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articles

departments

the cover

The "readout" itemizes topics covered in this special issue, which is devoted to a review of technology in the major areas of interest to EEs.

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spectral lines

Rasmussen revisited

More than 1800 pages of comments from 87 individuals and organizations were received in response to the issuance of the draft report of the Reactor Safety Study, known popularly as the Rasmussen Report. (The study was directed by M.I.T. Professor Norman Rasmussen with a team of 60 participants.) In the August 1975 issue, *Spectrum* published an article by Professor Rasmussen in which he analyzed findings of the report. (A sampling of comments relating to that article appears in Forum, along with Professor Rasmussen's reply.)

The comments on the draft report were reviewed and considered by the study group as it put together the final report, which is now complete.

The objective of the study was to estimate the public risks that could be involved in potential accidents in commercial nuclear power plants of the type now in use—namely, pressurized water and boiling water reactors.

The principal accident considered in the study is the core (fuel) melt. To melt the fuel requires a failure in the cooling system or the occurrence of a heat imbalance that would permit the fuel to heat up to about 5000°F (2760°C). Thus, a loss-of-coolant accident, or any of several conditions classified as "transients" that would require reactor shutdown, could lead to a core melt.

In the final report, the likelihood of a core melt is calculated to be about one in 20 000 per reactor per year (as compared with one in 17 000 estimated in the draft version), so that in the case of 100 reactors nationwide (projected for 1980), the chance is one in 200 per year. The study also estimated, by calculation, the health effects and the probability of occurrence for each of 140 000 possible combinations of magnitude of radioactivity release, weather conditions, and population exposed. As a result, the probability of an accident resulting in ten or more fatalities was determined to be about one in 30 000 for a group of 100 similar plants. The probability of accidents causing 1000 or more fatalities is calculated to be one in one million per year.

The least likely core-melt accident, for a single reactor, was determined to have a probability of occurrence of once in one billion years of operation; the fatality estimate for this occurrence is 3300, up from 2300 in the draft report. The estimated number of early illnesses resulting from an incident of this magnitude is 45 000, up from 5600. The corresponding estimate for property damage is $14 billion, up from $6.2 billion. The decontamination area for this least likely of situations is estimated to be 3200 square miles, up from 400 square miles. In the event of such an occurrence, the area from which relocation might be necessary is estimated to be 290 square miles, and agricultural products—milk, in particular—would have to be monitored for one or two months over an area about 50 times larger.

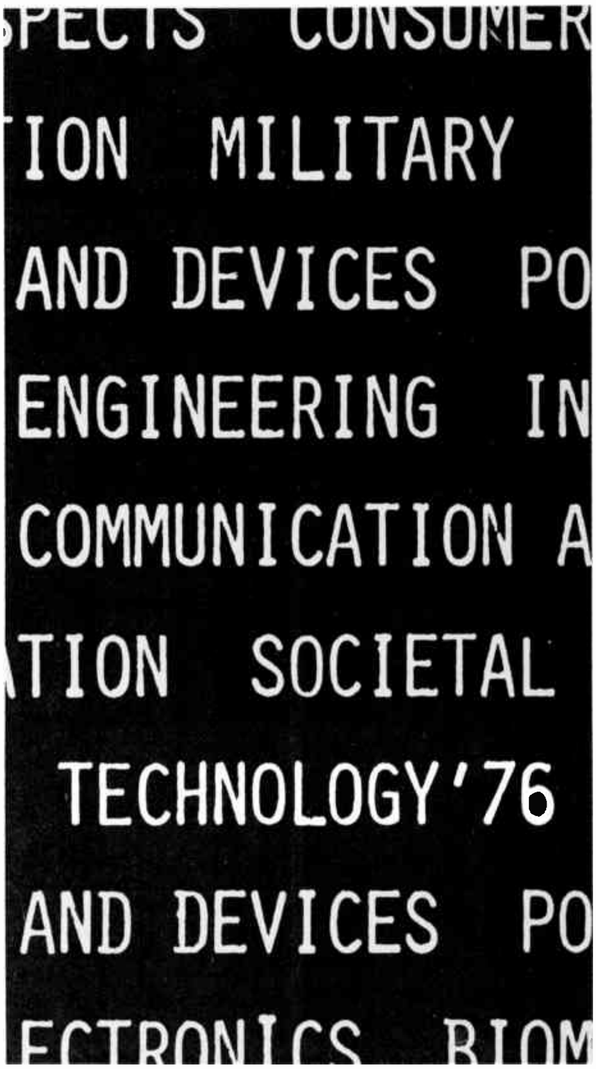
Those in favor of nuclear plants and opponents alike have urged comparisons of the likelihood and probable consequences of reactor accidents with those from other types of disasters, both natural and man-made. The study draws such comparisons, and concludes that, in terms of probable fatalities, the core-melt accident is comparable to that of a meteorite impact. For example, the probability of 1000 or more fatalities resulting from either is one in one billion years. This compares to one in 120 years for a man-caused explosion, and to one in 25 years for a hurricane. With regard to property damage, the most likely core melt would probably cause damage of less than $1 million.

