1973
Vermont					
Vernon	Vermont Yankee	540	BWR/GE	Vermont Yankee Nuclear Power Corp.	1972
Virginia					
Gravel Neck	Surry 1	820	PWR/W	Virginia Electric and Power Co.	1972
Gravel Neck	Surry 2	800	PWR/W	Virginia Electric and Power Co.	1973

State and Location	Plant	Net MW	Type/Mfr.	Utility	Operable
Washington					
Richland	Hanford-N	800	Graphite/AEC	U.S. Atomic Energy Commission (Power distributed by Washington Public Power Supply System)	1966
Wisconsin					
Two Creeks	Point Beach 1	497	PWR/W	Wisconsin Michigan Power Co. (Wisconsin Electric Power Co.)	1970
Two Creeks	Point Beach 2	497	PWR/W	Wisconsin Michigan Power Co. (Wisconsin Electric Power Co.)	1972
Genoa	LaCrosse	50	BWR/AC	Dairyland Power Cooperative	1967

(There are also 18 letters of intent-options for reactors representing capacity of 19 320 net MW.)

Note:

The reactor types listed are pressurized-water reactor (PWR), boiling-water reactor (BWR), and high-temperature gas-cooled reactor (HTGR). The reactor manufacturers are Babcock & Wilcox (B&W), Combustion Engineering (C-E), General Electric (GE), Gulf General Atomic (GGA), Westinghouse (W), Allis-Chalmers (AC). Utilities having a 20 percent, or greater, interest in any particular unit are listed in parentheses after the operating utility.

quires considerable land area for rights of way; however, the technology for transporting energy sources in underground pipelines is well established by both the petroleum and natural gas industries. Industrial hydrogen already is being piped over short distances.

It therefore seems that a number of the problems confronting the power industry—siting of nuclear plants, the lack of energy storage facilities, etc.—can be mitigated to some degree by the hydrogen economy. (It would require some improvements, however, in basic components.)

Some mandatory planning modifications

The fuel/energy crises, culminating so suddenly and unexpectedly, have forced both the U.S. and its Western allies to reorder their schedule of priorities and planning for increased energy use and industrial expansion. In the U.S., for example, the renewed exploitation of our vast (and polluting) coal resources will be the most expedient short-term stopgap answer. But even here, difficulties loom large: at least two years would be required to construct and deploy the massive drag-line equipment needed for strip mining; huge numbers of gondola cars would have to be built, rebuilt, or reconditioned to haul the coal; and there would be the agonizing reconciliation and compromise necessary with environmental groups firmly opposed to a return to high-pollution fuels.

To exploit our domestic petroleum resources, clearance for the construction of the Alaska pipeline, plus a quantum increase in offshore drilling and extraction appear to be inevitable. A streamlining of licensing procedures for nuclear power plants is almost a certainty, and renewed emphasis on this form of generation will be difficult to resist. Finally, intensive efforts are and will be made to reduce costs of coal gasification and the use of LNG; crash programs are already underway in evaluating the cost feasibility of extracting fuel from oil shale and tar sands.

In Western Europe, there are some rationales and reactions that are analogous to those in the U.S. For instance, public resistance to the construction of nuclear plants in Great Britain and most of the EEC countries has been far less vocal, and public acceptance in these fossil-fuel-poor nations is a fact of life. Germany, however, may be the exception. There, one finds a considerable resistance to nuclear plant construction, especially along rivers such as the Rhine where an international understanding has prevented such plants—thus far—from being constructed.

Germany, however, has large coal deposits in the Ruhr Valley, and considerable effort is being expended toward the development of economical coal gasification processes. The Federal Republic, however, since the partition of Germany, has a very small coastline on the North Sea and cannot take much advantage of the prospect of extracting offshore natural gas that has been discovered in that region.

Austerity and sacrifice

Even if there had been no violent flareup in the Mideast last fall, the domestic fuel situation would have been grim, with the threat of brownouts, fuel-oil and gasolines shortages, rationing, and many more unpleasant facts of life that are unpalatable to the citizens of affluent nations. In the U.S., the price of crude petroleum and its refined products have already begun the sinister upward price spiral to—God knows where! It is widely predicted that gasoline, which has already reached 50¢ per gallon, may even peddle for $1.00 a gallon.

In short, it appears that the U.S., Western Europe, and Japan will be "strapped," to put it mildly, as far as oil and natural gas supplies and reserves are concerned, at least over the next three to five years. How the impact of the coming austerity and sacrifice will affect industrial expansion in the U.S., Japan, and Europe* is an unknown in the fuel/energy equation. One indication, however, as to how tightly the economic-political-technological fabric of the U.S. is interwoven came early last November when the prestigious *Wall Street Journal* ran a lead article on why the oil shortage could curtail industrial expansion and the GNP. That same day, the Dow-Jones industrial averages on the New York Stock Market fell by more than 24 points. And, after President Nixon's fuel policy speech of November 25, the D-J plummeted over 29 points in one session.

*It should be noted, however, that the rate of application of nuclear plants in Japan and Europe is 5 to 7 times the rate in the U.S.

The author wishes to thank J. B. Owens, President of the Power Engineering Society, IEEE, for his thoughtful input in reviewing the technology of the electric power industry during 1973.

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Progress in rail transportation

Next: London to Paris in just over 3 hours, and a fast ride from Oakland to San Francisco for 60 cents

Similar perhaps in technologies, 1973 transportation schemes differed considerably in priorities from nation to nation. The U.S., while toying with the interurban Amtrak network, primarily concentrated on its commuter plans—BART, its already operating model system, and PRT (personalized rapid transit), a scheme for the urban future.

On the other hand, Europe and Japan were busily evolving plans for massive interurban rail networks that would require billions of dollars to implement. Only secondarily were they attempting to improve their intra- and suburban commuter systems. But, in all cases, the technology involved was often quite exciting.

Interurban rail—Europe vs. the U.S.

▶▶▶ *computer traffic control*

For openers, Europe's International Union of Railways announced, in November, its formulation of a plan for a 160-km/h, high-speed intercity railway network that would eventually crisscross the entire face of Western Europe (Fig. 1).

By building 5700 km of completely new trackage (including the English Channel tunnel) and substantially modernizing 13 500 km of existing track, European railway authorities—including British Rail—hope to launch the 20th century's most ambitious project for adapting their services to modern requirements and effectively competing with the private car, truck, and airplane.

The plan is based on a detailed market survey of the potential traffic flows between 58 principal European traffic centers from Glasgow to Istanbul. Included in the scheme are strict service objectives such as speed, frequency, and reliability of passenger trains, and guaranteed departure-to-arrival schedules for fast freight.

▶▶▶ *locomotives*

To compete with private motor cars running at an average speed of 90 km/h, for example, the railways must be able to average 135 km/h for passenger service. This would mean that an express train's "cruising speed" has to be at least 160 km/h. And, on some routes, even higher speeds will be sought so that passengers can make return journeys in one day between cities 480 km apart.

The desired travel times envisioned in the plan are

1. London to Paris, 3 hours 15 minutes.
2. Paris to Zurich, 3 hours 40 minutes.

Although the plan makes no cost estimate for the total project at this stage, it would probably exceed $12 billion. Included in this preliminary price estimate is a provision for traction equipment that will ultimately be capable of speeds of 300 km/h!

Gordon D. Friedlander Senior Staff Writer

The ambitious scheme also calls for the pan-European standardization of track gradients, curve radii, rails and ballasting, catenary construction, signal systems, and overall operating procedures. In addition, loading gauges would be increased to permit the railways to carry large containers and "piggy-back" train/truck trailers.

All members of the International Union have been asked to reexamine their national development plans to see how they can best be incorporated into the overall scheme. Our contact with British Rail informs us that the comprehensive strategy of the grand plan matches closely with British Rail's concepts concerning the strengthening of its own services in the U.K.

As one element of the master plan, a high-speed, high-density-traffic, computer-controlled system is currently being tested on the Hamberg-Bremen mainline. Although current speeds, for the sake of evaluation, are being kept at the 160-km/h maximum level, the eventual ultimate speed may be as high as 480 km/h!

The overall lines of this European rail plan mesh closely with British Rail's ideas concerning the strengthening of its own services. Early in 1973, British Rail submitted a plan to the British government for a $4.3 billion development program that would involve greater emphasis on its own intercity services. A government reply to British Rail's proposals is imminent.

British rail was a major supporter of the Channel tunnel project, and the government's "green light" for the tunnel implies support for the principle of the European rail network.

Italian officials of the State Railways system (FS) announced in November that a new service has been inaugurated between Rome and Moscow, via Budapest and Zagreb. This additional passenger express service is necessary because of the large increase in tourist travel between the two countries. Also, the FS revealed that a new class of high-speed electric locomotive—capable of attaining speeds in excess of 210 km/h—was put in service on the Rome-Florence express line. The new locomotives can haul more cars, at higher speeds, than the "Tartaruga" express that made record runs between the two cities.

Compared to the sophisticated planning evident throughout Europe, the U.S. activities in interurban rail transportation during 1973 were primitive—and this at a time when the car and even the airplane (the half-filled one, anyway) are proving unacceptably inefficient.

In October, Amtrak (National Rail Passenger system) announced that its fleet of Metroliner cars will be doubled to extend high-speed Metroliner service along the Northeast Corridor (Washington–New York–Boston). Amtrak signed contracts for $63.5 million in new rolling stock including

- Fifty-seven new Metroliner-type coaches, capable of operation in trains hauled by either all-electric or diesel-electric locomotives.
- Eleven new 4500-kW electric locomotives (in addition to 15 ordered earlier in 1973) to replace the 37-year-old Penn Central "GG-1" electrics.
- Seventy new diesel-electric passenger locomotives for other Amtrak routes throughout the U.S.

With the award of the contracts in October. Amtrak committed $110 million during 1973 for new traction equipment and passenger cars.

The powerful new electric locomotives, which will be built by General Electric, are expected to match favorably in specifications with the big electrics presently in operation in France, West Germany, and Sweden.

Urban and suburban mass transit

In the area of commuter transit systems, as in interurban systems, 1973 saw the U.S. concentrating on very different problems than the rest of the world. Thus, for example, while the Europeans and Japanese were most concerned with controlling traffic more efficiently in the systems already operating, the U.S. was primarily focused on the behavior of its model system, BART.

For the U.S., 1973 was the "year of BART." Despite all of the defects and deficiencies in attempting to operate at minimum headway under full automatic control, it nevertheless represents the first major all-modern high-speed mass-transit system to be especially constructed in the U.S. from the ground up (and from the ground down in its subway sections in San Francisco) in more than 60 years.

As a result of continuing trials and tribulations of BART—both financial and technological—the schedule for full service operation, over the entire 120 route kilometers, has been delayed far beyond the original optimistic predictions. And despite a present operating deficit that promises an upward revision of the fare structure, BART has apparently lured a noticeable percentage of former car commuters to relax in climatized comfort en route to and from suburbia and their urban offices. Good usage is being made of commuter parking lots. There have been reported reductions in peak-hour vehicular traffic along the East Bay freeways (especially the Grove-Shafter, Route 24 freeway), and in late November, a record was set when BART transported 110 262 riders in a single day (far above the 70 000 passenger-per-day average).

The BART service has been extended piecemeal along its principal north–south and east–west routes in the East Bay region during 1973. On November 5, service along a 12-km section of the line in the city of San Francisco (from the Montgomery Street underground station to the elevated terminal at Daly City) was inaugurated. Still remaining to be placed in service is the 13-km-long Transbay tunnel, the final link in completing service over the entire line. But because of technical problems involving the reliability of BART vehicles, signal sensors, and passenger safety, BART's management could not, as of this writing, advise us when the adequate backup ATO system would be installed in the tunnel, or when retrofitting would be accomplished on the rolling stock to permit opening this last section for revenue service.

◀◀◀ *rolling stock*

As of mid-November, the word from BART headquarters was that all 250 cars in the original order had been delivered *but*, because of necessary modifications in vehicle specifications and shortcomings in quality assurance, only 59 out of the 100 delivered "B" units—cars without multiple unit (MU) controls—had been accepted. However, 150 "A" units—with MU controls—were in service. Thus, retrofitting was needed on the remaining 41 "B" units prior to acceptance.

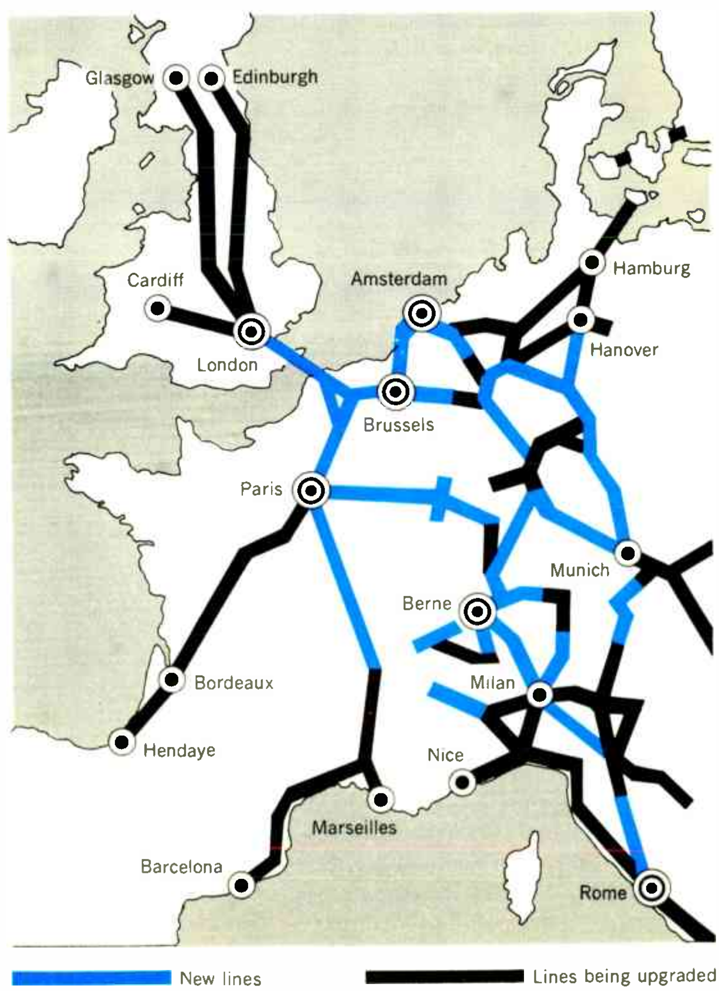
multiple unit controls

BART is still operating under manual-block constraints and will continue to do so until a satisfactory backup ATO mode is installed. Therefore, BART is still a long way from its promised 90-second peak-hour headway operating under full ATO. Present headways are 10 minutes, irrespective of time of day.

BART has on paper, at least, the most comprehensive automatic train, or "command and control," system and should serve as the criterion against which to calibrate the work of other countries. Several other countries, however—including Japan, Brazil, West Germany, and the United Kingdom—have C&C sys-

◀◀◀ *BART*

[1] Map of Europe's proposed high-speed intercity rail network that is included in a plan formulated by the International Union of Railways.



tems in use or in design phases that rival the BART system.

And there is nothing in the U.S. to rival international efforts during the past year in the areas of centralized traffic control (CTC) and cybernetics. France, Germany, and Japan, especially, have been working hard to develop cybernetic systems for optimizing train movements on heavily trafficked lines in the vicinity of major cities.

centralized traffic control (CTC)

In October, for example, an automated train-control system was made operational at the French National Railway's (SNCF) Gare du Nord in Paris. The Paris-Nord terminal passenger traffic (some 300 000 commuters daily) is especially heavy on three suburban lines. This has resulted in an automated suburban train-operating system, an automated long-distance mainline train "fluidizing" system, and a cybernetic train-dispatching scheme that utilized a central computer in association with a visual CRT (Fig. 2) display upon which "corrective action" can be made in retarding or advancing trains' speeds by means of a "light pen." This system has been tested over the past two years on an experimental basis, and a 30-percent increase in traffic capacity at the terminal is expected during the first year of operation. The computer at Paris-Nord enables automatic train dispatching, and the control of all relay signal boxes and display devices. These capabilities enable the control tower operator to foresee, supervise, and make decisions by means of peripheral subsystems of processor, readout, and printout equipments.

CRTs

processors, readouts, printouts,

The objective of more efficient train control by automation is attained by adopting criteria for minimizing train delays in case of traffic disturbances. The SNCF's automation program (1) improves the quality of service at Paris-Nord, (2) presents information automatically to enable signalmen and dispatchers to forecast events and potential difficulties before they occur, and (3) permits railroad personnel to monitor all trains movements with a minimum of manual intervention and effort.

Automated CTC in the Munich area. Munich is presently experiencing a new generation of public transportation. The newly installed commuter service (S-Bahn) system was totally integrated with all other transportation services—subway (U-Bahn) and mainline (DB)—within the city of Munich.

The S-Bahn commuter service evolved from the former commuter lines of the German Federal Railways (DB). Nine of the present 14 branches terminate in Munich's Main Station (Fig. 3) and five at the Munich-East station. Where these branches merge into the trunk line within city limits, the train headway during peak hours is from 2 to 4 minutes. But because of the high traffic density on the trunk line itself, a totally automatic CTC permits train headways to be reduced to 90 seconds.

A new commuter service management has permitted the establishment of three train-control areas. In coordinating new automatic signal systems, EDP has created a new functional level that assists human operators in command and control and, also, will make decisions for the operators in the near future.

computer duplex systems

Three computer duplex systems (one for each control area) receive, via 10 data channels, all important data concerning train dispatching and movements

[2] Downward arrow, or "fleche," indicates to the train operator on the French National Railways that a decrease in speed must be made to the indicated 40 km/h. This indication is made automatically from a computer-controlled tower system.

[3] From Munich's Main Station signal cabin, about 1000 train, 5000 shunting, and 600 locomotive operations are controlled daily by a sophisticated CTC system. Formerly, this same quantity of operations had to be handled by 11 cabins, five block posts, and one junction location.

from 60 stations and interlockings within the computer area, and some 50 stations outside of the control territory. The control regions are related to the computer system in such a way that the utilization of the three computers is equalized and the data exchange between them is held to a minimum. The computer C&C areas are divided as follows:

Machine 1, Control Area North (Munich–Ingolstadt–Treuchlingen, and Munich–Landshut).

Machine 2, Control Area East and Southeast (Munich–Rosenheim–Salzburg–Kufstein; Munich–Holzkirchen–Kreuzstrasse–Erding, and Ismaning).

Machine 3, Control Area West and Southwest (Munich–Augsburg, Olchning–Munich–Trudering; Munich–Tutzing–Geltendorf, and Herrsching).

The data channels are connected, via a line scanner, a converter, and teleprinter to the processors. The three computers receive discrete information from each control area independently from each other. Output via peripheral units is accomplished by the primary units. During a failure mode, or maintenance period, a backup computer can take over the entire task of the primary computer.

Within the entire computer-controlled areas, about 100 trains are in simultaneous operation. However, trains stopped at stations and at interlockings raise this number considerably.