Among the questions and criticisms raised in response to the draft report were those concerning the validity of the estimating methodology. The final report includes an addendum to the main body of the study that provides an overview of the study methodology. One question—"How do we know that the study has included all accidents in the analysis?"—was addressed specifically in the summary to the final report, with this reply: "The study devoted a large amount of its effort to ensuring that it covered those potential accidents of importance to determining public risk. It relied heavily on over 20 years' experience that exists in the identification and analysis of potential reactor accidents. While there is no way of proving that all possible accident sequences which contribute to public risk have been considered in the study, the systematic approach used in identifying possible accident sequences makes it unlikely that an accident was overlooked which would significantly change the overall risk."

Major tools used in the study were event trees and fault trees. An event tree defines an initial failure within the plant, then tracks its consequences through a series of events related to the satisfactory operation or failure of systems that are designed to prevent a core melt and the release of radioactivity. A fault tree determines the probability of failure of the various systems in the event-tree "accident path."

Two observations regarding the Reactor Safety Study are important. The first is that the study was hardly trivial. Carried out over a period of three years, the study involved a team of 60 people, plus consultants, 70 man-years of effort, and some $4 million. The second observation is that the report makes no attempt to judge the acceptability of nuclear risks, noting, in its summary, "The judgment as to what level of risks is acceptable should be made by a broader segment of society than that involved in this study."

Donald Christiansen, Editor



Applications review

Technology '76

State-of-the art and near-term-future developments as seen by the experts in the electrical and electronics industries

Just as the vacuum tube was at the heart of nearly all electrotechnology through the forties, as were the transistor and integrated circuit through the sixties, the core technology of the seventies, and perhaps beyond, seems certain to be the microprocessor. It is entrenched in applications that were merely hinted at a year or two ago, and is now insinuating itself into many unlikely corners of industry. In the report that follows, scores of experts, including numerous members of IEEE Groups and Societies, aided *Spectrum*'s editors in uncovering not only new applications of microprocessors, but new developments in a broad spectrum of electrotechnological applications that ranges across commercial, industrial, and Government areas. In this special issue, we attempt to emphasize present and near-term developments as opposed to long-term projections. Thus, existing hardware and software are referred to, and are further identified by manufacturer when to do so is significant.

A field of broad interest that has benefited from the microprocessor is that of instrumentation. Until now, the microprocessor has been exploited by instrument makers in a relatively straightforward way, to reduce the cost and complexity of test gear and to provide parameter conversion and store and recall features. But in the offing are a variety of applications in which the user can alter an instrument's stored program through external accessing of the microprocessor.

Microprocessors are used in instrument interfacing, as in the case of digital interfacing of programmable instruments, and they are serving as a stimulus to unify analog test subsystems using a common bus structure.

The microprocessor is penetrating industrial applications on a broad scale, bringing with it greater accuracy, along with reliability, and simplified maintainability. It is useful as either a programmable controller or as a dedicated processor. And on the consumer front, microprocessors are designed into a Singer sewing machine, air conditioners, and microwave ovens. In

Donald Christiansen Editor

the military, microprocessors are designed into complex electronics gear at key points to monitor its reliable operation.

As important as the microprocessor is, there have been equally important hardware and software developments in other areas.

Stand-alone computers for specialized applications such as hospitals, food wholesalers, and the construction industry are coming on the market, as are new small computers-in-a-terminal. One of the latter uses a 48-kb memory chip. Developments in mass storage systems permit on-line access to billions of bytes. Machines combining wide-tape and large-disk technology marry the fast access time and random retrieval capability of disks to the economy of tape.

Fault-tolerant computing techniques, once limited primarily to the military and aerospace industries, are making inroads into commercial areas: air traffic control, patient monitoring, and telephone switching. A trend to greater use of error-detection and error-correction codes is evident.

In communications, the most significant and promising discovery, perhaps, is that of the "optical transistor," or the direct amplification of laser beam signals. Although no practical devices have yet been constructed, it may become an important tool in the bag of the optical communications specialist. Meanwhile, RCA has made commercially available an aluminum gallium arsenide laser system providing a radiant flux output of 5–10 mW at 820 nm. Low-loss optical cable has been introduced by Corning, and low-loss connectors are promised.