The control center dispatcher is assisted by computer-controlled CRTs for his routings and track assignments. The train numbers and related track sections are automatically updated in the computer memory by means of track circuits and axle-counting equipment along the wayside. These data are automatically transmitted while a train moves from one track section (or block) to another, either by occupancy or clearance.

State of the art in Japan. In what is called "Category A" (high-speed interurban lines) systems, including the new Tokaido and Sanyo lines, the control system is based on ATC and CTC. In order to operate the entire line efficiently over 1000 route-kilometers, a computer-aided traffic-control system (COMTRAC) has been developed. The functional operation of this system is analogous to that of the German Federal Railways in that the computer control is indirect via the CTC system. The essential difference between the German and Japanese systems is that, in Germany, distributed control is employed for each 40 km of route; in Japan, the control system is centralized in Osaka. COMTRAC is based on a 32K memory, 2-μs access duplicated computer with a 16K, 1.6-μs satellite computer for controlling and adjusting schedules. Thus, by computer standards, it is not a very complex system. The CTC system is as up to date as any other system, but it is still based on relay technology. Because of the extreme distances over which control is exercised, primary responsibility for safety resides in the reliability of the CTC.

In ancillary systems, Japan National Railways (JNR) has experimented recently with a microwave (Gunn diode) doppler radar speedometer in marshalling yards, and a laser-detector-based automatic car identification system. In addition, basic research is beginning on ultrahigh-speed railway concepts at JNR's R&D laboratories, planning toward a 1980 service date.

Solid-state electronics

Toward the end of the 1960s, electronics development reached the stage where it was considered feasible to design a thyristor convertor for traction service. Following detailed investigations, the Swedish State Railways (SJ) ordered a prototype designed as a phase-controlled cycloconvertor with an output of 6 MVA. In the course of a continuing test and trial program, conducted by SJ, in cooperation with the Swedish State Power Board and the National Swedish Telecommunications Administration, the technical advantages, higher efficiency, and very short starting time were confirmed. During 1973, static frequency convertors were designed for SJ that will be able to supply continuous single-phase power of 15 MVA. The first of these will be delivered to SJ during this year.

The first convertors supplied were of stationary type and were installed in convertor substations. A recently developed transportable version, mounted on railway carriages, offers the following advantages over the stationary type:

- The output of a convertor can be easily matched to the actual requirements.
- The convertor carriages can be readily hauled to a central workshop for maintenance and repair.
- Transportable convertors are easily adapted to provide a temporary convertor station in the event of an outage or serious disturbance at a conventional stationary substation.

And in Great Britain . . . The first electric-powered prototype of British Rail's "Advanced Passenger Train" (APT) will have thyristor drive, including traction motors and auxiliary equipment. To be delivered in 1974, the train will be capable of attaining speeds in excess of 250 km/h. A notable feature of the APT will be the banking, or "tilting" of the coach bodies to permit higher speed when running through curves, without the usual discomfort to passengers.

The APT will be a double-ended, articulated, and streamlined train, with motor units and controls at either end.

Exotic systems

Internationally, during 1973, many nations were putting money into R&D of what might be called "exotic" systems of urban and suburban transit. In the U.S., for example, the Department of Transportation (DOT) has been testing high-speed tracked air-cushion vehicles (TACV) built by Grumman Aerospace and Garrett Corp. at its 5-km-long test-track facility in Pueblo, Colo. The Grumman version is designed to operate at ground speeds up to 480 km/h (*Spectrum*, June 1972, pp. 89–90).

The magnetic-levitation, or Maglev, vehicles in both the attractive and inductive concepts are in both the R&D and full-scale test stages in Europe, Japan, and the U.S. An operating model of the "Magneplane" has been built to 1/25th of full scale at the Massachusetts Institute of Technology for studying the motion of the vehicle and the function of the propulsion control system. The NSF is funding the M.I.T. program through 1974. Professor R. D. Thornton, of M.I.T's Electrical Engineering Department, reported in November that the DOT has made no commitment as yet for testing a full-scale Maglev vehicle at Pueblo,

◀◀◀ track circuits

tracked air-cushion vehicles

Maglev vehicles

◀◀◀ Doppler radar

[4] Bird's-eye view of the Morgantown experimental PRT guideway and typical vehicle, along an elevated portion of the 11-km-long line financed by DOT's Urban Mass Transit Administration.

despite the fact that operational prototypes have been built in the U.S., Germany, and Japan.

ROMAG vehicles

The Rohr Corp. has a small testing facility and a short test track in Chula Vista, Calif., where its ROMAG (attractive system) vehicles for personalized rapid transit are being tested in a continuous program. A DOT spokesman informed this writer that Rohr's test track may be "physically transplanted" to the Pueblo facility.

personalized rapid transit

But Toronto, Canada, is proceeding with an "attractive" Maglev concept for a personalized rapid transit (PRT) system. ITT is working on the total C&C system for this project.*

The degree of success of newer transit concepts, such as PRT, will depend to a large extent on how the C&C subsystems are evolved during the R&D stages. This particular technology may benefit particularly from aerospace C&C spinoff. The three areas in which this technology may be applicable are vehicle headway, passenger capacity, and safety.

In the nutshell (for those who are unfamiliar with the scheme), PRT would provide a modest number of passengers with on-demand, point-to-point service to their destinations. The computer-controlled, unmanned vehicle would be summoned by a call button and would then proceed along either an overhead or at-grade guideway over the route considered to be the best, by machine decision, to its destinations. In such a system, of course, headway becomes a critical consideration because, with limited passenger-carrying capacity and individualized service, many more vehicle will be needed than those in conventional transit systems—and headways will have to be drastically reduced.

Thus, in PRT schemes, where small vehicles will operate at 8 to 19 seconds headway, adequate consideration of the benefits and safety hazards are required before such operational systems are feasible.

The pioneering demonstration PRT project, sponsored by DOT's Urban Mass Transportation Administration (UMTA), was dedicated on October 24, 1972, in Morgantown, W. Va. The vehicles (see Fig. 4) seat eight people, and there is space for an additional 13 standees. According to the scheme, the 11-km-long line will use 70 automatically controlled cars in serving the city's downtown business district and the three campuses of Morgantown's West Virginia University. Its objective is to relieve the city of a chronic threat to its socioeconomic well-being: slow strangulation by automobile traffic.

Like scores of American cities, Morgantown suffers from traffic congestion, noise, and air pollution. The activities of 30 000 residents, plus 23 000 students and faculty members, are compressed into a narrow corridor between high hills and a river. Traffic reaches peak levels every hour on weekdays when students move from class to class. The short trip by auto sometimes takes as much as an hour. Thus, the environment of the business district, before the PRT construction, was chaotic.

During 1973, the Morgantown PRT experimental system underwent extensive engineering and performance tests. At the outset, the control system was designed to operate at 15-second headway intervals. Now, feasibility tests have demonstrated 7.5-second, reduced headway.

In other cities, the PRT scheme—as of 1973—shaped up as follows:

Hagen, West Germany. An advanced engineering team began the operation of a 160-meter-long test track last May. It represents the forerunner of a high-capacity system, operating at 35 km/h with 0.5 to 1.0 second headways. The test vehicles carry three people.

France. Under the direction of the French government, a high-capacity PRT system, accommodating up to 12 000 passengers per hour in a unidirection lane, is being developed. A 300-meter-long full-scale test track started its operation in May 1973, with three four-passenger vehicles.

Japan. A 300-meter-long test track has been in operation since October 1972, and an additional 4.7-km-long track for service with 90 four-passenger vehicles began full-scale testing last month. The latter system is designed to operate at 0.6-second headway at speeds ranging from 32 to 64 km/h.

In the United States during 1973, UMTA technical studies grants, under which PRT system plans are in developmental or planning stages, were awarded to the following cities: Denver, Colo.; Seattle, Wash.; and Trenton, N.J.

*A West German firm was awarded the contract to build a 3360-meter-long first-stage demonstration system, complete with four stations. The Maglev vehicles should be in operation by late this year.

Military and aerospace

Dollars for many projects may be grounded, but efforts to spend wisely are soaring

Where high-level technology is concerned, questions of cost-benefits and funding now often rival the once dominant hardware and engineering problems as major program challenges. Space shuttle proponents point to significant savings expected over the comparatively inefficient Saturn/Apollo launch and recovery system and indicate that a wide cross section of scientific interests will profit from direct access to extraterrestrial experimentation. Even engineering work on unmanned flights is geared toward squeezing a better power/weight ratio out of solar cells, storage batteries, and power control electronics. As a direct result of the Mideast war, budgeting for U.S. military R&D must now confront the immediate challenges of new Soviet ECM and their SA-6 surface-to-air missile as opposed to projected and perhaps speculative benefits claimed for the billion dollar Trident submarine program.

But space age know-how is also being used to solve more immediate problems that the general public is facing, such as safe landings at congested airports. Barring a lack of fuel oil—making jet travel problems academic—new developments in traffic control are under way promising greater peace of mind for tomorrow's airline passenger.

New eye on a crowded sky

As a complement to airport radar, the Air Traffic Control Radar Beacon System (ATCRBS), currently in wide-spread operation, provides the ground controller with aircraft position, identity, and altitude data. But the growing number of beacon-equipped aircraft and ground interrogators and the inherent self-interference limitations of the ATCRBS have motivated the development of improved hardware dubbed the Discrete Address Beacon System (DABS). In addition to providing improved surveillance, DABS includes a digital data link as part of the air-ground interchange (see Table). Since 1971, Massachusetts Institute of Technology's Lincoln Laboratory, under the sponsorship of the Federal Aviation Administration (FAA), has been investigating various DABS design options.

Preliminary designs for the ground interrogator and airborne transponder have been established and experimental equipment is now under test. By early 1974, specifications will be prepared for the FAA that will permit the procurement of prototype equipment for further evaluation.

A key consideration in the design of DABS is maintaining complete compatibility with ATCRBS. The DABS interrogator must operate with both DABS and ATCRBS transponders, and the DABS transponder must be capable of responding to both DABS and ATCRBS interrogators. Other basic design factors include a data link capability adequate to meet all foreseeable air traffic control (ATC) needs, and development of the system in a low-cost version acceptable to the general aviation pilot. All these requirements must be met while maintaining high reliability in the face of heavy interference.

trans-ponders

Compatibility will be achieved by having new DABS ground stations alternately transmit first a standard ATCRBS interrogation, which will elicit replies from existing transponders, followed by a DABS-type interrogation that will cause DABS-type transponders to reply. Similarly, existing (non-DABS type) ground stations will receive a conventional radar beacon reply to their interrogations from both standard transponders and DABS-equipped aircraft.

interference

As the name implies, DABS will have the ability to discretely address any particular aircraft and to elicit a response from it and not from its neighbors. In this manner, interference on the channel is reduced and overlapping returns from closely spaced aircraft are eliminated. Since DABS is a new generation of equipment, it can exploit improved coding and digital processing technology to achieve added flexibility and reliability. To reduce the interference in the channel, DABS uses monopulse direc-

Comparison of DABS and ATCRBS performance

Parameter	ATCRBS and VHF Voice	DABS
Surveillance accuracy:		
Range—	152 meters	46 meters
Azimuth—	0.5°	0.1°
Interrogations used for surveillance update:	20	1 or 2
Communication capacity:	Voice limited ($\simeq$ 5 aircraft per controller per minute)	$>10^4$ 100-bit messages per 4 seconds
Maximum number of instrument flight rules aircraft handled per controller:	$\simeq$ 7	$\simeq$ 14 (with intermittent positive control)
Air traffic control service for visual flight rules aircraft:	optional (as time permits)	continuous (with intermittent positive control)

Don Mennie Associate Editor

tion-finding techniques, which enable a single interrogation and response to update a surveillance track on an aircraft.

▶▶▶ *uplink interrogation*

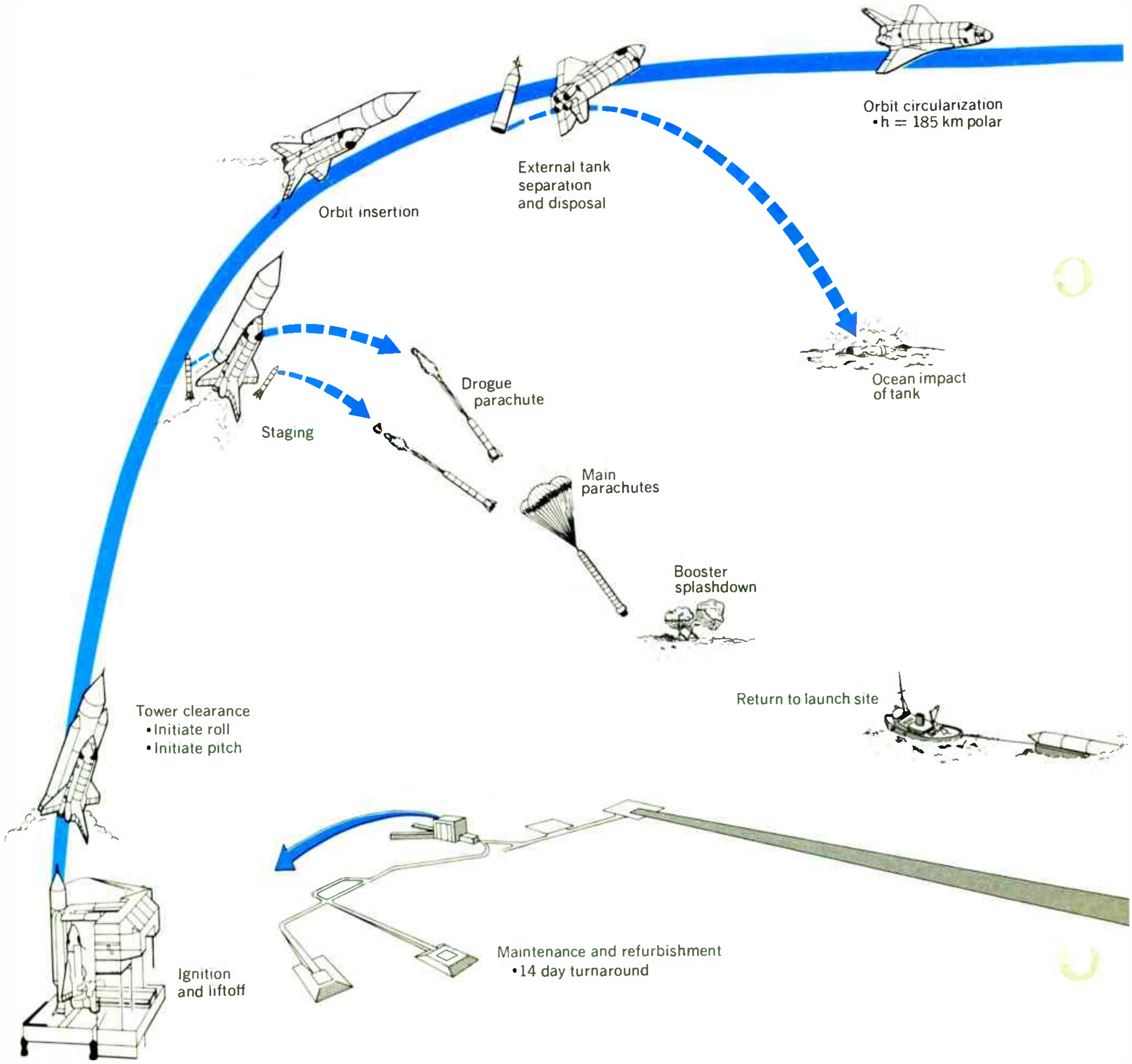
DABS will also function as a data link to pass digital messages from the ground facility to and from an aircraft. The availability of such a data link for routine ATC messages leaves the VHF voice channel free for backup.

In the future automated system, all aircraft will be able to receive, via DABS, conflict advisories and collision avoidance commands completely automatically, without controller involvement. DABS is currently being developed to support two forms of conflict detection: Intermittent Positive Control (IPC), which is ground-based and centralized; and Synchro-DABS, a mode of operation wherein each DABS ground site schedules its interrogations to synchronize the reply times of the aircraft transponder. Then, each DABS-equipped aircraft, by listening to the replies of all its neighbors, can compute its own collision avoidance maneuvers.

Each DABS uplink interrogation (on 1030 MHz) begins with a pair of pulses spaced 2.0 μs apart, followed by appropriate synch and initializing waveforms. The pulse pair prevents random triggering of ATCRBs transponders by simulating an ATCRBS sidelobe suppression. Following this preamble is a multibit format with differential phase shift key (DPSK) modulation at a 4.0-Mb/s rate. Each interrogation is composed of three segments: a link control segment, a variable length message segment, and an address segment. The 24-address bits allow each aircraft its own unique identity.

▶▶▶ *downlink transmission*

Downlink transmissions (on 1090 MHz) use a redundant form of pulse amplitude modulation (PAM) at an information rate of 1.0 Mb/s. The downlink formats also contain three segments: link control, variable length message, and address.



Postlunar is not posthumous

Coupled with a reshuffling of national priorities, space exploration has shifted from the drama and expense of moonwalks to the task of providing an efficient means of performing routine missions. While unmanned flights continue to provide valuable data on distant planets, manned experiments in the ongoing Skylab program are contributing much knowledge about man himself when he is exposed to long periods of weightlessness. Upcoming is the joint U.S. Soviet space venture called the Apollo/Soyuz Test Project which will be as important to international politics as it is to science.