In still another communications development, Bell introduced its Transaction II telephone for credit-card authorization and other electronic funds-transfer applications; it features eight-character display and hands-free operation.

Despite soaring material, labor, and fuel costs, progress was made in transportation. Limited revenue service is scheduled to begin over a segment of the Washington (D.C.) Metro, and new high-speed transit systems are under construction in several West German cities. A computer-controlled train guidance system has been designed by Siemens and placed in service in Cologne's rapid-transit system. And the FAA has initiated a series of tests utilizing acoustic pulses to determine the degree and nature of wind shear at JFK, Logan, and Dulles International Airports.

In the power/energy arena, the zooming costs of nuclear power plant construction may fuel the search for novel ways to finance such construction.

During the year just past, a short segment of gas-insulated underground transmission line became operational as part of the Bonneville Power Administration's network; construction of a 1100-kV UHV overhead test transmission line was begun in Oregon; in West Germany, preparations were made to undertake a demonstration compressed-air-driven turbine power plant for peaking use; and, in California, another off-peak project contemplates the employment of giant flywheels (a prototype flywheel that will be tested in a vacuum chamber at up to 25 000 r/min. is under construction).

Lightweight polymer/fiberglass insulators for UHV applications are undergoing continuing field tests; units for 800-kV use are planned for introduction this year. And during 1975, work continued on the Florida Power and Light Company's new high-pressure-ratio, high-performance, 100-MW industrial gas turbine.

Developments in the biomedical field worthy of attention include those in noninvasive medical imaging techniques, as well as in prosthetic devices and in electric stimulation devices for muscle activation and for the control of pain. Ultrasonic diagnostic procedures of a noninvasive nature are undergoing continuing development, as are procedures for the unambiguous evaluation of ultrasonically generated images.

In the semiconductor device area, developments abound. Progress in digital ICs tended to outpace that in linears. Digital designers' options have been expanded through new high-speed Schottky TTL and low-power Schottky TTL standard logic families, along with new I^2L and CMOS logic lines. A subnanosecond ECL line was introduced by Fairchild.

Memory specialists are preparing for the advent of bigger RAMs—16 kb perhaps—to provide even lower cost per bit. RAM developments emphasize faster access, too. RCA has come on the market with several low-power 1-kb CMOS/SOS RAMs.

In the display area, LEDs dominate, with inch-high digits available from several makers, and choices of red, orange, yellow, and green colors. Improvements in liquid-crystal displays have increased lifetimes up to 50 000 hours. And plasma-panel displays for point-of-purchase uses have been made more efficient and versatile.

In the realm of power devices, larger-diameter thyristor and rectifier units have been developed to handle multi-kVA industrial applications at fast (microsecond) switching speeds. Ignitrons and thyratron vacuum tubes may be displaced by a reverse-blocking thyristor introduced by Westinghouse. Some power transistors have attained speeds of 200 ns at 3-kV ratings, and Texas Instruments introduced a plastic package (for thyristors and transistors) capable of dissipating 65 watts at 100°C case temperature.

Scarcely to be overlooked are key issues involving the impact of technology on societal matters. Among those of major import during the past year were the use of satellites to extend education and health services, ground sensors for peace keeping, and legislation concerning a national energy policy.

The foregoing topics and many others are treated in the articles that follow. ◆

Computers: poised for progress

Microprocessors, memories, and fault-tolerant systems pace current developments

With the emergence this year of LSI and microprocessor-based, small, stand-alone systems, the computer industry seems poised to tap the vast small-business market. New prosperity seems just around the corner with two computers in every store and a calculator in every pocket.

Microprocessors promise as well to further automation, relentlessly replacing with machines ever-greater numbers of human workers on the production line. This time, it's the decision-making powers of the worker that are being appropriated—by computers-on-a-chip.

In more conventional areas of large computer system equipment, laser beam printers appeared last year, bringing the speed of printed output a bit closer to that of electronic processing. The past year was also an important one for progress in computer memories. Useful charge-coupled-device 16 000-bit memory chip units became available, and developmental 100-kb bubble memories were showing reasonable yields. Compact, high-density cartridge tape units were improving even as their costs dropped. And huge memories handling hundreds of billions of bytes became available from more than one manufacturer. To cope with the design of larger and larger information files, the new discipline of data base engineering emerged, bringing with it new ideas about data-independent techniques.

Beyond their established applications to military and aerospace computers, fault-tolerant techniques were finding increased use in commercial communications and control systems, and in general-purpose computers as well. Meanwhile, there has been a major casualty in the computer network communications field—its first—and this may presage future data communications battles.

Computer software specifications were becoming more precise, and were themselves being machine processed, as computer languages for specification emerged. For minicomputers, readily altered extensible languages promise to become the standard programming vehicles, while universal compilers allow a single program to be run on a variety of different machines.