But according to Robert G. Wilson, director of advanced payloads analysis at NASA headquarters in Washington, D.C., the next big challenge is more financial than technical. Dr. Wilson concedes that although the Apollo Command and Service Module and its Saturn launching system accomplished objectives efficiently, the special purpose design severely limits its further use. At EASCON '73, he called for "a more practical and less costly way of conducting our future [U.S.] space operations" and outlined the following details.

recoverable orbiter

A prime factor in boosting the cost effectiveness of the Space Transportation System (STS) is the Space Shuttle, presently under development. Its major element is an airplane-like orbiter which contains the crew, the cargo, and the liquid-fueled rocket engines in the rear. The orbiter is fully recoverable and is potentially capable of landing at any airport which has a 3-km runway. Underneath the orbiter is a very large external tank which carries hydrogen and oxygen fuel. This external tank is the only nonrecoverable part of the shuttle.

payloads

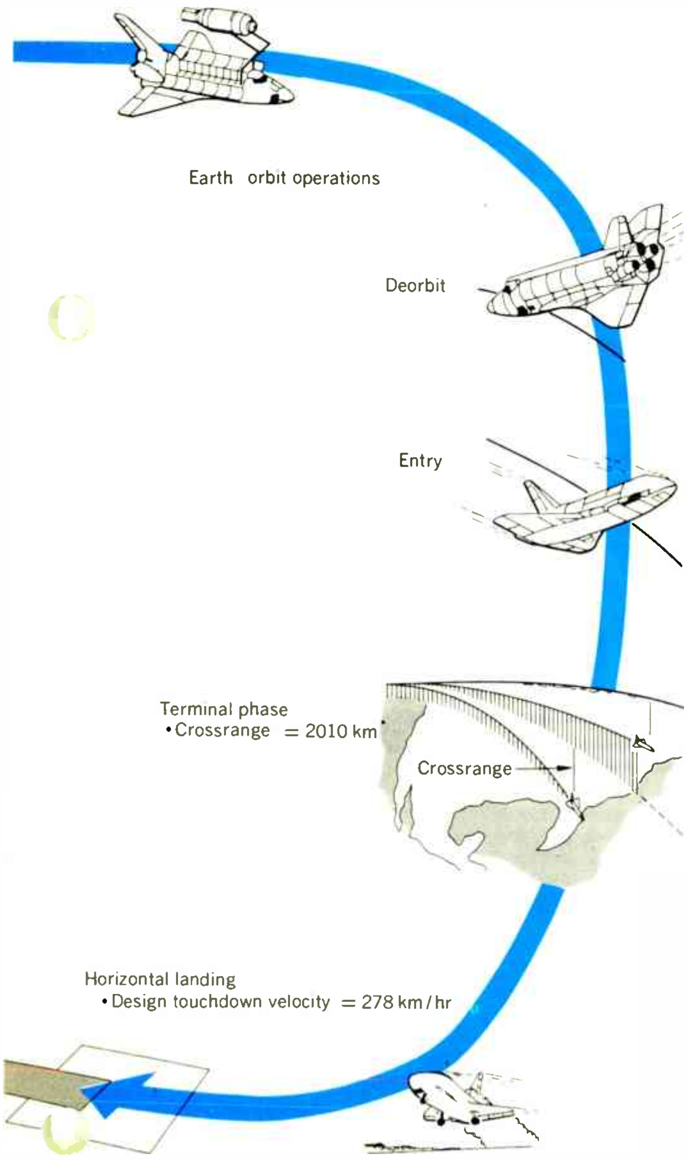
Roughly comparable in size with a DC-9, the shuttle by itself is basically a low-altitude device. It can deliver 29 500 kg (maximum) into a due east launch from the Kennedy Space Center, conduct a self-sustained mission lasting as long as seven days, and return with a cargo of 14 600 kg (maximum). It will be manned by a crew of four: a pilot, a copilot, a systems specialist, and a payload specialist. Additionally, the forward compartment can accommodate six passengers who, together with the crew, will be in a shirt-sleeve environment without spacesuits. They will encounter a maximum force of 3-*g* acceleration during launch and reentry—no problem for healthy individuals (Fig. 1).

The space shuttle by itself will be capable of delivering payloads only to low earth orbits. In order to fly missions to higher orbits, a propulsive stage will be necessary to provide the additional energy to the payload. NASA analysis of future programs shows that about half of the planned payload orbits have higher energy requirements than it is possible to obtain with the shuttle alone.

space tug

Since benefits from the space transportation system will come in a large measure from the refurbishment and reuse of the payloads as well as the delivery system, long-term interests may best be served by development of a space tug which has not only the capability to place payloads in high-energy orbits, but also, to retrieve them from, or repair them remotely in these orbits. At present, a number of NASA and Air Force studies are under way on the tug. These vary from considerations of the initial use of existing expendable stages to the development of a full-capability, high-performance tug. The problem is a typical one—money.

Although not a formal part of the space transportation system, an important new form of oper-



[1] At launch, the Space Shuttle's twin solid fuel rocket boosters will ignite simultaneously with the orbiter main engines and burn in parallel to a height of about 40 500 meters where the recoverable boosters will be jettisoned. The orbiter continues on its flight path and the external fuel tank is discarded shortly before orbital insertion (with subsequent impact in an isolated ocean area). At the conclusion of a mission, the orbiter reenters the atmosphere and makes a conventional runway landing. It then begins processing that will permit launching again in only 14 days.

sortie mode

ation that will become available with the shuttle, is the sortie mode. Basic to this concept is a large pressurized man-carrying laboratory which is installed in the payload bay. This space laboratory can be outfitted for many kinds of activities, but, it always remains in the shuttle. It is capable of supporting six men for missions of from seven to thirty days in duration and will function very much like a small transient Skylab or space station.

flight training

The training requirements for a passenger scientist will be minimal, and although the screening criteria are not yet fully defined, scientists who want to fly with their own experiments will probably require two to three months of specialized instruction including parabolic aircraft flights and underwater neutral bouyancy activities to stimulate zero gravity conditions.

Michael McDonald, shuttle payloads program engineer at NASA's Washington, D.C., headquarters reports that scientists are already busy examining the requirements for future space shuttle missions. Much early planning was done by NASA "Working Groups" which examined scientific use of the shuttle from ten distinct vantage points:

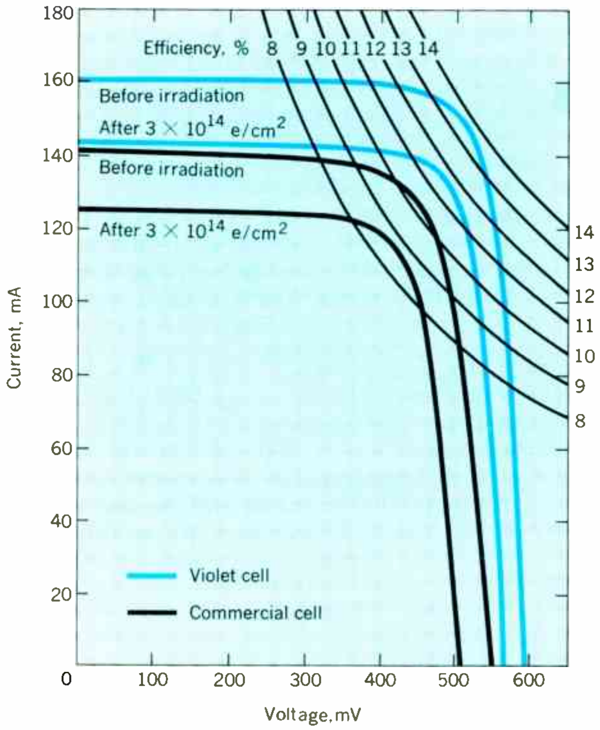
- Astronomy
- Atmospheric and space physics
- High-energy astrophysics
- Life sciences
- Solar physics
- Communications and navigation
- Earth observations
- Earth and ocean physics
- Materials processing and space manufacturing
- Space technology

Participating in these studies were many noted scientists (working outside the immediate orbit of NASA headquarters) representing a broad cross section of the scientific community. Their final report was filed in May, 1973, and the information is available from NASA in Washington, D.C. However, individual copies are not plentiful and will not be distributed unless a second printing is authorized. Later in the year, a further probing of shuttle possibilities was conducted as a summer study by the National Academy of Sciences at Woods Hole Mass. Their report will be published soon.

There are many competing philosophies on use of the shuttle, concludes Dr. Wilson, but of primary importance is the concept of carrying multiple payloads and performing a spectrum of functions during each flight so that each individual user will bear only a fraction of the total expense. Present cost estimates for one shuttle flight run in the neighborhood of $10 million. If a tug is also required, then an extra charge of about $1 million must also be added. The first manned orbital flight is planned for 1978 and the first operational missions will occur at the end of 1979.

Watts in orbit

While manned space missions may never recapture the bravado they enjoyed during the 1960s, important progress continues to be made toward expanding the capabilities of unmanned projects.



[2] Current/voltage characteristics for the new "violet" solar cells show improved performance compared with presently available commercial cells. These curves define cell output both before and after irradiation with electrons.

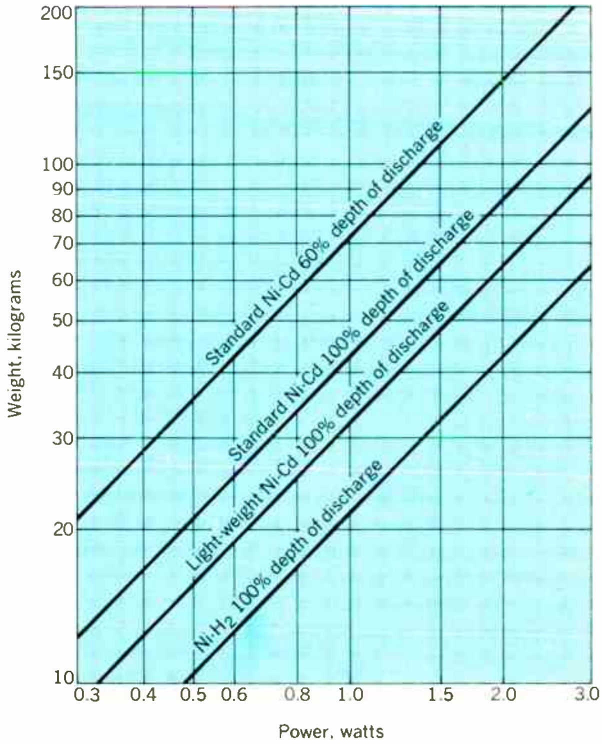
Edwin J. Stofel, assistant department manager for space power at Hughes Aircraft in El Segundo, Calif. explained to an EASCON '73 audience how updated power systems will impact the design of unmanned spacecraft over the next five years.

Spacecraft weight reduction and efficiency improvements are expected in four key areas—solar cell output, light-weight solar arrays, the potential for nickel-hydrogen energy storage, and restructuring power control electronics to work at higher voltages. Dr. Stofel noted that specific applications will depend upon spacecraft requirements and orbit configuration. For example, satellites in near-earth orbits are more dependent upon energy storage capacity than those in synchronous orbits. He illustrated how the configuration of power generating and handling equipment relates to spacecraft orbit with two examples of existing hardware: Intelsat IV and Orbiting Solar Observatory-I (OSO-I).

▶▶▶ centralized regulation

Synchronous communications satellites, such as Intelsat IV, having only one major type of payload can effectively use a simple, two-bus system with centralized regulation. Each bus consists of a main solar cell array, two smaller arrays to assist in battery-charging, a battery, and power control electronics.

Another representative power subsystem is contained in the Orbiting Solar Observatory-I which will be placed in a 556-km circular orbit with a 33-degree orbit inclination for making detailed solar observations with several different scientific instruments. Design life is one year.



[3] The nickel-hydrogen energy storage system displays a better than 50-percent weight reduction against electrically equivalent nickel-cadmium cells over a wide range of output power requirements.

This spacecraft has both a regulated and unregulated power bus. The regulated bus (for experiments) operates at 28 volts ± 2 percent, while the unregulated bus (for general spacecraft operation) operates at 28 volts ± 5 volts.

regulated bus

But whether immediately used or stored, almost all spacecraft power is obtained from silicon solar cell arrays. For the past several years, these have exhibited a sunlight to electrical power conversion efficiency of about 10.5 percent when manufactured in mass production. Recent work at COMSAT Laboratories, however, has demonstrated that cells of 14-percent efficiency are obtainable with today's technology. Such cells have been made by COMSAT in sufficient numbers to demonstrate that they are practical. Production quantity cells of at least 13-percent efficiency are expected to be available within the next year.

The major features of the new COMSAT cells are better crystalline perfection at the front surface of the cell, a shallower N/P junction, improved electrical contact configuration, and an optimized optical coating on the front surface. Dubbed "violet cells" by Joseph Lindmayer, their principal developer, much of the improved performance is the result of a more efficient response to the blue and near-ultraviolet portions of the sun's spectrum (Fig. 2).

"Violet" cell

Attention to weight reduction on spacecraft has led toward the development of lighter weight solar arrays. Several design approaches now propose mounting solar cells on a thin sheet of plastic rather than on rigid "honeycomb" boards. The flexible sheets of plastic, covered with cells, would be stored compactly during spacecraft launch either by being rolled tightly around cylindrical drums or by being folded accordion-fashion and restrained in a tight box.

solar arrays

Feasibility studies indicate that specific energies of 40–110 W/kg are possible. This compares favorably with the 8.8–22 W/kg achieved presently with rigid honeycomb-type substrates.

One project, the Flexible Rolled-Up Solar Array (FRUSA) program, under sponsorship by the USAF Aero Propulsion Laboratory, has progressed to a successful flight demonstration. The first FRUSA was launched into near-earth orbit in October 1971 and easily exceeded its six-month design goal. Operation at 1500 watts was maintained without producing any detrimental mechanical vibration interactions with the spacecraft. Ten extension and retraction cycles were successfully performed.

Spacecraft must continue to function during launch or when eclipsed from the sun. Nickel-cadmium batteries have been used as a rechargeable energy storage system, but the newest approach to achieving light-weight energy storage is harnessing the nickel-hydrogen couple. Results of these recent COMSAT experiments have also been very promising (Fig. 3).

The nickel electrode of this couple is composed of nickel hydroxide impregnated in a nickel sinter similar to the nickel electrode of the nickel-cadmium couple. The hydrogen electrode is a porous, hydrophobic sinter containing platinum powder to catalyze reduction or oxydation of hydrogen during operation—similar to the hydrogen electrode of an oxygen-hydrogen fuel cell. The hydrogen gas of the charged cell is stored within the gas-tight, light-weight pressure vessel constituting the outer container of the cell.

The resultant nickel-hydrogen couple is considerably lighter than the equivalent nickel-cadmium couple. The nickel-hydrogen couple is equal in weight to projected oxygen-hydrogen regenerative fuel cells, while boasting an improved lifespan. Regenerative fuel cell development has been plagued for years by oxidation corrosion of the oxygen electrode as well as gas leakage between the oxygen and the hydrogen gas chambers.

The nickel-hydrogen system has additional advantages besides light weight and long life. With proper thermal design, the system can be safely overcharged at high rates for long periods of time. More important, it can be put into continuous reversal safely. The possibility of nondestructive overcharging or overdischarging a storage unit is unique to nickel-hydrogen. This could simplify the electronic controls required, an important spacecraft reliability feature.

For most spacecraft, bus voltage is maintained at a nominal 28 volts. This provides a low stress on semiconductor components for long life. However, inherent voltage drops within the semiconductors means efficiency is typically less than 90 percent. High-voltage, high-reliability semiconductor devices are becoming more readily available, making possible spacecraft bus voltages up to 200 volts and efficiencies greater than 90 percent. In addition to conserving energy, this reduces thermal dissipation problems and reduces the size and weight of current conductors.

▸▸▸ *process control*

Dr. Stofel of Hughes concludes that solar cell power systems will continue to dominate space power applications for at least the next five years. Weight savings made possible by the aforementioned technical improvements will permit larger spacecraft to be deployed with existing rocketry.

▸▸▸ *test filter circuit*

GHz on the ground

Be it an individually launched "expendable" collection of hardware with a limited lifetime, or a reusable, serviceable module made possible by the space shuttle, all satellites need a complement of ground stations to be functional. Employment of microwave integrated circuits (MICs) in this earthbound equipment has helped bring down both the cost and size of fixed installations. In fact, ITT Defense Communications Division in Nutley, N.J. is now engaged in the design, development, and production of a man-transportable satellite communications terminal for the U.S. Army Electronics Command in Fort Monmouth, N.J.

trans-portable earth terminal

It is important when discussing MICs not to confuse these devices with the more commonplace linear and digital integrated circuits built on a silicon wafer. MICs are passive assemblies built on dielectric (much like earlier stripline circuits), with any necessary active elements (diodes, transistors, etc.) added after all photoresist and etching processes have been completed (Fig. 4).

Contacting the MIC design group at ITT Defense Communications, *Spectrum* spoke with Alan Gruber, member of the technical staff and MIC engineer, who commented on the advantages and limitations of this microwave design technique. He claims the secret to success with MICs is process control. Masking, photo reduction, and etching must be held to tight tolerances. Closely related to these parameters is consistency of the alumina dielectric upon which MICs are constructed.

Quality control of the dielectric can often be established by the electrical characteristics of a special test filter circuit. Since this material is bought already covered with the necessary chrome–gold metalization, which will later form the finished circuits, simply taking a sample and etching on a filter circuit of known properties provides the basis for batch acceptance or rejection. Out-of-spec alumina will cause a very noticeable change in the test filter's characteristics.

Once the MIC is built, it must be carefully mounted. Use of Kovar is recommended as the carrier material (support) since this alloy matches the coefficient of expansion for alumina. Mounting directly on an aluminum chassis should be avoided.

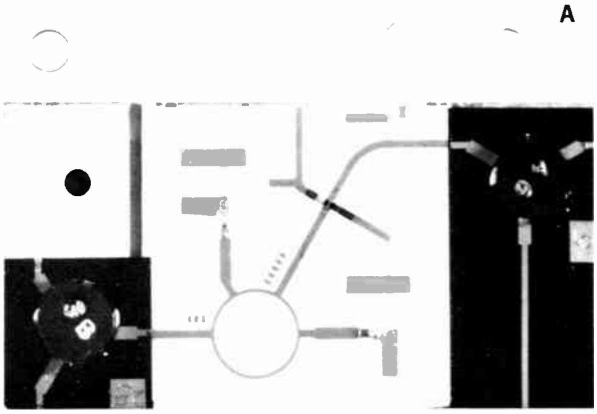
At present, MIC designs are constrained primarily by dielectric losses. This limits their practical use to low-level portions of transmitters and "front end" work on receiver applications (through Ku band). And compared with waveguide or coax, MIC filter designs suffer from reduced "Q." Successful military projects at ITT Defense Communications using MICs now include several pieces of ground station equipment and line-of-sight communications gear.

MICs are readily suitable for volume manufacture since they are cheap to produce in quantity and require minimal tuning or trimming during final assembly. They exhibit excellent temperature stability and are almost immune to vibration. Humidity does present some problem, but this can usually be handled by a hermetic seal.

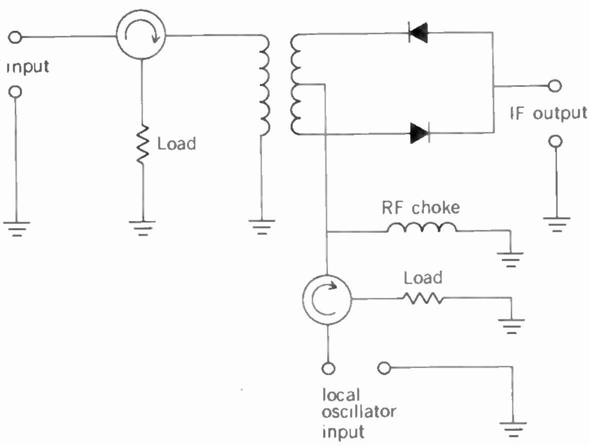
Ed Wolf, acting assistant chief, Communications and Navigation Division at NASA's Goddard Spaceflight Center in Greenbelt, Md., says MICs will soon try their wings in the Applications Technology

[4] This MIC mixer (white alumina square) is part of a down converter for a military ground station (A). Isolators for the RF and local oscillator inputs (black rectangles) are built on a garnet substrate, and each includes a small cylindrical permanent magnet. A DC path to ground for diode biasing is provided by an RF choke (upper right corner on the mixer). The diodes are fed 180° apart, at 11 o'clock and 3 o'clock respectively, off the circular "transformer" which is 3λ/2 in circumference. A schematic is shown (B).