Overall, this past year's computer developments seem once again dominated by the large-scale integrated circuit and its most pervasive embodiment—the microprocessor.

Announcements of small systems tailored for the end-user and matched to his problem environment seemed to be increasing during 1975, with the trend apparently moving toward an ever-broader variety of applications packages that can be used by novices—that is, users who are not skilled programmers.

Howard Falk Senior Editor

Computers for every man

In recent years, companies such as Basic 4, NCR, Burroughs, Datapoint, Singer, and Wang have introduced stand-alone computers serving specialized market areas. NCR and Burroughs have dominated this market, but with the announcement of its System 32, IBM has become a serious contender for the small business market. System 32 includes a processor with 26 kbytes of main memory, a typewriter keyboard, a 240-character CRT display, a diskette drive, a nonremovable disk of either 5.1 or 9.1 million bytes, and a printer. System 32 may be connected to a larger host via either the synchronous data link control (SDLC) procedure or the binary synchronous communications (BSC) procedure. Its software is tailored for specific business segments such as hospitals, wholesale food, wholesale candy and tobacco, hardware goods, and construction. Industry experts believe that within a decade, there will be more placements of this machine than any to date.

For those who need to handle remote data, Raytheon Data System recently announced the PTS-1200 system that combines a 64–128-kbyte programmable processor with CRT terminals, a Centronics printer, and Diablo disks. Up to 24 PTS-1200 CRT stations can be connected in clustered fashion, each terminal capable of displaying up to 1920 characters and

Touching some new data bases

Just emerging into prototype stages are five different approaches to data base modeling. These approaches deal with the properties of the data itself, rather than with conventional memory and access hardware arrangements.

Data base task group (DBTG) approach. Based on the work of a task group of the Conference on Data System Languages (CODASYL), and influenced by C. W. Blachman of Honeywell, Inc., this approach treats records in the data base as parts of an interconnected network. Each record-type is either a "member" of another record-type or an "owner" of another record-type. These owner–member relationships (which can be arbitrarily defined, but must be consistent) trace the access paths of the data base. Proper navigation through the sea of records requires that the user have a thorough knowledge of the owner–member relations involved. DBTG-type prototype systems have reportedly been developed by Sperry-Univac, Burroughs, and Digital Equipemploying a standard typewriter keyboard with numeric pad. Like Four Phase's system offering, the PTS-1200 can communicate with large IBM host computers. Target industries for this system include airlines, travel firms, communications firms, banks, financial institutions, and government agencies. The software includes edit data entry, file retrieval routines, and a language called Macrol.

Advances in LSI technology have made possible a number of new small computers-in-a-terminal. One of the most notable of these is the IBM 5100, a compact unit that includes a typewriter-like keyboard, a 5-inch diagonal CRT with 1024-character display capability, and a tape drive for a 204-kbyte cartridge. Main memory for the unit includes read-only storage provided by a 48-kb n-channel memory chip. This is the highest-density ROM currently known to be in use. Two interactive languages, APL and Basic, are offered together with special IBM application program packages. The business and financial library consists of programs written in Basic and they perform functions such as return on investment, lease vs. purchase analysis, and cash flow studies. The engineering user is provided with a statistical and math library, available in either Basic or APL, that includes programs for elementary statistics, nonparametric statistics, calculus, and functional analysis. A similar machine, the Tektronix 4051 personal computing system, has an 11-inch CRT with a 2520-character display and a 300-kbyte tape cartridge as well. Basic is the standard software language supplied, along with other firmware, on a 32-kbyte ROM. Applications programs now include mathematics, statistics, advanced graphics, and electrical engineering packages.

In the areas of data entry and accounting, NCR has introduced a CRT terminal, the 7200, that employs the Intel 8080 microprocessor. And Burroughs has provided a typewriter-style unit known as the "Audit Entry" AE501 that uses LSI/MOS circuits. These systems provide computing capability for stand-alone use without requiring connection to a central computer. They are indicative of a trend to supply an increasing amount of computation ability for business and scientific users on a "hands-on" basis. If expanded processing capabilities are required, optional communication interfaces may be purchased to interface these units with a large computer.

Computers in a terminal

Chicken-choosing microprocessors

With the advent of microprocessors, automation has launched into a new phase in which the decision-making production worker is being replaced. For example, a microcomputer now automatically performs a chicken-selection task that was formerly a matter of human judgment. Supermarkets receive their chickens in large boxes, each of which contains 65 pounds of the birds. To avoid short-weighting the supermarkets, the chicken packinghouses have been employing workers who handpick the last few birds in each box, thereby ensuring a total weight greater than or equal to 65 pounds. Now, a microcomputer-based system checks the weights of the individual chickens as they come down the packinghouse assembly line, and sorts the chickens in order to place the correct weight in each box. The result has been a better job of minimizing the amount of extra weight (over 65 pounds per box) delivered.

Use of distributed processing on a new scale—involving groups of microcomputers—has become a strong trend in military computer designs. For example, a current navigation computer design is likely to include about ten microprocessors, each dedicated to performing a separate and highly efficient part of the overall navigational computation. When problems can be broken into pieces and solved in this way, the loss of one of the microcomputers needn't completely disable the computation, which can continue—albeit at some degraded level of efficiency—despite the part failure. Use of a microprocessor to check the operation of a computer system, or of large amounts of electronic gear, is becoming fairly standard practice in designs of new Naval equipment. This type of monitoring is being applied to the operations of entire ships, monitoring such functions as damage control.

In a stunning merger of the very small and the very large, IMS Associates Inc. announced that it has com-

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ment Corp. in the U.S., as well as by many European computer companies.

Relational approach. In these data base systems, a record is conceived of as an instance of an n-tuple expression like the 4-tuple named *personnel* whose attributes are: *name, salary, height, and weight.* Complicated relations contain attributes that are the names of other relations; simple relations contain only values. Simple relations can be manipulated by such operators as *join* and *projection*. Complicated relations may be broken down into simple ones by a process called normalization. This work was originated by E. F. Codd. The largest relational data-base implementation effort is System R at the IBM Research Center in San Jose, Calif.

Set-theoretic approach. As in relational models, the set-theoretic approach represents record-types with mathematical notation. However, the conventional set operations, such as union, intersection, and complement, do not seem to be sufficient for data base manipulation, so new set-theoretic operations are being developed. This work is being performed mainly by D. L. Childs at the Set Theoretic Information Systems Corp. in Ann Arbor, Mich.

Attribute-based approach. Orginated by David K. Hsiao, this approach deals with relations between unit records. It is expected to be useful in studies of data bases compartmentalized for security reasons, and of data clustering for reduction of memory paging. In addition, it is expected to be used as a tool for the design of data base record organization, file structures, access and update algorithms, and garbage collection algorithms.

Entity set approach. This is a multilevel approach; originated by M. E. Senko at the IBM Research Center in Yorktown Heights, N.Y. The highest level, concerned with names and intrinsic relations of the data entries, is data-independent. Other levels deal with logical and physical representations.

Huge microprocessor arrays

bined many Intel 8080 microprocessors to form huge computers, capable of true parallel operation. The largest of these—the Hypercube IV—uses 512 8080s. Observers believe that machines of this type may effectively reduce the top-heavy burden of system management that cripples many large systems. In addition, the machines promise to simplify problems of file security and privacy. Unfortunately, observers believe that software for these systems still leaves much to be desired. One severe unsolved problem is to devise protection against the possibility of a cancerous growth of errors. An error in one subsystem can rapidly spread throughout the entire system, resulting in overall collapse. Adequate methods for error recovery have yet to be developed.

Although microprocessors have been behind many of the most exciting developments in the computer field, there have been oustanding developments in other areas as well.

Laser beam printers

Printing 13 360 lines per minute

Following the 1973 introduction of the Xerox 1200 optical character generator computer printing system, IBM and Canon announced electrophotographic printing systems in which print lines are generated by scanning a modulated laser beam across a light-sensitive drum surface. The IBM unit, called the 3800, is capable of printing speeds of up to 13 360 lines per minute at 8 lines/in or 10 020 lines/min at 6 lines/in. Characters may be of different sizes and font styles, and the customer can design his own characters using a utility program. A forms overlay feature enables users to optically merge such constant data as report forms with printed material. The Canon LBP-4000 has similar features, but the print speed runs from 2000 to 4000 lines/min. Three different character sizes may be generated with either 136 or 272 characters per line at 66 or 132 lines per page. With both of these systems, print speed is dramatically faster than with electromechanical printers, and yesterday's oversized 11- by 14⅞-in form can now be reduced to a more standard 8½- by 11-in page.

Recognition and robots

Pattern recognition based on statistical and linguistic approaches is now widespread. In the form of character recognition, it is implemented in commercially available systems that read printed, typewritten, and handprinted characters, and is embodied in equipment such as post office machines, bank check readers, credit card readers, and Social Security and income tax form readers. In the area of picture recognition, research and development activities have concentrated on software for such applications as automatic image interpretation of data gathered by remote sensing, machine classification of chromosome patterns, cell images, X-ray pictures, fingerprint patterns, and simple three-dimensional objects. Recently, speech recognition and understanding have been receiving more intensive research attention.