A



B



Satellite built for NASA by Fairchild Industries, Germantown, Md. This spacecraft, built to develop advanced communications techniques, will contain tunnel diode amplifiers and mixers operating at 12. 18, 20, and 30 GHz. Dr. Wolf claims the MICs involved (used on lower bands only) already have been space qualified, and launch is scheduled for mid-1974.

New systems and surprises for the military

The technology which permitted a NASA scientist in Houston to control a TV system on the moon could make practical a defense concept that saves both men and money. Some air missions of the future may be conducted without pilots and at a fraction of present manned air operations costs. RCA is presently performing concept studies as a prime contractor in the Air Force's Remotely Piloted Vehicle (RPV) Control and Data Retrieval System program, according to Edward D. Carfolite, program concept manager at RCA Government and Commercial Systems, Moorestown, N.J.

The idea of using unmanned planes for reconnaissance or strike attack missions is not new. TV-guided drones were used in World War II. Recently the aerospace industry has been developing control systems capable of sending large numbers of aircraft into engagements under simultaneous control from a remote center.

RCA's "smart bird" concept is not just to replace the pilot with a TV camera and have the ground-based operator "feel" he is in the aircraft. This method is acceptable when a few RPVs are operating in a given area, but the RF bandwidth required to control large groups would seriously limit their number. With enough onboard equipment, the RPV can be its own navigator, reporting its status to a control computer that has its preprogrammed plan against which to compare. The man in the loop at the control center acts only as a monitor, taking over only when corrections are called for.

Miniature computers, the heart of the system, handle navigation, flight control, and aircraft status. In addition, they operate the sensors that provide data to depict the real-time situation to the remotely based operator/pilots. High-flying aircraft or satellites may be used to relay nonjammable data between the RPVs and their control station during long-range missions.

To check on performance and position, a couple of "video snapshots"—one frame of a TV picture—can be taken occasionally to verify navigation check points. Once a flight has arrived on target, an individual controller would take over terminal guidance for each plane. He could pinpoint the plane's approach to target by reading a single frame "snapshot" on his TV display each second, or switch to continuous video (10–30 pictures per second).

Such advances may come none-too-soon to the American arsenal. Already the world's largest outdoor proving ground for conventional military hardware has moved from Viet Nam to the Sinai desert. With the new environment have come some fresh and unpleasant surprises for the local U.S. clients. The Soviet-built SA-6 Gainful surface-to-air missile used by the Arabs features a rocket–ramjet propulsion system and guidance electronics which have proven extremely difficult for the Israeli's American-built ECM to counter.

The SA-6 command-guidance electronics is said to operate at three frequencies—5 GHz for low-altitude acquisition, 6 GHz for high-altitude detection/acquisition, and 8 GHz for target tracking once lock-on is obtained in the 5- or 6-GHz bands. Target detection is possible at ranges up to 80 km.

acquisition and tracking

Propulsion is provided by an integral rocket–ramjet system. The housing for solid rocket fuel becomes the combustion chamber for the ramjet engine once the booster is burned. After boost speed is attained, the transition from rocket to ramjet occurs. This rocket–ramjet combination offers significant savings in weight, volume, and cost for missiles operating in the atmosphere.

rocket-ramjet

But the big military dollars are still earmarked for long-term modernization of the U.S. nuclear deterrent. Trident, a key element in this process, has been called the most expensive weapons acquisition program in history. Estimated cost, which includes ten Trident submarines and procurement of Trident I and Trident II missiles, is about $13 billion.

Trident

As outlined in Library of Congress publication UC 400 USE 73-173 F on Trident, the new boats will travel faster, dive deeper, run quieter, and stay at sea longer than the present Polaris and Poseidon missile-firing submarines. The first Trident is to be ready in 1978, and the long-range (6400- or 9600-km instead of 1120-km) missiles it carries will open up millions of additional square kilometers for evasive maneuvers while the submarine remains within striking distance of potential targets.

Polaris

Both Trident missiles will feature the multiple independently targetable reentry vehicle (MIRV) warhead. The 6400-km Trident I should be deployed in 1978 and will also be used to retrofit the 31 newest submarines of the Polaris–Poseidon fleet. The larger 9600-km Trident II is linked solely to the Trident submarine and will not fit any submarines now in service.

◀◀◀ *computer control*

Herbert F. York, professor of physics, director of the Program on Science, Technology, and World Affairs at the University of California at San Diego and author of several articles on arms control, believes that MIRVs threaten the stability of the nuclear balance of power. And he told *IEEE Spectrum* that "Trident is simply unnecessary at this time." Dr. York's objections to the program focused on the development of a totally new submarine–missile system, with Trident I a minor issue.

Because the MIRV system allows a single rocket to launch several warheads (each aimed at different targets or made to approach the same target on different trajectories), MIRVs simply exhaust the capability of defensive action rather than confuse or evade it. Dr. York believes MIRVs undermine deterrent because they *seem* to make preemptive attack a more favorable strategy by increasing the probability that one offensive missile can kill another still in its silo. He favors a "substantial unilateral initiative" regarding U.S. contributions toward international disarmament.

Consumer electronics

From calculators and cameras galore to video recorders, the shopping list grows

calculators

Evidence of the vast inroads of electronics into the consumer market is all around us. The steady drop in integrated circuit costs has, on the one hand, put $29.95 calculators on the market and, on the other, made possible the introduction of sophisticated electronic cameras, electronic ranges, and—want it or not—seat-belt interlock systems for the family car.[1,2] Consumer products that would have been too expensive to be marketable a few years ago—if, indeed, they could have been produced at all—are now on the market and all indications point to the fact that more are on the way.

cable television

Two-way cable television systems continue to show promise for an almost endless number of applications but, as in the past, are almost completely experimental. The roadblock seems to be the lack of inexpensive terminal equipment to be used in subscribers' homes as well as a continuing lack of real interest in two-way systems on the part of potential subscribers. Nonconsumer applications—remote diagnosis in the health care field, for example—are more apt to be implemented first.

video disc

four-channel stereo

In the entertainment segment of the consumer market, four-channel stereo has made steady, but somewhat slow, progress. And video record and/or playback devices for home consumption seem to be in a state of transition. Whereas, initially, all of the emphasis was on development of magnetic, holographic, and film tape units, most of it has now shifted to lower-cost discs. One notable exception is evident in Japan. The Japanese are determinedly following the tape route and are not talking much about any disc activity that is probably also going on. For example, Matsushita Electric announced in mid-November of last year two new models of 0.5-inch color video cartridge recorders with built-in 18-inch color television receivers. The models are only for the Japanese market, where they will retail for about $2100 and $2300—the more expensive unit includes a built-in tuner and timer so that one program can be recorded while another is being viewed. And just a few months earlier, Matsushita had announced two ¾-inch home tape models, priced at about $1490 and $2100.

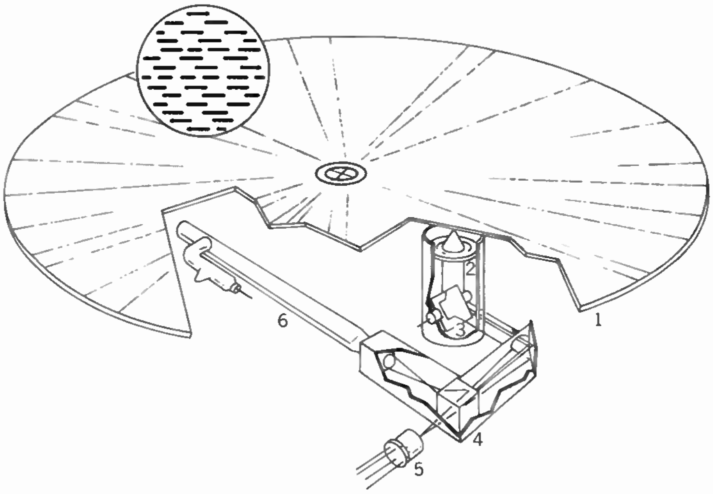
Ronald K. Jurgen Managing Editor

Telefunken video disc playback system

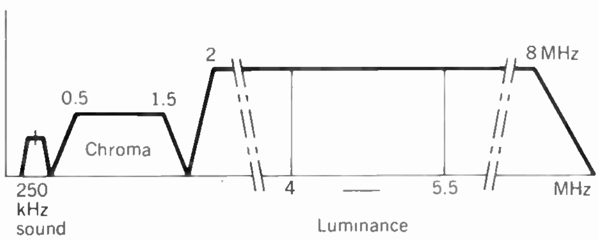
Outside of Japan, there is a considerable amount of activity going on in video disc playback systems. One unit, the Telefunken TED player, was scheduled to be on sale this month in Germany for about $450 with discs ranging in price from $4 to $10, but Telefunken has run into a problem. The TED system uses a flexible plastic disc, about 18 cm in diameter, which spins at 1500 r/min on a cushion of air. The disc is packaged for protection in a paper jacket that is left on when the disc is inserted in a playback unit. Apparently the jacket, during storage and shipment, can cause surface changes in the disc that can affect picture quality. Telefunken may have to make a design change in the playback unit as well as the disc jacket to get rid of the problem, thereby delaying introduction until later this year.

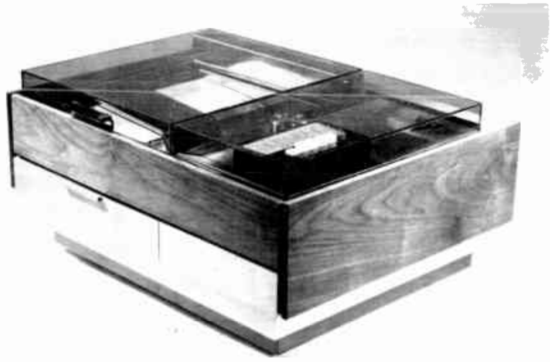
In the TED system, a "pressure" stylus serves as the transducer. Each disc plays ten minutes worth of programming in color. For the U.S. market, a version of the TED system will spin the disc at 1800 r/min (to be compatible with the NTSC color system) but will still play for ten minutes.

[1] Components of the Phillips' VLP disc player. Playing time is 30 minutes per disc side.



[2] Frequency spectra of recorded signals in the Phillips' VLP system. S/N ratio is better than 40 dB for the luminance signal and better than 57 dB for the audio signal.





[3] Multiple-disc player/changer for the MCA Disco-Vision system is expected to retail for under $500. Total playing time is up to 6-⅔ hours.

Matsushita's new color cartridge video recorder with built-in color television receiver.

Philips' video long-play system

Another entry in the video disc field is from N. V. Philips' Gloeilampenfabrieken in the Netherlands. The VLP (Video Long-Play) system also uses a plastic disc.[3] The prerecorded and coded TV programs are pressed into the surface of the disc. Figure 1 shows an artist's rendering of the VLP player. Light from a 1-mW HeNe laser (6) is focused by a lens before passing three reflective elements. The last one (3) is a pivoting mirror. The beam is focused again by a microscope objective (2) onto the surface of the disc (1), which is covered with a thin metallic reflective layer. The reflected light passes back through the lens along the same optical path until it impinges on the last prism (4). This prism acts as a transmitting element and the light from it is focused on a photodiode detector (5). As the disc rotates, the track moves across the light spot and the light hitting the detector (5) is modulated according to the track pattern.

To register a normal video signal on a VLP record requires processing to reduce the 16-octave frequency span and to encode the signal for two-level recording in disc depressions of constant depth and constant width. In one processing technique, the maximum video frequency is limited and the luminance signal is frequency modulated with a sweep from 4 to 5.5 MHz. During playback, most of the upper first order side band is lost. Spectrum space is available at the lower end to accommodate chrominance and audio signals, as shown in Fig. 2. The audio signal is frequency modulated on a 250-kHz carrier and the chrominance carrier is shifted down from 4.43 to 1 MHz. An exact restoration of the original 4.43-MHz carrier can be played back because a subharmonic of the 1-MHz oscillator is phaselocked to the line synchronization. As with the Telefunken system, the disc is rotated at 1500 r/min in Europe and 1800 r/min in 60-Hz countries. Playback time is 30 minutes per disc.

Philips is aiming for a mid-1975 market introduction. No price has yet been announced for the system.

MCA Disco-Vision system

Similar in basic concept to the Philips' VLP system is the Disco-Vision system developed by MCA Disco-Vision, Inc., in California. The Disco-Vision system also uses an optical playback scheme with HeNe laser which, as in the Philips' system, has the advantage of not wearing out the disc. The plastic disc used by MCA provides 40 minutes of playing time per side and revolves at 1800 r/min.

◀◀◀ *long-play system*

MCA has exhibited prototypes of both single- and multiple-disc playback units. A multiple-disc player/changer is shown in Fig. 3. Discs can be stacked in the unit to give a total playing time of up to 6-⅔ hours. The single-disc unit is expected to retail for under $400 and the multiple-disc unit for under $500. Both units attach to the VHF antenna input terminals of any standard home television receiver.

Other video disc systems

In addition to Telefunken, Philips, and MCA, other manufacturers are also active in developing video disc playback systems. RCA is reported to be developing a capacitive pickup system that plays grooved records at 450 r/min. The records, or discs, are said to have 20 minutes of programming on each side. And Thomson C.S.F. in France is said to be working on an optical system.

One decided advantage the video disc systems apparently have over video tape systems is the much lower cost of disc material. Whether or not the disc systems run into the same software problems as did the tape systems remains to be seen.

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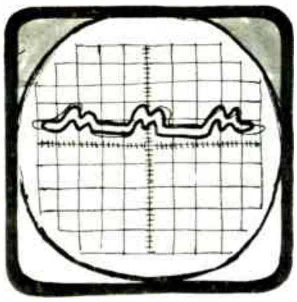


Technology in health care

Medical "early warning systems" may lighten the load on patient treatment systems

Health care delivery today is beset by mounting costs and the demand for better care from an ever-increasing portion of the population. It would seem, then, that any device, technique, or system that could help reduce costs and or do a job faster or better should be welcomed with open arms. But even though technology can help reduce costs—if quality remains fixed—it is more apt to raise costs when improving quality in some manner. And even then, according to some physicians[1], the major emphasis on technology in the health care system has been at the end point—in treatment, rather than in diagnosis. It is easier to instrument an intensive care unit with monitors, for example, than it is to design systems that will permit early identification of medical problems.

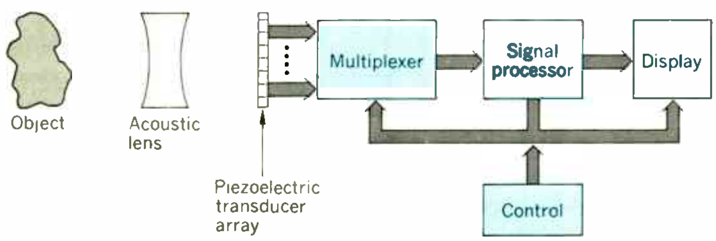
▶▶▶ *piezo-electric array*

It is gratifying to note, therefore, that at least one existing technology that was well exploited during 1973, should permit earlier identification of some diseases. This technology is the use of ultrasound in diagnostic instruments—instruments that permit markedly improved cardiac examination as well as abdominal surveys for cancer detection. The broad implications of these developments are that diagnosis and monitoring of cardiac and vascular diseases and cancer should be improved. And in 1972, these diseases alone were responsible for approximately 70 percent of the deaths in the U.S.

Ronald K. Jurgen Managing Editor

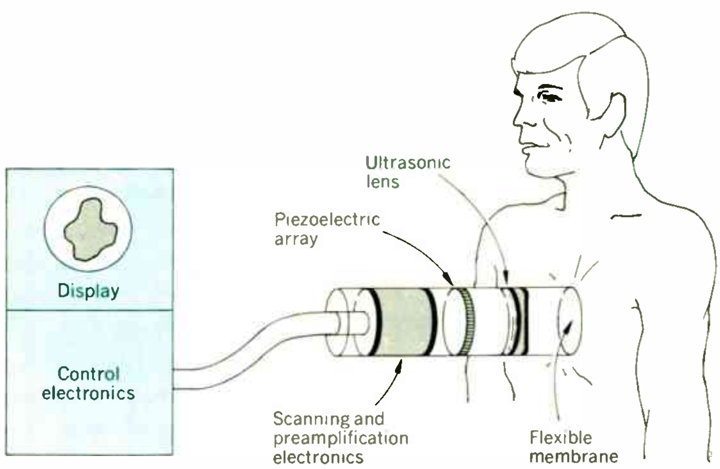
Ultrasonic imaging systems

One new ultrasonic imaging system[2] uses a monolithic piezoelectric array of transmit/receive transducers which operate in a multiple A-scan, B-scan, or C-scan mode. (In medical applications, A-scan is an amplitude vs. time display where time corresponds to distance into the body; B-scan is a light intensity vs. time display; and C-scan is a cross-sectional display of a horizontal or vertical plane within the body.) A block diagram of the system is shown in Fig. 1 and its physical configuration in Fig. 2. The acoustic lens system focuses the transmitted energy of the piezoelectric array onto an element of the object under examination (the patient's chest in Fig. 2, for example). This same lens refocuses the reflected energy from the object element onto the corresponding array element.



[1] Block diagram of an ultrasonic image sensor that uses a monolithic array of transmit/receive transducers.

[2] Physical configuration of ultrasonic image sensor of Fig. 1.



The two-dimensional array of ultrasonic transducers is formed within a monolithic wafer of piezoelectric ceramic material. The X–Y address lines for each transducer in the array are deposited on an adjacent insulating substrate supporting a two-dimensional matrix of electric contacts to the transducer array. An array of silicon monolithic integrated circuits is bonded to the insulating substrate. Each circuit contains a group of matched, high-voltage, low-resistance FETs which perform the transmit receive multiplexing for corresponding elements of the transducer array.

An analog signal processor; a digital controller that permits operation of any single transducer in the A-scan mode, any row or column of transducers in the B-scan mode, or the full array of transducers in the C-scan mode; and a display subsystem consisting of a CRT, interface circuitry, and interpolation circuitry for the C-scan mode complete the system.

A preliminary model has been developed that uses a 10 × 10 monolithic transducer array with an ultrasonic frequency of 3.5 MHz, a maximum range of about 20 cm, a field of view of 3.8 × 3.8 cm, a resolution of about 0.4 cm, and a frame rate of about

30 per second. Initial applications of the instrument in echocardiography have demonstrated its unique ability for medical diagnosis.

Another ultrasonic imaging system, called the Electroscan, has been developed for imaging of the brain.[3] The system uses a probe consisting of an array of several elements, spaced one-half wavelength apart, that are excited successively for varying but mutually equal time intervals. Pulses can be transmitted in several directions within a sector of 90 degrees. Reception is accomplished with electrically variable delay lines. If a sector consists of 32 different directions, for example, the sector scan rate is about 30 scans per second. Experiments on simplified models of skull bone have shown that the distortional effects of the bone on the obtained image are small, probably because the beams are radiated in all the directions through the same small area of bone.

Clinical results with Electroscan have shown that several reference structures can be obtained, making localization of other structures possible. Most brain tumors can be detected either directly or by displacement of reference structures. In hydrocephalus, ventricle widths can be measured. And moving structures, such as pulsating arteries, can be observed and recorded in real time.