In the field 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 a particularly important trend to watch, as robots may help increase productivity and relieve workers from dehumanizing tasks on the one hand, but may cause transitional unemployment and other undersirable side effects on the other.

Aided by rapid developments in new computer input-output devices for handling one-, two-, and three-dimensional patterns, and by the availability of compact and economical microprocessors, it is expected that the fields of pattern recognition and artificial intelligence will play an increasingly important role in the technology of the next decade.

K. S. Fu
Purdue University

Memorable progress

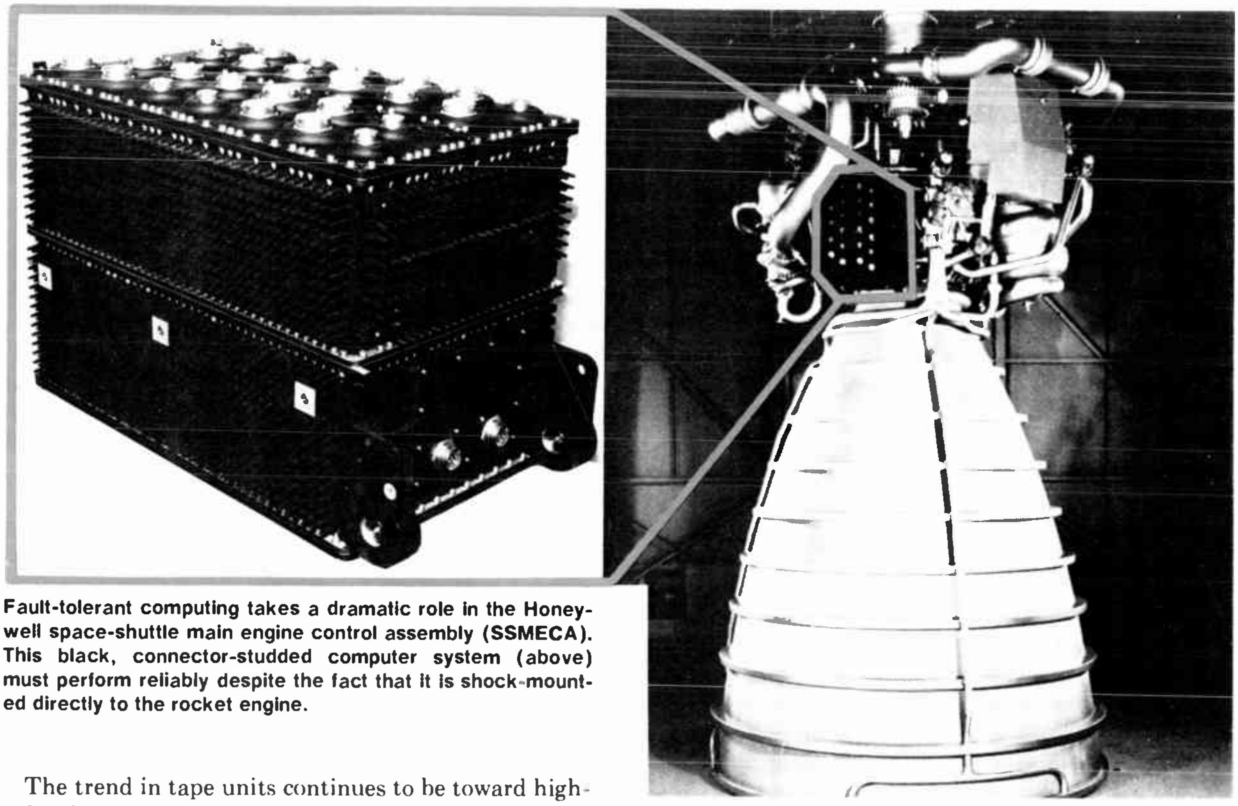
During the past year, the movement in semiconductor memories has continued toward devices with larger capacities on a chip. Production volume has continued to rise for static and dynamic semiconductor 1k and 4k memories, and there has been considerable discussion of 8k and 16k chips.

Faster CCD memories

Charge-coupled-device memories with 16 kb on a single chip were introduced by Fairchild Semiconductor and Intel. Unlike earlier CCD memories, these devices have sufficient speed to serve as extended main memories when operated in conjunction with a cache memory. These CCD devices seem best-suited for use in memories of up to a few million bytes of storage. They offer assess-plus-block-transfer times of 10–100 μs. Despite their virtues, however, it may be some time before CCDs replace small head per-track disks. CCD costs are still relatively high (although their per-bit prices in 1976 will likely be considerably lower than those of 4k semiconductor RAMs). Disk replacements will undoubtedly occur as CCD prices drop. Some say this can happen in 1976 but 1978 may be a more feasible target date.

Higher-density bubbles

The news about magnetic bubbles has been encouraging. Bubble investigators have been claiming for some time that photolithographic processing for bubble devices was simpler than that for semiconductor memory devices because of fewer masking steps. These claims have been discounted because bubble devices have required finer line widths for a given bit density than do semiconductor devices. However, recently discovered contiguous disk and bubble lattice propagating structures allow bit densities approximately 50 times greater than previous bubble structures, for a given line width. These densities are considerably greater than those achievable with present-day semiconductor memories. Developmental 100-kb Y-bar chips at Rockwell International, in Anaheim, Calif., have shown reasonable yields and these devices now promise potentially lower costs per bit than semiconductor memories. Meanwhile, disks continue to be a very viable storage technology, especially for microprocessors and small computers. The random access capability of these devices makes them very attractive when compared with serial tape media such as cassettes or cartridges. During the past year, several incremental enhancements have occurred. Shugart and Control Data have introduced a double-density recording technology that doubles the storage capacity of each disk. In addition, vendors like Shugart (Sunnyvale, Calif.) and Diablo (San Jose, Calif.) have introduced dual floppy disk drives in which two disks share a common spindle and the same read-write and positioning elements.



Fault-tolerant computing takes a dramatic role in the Honeywell space-shuttle main engine control assembly (SSMECA). This black, connector-studded computer system (above) must perform reliably despite the fact that it is shock-mounted directly to the rocket engine.

The trend in tape units continues to be toward higher bit densities and lower costs. For example, an Emerson Electric unit provides up to 153 Mb (1600 b/in) in each of its compact tape packs, while recording speeds are as high as 30 in/s. And the electron beam memory continues to contend as a large-scale memory entry. For example, the General Electric BEAMOS memory offers more than 30 Mb at a cost that makes it appear attractive—provided the user is willing to make the necessary high initial investment—as a paging drum replacement for large systems. Costs are projected in the 0.02 to 0.05¢/b range with 10–30-μs access times and 10–30-Mb transfer rates.

Billions of bytes

Mass storage systems

Mass storage systems that allow on-line access to billions of bytes now promise to revolutionize the storage and retrieval of large masses of information. First introduced about a year ago, the IBM 3850 system combines wide-tape and large-disk technologies to provide storage space for 30 to 236 billion bytes. This combination gives the fast access time and random retrieval capability of disks with the low price of tape. Each 3850 tape cartridge has a capacity of 50 Mbytes. The cartridges are stored in a honeycomb nest that not only serves as a receptacle, but also provides physical security. Control Data Corporation's mass storage system, the CDC 38500, provides a minimum of 16 billion bytes of data that may be placed under the control of up to four IBM system 370 computers.

Other mass storage offerings include Ampex's Terabit memory based on video recording, CALCOMP's automated tape library for mechanized access to standard magnetic reels, and International Video Corp.'s MMR.

Engineers move into data bases

Data base engineering is a new and rapidly developing field of computer technology, born out of the need to organize and manipulate economically ever-larger collections of data. Until just a few years ago, data base techniques were shaped by the specific storage hardware—disks, drums, cores etc.—used in a given system. Recently, data base models have been developed to allow a more thorough analysis and sophisticated understanding of data base management problems. During the past few years, some of the newer data base concepts (see box on pp. 4 and 5) have begun to take the more practical form of prototype systems, and, during 1976, more extensive use of these systems is expected.

Fault tolerance goes commercial

When a computer can consistently give correct results even when the system is defective, either the user is hallucinating or he has a fault-tolerant machine. The basic ingredient of fault-tolerant design is the use of built-in redundancy in the form of repeated calculation, added software, or extra hardware. Because of the extra costs involved, use of fault-tolerant techniques has been limited mainly to aerospace and military computers. But, commercial fault-tolerant systems, too, are beginning to make their appearance. Fueled by the availability of low-cost LSI hardware and the growing need for improved reliability and maintainability, systems for air traffic control, hospital patient monitoring, and telephone switching increasingly use fault-tolerant techniques. The art of designing and producing fault-tolerant computers is still a growing one, encompassing fault detection, fault diagnosis, and fault correction.

Error-correction for memories

One current trend in fault detection and diagnosis is increased use of error-detection and error-correction codes. For example, correction of memory data using codes is now available in minicomputers such as the

Data General Eclipse; and an LSI circuit from Fairchild is available for implementing the cyclic redundancy check for serial data in disks, cassettes, and data communication systems. A second trend is the use of design aids for test generation and hardware modification to simplify fault diagnosis. As an example, the Bell Laboratories LAMP (logic analyzer for maintenance planning) system is a set of programs that provides capabilities for design specification, logic simulation, and automated test generation. In their oil drillship automatic station-keeping system, Honeywell, Inc., uses a dual redundant minicomputer controller. Both controllers operate in parallel, one operating online, the other in active standby.