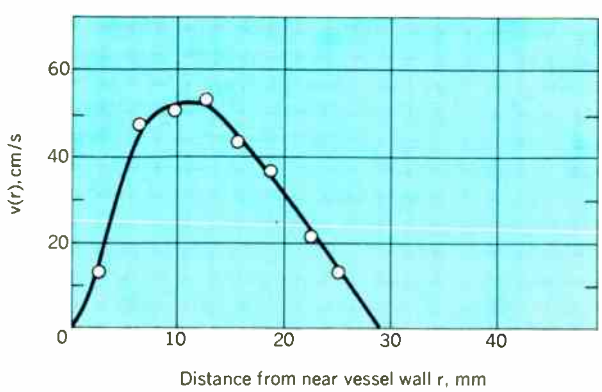
Doppler ultrasonic blood flowmeters

A number of Doppler ultrasonic blood flowmeters have been developed for a variety of applications. One is designed for intraoperative measurements of blood flow in the exposed human ascending aorta.[4] In addition to mean velocity and volume flow outputs, it provides information on the velocity distribution in the vessel, enabling detection of flow abnormalities and hemodynamic irregularities not necessarily indicated by volume flow. The usefulness of the instrument has been demonstrated in 25 open heart surgery cases. Figure 3 shows a typical mean flow velocity profile from a coronary bypass patient.

An ingenious method is used for obtaining ultrasonic coupling to the aorta. A small clot of unheparinized blood is used between the transducer and the vessel. The piezoelectric transducer transmits one-microsecond bursts of 6-MHz ultrasound at a repetition rate of 15 kHz. After the initial burst, the transducer functions as a receiver and the returning signal is phase-detected against the 6-MHz oscillator to provide a 500-kHz-bandwidth video signal corresponding to the Doppler return.

echocardiography

[3] Typical mean flow velocity profile obtained from a coronary bypass patient by means of a Doppler ultrasonic blood flowmeter.



Nonphotographic imaging in radiology

An important advance in 1973 in another area of application of technology to medical problems was the introduction by Electrical and Musical Industries of Great Britain of their Axial Tomographic Scanner. It is an X-ray machine that produces displays, usually cross-sectional views of the brain, in a novel manner. The basic data are collected as a matrix of 160 × 160 measurements of the attenuation of a narrow beam of X-rays as a rotating yoke containing the X-ray tube and scintillation detector rotates around the patient's head. The data are analyzed in a computer to form an 80 × 80 element matrix of absorption values. The data are presented numerically or as a CRT display.

Tomographic X-ray Scanner

The novelty of the system is that it is the first really successful device that offers nonphotographic imaging in radiology. It should trigger other efforts to extend the technique to other organs and physiological functions.

Implant telemetry units

Solid-state technology has been used to design implant telemetry units of minimum size and weight with micropower consumption. The same technique has been used to design or improve medical transducers such as dry electrodes, implantable pressure transducers, and pH and pO_2 transducers. The improvements provided include reduction in size and weight, reduction in power consumption, improved signal quality, and improved reliability through use of a more complex modulation technique.

implant telemetry units

Telemetry applications presently under investigation are: fetal monitoring, infant care, intracranial pressure monitoring, and intensive care of children.

Implant telemetry systems and stimulators are new techniques now available to medical researchers that can "detect" and "control" body functions without continuously invading the body's boundaries.

stimulators

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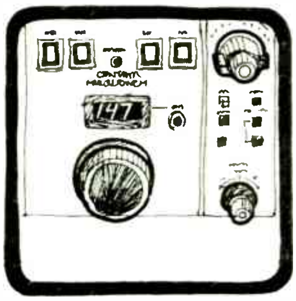


Instruments and test equipment

Computers have snuggled into the measurements domain to tackle new tasks

spectrum analyzers

CRTs

In view of 1973's $2.5 billion market for instruments and controls—which according to the U.S. Department of Commerce reflects an overall 11-percent increase in total electronics business over 1972—there is every indication that the instrumentation market will continue to thrive in 1974.

The evolution toward today's vastly improved test and measurement apparatus has been based on thoroughly proven advances in specific areas—mainly integrated circuitry, digital displays, fast CRTs, minicomputers, and device fabrication. These, in turn, have led to a faster, smaller, more accurate, highly reliable, and relatively inexpensive test instrument that is not only more profitable than ever, but can serve as a programmable building block for multifunctional test systems.

A very significant and visible trend during 1973 was the ever-increasing influence of *computational* power, with lower component costs and improved diagnostic techniques making the solution of more and more complicated measuring problems economically feasible. One of the reasons for the increased computational power of instruments has been the *minicomputer*, either as a complete unit or in the form of a subsystem on PC boards. As such, the minicomputer can be regarded as a "component" in the traditional sense of the word. Interest in 1973 also centered about the *microprocessor* or chip calculator—introduced by Intel Corp. (Santa Clara, Calif.) a year ago—representing the state of the art in MOS large-scale integration. According to one source, the foremost application of general-purpose microcomputers is in replacing hard-wired controllers in commercial and industrial machines. Compared to controllers with 100-odd transistor–transistor logic (TTL) circuits, microcomputer control can be 20–50 percent less costly.

minicomputers

microcomputers

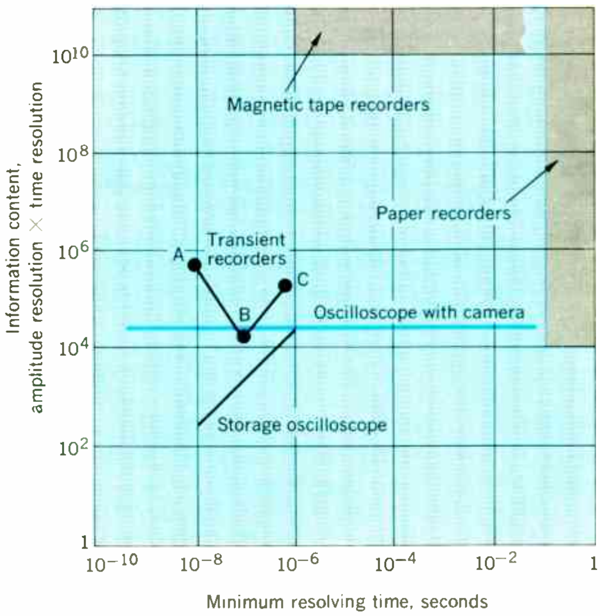
transient recorders

Memories, too, have been falling in price, with more and more instrument makers incorporating them into their designs. Good examples are transient (single-event) recorders, such as those from Biomation (Cupertino, Calif.), which not only compare favorably with other recording devices (see Fig. 1), but with conventional A/D converters as well (since transient events are captured and displayed digitally, these recorders may be considered data acquisition devices). Signal recorders and analyzers also use memories, and Nicolet Instrument Corp. (Madison, Wisc.) has just introduced one of the first digital storage oscilloscopes (Model 1090), with a mid-signal triggering and waveform expansion capability. In essense, the 1090 is a transient recorder with a CRT display.

Instrument makers have estimated that a third of the world's money purchases of electronic test equipment is dedicated to *oscilloscopes* and *spectrum analyzers*. That the user is getting his money's worth can be seen in the type of CRT that is available today. Two companies alone—Hewlett-Packard (Palo Alto, Calif.) and Tektronix, Inc. (Beaverton, Oreg.)—have increased writing speeds at a dizzying pace over the past few years, with Hewlett-Packard's Model 184 offering the present high at 400 cm/μs. Bandwidths have also increased, and Tektronix scopes can now be purchased with bandwidths of 500 MHz, a range that can be doubled by directly accessing the CRT.

Digital spectrum analyzers, first introduced by Hewlett-Packard in 1963, have also been considerably improved and simplified. One of the most important advances in the low-frequency range has been by Hewlett-Packard, whose Model 3580A func-

[1] Relative performance characteristics of different recording devices. Transient recorder A is an 8-bit, 2048-word, 10-ns device; B, a 6-bit, 256-word, 100-ns device; and C, an 8-bit, 1024-word, 500-ns device. Note that resolving time is defined as rise time, or the maximum sampling rate in the case of digital instrumentation. The writing rate of storage scopes requires smaller beam deflections for wider bandwidths, thus reducing information content; data is based on a writing rate of 5 cm/μs.



Marce Eleccion Staff Writer

tions from 5 Hz to 50 kHz using a digital memory with 1-Hz resolution to eliminate the need for CRT variable-persistence analog storage. In the medium-frequency range for nondigital analyzers (0-1.8 GHz), the Tektronix 7L13 features a resolution of 30 Hz, 70-dB dynamic range, and −128-dBm sensitivity. Microwave spectrum analyzers can now operate to 40 GHz with a 70-dB dynamic range and variable persistence display.

In *microwave* measurements, scientists of the National Research Council, Australia, continued their work with reflectometers to locate and measure impedance discontinuities. With the substantial improvements in sensitivity and accuracy that were made during 1973, work progressed in the application of Josephson junctions for measuring attenuation at high frequencies. Resolutions of 0.001 dB were achieved over a 60-dB dynamic range.

New appearances of *hybrids*—ICs and discrete components on ceramic substrates—during 1973 enabled small subassemblies to enhance high-frequency applications, with Hewlett-Packard's 435A microwave power meter giving a VSWR of less than 1.3 from 30 MHz to 18 GHz. This instrument also incorporated the input circuitry into a small measuring head that is separated from the main instrument. Hybrids—a godsend in assuring compactness and portability—were also used in HP's new hand-held digital multimeter, the 970A, which is the smallest available, a mere 7 ounces with batteries.

The digital takeover is now a reality

While analog readouts haven't been completely obliterated, more and more multimeters, panel meters, and the like are going digital—along with the control circuitry. Moreover, digitizing signals by using new A/D conversion techniques has not only cut costs and reduced complexity, but improved accuracy exponentially, with accuracies within ±0.001 percent and resolutions to almost seven digits. Even field equipment is now offered with better than ±0.01 percent accuracies. And greater resolution does not necessarily imply high cost either, as typified by Keithley Instruments' (Cleveland, Ohio) 190 digital multimeter (DMM), which offers 5½-digit ac/dc voltage and current as well as resistance measurements at the lowest price on the market—$750. Keithley's 167 was the first DMM to provide digital readout directly from a probe.

The trends illustrated by the new vintage multimeters now appearing include not only better accuracy and resolution, but increased functional operation as well. Wide-ranging DMMs now feature such advantages as autoranging, isolated outputs, external programming capability, and even some computational power (e.g., ratio indication). With increased capability at reasonable pricing opening up new markets, unit volumes have begun to increase and force down the prices of such instruments as DMMs. At Weston Instruments, Inc. (Newark, N. J.), a new 3½-digit bipolar digital panel meter (the 1230) featuring dual-slope integration and automatic zeroing is selling for under $90 at OEM quantities. Weston has recently reduced the price of their most popular digital multimeters and panel meters by 15-20 percent because of a larger production schedule than had been anticipated.

One of the outstanding examples of the application of digital techniques to instrumentation during 1973 was introduced by Tektronix. Called the DPO 31 Calculator Test System, this new instrument combines the programming ease of a calculator with minicomputer processing power and the signal acquisition capability of a laboratory oscilloscope, plus the advantage of adding a wide array of plug-in acquisition units such as multitrace amplifiers, spectrum analyzers, counters, and reflectory systems. With the DPO 31 at his disposal, a user can process a signal of interest—which has been digitized, put into memory, and monitored by scope—using a variety of analysis routines by simply pressing a button. This marriage of signal capture and complex analysis with virtually no user software demands is a concept with great future promise.

Although light-emitting diode (LED) digital displays continued to encroach on the gas-discharge Nixie tube, planar gas-discharge panels such as Burroughs' Panaplex and Sperry's half-digit units also made strides forward. LEDs found good buyers in the multimeter and counter market, although they were used substantially more by the hand-calculator manufacturers. For reasons of speed, appearance, and operational characteristics, liquid crystals—widely talked about by the digital watch manufacturers—made appearances in only a few of the new instruments of 1973. For high illumination applications, there remains the filament display such as RCA's Numitron.

Automatic testing

A major area of instrumentation—now representing a huge percentage of total instrument sales—is *automatic testing*, which according to Robert A. Grimm of Hewlett-Packard constitutes 15–20 percent of all instruments sold today. Ironically, despite the fact that automatic testing equipment (ATE) has been used by IC houses for years, it is the IC itself—along with overall system complexity—that has contributed to the need for rigorous system and component testing by manufacturer and user.

Hewlett-Packard, Teradyne (Boston, Mass.), and General Radio (West Concord, Mass.) made significant contributions in building test systems operated under minicomputer control. Although analog sensitivity and accuracy were not substantially improved over older and simpler test setups, both the number and the variety of measurements and decisions made economically on a device, subassembly, or finished product were decisively increased.

Even standard desk-top calculators—introduced by Hewlett-Packard and Tektronix—have begun to incorporate improved testing capabilities, providing an important basis for a measuring, decision-making, and data-logging system.

Test design and programming, recognized as the overriding cost factor in the effective deployment of automatic test equipment (ATE), is finally receiving its deserved attention. Computer-aided test design tools such as logic analysis stimulus and response (LASAR), developed by Digitest Corp.

◀◀◀ microwaves

◀◀◀ hybrids

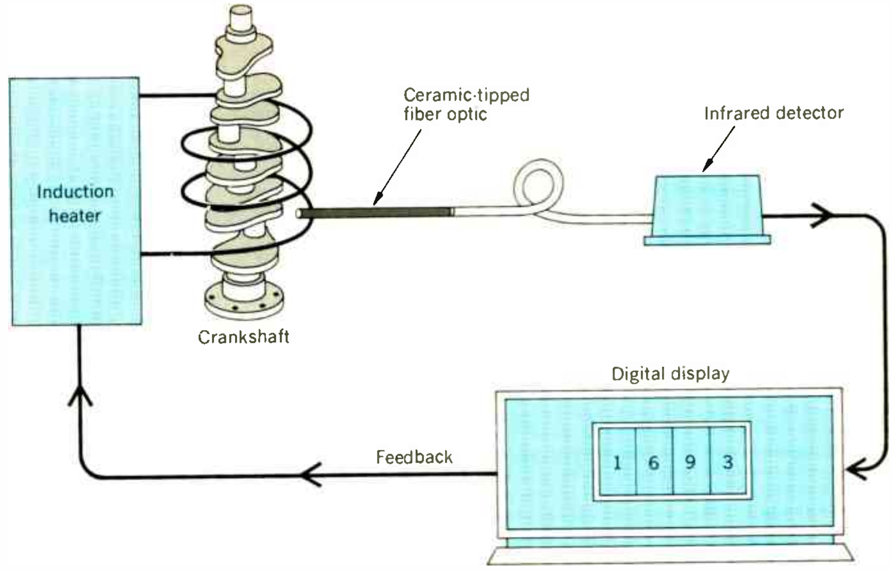
digital displays

◀◀◀ digital multimeters

computer-aided testing

calculators

test programming



[2] Process control of crankshaft induction-hardening by infrared-radiation detection, one of many new uses for IR sensors.

(Fort Worth, Tex.), are being effectively used to develop digital test programs. Computer-aided test design for analog problems lags behind that for digital—but significant efforts are at last being taken toward their solution.

Interfacing the real world

sensors

Any instrument that measures real-world parameters—whether in a deep-ocean or space environment or in the more practical situations of process control or traffic signaling—must be interfaced by sensors or transducers with appropriate operational characteristics. Although the visible spectrum and sound have been the main vehicles of the sensor field, there was increasing interest in the infrared (IR) region during 1973, with X-ray sensors playing an important part in deep-space probes and microwave sensors expected to come into their own within five years.

Despite the many test instrumentation systems and transducers that have been developed to date, all have limitations of one sort or another. Those that are most commonly encountered are poor resolution and accuracy, intermittent output, unwanted sensitivity to corollary parameters, fragile construction, response to ambient conditions, under- or overdamped response, and inordinate size, shape, or weight.

Some of the more important new test instrumentation systems that have been developed through NASA are given in publications that may be obtained from the National Technical Information Service, Springfield, Va. 22151. They result from new techniques developed at various NASA research centers to overcome the many limitations encountered by older test systems and transducers.

industrial sensors

Until recently, measurement of the IR radiation emitted by materials in the industrial environment was limited to a few, relatively simple applications. Outside the production world, however, IR techniques were being evaluated for a wide variety of applications, and IR equipment has begun to supplement industrial test and process-control methods.

Perhaps the most interesting recent IR innovation has been the replacement of conventional optical systems by IR-transmitting fiber optics that allow detectors to monitor targets located in otherwise inaccessible areas. Among the numerous applications of these systems include metal treating by induction heating (Fig. 2), polymer melting in plastics extruders, automated semiconductor chip bonding, steel annealing, galvanizing, and welding, and vacuum-furnace crystal growing, doping, and epitaxial deposition.

Another successful development that has emerged is the uniting of an IR line scanner with a computer, a system that yields alphanumeric IR signatures of every component on electrically energized printed-circuits cards. The major advantage of this new approach for testing PC boards is that the performance of each component is individually measured.

In the field of *coherent* IR radiation, silicon vidicons and detectors are now being used with fiber optics to monitor the performance of semiconductors. Using a form of coherent radiation called "recombination radiation" that occurs at all p-n junctions, this technique gives real-time measurement at every point of a junction to assess current crowding and voids for better design evaluation and tighter manufacturing control.

One technique that is presently in its infancy involves the use of a laser for heat injection into non-self-heating targets such as multilayer PC boards or sandwich assemblies of laminates and honeycomb materials. An IR scan of such targets immediately after laser heating reveals the heat-transfer characteristics of each injection point, disclosing material discontinuities and defects often impossible to find by other methods.

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Systems and cybernetics

Tools of the discipline are progressing from the inspirational to the practical

Be they living animals, machine systems, or human societies, the internal control and communication functions can be broken down and studied with the tools of systems engineering and cybernetics. This is a diverse field encompassing (a) integration of communication, control, cybernetics, and systems theories; (b) development of systems engineering technology; and (c) practical applications at both the hardware and software levels.

Recent and projected developments are taking place in at least five important areas, technological forecasting and assessment, complex systems modeling, policy analysis, pattern recognition, and artifical intelligence. Applications have moved far beyond the feedback control systems described in Norbert Wiener's *Cybernetics* first published only 25 years ago.

◄◄◄ *technology forecasting*

Based on certain known or expected social, technical, and environmental factors, technological forecasting projects the future success of further technical developments. By contrast, technology assessment studies the effects on society that may occur when a new process is introduced or an old one is modified. The emphasis here is to uncover any unintended or delayed impacts. If not absolute, the methodology involved is at least inspirational with such distinctive designations as morphological analysis, cross-impact matrices, relevance trees, trend forecasts, Delphi method, and the rigorous approach of decision analysis. The increasing complexity of society demands the best possible understanding of technical uncertainties and a continuing review of related public policies.

◄◄◄ *systems modeling*

Systems modeling is the representation of real world phenomena by equations—most often handled through computer simulation. Much effort has been made recently to model complex social phenomena for studying the impact of public policies. The controversy around pioneering applications of such "system dynamics" to social modeling, which started in the early 1970s, resulted in a number of extensions and refinements of this modeling approach. Among the more constructive modifications are models that emphasize individual components in any representation of the real world, the use of observed data in the structure, and the inclusion of human reaction and social cybernetics in the model. There is increased recognition that social system models merely underline the subjective nature of social problems.

Experiments in the area of urban public policy, for example, now break down the model of a given issue into three distinct subcategories—the goal (intent space), the reality (physical space), and the policy (instrumental space). Because such politically explosive areas as energy supply and communications are largely technical undertakings, electrical engineers will become increasingly involved as researchers for the required public policy decisions. This is considerably different from their contribution to the single-goal space and defense programs of the 1960s. Today's comprehensive policy analysis is designed to confront subjective issues, each with several diverse goals.

pattern recognition

Pattern recognition based on cybernetic principles is now widespread in both character recognition and picture recognition. Applications of the former now include scanning equipment used by post offices and banks to sort mail or read credit cards. Even the U.S. Government has gotten into the act with automated hardware which scans and then speeds the processing of social security claims and income tax forms. Picture recognition is somewhat behind character recognition in widespread commercial use. Active research and development of picture recognition are concentrated on software for automatic image interpretation of data gathered by the remote sensing of chromosome structure, cell images, fingerprint patterns, and very simple three-dimensional objects.

Now in the R&D phase at NASA, parallel image processing techniques for spacecraft applications are being explored. This will allow satellite-born earth observation equipment to interpret images and give a summary report to ground interrogators rather than simply relaying entire pictures for human examination.

robots

In the area of artificial intelligence, robots have been designed by industrial firms as well as research institutes to perform relatively simple tasks such as arranging blocks, assembling simple pumps, and mounting wheels on automobiles. The use of industrial robots is an important trend since robots can increase productivity and relieve workers from dehumanizing tasks on one hand, but could cause transitional unemployment on the other.

The technology of systems and cybernetics is undergoing rapid growth and will have a profound affect on society. Such developments—by their very nature—give evidence of this impact and the corresponding need for self control.

Don Mennie Associate Editor

This report is based largely on material contributed by Dr. Kan Chen, President of the IEEE Systems, Man, and Cybernetics Society.

Societal aspects of technology

Embedded within the energy crisis are lessons applicable to other areas of sociotechnical impact

As the year begins, the social impact of technology has never been more deeply felt across the globe. In the United States, by mid-November of last year, President Nixon and his advisors were predicting a 17-percent fuel storage. Simultaneously, Senator Henry M. Jackson (D—Wash.) was warning of a 24-percent shortage. Further, a debate was raging over the identity of the villains responsible for the crisis. And the stage was set for a furious debate over methods to alleviate and eventually resolve the crisis.

Meanwhile on the international scene, the Arab oil freeze had caught nearly every industrialized nation unaware so that the European countries and Japan, in particular, were frantically jockeying in the diplomatic sphere while preparing at home for the possibility of a sudden starvation diet of fuel. In fact, even the developing countries were prey to the social implications of fuel-hungry technologies—they could see in the Mideast War the all-too-possible prospect of being drawn into a cataclysmic global big-power fuel fray.

▸▸▸ *wired community*

For the individual citizen, the energy crisis had as much meaning as it did for his government. Before him was the specter of layoffs, shortages, strikes, financial insecurity, and a host of other, at best, inconveniences. Unfortunately, caught up in this drama of unfolding crisis, the mass media—and the major part of the international populace—were too preoccupied with the immediate controversies spawned by the crisis to consider its deeper significance.

"Future shock"

An exception to the tendency of media to concentrate on the political and economic ramifications of the energy crisis, rather than its social, or philosophical, ramifications, was embodied in the interview on a national television network news show of Alvin Toffler, best known as the author of *Future Shock*. Feeling perhaps vindicated concerning his forecasts, now three years old, but certainly saddened by the specter of their coming to fruition, Dr. Toffler pointed to the current energy crisis as "the first in a long series of crises" to be faced by the industrial societies proliferating around the globe. He considers this crisis as part of a "megarevolution" and questions our fate if we continue to do nothing to prepare ourselves for future crises. In terms of the U.S., but no doubt equally applicable to other highly industrialized nations, Dr. Toffler's main concern is that there has been not only a demonstrable "lack of energy policy," but a "lack of a place in Government for such a policy to be designed."

energy policy

Ellis Rubinstein Associate Editor

Thus, even if President Nixon's hopes come true—that the U.S. can achieve energy independence by 1980—we may not be so fortunate the next time around. More than a seven-year period of industrial and consumer sacrifice may be at stake. Perhaps the entire fabric of our society could be torn for lack of adequate planning.

To many besides Dr. Toffler, such a prospect hardly seems unlikely. Gerd D. Wallenstein, former vice president of planning at GTE Lenkurt, San Carlos, Calif., and since his retirement, a member of both the novel Cybernetic Systems Program of San Jose California State University and the Engineering-Economic Systems Department of Stanford University, is one of those who feel, "the field of communications may be the next critical area where technological planlessness can impact society adversely." In the "wired community" projects now under study by technologists such as Peter Goldmark, best known for his work as director of CBS Laboratories, Mr. Wallenstein sees the looming specter of Orwell's "Big Brother." Who, he wonders, is guarding against the possible misuse of the sophisticated communications systems now being contemplated?

But more of the specifics of communications later. The central question, for the present, is whether or not the current energy crisis affords us a model of future crises—that is, can we do more than merely discuss the tradeoffs available between environmental concerns and the technological and cost-benefit features of alternative energy sources? Perhaps it isn't enough to say, as many technologists do, that technology will always be abused and misused by corrupt, or merely egocentric, interests (by which they mean people). Perhaps something more *can* be said; perhaps precautions *can* be taken based on an understanding of the inadequacies of the past.

Energy crisis as object lesson

In order to extrapolate lessons from the energy predicament of the industrialized world, we must consider the causes of the crisis. So far, two approaches have been aimed at assigning responsibility: On the one hand, there have been the charges and countercharges leveled by and against special-interest groups—e.g., the oil interests and/or the utilities lulled us to sleep; the environmentalists paralyzed our remedial efforts; Government adopted a do-nothing attitude; the consumer was, and continues to be, frivolous in his pursuit of convenience. But such charges, in themselves, can do little more than air partial truths. And in retrospect it is remarkable how every group can claim to have had clean hands in the formation of the crisis.

On the other hand, many analysts have taken a broader look at the roots of the crisis—one that criticizes what has been termed a "*laissez-innover* ideology" of at least the sixties. For example, the noted biologist Barry Commoner, more than a year ago, pointed out[1] that, since 1946, electricity generation in the U.S. had increased 50 percent faster than industrial production. He explained this disparity by citing the development of new materials requiring greater power inputs in their manufacturing process. Few, if any, consumers in the U.S., or anywhere else, realized that the shifts from steel to more power-intensive aluminum, from soap to detergents, from natural to synthetic fibers, were eventually to contribute to the depletion of our resources.

Similarly, New York architect Richard Stein, at the same time, estimated[1] that on-site generation of steam for heating and cooling and the restriction of lighting levels of skyscrapers would cut energy consumption in half.* But a year or more ago, such appraisals—and there were many—seemed to have no urgency attached to them. Today, however, the problem is to decide who was to have forecast societal needs and how were the results of such forecasts to have been assessed and converted into policy?

Where were the forecasts?

John A. Casazza is general manager of planning and research for Public Service Electric and Gas, Newark, N.J. He wastes no time on witch-hunts, but instead takes a constructively broad view of our dilemma. To Mr. Casazza, the core of the energy crisis is our "affluent society"—one that has become, since 1968, "service-oriented" rather than "product-oriented." He says that "the Btu's required per dollar of gross national product" are increasing as a result (see Fig. 1). In combination with environmental constraints and political realities, depletion of our resources should have been foreseen.

*See also: Friedlander, G., *IEEE Spectrum*, pp. 36–43, Nov. 1973.

Why wasn't it? Mr. Casazza says that as long as 25 years ago, the public utilities were involved in technological forecasting. "But we missed the rapidly changing environmental concerns that would appear," he laments. He goes on to admit that "there weren't any nonengineers included on our panels," though this weakness has since "been rectified in large measure." Thinking of a problem currently before him on his desk, Mr. Casazza asks "how engineers can properly consider social implications in reviewing the costs and benefits of putting a power line underground" without consulting professionals from other disciplines. "It might cost $100 million, and with that money, what urban problems could be solved, how much could cancer research benefit?"

Further, Mr. Casazza stresses that there are no malevolent interests contributing to our sociotechnical dilemmas, but that there are also "no societal mechanisms for coordinating data and reaching solutions." What we need most, he asserts, is not to raise the already rising social conscience of the technologist and his management, but to improve information transfer among the experts and from them to the general public. Problems can be most effectively solved, he feels, by entrepreneurs working toward public goals as nationally determined by an informed citizenry.

A role for government?

Ideally, in nonautocratic societies, government should be the arbiter between special-interest groups

One important feature of the U.S. brand of energy crisis: beginning in 1968, as the U.S. economy shifted from its former product orientation to a service orientation, the Btu's per dollar of gross national product began to rise dramatically for the first time in over 20 years, thus contributing to an unacceptable drain on U.S. resources. (The graph has been calibrated in British thermal rather than SI units.)

as well as the protector of the public interest. But this does not guarantee that, within government, there are those who can read conflicting forecasts and assess their inevitable defects. And it further says nothing about the realities of politics that create special interests even within government. Thus, for example, the fact that there is now an Office of Technology Assessment in the U.S. Government does not prevent—and may even increase—such internal bickering as exists between Congress and the Executive.

To John Casazza, the debate about who first proposed remedial measures is useless. "Lead times in energy and power," he points out, "are great. People get committed to systems that last many years," and they are unwilling to throw everything away at a moment's notice. Thus, in Mr. Casazza's view, a minimum of ten years is required to make significant changes in utilization systems, and of 15 years for supply systems. And this brings him back to his cry for long-range policy planning.

But if John Casazza sees the political bickering as useless, Gerd Wallenstein sees it as indicative of a deeper problem. He says that the U.S., glorying in a tradition that dates back to the Magna Carta, has long been enamored with the "adversary system." According to Mr. Wallenstein, the adversary system may serve well in resolving simple questions of truth and falsehood, but it performs poorly in producing the kind of "complex policy decisions" necessary to guide societal progress through a labyrinth of value judgments, or cost-benefit tradeoffs.

cost–benefit

Consequently, Government officials have been faced with the task of resolving conflicting claims without an alternative tradition to the adversary system available to them. Such a tradition, according to Mr. Wallenstein, may be the diplomatic one more often used in international organizations where differences are downplayed so that, in effect, there are no losers. Says Mr. Wallenstein, "Collaboration is the message, tacit acquiescence." Minimally, he feels, there should be a kind of "Common Cause" of the engineering institutes.

Increasing numbers of technologists believe there must be forums for "adversaries" permitting unpublicized bargaining. From such forums, recommendations could be issued to government legislators whose only duty would be to enact the recommendations according to available governmental procedures. Perhaps the best aspect of such a method of handling complex sociotechnical problems would be that the responsibility for their solution would be taken out of the hands of what John Casazza calls "the procedures-oriented lawyer-dominated bureaucracy" and placed in the hands of "results-oriented technologists."

The technologist's role

William D. Rowe, Deputy Assistant Administrator of the Environmental Protection Agency for Radiation Problems, agrees with John Casazza that the technologist must supersede the role of the government official in order to solve future sociotechnical crises. In a recent paper[2], Dr. Rowe expressed his view that, in general, Congress reacts to problems only after they have approached crisis proportions. "This is understandable," he points out, "since many of the issues are extremely controversial—issues such as population control, genetic control, and Governmental regulation of land use." Because Governmental officials serve at the public whim and, consequently, must await public awareness of imminent crisis before taking action, "the early assessment of these types of problems must be approached by nongovernment organizations in the public domain. Further, these organizations must be able to examine these activities, these controversial problems, in a scientific and professional manner in which the validity of the methods and the manner of drawing conclusions is beyond question, although the results will be highly argumentative and speculative by the very nature of activity . . . ."

What Dr. Rowe is suggesting is that the technologist join in the procedure of policy planning through his technical society. Why have the technical societies been so leery of the process in the past? One answer is offered by IEEE Executive Director Donald Fink, who attributes the engineering societies' reluctance to enter the area of making policy recommendations on a national scale to an understandable fear of losing technical credibility. A rather different explanation is that the engineer, through past experience, has found technology forecasting—the tool of policy planning—relatively useless. Shockingly, this opinion was offered by a member of IEEE's Technology Forecasting Committee! Dr. Rowe offers a third explanation: just as the lawyers who populate Government in such numbers have a professional bias, so has the engineer. If the former is "procedures-oriented," the latter sees himself as the embodiment of a scientific need for perfection. According to the "scientific attitude," unless the engineer is 100-percent certain, he would prefer not to offer an opinion.

As far as Dr. Rowe is concerned, "technologists and Government must work together more closely" if there is to be sociotechnical progress. He suggests seminars "hitting model problems, say, to allow the technologist to learn to supply the information the regulator needs," as opposed to the information the technologist thinks he needs.

And finally, Dr. Rowe suggests that bridges must be built between those he terms "people-oriented" and those who are "thing-oriented." There are rare people in the world, he maintains, who are "concept-oriented," but they are currently underutilized. Consequently, lacking forums for dialogue and leaders to arbitrate between two very different types of beast, neither the public servant nor the engineer will act until there is a crisis. Or, at least, such has been the case in the past.

What happens if no one acts? A test case

If, thanks to crisis conditions, energy policy is finally being implemented in the various industrial nations despite the frustrating complexities and tradeoffs that fog the future, a coherent communications policy, for lack of crisis, exists nowhere. And in 10 or 20 years, presuming the energy-environment crisis is well behind us, we may regret our lack of foresight.

Consider the state of the art in 1973:

• In the new, planned town of Jonathan, 25 miles southwest of Minneapolis, Minn., a joint effort of the

U.S. Department of Housing and Urban Development (HUD) and Community Information Systems, Inc., has produced an experiment in two-way interactive cable television. Called the Jonathan/Chaska Community Information Systems Experiment, the service provides hands-on consumer experiences in education, home security, opinion polling, entertainment, information retrieval, merchandising, and data communications. To describe the scope of the system, two examples should suffice: on the one hand, doctors in two hospitals, the Lakeview Clinics in Jonathan and Waconia, are linked by CATV to facilitate long-distance consultation; on the other, home subscribers can play tic-tac-toe against the system computer.

- Throughout the world, numerous experiments are utilizing broadcast and cable TV in education. In Britain, for example, the British Open University offers, over broadcast television, university-level courses to thousands of adults who couldn't otherwise attend a university. Similar experiments have since been begun throughout the U.S. in which the capabilities of CATV are being applied to a variety of teaching levels. (For a list of institutional services, as well as consumer services, contemplated by the various "think tanks—in this case, the Rand Corp.—working on such possibilities, see the table below.)

- And there is one other project worthy of mention: the Advanced Research Project Agency (ARPA) network. Only five years after its initiation as a research project, the ARPA network now consists of more than 40 computers—*19 different types*—located at 36 sites from Boston, Mass., to Santa Barbara, Calif., all linked by nationwide communications. The significance of the network should be evident: through the use of minicomputers, together with packet-switching techniques, any computer can be plugged into any other computer, and their data and capabilities can then be shared.

two-way CATV

A new era: enlightened self-responsibility

The foregoing examples represent, of course, only a random selection from the many exciting communications projects currently under way throughout the world. There are elaborate plans being formulated—and even funded, as in Peter Goldmark's experimental "wired community" project to be implemented in Connecticut—for a blue-sky future of two-way cable TV, Picturephone service, instant-access data banks, complete home entertainment systems, and the like. The positive effects of such technologies on future society may be clear: problems of urban crowding, safety, transportation, and, most important, regional inaccessibility or underdevelopment *might* all be overcome by sophisticated communications systems.

video telephone

data banks

But what of the negative effects of such a future technology? Under the lowering specter of Watergate, is

Some Proposed Interactive Services for Cable Television*

Subscriber	Institutional
Interactive instructional programs	Computer data exchange
Fire and burglar alarm monitoring	Teleconferencing
Television ratings	Surveillance of public areas
Utility meter readings	Fire detection
Control of utility services	Pollution monitoring
Opinion polling	Traffic control
Market research surveys	Fingerprint and photograph identification
Interactive TV games	Civil defense communications
Quiz shows	Area transmitters/receivers for mobile radio
Pay TV	Classroom instructional TV
Special interest group conversations	Education extension classes
Electronic mail delivery	Television municipal meetings and hearings
Electronic delivery of newspapers and periodicals	Direct response on local issues
Remote calculating and computer time sharing	Automatic vehicle identification
Catalog displays	Community relations programming
Stock market quotations	Information retrieval services
Transportation schedules	Education for the handicapped
Reservation services, ticket sales	Drug and alcohol abuse programs
Banking services	Health care, safety, and other public information programs
Inquiries from various directories	Business transactions
Local auction sales and swap shops	Credit checks
Electronic voting	Signature and photo identification
Subscriber originated programming	Facsimile services
Interactive vocational counseling	Industrial security
Local ombudsman	Production monitoring
Employment, health care, housing, welfare, and other social service information	Industrial training
Library reference and other information retrieval services	Corporate news ticker
Dial-up video and audio libraries	Telediagnosis
Videophone	Medical record exchange

*It is unlikely that all of these services will be economically feasible on cable television networks. Some may not even be socially desirable. They have been compiled from various reports, FCC filings, corporate brochures, and advertising materials. Adapted from Baer, Walter S., *Interactive Television*, Rand Corp., R-888-MF, Nov. 1971.

Gerd Wallenstein wrong to ask who would assure his privacy, retain his records, control town meetings conducted over CATV,* etc.? And this is not to mention the psychological effects possible of a society in which no one need go out of his home.

William Linvill is chairman of the Engineering-Economic Systems Department of Stanford University. In the introduction to a fascinating paper offered at the Engineering Foundation Conference, "Technology and Social Institutions," held in Pacific Grove, Calif., May 1973, Prof. Linvill states the following principles:

> Most components of our society are working very well. The vast majority of our citizens are free, healthy, and well fed, with high individual mobility and access to opportunity.
>
> Generally, wide application of technology has made such material well-being feasible.
>
> Recently, however, extensive increases in the use of technology have caused an emerging shortage of natural resources . . . to appear.
>
> Societal transitions necessary to realize maximal human benefit from further technological advance are sweeping and have interlocking effects.
>
> Such societal transitions require a single integrated set of societal choices. Thus, integrated societal choices leading to technological innovation require integrated initiative from many separate sovereign client-sponsors and integrated production of many separate producers.
>
> This many-to-many coupling problem—to couple many sovereign producers in a single function initiated and sponsored jointly by many independent groups of consumers—is the *compound barrier* to the innovation of solutions to many of our societal problems.

In the area of communications, there is evidence that attempts *are* in the offing to overcome Prof. Linvill's "compound barrier" even before crisis hits. James A. Lippke, editor of both *Broadcast Management/Engineering* magazine and *Broadband Communications Report*, reports that "as we enter an era of a communications technology that promises an abundance of bandwidth as opposed to a scarcity of channels, we find large numbers of people aware of the potentials and pitfalls before us. Many cities, large and small, have, as a procedural matter, appointed citizens' committees to study what the community should seek or insist on before awarding a CATV franchise."

But Mr. Lippke is quick to point out that more is needed than mere public awareness: "Technologists in the communications field cannot really escape from the responsibility of making public judgments because—unlike in the cases of the petroleum, coal, and gas industries—the Federal government has long been involved in regulating communications services and development."

Will technologists fulfill the kind of role expectations of Mr. Lippke? He claims they already are! "Of 300 individuals advising the FCC on CATV and CATV-distributed broadband communication services," he says, "150 are engineers serving on the FCC's Cable Technical Advisory Committee."

* See Etzioni, A., "The impact of cable communications on the political process," *Symposium on Urban Cable Television*, MITRE Corp., pp. 51–70, Oct. 1973.

Thus, the engineer, as technologist, consumer, and citizen, depending on his hat, is having to reassess his social role—the energy crisis is forcing him to! Says William Ittleson, EE, doctor of psychology, and chairman of a unique program within a graduate-level psychology department—the Environmental Psychology Program of the City University of New York—"The energy crisis is not a technological but a social crisis." He is perhaps exaggerating to make an important point: society's future is inextricably bound to the future of technology. In the light of this inescapable reality, increasing numbers of scientists—engineers included—are facing and discarding myth-bedevilled concepts regarding technological forecasting. Prof. Ittleson summarizes past misconceptions as follows: "(1) You *can't* predict the consequence of technology, but (2) you *can* predict that they'll be good."

Executive Director Fink is one of those who recognize the role technology forecasting must play. Addressing himself to our current crisis at a recent meeting, he asked rhetorically, "Who is to decide if Westinghouse or GE is right about the best approach to the breeder reactor?" IEEE President (for 1973) Harold Chestnut speaks of the need for intersociety coordination in an effort not only to inform, but also to press Congress to act on the energy crisis. Donald Fink says the engineer-technologist has entered a new era—one of enlightened self-responsibility. "Engineers," he goes on to say, "will be the only referees in the biggest ballgame ever!"

But if many have come to agree that the engineer has a technical role to play in social problems, William Rowe of EPA goes one step further. Dr. Rowe's point is that the engineer, as a citizen-technologist, has both a special perspective and a special responsibility. More than to act as a technical referee, the engineer, in Dr. Rowe's words, "must also strive to assure the existence and effectiveness of the social and political structures" within which sociotechnical decisions are made (or, in some cases, bypassed). In other words, as citizen-technologist in a society whose future is increasingly entwined with that of technology, the engineer must act, not only as a technical arbiter offering the "facts," but as a technical expert with social concerns who can provide sociotechnical value judgments, and as both a critic and definer, who can effect the social mechanisms needed to implement those value judgments.

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Cutting the frills and the costs

Concerns about the high cost of U.S. defense systems procurement has prompted a proposal that emphasizes unit production cost

It may become just another buzz word, but its coiners hope not. "Design to cost" (DTC), a term that originated within the Dept. of Defense, has been embraced and elaborated as a concept by a task force of the Defense Science Board. The charter of the group was implicit in its title: "Task Force on Reducing Costs of Defense Systems Acquisition." Under the chairmanship of J. Fred Bucy, Jr., executive vice president of Texas Instruments Incorporated, the task force's members were chosen to include those having a wide variety of experience in commercial industry. In a report prepared during 1973 at the request of the Office of the Director of Defense Research and Engineering (ODDR&E), the task force made several recommendations to the Department of Defense which it urged DOD to implement, or to use as goals for cost reduction. Already, as a result of the report, several directives concerning implementation have been issued by DOD. But to equate this action with widespread acceptance or even understanding of DTC would be a mistake. At EASCON last fall, a panel chaired by Jacques S. Gansler, assistant director for planning for ODDR&E, discussed the proposed technique.

I. What is DTC?

At least one of the EASCON panelists defined DTC as "giving cost primary consideration relative to performance and delivery." The task force itself did not quite see it that way, giving this description: "DTC establishes, as a design goal, a unit production cost which the DOD can afford to pay (for the quantities it needs) as a primary design parameter (equal with performance)." It also emphasized that costs must be continuously stressed in tradeoff decisions, and that the contractor must demonstrate this cost on an incremental basis before award of the production contract. The objective is to forestall high unit production costs and unnecessary system sophistication and complexity.

II. Cultural Change

An "overriding reservation" of the task force concerning the value of DTC is the defense acquisition "culture" that now exists. This was underscored in the following conclusion: "In essence, cost reductions and design-to-cost cannot now overcome the pressures of contravening forces. As long as cost justification equals increased profits, and program managers lack tradeoff authority, even the best improvements are doomed."

To alter the present culture, the task force had some specific suggestions. First, the process of contract negotiation and award for production phases should not focus on cost justification but rather on unit cost or price. Second, a more effective system of awards and penalties is needed to motivate and hold accountable both military and civilian DOD personnel. Third, the role of the program manager is all-important—particularly his understanding of the cost/schedule/performance tradeoffs, his absolute authority to make such decisions, and his access to tne necessary high authorities. Fourth, hardware competition must be maintained throughout the life of the contract ("competition is a forcing function that will cure many ills"). And, finally, more emphasis must be given to prior performance and responsiveness of contractors to DOD's needs.

III. Impact on the designer

DTC may mean a new way of life for the designer at the prime and subcontractor level. Those who were principally concerned with what "wins the technical competition" may have to give equal emphasis to what makes for low cost. Daniel Dudas, vice president of Litton System's data systems division, notes that too many "technical monuments" are invented in the proposal stage. He urges a challenge of requirements at this stage, the elimination of "how to" specifications which may simply result in unnecessary "invented detail," and credible substantiation of the target unit cost using "real instead of fabricated" evidence. Unfortunately, says Mr. Dudas, the designer with the clever, innovative approach often gets promoted over the designer with the low-cost approach. The designer is held accountable for the development schedule and system performance in that order, with development cost a "deep third," he says. Under DTC, unit production cost must be given high priority.

IV. When to start

The key to DTC is starting early. Once a system is in the production phase, leverage for cost reduction is largely gone. Myron F. Wilson, manufacturing vice president for Collins Radio, urges DOD to take a page from commercial system producers in which performance, schedule, and price are all key factors (price is "sold in"). Step one, he says, is settling on the price. The next step is to "back off" to the manufactured cost. Finally comes designing to meet that cost, with the knowledge that the manufacturer is responsible in a definable way during the life of the product. Mr. Dudas of Litton observes the importance of beginning early by stressing that the contractor must isolate the too-difficult spec items early and must not pursue them even though it may "take somebody's game away from him." He urges prompt elimination of the "white lace and promises" invented during the proposal stage, and recommends that Government program managers and engineers avoid "overreaction to problems" occurring during test and evaluation to help ensure unit production costs.

V. What to sacrifice

Because of the emphasis given cost, observes Collins' Wilson, one cannot always get all the features that were

Norman W. Parker
For contributions in the design of color television receivers

Irene C. Peden
For contributions to radioscience in the polar regions, and for leadership of women in engineering

Samuel C. Phillips
For management and leadership of aerospace vehicle and space programs

Virgel E. Phillips
For contributions in the fields of power circuit breaker design, performance, and power system interaction

Kendall Preston, Jr.
For contributions in the fields of synthetic aperture systems, optical computation, and pattern recognition

O. Thomas Purl
For contributions to high-power traveling-wave tubes, and for leadership of microwave electron device engineering

James B. Reswick
For contributions to biomedical and rehabilitation engineering

Leon J. Ricardi
For contributions to the theory and design of microwave antenna systems for communication satellites and deep space radar applications

Edward A. E. Rich
For contributions to automatic process control in the cement and glass industries

Robert J. Ringlee
For contributions to practical methods for assessing and improving reliability of power apparatus and systems

Robert K. Roney
For leadership and inspiration in the exploration and applications of space technology

Charles A. Rosen
For contributions to solid-state physics and the development of computer-controlled robots

Wilhelm T. Runge
For early leadership in microwave techniques

Clyde L. Ruthroff
For contributions to microwave radio system design

Shigebumi Saito
For contributions to microwave and laser technology

David J. Sakrison
For contributions in research and teaching in communication theory and its applications

Norikazu Sawazaki
For contributions to the development of video tape recorders

Amarjit Singh
For contributions to the knowledge of microwave plasmas and devices, and for research leadership

Robert A. Soderman
For contributions to the development of instrumentation and measurement methods, and for leadership in the establishment and acceptance of associated standards

Robert Stratton
For contributions to the theory of semiconductor devices and to technical management of semiconductor research and development

Edgar R. Taylor, Jr.
For contributions in radio and audible noise resulting from extra-high-voltage transmission, and to the study of transients and surges on EHV systems

Kees Teer
For contributions to television, acoustics, and electronic systems, and for leadership in research

Michael Temoshok
For contributions to the continuing development and application of excitation systems for large alternating-current generators

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For contributions to the theory and practice of VHF and UHF antennas

Hans G. Unger
For contributions to the theory of multimode millimeter waveguides

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Gottfried K. Wehner
For contributions to the understanding of the sputtering process

Marvin H. White
For contributions to the theory and development of solid-state electronic devices, especially memory transistors and charge-coupled imaging arrays

James C. Wiltse, Jr.
For contributions to microwave and millimeter-wave technology in the areas of radar, radiometry, and transmission line research

Shmuel Winograd
For analysis of computational complexity which established bounds on the time required to compute certain mathematical functions

Victor R. Witt
For contributions to magnetic recording on tapes and disks and to secondary storage devices for computers

Eugene Wong
For contributions to the theory of random processes and its engineering applications, and to engineering education

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For contributions to engineering and economic analyses of large-scale electric power systems

Sakae Yamamura
For contributions to the theory of high-speed linear induction motors and development of the numerical control technique

Moshe Zakai
For contributions in the field of statistical communication theory

Stanley Zebrowitz
For contributions to the introduction of microwave systems in developing nations

* Deceased October 1973

Communications plans special issue

The potential benefits of two-way interactive broadband communications networks for the home, business, education, and other societal needs are receiving increasing emphasis and attention in North America, Europe, and Japan. In recognition of this emerging field, a special issue of the *IEEE Transactions on Communications* is being planned for 1974.

The special issue proposes to elucidate important technical factors that need to be considered, pilot and developmental systems and techniques, and social and economic considerations relating to new urban communications, broadband interactive networks, and cable television.

Papers are sought in the areas of new techniques; new applications of technology; measurements, standards, or engineering practices; system design and analysis; computer applications and software; and emerging teleservices. Manuscripts, prepared in accordance with the "Information for authors" that appears on the inside back cover of the *Transactions* should be sent to the editors, William F. Utlaut and Richard C. Kirby, at the U.S. Department of Commerce, Office of Telecommunications, Institute for Telecommunication Sciences, Boulder, Colo. 80302. Preferably, they should be received by May 1, but no later than May 30, 1974.

Microfiche format reduced

Beginning with the 1974 issues, IEEE publications on microfiche will be issued in a modified format.

To conform to the standards of the National Microfilm Association, a maximum of 98 pages each has been set. Also, the page size is reduced by a factor of 24 rather than the present 20. However, the 20× lens in current viewing equipment can still be used. The new format is being adopted by most publishers of microfiche and by U.S. Government agencies.

hoped for at the proposal stage, and, furthermore, one cannot always afford to employ the newest technologies in producing the system. What stays and what goes is largely the province of the project manager.

Under DTC, Mil Spec compliance should be secondary, or at least judged on a product by product basis, some of its proponents insist. As a bad example, they cite the case of the ILS spec'd to work at 70 000 feet.

EASCON panelists also observed that DTC unit costs cannot be met if the manufacturer cannot get down on the learning curve for reasons of low production, or frequent revisions.

VI. A commercial lesson

The DTC task force underscored lessons to be learned from commercial practice. For example, it noted that in commercial practice, a look at costs is an inherent part of business planning—based on the elasticity of demand with price, along with price of competitive products—factors which do not exist in the DOD requirements process. Acknowledging that the concept of continuing tradeoffs between cost and performance has been introduced in a limited way into the DOD systems acquisition process, the task force said that even when tradeoff decisions cannot be made, "an attempt should be made to establish tradeoff reationales and criteria as an integral element of military requirements formation." Such an attempt, the task force report went on, "would provide a basis for subsequent cost/performance tradeoffs by the program manager and the contractor in later phases of system acquisition. Ordinarily, such an approach would mean that no military requirements would be issued in final form until there had been two or three iterations (based on tentative or draft requirements) of exchanges between requirements agencies and development agencies .... assisted by contractor studies and proposals."

Further, the task force noted, in commercial practice, competition begins with program commitment and continues through the production-life cycle of the product. The opposite generally prevails in the defense industry, where competition is high *before* program commitment, but tails off after program award.

To spur competition, the task force endorsed, for selected instances, the DOD presently limited practice of asking for competitive prototypes. It cited the AWACS radar program as an example of that technique successfully applied. In that case both Hughes and Westinghouse competed vigorously to the point of incorporating hardware changes to peak up performance in a given flight-test time frame. The prime contractor, Boeing, reported that, as a result of the competition, in a matter of weeks instead of months both companies made significant improvements.

The end result was that Hughes was able to increase the dynamic range of the system and incorporate a new mode which permitted operation in the large main beam clutter found in the Northwest. Also, Westinghouse added a new stalo with improved stability and changed the PRF to cope with the large main beam clutter and altitude line problems. Boeing concluded that without the competition the cost could have been as much as $100 million more for a system providing 25 percent less performance.

VII. The program manager

With regard to program management, the task force focused on the inadequate authority of program managers, and the scarcity of "dedicated" high-level people from the participating organizations. The biggest difference between the commercial and defense program manager, it noted, appears to be the industrial manager's freedom to act without lengthy precoordination, especially on a strictly commercial project. To illustrate the point, it cited the industrial situations in which the pressure of continuing expenditures against committed schedule milestones generates an urgency for prompt and decisive redirection in problem areas. The task force report said: "The Governmental program manager is seldom able to match his industrial counterpart in reaction to the unforeseen and may not be able to get the necessary approval for proposed redirections in time to avoid unnecessary overruns or schedule slides."

Further note was taken of the heavy staffing that DOD requires to defend itself against "attack from the sociopolitical environment." And, it added, the heavy burden on the program manager to verif performance often precludes the proper emphasis on cost reduction. The Government program manager is burdened with specifications and paperwork.

In contrast, the DTC team noted, in industry, documentation is held to a minimum.

VIII. Concentrating authority

In commercial practice, management teams are usually kept as small as possible. This permits close communication among members, as well as with top management and with the customer. But in DOD procurement, the DTC task force pointed out, project authority rests principally in documentation, and only secondarily on a project manager with a large assigned team. The biggest "evils" from "management by document," the DTC team's report concludes, are rigidity and overstaffing. Instead, DTC would cut back on DOD staff who are generally inexperienced in the specific project area, and instead rely on the commercial contractor's abilities and recommendations concerning their product's development and production.

The Federal Aviation Administration was given as an example of how such a system would function. By law, the FAA can delegate to qualified private individuals (including employees of aircraft manufacturers) certain functions relating to the examination, inspection, testing, and issuance of certificates.

IX. Qualifications

The DTC concept as proposed by the task force must be considered as still in its infancy. Questions of implementation and interfacing with existing techniques, such as total package procurement must be thrashed out. As stressed by the EASCON panel, accounting systems must be designed to provide the maximum visibility from which to make tradeoff decisions.

Rear Admiral David Webster, Director, Ships, Weapons, and Electronic Systems, said a poor accounting system could kill DTC. Many procurement specialists believe that dollar rewards and penalties are a must to assure vendor responsibility for life cycle performance.

Finally, it should be noted that semantic disagreement does exist regarding DTC. Some feel that "design-to-price" would be a more appropriate phrase. Others say it's merely a matter of viewpoint—whether you are the vendor or the customer. In any event, whether DTC (or DTP) becomes more than a buzz word remains to be seen.

Donald Christiansen, Editor

New solid-state circuits

A 500-kb bucket brigade scanner and a 4-watt audio amplifier are but two of several promising new developments

Good indicators of what's ahead in solid state are found annually at the International Solid State Circuits Conference. The 1974 meeting, to be held next month, is no exception. The program reveals a healthy crop of R&D spectaculars, yet more than half of the papers deal with conventional design, processing, and fabrication techniques. One member of the technical program committee, IBM's David Pricer, characterized the conference climate: "Last year we presented ideas and this year we are trying to make them practical." In preparation for producing this special report, *Spectrum* talked with several ISSCC session chairmen to gain an insight into the developments that will be detailed at the conference.

New fabrication methods

A significant new process development is the application of JFET and MOSFET technology (until now the spearhead of *digital* LSI) to *linear* ICs. Although the idea is not new, the recent interest has been aroused by new processing methods, such as ion implantation, that make the combination of bipolar and FET devices practical. Interest is especially strong in A/D and D/A converters, operational amplifiers, and signal processing. Four of six new op amps to be described involve FET-bipolar combinations. Among new developments: a fast PMOS bipolar op amp with on-chip trimming, that draws less than 10 pA input current and develops an offset voltage comparable to that of bipolar amplifiers; a low-offset, wideband, fast settling, FET-input op amp and a high-speed, quad analog switch, both using JFET-bipolar technology; and a FET-input op amp having feed-forward compensation, which provides a drift rate of 1 μV/°C, input current of 25 pA, and a slew rate of 15V/μs.

Although the digital world seems to be turning away from PMOS to NMOS technology, PMOS seems to be advantageous in MOS-bipolar combinations. PMOSFET and PJFET devices offer P-type polarity which permits them to replace PNP transistors for complementary symmetry configurations (the equivalent of PNPNPN).

The advantages of PMOSFETs or PJFETs over PNP transistors in linear devices include much reduced input currents (due to low gate leakage), order of magnitude improvements in slew rates, and wider bandwidths. The slew rate improvements occur because FETs have an inherently lower transconductance than bipolar devices at similar currents.

A new approach to bipolar logic is integrated injection logic, a circuit technique in which a lateral PNP transistor is used as a bias source for NPN transistors. The advantages are that it can be operated by a single power supply and the narrower spaces between active areas make the entire chip surface available for wiring. Packing densities of 400 gates/mm^2 and speed-power products of 0.13 pJ are projected for these circuits. The use of oxide isolation of these structures help optimize their speed-power performance.

Another radical design innovation is increasing use of diffusion areas whose functions may vary from one moment to the next, although the geometry does not change. For example, a given diffusion island may be the collector of a lateral PNP device in one mode of circuit operation, and later may take on the role of the emitter of another lateral PNP transistor. This functional change is achieved by varying the bias on the input nodes. One way this may be accomplished is by saturating a transistor that is already turned on, thereby causing the collector to become forward biased and to act as an emitter. Similar circuit techniques have been applied to small portions of ICs in the past, but a new current-hogging logic device makes extensive use of changing diffusion functions, with NOR, NAND, and complex gates having been created by switching the lateral injection currents within PNP structures. The resulting devices exhibit high densities and high noise immunity.

Charge transfer devices are being developed as photosensors and memories. Commercially available charge-coupled photosensors are presently limited in size to 100 × 100 arrays. A substantial improvement in related bucket brigade sensors has produced a 512- × 1024-bit scanner. Other developments include a three-phase polysilicon approach to building charge-

Gerald Lapidus Associate Editor

Getting the scoop firsthand

The 1974 International Solid State Circuits Conference will be held on February 13, 14, and 15 at the Marriott Motor Hotel, Philadelphia, Pa. Programs containing registration forms can be obtained by contacting Lewis Winner, 152 W. 42 St., New York, N.Y. 10036, or from the IEEE office of the Moore School of Engineering, University of Pennsylvania, Philadelphia.

The advance registration fee is $30 for IEEE members and $35 for nonmembers. At the conference, the rates are $35 for members and $45 for nonmembers. Each registrant will receive a digest of the technical papers, containing 800–1000-word summaries. Additional copies of the digest are available for $15 for members and $25 for nonmembers.

coupled devices; cascode MOS image sensors that produce a spike noise level significantly less than conventional MOS sensors; and JFETs as photosensitive elements for gain and nondestructive readout.

Are transformers returning to audio amplifiers? For more than nostalgic reasons, an IC audio amplifier has been built for use with an output transformer. The combination, designed for battery-operated equipment, can produce an impressive 4-watt output from a 9-volt battery. The reason for the transformer is to overcome the inherently low output voltages available in portable equipment. The supply voltage usually is so low, that it is difficult to produce enough power for even a low-impedance speaker. Since it is not possible to build practical speakers with sufficiently low impedances, the alternative is increasing the power by raising the voltage with the transformer. Also for audio devotees, a monolithic quadraphonic demodulator includes a complete carrier recovery system and audio mixing circuits.

LSI reaches out in new directions

The influence of LSI technology, once largely confined to computer logic and memory circuits is spreading. In the consumer field, LSI is appearing in the hand-held calculator and the electronic watch. A CMOS/SOS, crystal-controlled watch circuit exploits inexpensive, high-frequency, thermally stable, AT-cut quartz crystals. The circuit can operate at 1.4 volts at 4 MHz, while consuming less than 12 μW.

An example of the high level of integration possible on a single chip is a monolithic 16- × 16-bit multiplier consisting of 17 000 transistors and resistors on a 301- × 279-mil wafer. It can perform a multiplication in less than 350 ns.

In MOS memories, the long sought-after *nonvolatile read-write device* seems to be in the offing, heralded by a 2048-bit MNOS block-oriented RAM array. This device is indicative of the speed gains that have recently been made in MNOS, with a respectable cycle rate of more than 2 MHz. In addition, the device operates with only a 400-mW power dissipation.

> ### Airing the great controversies
> While the formal daytime papers at ISSCC delineate the facts about specific subjects, they represent the views of one or more speakers and they tend to play down discussions of competitive devices or technologies. However, free-swinging nighttime discussions have become a tradition at ISSCC, allowing the audience and panelists to debate their views. These meetings offer rare insight, beyond ballyhooed advertisements and formal treatises, by dealing with the problems, trends, and the competitive climate of the semiconductor industry.
>
> On the docket for Wednesday evening are five discussions: lithography and the device designer, microwave transistors, function shaping and generation, interface circuits, and the commercial reality of charge transfer imaging. Scheduled for Thursday are solid-state microwave power combining, the potential of MOS for linear applications, what's next in MOS technology, automotive electronics, and signal processing with charge-coupled devices.

CMOS also may emerge as a serious contender in static memory applications. A 4-kb CMOS/SOS chip yields better overall performance than dynamic memories, but is still expensive.

In bipolar LSI, a 200-gate ECL logic device has been built; it exhibits only a 1.5-ns loaded delay and dissipates 2.5 watts. Bipolar memories are also making rapid strides in packing density. The basic cell of a 1024-bit random access device is a compact, inverted transistor flipflop.

Microwave devices entering millimeter range

At the low end of the microwave spectrum, gallium arsenide (GaAs) FETs have enabled three terminal devices to be built in the X and Ku bands. They take up where the small signal performance of bipolar transistors falls off, at about 8 GHz. (High-power performance drops off at 5 or 6 GHz.) In the past year, the state of the art has advanced to the point where GaAs transistors now operate up to 16 GHz for small signal operation and 10 GHz for higher power signals. The newer Indium Phosphide FETs promise still higher frequencies, perhaps 25 GHz or greater. An advantage of semiconductors in this frequency range is that they bring with them low-cost fabrication techniques, replacing tiny waveguides.

Typical integration levels for hybrid, microwave ICs are much lower than the thousands of transistors per chip found in lower frequency devices. The design problems in integrating microwave transistors are both electrical and mechanical. Another difficulty is that since silicon microstrip lines function both as the active device and the transmission line, a good design for an active device usually makes for a poor transmission line, and vice versa.

New applications of integrated electronics

Medical electronics will benefit greatly from IC technology. Among the most important opportunities are implantable systems, percutaneous sensors, and transcutaneous sensors. In the diagnostic area, a real time, noninvasive, ultrasonic imaging system for observing cardiac structures and other internal organs has been built with custom ICs that include high-voltage, double-diffused MOS transistors.

In the communications area, notable progress is being made in increasing the message-handling capabilities of conventional telephone systems and in developing all-new types of systems. One method that holds great promise for increasing the capacity of existing lines is digital transmission. Such a system would require digital coding of voice signals. An integrated circuit designed for this purpose converts speech into 10 Mb/s digital code. The circuit uses a charge-parcelling integrator providing a 3-mV step size, to achieve greater than 11-bit resolution.

The devices described above generally are at least in the prototype stage and many are in or near production. But how far can the present technology go? Some observers believe we will be building the ultimate transistor in ten years. For example, they point out that attempts at greater miniaturization will face the problems of oxides so thin that tunneling currents will occur and junctions so close as to encounter immediate punch-through.

Applications literature

How to get large-scale integrated circuits at low cost

This 16-page brochure discusses the integrated circuits industry and the economics of producing MOS/LSI circuits.

Cost factors in systems design are analyzed, taking into account capital investment as well as production costs. The alternatives of custom or standard LSI are presented and weighed. The procedure and costs for obtaining custom MOS/LSI circuits are given.

Production processes for fabricating MOS/LSI circuits are described, including the structural sequence in the fabrication of silicon gate mosaics.

The brochure is published by Mosfet Micro Labs, Inc., Penn Center Plaza, Quakertown, Pa. 18951.

Circle No. 43 on Reader Service Card

Basic amplifier error sources are explained

The four most important sources of instrumentation amplifier errors are explained in detail in this 12-page brochure.

Common-mode rejection errors are discussed as functions of frequency, amplifier gain, and common mode voltage. Temperature stability is related to gain and zero shift values are shown, relative to input and output. Pumpout current, a commonly misunderstood performance parameter, is explained and related to temperature, source resistance, and signal amplitude.

The brochure is published by Preston Scientific, Inc., 805 East Cerritos Ave., Anaheim, Calif. 92805.

Circle No. 44 on Reader Service Card

Characteristics of lossy-ferrite feed-through filters

Equivalent circuits, performance characteristics, specifications, and construction details are given for miniature lossy-ferrite feed-through filters in this 4-page data sheet.

Inherent electrical properties of the one-piece titanate devices are explained. Performance curves include insertion loss vs. frequency, load current, and temperature.

The information is published by Capacitron Division of AMP, Inc., 1595 South Mt. Joy St., Elizabethtown, Pa. 17022.

Circle No. 45 on Reader Service Card

Basic information on ion-implanted semiconductors

Operating characteristics of several types of ion-implanted semiconductors are described in this 14-page catalog.

Electrical parameters are defined for the devices and detailed characteristics are given for hyperabrupt tuning diodes. PIN radio-frequency switching diodes intended for control application are also described.

Mounting methods for hybrid circuit chips and leadless inverted devices are discussed, including necessary assembly procedures.

The catalog is published by KSW Electronics, Inc., South Bedford St., Burlington, Mass. 01803.

Circle No. 46 on Reader Service Card

Principles of electrodes for chemical-sensing applications

Six different types of electrodes for chemical analyses are described and discussed along with an extensive presentation of analytical procedures based on the use of these devices, in this 32-page guide.

Methods are outlined for analyzing a wide variety of organic and inorganic substances using electrode technology. For each substance, the type of electrode and specific analysis method is listed. An extensive bibliography documents the listed techniques.

Applications in many fields are discussed, including air-pollution control, food processing, and water analysis.

The guide is published by Orion Research, Inc., 11 Blackstone St., Cambridge, Mass. 02139.

Circle No. 47 on Reader Service Card

Mechanical and solid-state switch applications

Equipment applications of various types of switches are explained in this 8-page note. Included in the specific application examples are controls for a Japanese heat-treating furnace, an automated audio tape carousel, a punched-tape rewinding system, and a hobbing machine. Operation of several types of solid-state, Hall-type switches is explained. These can be actuated by permanent magnets or electromagnets, and lend themselves to many applications.

The note is published by Micro Switch Division of Honeywell, Inc., 11 West Spring St., Freeport, Ill. 61032.

Circle No. 48 on Reader Service Card

Fundamentals of protective relay practice

This reference book covers many aspects of protective relays for power generation and distribution networks. Covered are the basic technology, fault calculations, and fundamentals of protective gear.

Compiled by engineers, the book also describes applications of protective relays in detail. It includes material on transformer, generator motor, and pilot wire protection, distance relaying, power line carrier, auto-reclose schemes, bus zone protection, as well as a chapter on testing and commissioning and relay application charts.

The book, available without charge to senior engineers, is published by the English Electric Corp., 500 Executive Blvd., Elmsford, N.Y. 10523.

Principles and techniques for modular power supplies

This 20-page handbook covers the fundamentals of modular power supplies for electronic systems, and discusses specific problems in various types of power supply applications.

Six fundamental power supply circuits are diagrammed. Combinations of these circuits, assembled to perform various functions, are described.

Application areas covered by specific discussions include: computer power supplies, process actuators, light controls, servo drivers and speed controls, temperature controls, ultrasonic generation, portable instruments, aircraft systems, electrooptics and photoelectronics.

The handbook briefly covers several general design considerations, including series-parallel combinations of supply elements, extension of input and output ranges, restrictions on frequency range and impedances, transients, and noise.

The handbook is published by Powercube Corp., 214 Calvary St., Waltham, Mass. 12054.

Circle No. 49 on Reader Service Card

Spectrum's Literature Review

To receive these items, circle the indicated Reader Service Card numbers. **Multiple pushbutton switches,** Switchcraft, Inc. [111]; **Solid-state pilot relaying systems,** Westinghouse Electric Corp. [112]; **Mobile communications applications,** Motorola Communications and Electronics, Inc. [113]; **Conductive elastomeric liquid crystal interconnector,** Technical Wire Products, Inc. [114]; **Low-current switch catalog,** Standard Grigsby [115]; **Resistor-capacitor test systems,** Teradyne, Inc. [116]; **Applications of magnetic fluids,** Ferrofluidics Corp. [117]; **High-purity materials,** Materials Research Corp. [118]; **Thermistor applications,** Thermistor Div., Keystone Carbon Co. [119].

New product applications

Minicomputer printer-plotter uses high-speed electrostatic imaging

According to Peter A. Highberg, Manager of Printer Products at Gould, Inc., very high output speed is the chief advantage of an electrostatic printer-plotter because speed means that plotting, as well as printing, can be done on-line to the host computer. Quick transfer to the printer-plotter data permits a minicomputer to return immediately to other tasks.

Although impact printers now dominate the computer peripheral market, it is doubtful whether this equipment will be able to meet future needs. Three thousand lines per minute appears to be the limit for impact printers, a speed attained after many years of engineering effort.

Since it is far easier to move an electric charge than a mechanical mass, electrostatic printer-plotters are now achieving speeds of nearly 5000 lines per minute for alphanumerics and 10 inches per second for graphics; a plot that would take a pen plotter 15 to 30 seconds can be output in just two seconds.

Low cost in initial purchase and maintenance is a second advantage that makes an electrostatic printer-plotter particularly attractive to minicomputer users. A 1200-line-per-minute electrostatic printer-plotter like the Gould 5000, priced at $7500, is about one tenth the cost of an 1100-line-per-minute impact printer like the IBM 1403-NI.

Wide choice in character style and size is a third major advantage of electrostatic printer-plotters. Weather symbols, foreign alphabets, and other special character-sets, are easily obtainable under software control or may be permanently fixed in hardware character-generator form. Shifting from engineering symbols to English, for example, is easily accomplished on the same page of output without manual operator intervention. The Gould 5000 offers 64 ASCII characters with the standard unit; the full 96-character ASCII set and an additional 128 characters are available as options.

Printer-plotter operation. In the electrostatic printer-plotter dielectrically-coated paper is charged by a row of stylii or wire ends. The Gould 5000 has 100 stylii per inch.

The paper is advanced to the toner head by a stepper motor operating at 80 or 100 steps per inch. Here the charged "dot" areas on the paper attract carbon particles, held in suspension in the toner fluid. Excess toner fluid is vacuumed off; and the paper emerges dry.

This electrostatic imaging process permits only one copy of the output to be printed at a time.

Choice of paper. The advantage of dielectric paper over the zinc-oxide paper used in some electrostatic copiers is that it can be made to feel like ordinary bond paper. Since the dielectric coating on the paper is not opaque, translucent-base papers may be used to obtain output that can be easily blueprinted.

Because of the similarity in texture, dielectric paper often is compared on a direct-cost basis with bond paper. Dielectric paper is plain paper that has been coated and obviously is more costly than ordinary computer paper—currently one to two cents more expensive. Paper used on pen plotters, however, is typically 2 to 10 times the cost of equivalent dielectric paper.

The Gould 5000 printer-plotter is produced by Gould Data Systems, 20 Ossipee Rd., Newton Upper Falls, Mass. 02164.

Circle No. 42 on Reader Service Card

Spectrum's hardware review

For more information on the following new products, circle numbers on the reader service card corresponding to bracket numbers.

5-Hz to 40-MHz digital counter, John Fluke Mfg. Co., Inc. [55]; **Isolation amplifier with adjustable gain,** Analog Devices, Inc. [56]; **Single-piece, multistation switch stations,** Electronic Engineering Co. of California [57]; **Phase-locked loop on a chip,** Plessey Semiconductors [58]; **50-, 60-, or 400-Hz frequency meters,** Simpson Electric Co. [59]; **Microwave transistor test fixture to measure S parameters and noise figure,** Wavecom Industries [60]; **3-terminal, 15-volt, 1-ampere voltage regulators,** Solitron Devices, Inc. [61]; **Anticipatory counter/controller,** Essex Engineering [62]; **Digital position controller,** Dynapar Corp. [63]; **Single and dual channel opto-coupled interrupters,** Sensor Technology, Inc. [64]; **200-ps sample and hold analog memory,** Optical Electronics, Inc. [65]; **Sunproof, infrared light operated limit switches,** Xercon, Inc. [66]; **NIM-standard timer-counters,** Ortec, Inc. [67]; **Model 214 palm-sized, dual trace storage oscilloscope,** Tektronix, Inc. [68]; **Miniature digital megohmmeter,** ITT Jennings [69]; **COS/MOS 4-bit arithmetic logic unit,** RCA/Solid State Division [70]; **12-volt citizens' band RF power transistors,** Communications Transistor Corp. [71]; **Logic-controlled traveling-wave tube amplifiers,** Hughes Aircraft Co. [72]; **Spark gaps for protecting circuits,** Signalite [73]; **CMOS logic modules,** Control Logic, Inc. [74]; **Dual 128-bit, MOS static shift registers,** Advanced Micro Devices, Inc. [75]; **Cable capacitance meter,** DCM Industries, Inc. [76]; **CMOS Timer stopwatch clock circuit,** Intersil, Inc. [77]; **Pushbutton actuated, fixed interval timer,** Bristol Saybrook Co. [78]; **Emergency latch type limit switches actuated by a trip cord,** R. B. Denison, Inc. [79]; **Portable RFI analyzer,** Singer Instrumentation [80]; **Pocket-size personal dosimeter for noise exposure,** Triplett Corp. [81]; **2-MHz sweep function generator,** Systron-Donner Corp. [82]; **High-voltage cable splice kit,** Zippertubing Co. [83]; **Thermocouple signal conditioner,** Ectron Corp. [84]; **Explosion-proof pressure transducers and transmitters,** Tyco Instrument Div. [85]; **Driver cards for step motor control,** Warner Electric Brake & Clutch Co. [86]; **UHF amplifier in micro-H package,** Motorola Semiconductor Products, Inc. [87]; **Elapsed-time indicator with stopwatch accuracy,** Veeder-Root [88]; **30-MHz function generator,** Wavetek [89]; **Silica yarn and cordage with 2400°F heat resistance for thermocouple wire braiding,** HITCO Materials Div. [90]; **Clip-on wattmeter,** Epic, Inc. [91]; **1.5-inch end-on photomultipliers,** Emitronics, Inc. [92]; **Insitu current meter equipped with a digital recording module,** Hydro Products Div. of Dillingham Co. [93]; **Rapid reset thumbwheel switch,** AMP, Inc. [94]; **Adjustable deadband voltage/current alarm,** Rochester Instrument Systems, Inc. [95]; **3⅝ inch square tube axial fan,** Amphenol Sales Div. [96]; **Self-latching magnetic reed memory matrix,** C. P. Clare & Co. [97]; **Digital phase shifters designed for TTL logic control,** Merrimac Industries, Inc. [98]; **Spacer for cables or hydraulic hoses,** Panduit Corp. [99]; **1000° F pressure measuring system,** Kaman Sciences Corp. [100]; **Liquid crystal display event counter,** Digilin, Inc. [101]; **Blue-sensitive silicon detectors,** Vactec, Inc. [102]; **60-pair surge arrester holder,** Telecommunications Industries, Inc. [103]; **Teflon insulated phono type jack for high-frequency applications,** Sealectro Corp. [104]; **0.25-percent, four-quadrant multiplier/dividers,** Teledyne Philbrick [105]; **Solid-state, single-shot timer,** Syracuse Electronics Corp. [106]; **Low-VSWR-impedance matching transformers,** Technical Research and Manufacturing, Inc. [107]; **"Zero-force" sockets,** Cambridge Thermionic Corp. [108]; **Programmable function generator,** Krohn-Hite Corp. [109]; **$195 three-digit multimeter,** Ballantine Laboratories, Inc. [110].