Redundant computer designs

The Honeywell and Bell systems are designed and programmed to perform specialized tasks. In such systems, intimate knowledge of the task at hand allows for special techniques such as the use of other codes to check the integrity of code segments. When fault-tolerant techniques are employed in general-purpose computers, these techniques must be transparent, in the sense that the user is able to program the fault-tolerant machine in the same way as any ordinary computer. A variety of techniques are used. For instance, at Sperry Univac such methods as data integrity checks, duplication and comparison, error-detecting codes, reasonableness checks, bound checks, and stall checks are used. In the IBM System 370/168 Multiprocessor, most instructions are retried automatically by the hardware if a failure is detected during execution; the redundant interconnected nature of this system permits it to survive serious hardware failures.

Space Shuttle computers

A number of new fault-tolerant systems for military and aerospace applications are in their final test stages, or have been recently delivered. For example, field operational data for a rugged computer, built by the Defense System Division of Sperry Univac, indicate a deployed mean time between failures (MTBF) of over 14 000 hours. To achieve this level of reliability, the entire machine is cycled through various environmental conditions, and this overall burn-in process is preceded by component screening and burn-in to eliminate marginal parts.

Honeywell is building a digital automatic flight control system, to be used in the Swedish JA 37 Viggen Interceptor. To achieve fail-safe operation in this single-channel system, conservative design philosophy was used along with highly reliable parts to insure low failure rate, and large amounts of in-line monitoring and self-testing capability were designed into the system.

Specification languages

Hardware redundancy is featured in the Sperry Univac Microprogrammed Controller II to allow total observation of the internal machine state as well as the loading of its microinstruction register and microprogram counter, thus to facilitate program-controlled diagnosis. Multiple paths for loading microdiagnostics and kernel hardware integrity check are provided. Input–output channels in this machine can be looped back on themselves to enable testing under microprogram control. A single-error-correction double-error-detection Hamming code is used on the semiconductor RAM memory. Finally, macrolevel instructions have been added to the machine to enable direct accessing to the memory error logging array and the check bits of each memory word.

Now in the final stages of testing is a five-computer system that will serve as the core of the Space Shuttle's integrated avionics. Standard IBM flight computers are used and the system is programmed to achieve some multiprocessing along with a high degree of fault tolerance. Honeywell is developing the main engine controller assembly (SSMECA) for the Space Shuttle. This digital control system provides closed-loop control of thrust and mixture ratios for the liquid-fueled rocket engine. The duplex processor and triplex sensor design must maintain operational status under the incidence of faults with no hazard to either personnel or related hardware.

Meanwhile, an intensive effort is underway by Raytheon and Logicon, using Air Force support, to get a fault-tolerant computer ready for a satellite test launch in December 1978. The computer will be the first in a series, and will feature user-optional configurations, such as duplex or triple-modular redundancy.

Wide application of large-scale integration (LSI) to microprocessors seems to be encouraging the construction of computers by replication at the processor, memory, and switch level. In fact, lower-cost LSI hardware is opening many doors to techniques that were previously too expensive. For example, duplication and comparison techniques can now be expected to become practical methods for use where fault detection has been difficult in the past. Furthermore, LSI chips will likely be built with special features, such as internal status checks, to assist in fault-tolerant design.

Microprocessors and lower memory costs will make multiprocessor systems common in the near future. Multiprocessors have the property of incremental expandability and the potential for graceful degradation and reconfiguration.

Software specifications

Large software systems are costly but they are essential for such real-time applications as ballistic missile defense and air traffic control. In these systems, the critical programming problem is to develop error-free software, since a software bug can produce a large-scale disaster. To transform system requirements—generated by policy makers—into a set of programs that will perform reliably, well-defined specification methods are needed. Specifications have often been informally developed by system designers, but when a large system is designed by several different individuals, the result can be an inconsistent and potentially error-prone overall system design.

To allow system specifications to be developed uniformly, with rigorous testing for completeness and consistency, computer-processable specifications languages are now being developed. These express, with precision, the intent of the system requirements, but do not necessarily force the software designer into any particular solution. Led by Charles Vick, a group at the Army Ballistic Missile Defense Advanced Technology Center has developed a successful specifications language and software engineering methods for a complex defense system. The specifications developed by using this language have been used to check each stage of software development. Time and effort for software validation and verification are estimated to decrease by an order of magnitude when this approach is used. Furthermore, modifications in specifications requirements can be rapidly implemented. Similar work has been reported at Softech, in Waltham, Mass., and at the Stanford Research Institute in Menlo Park, Calif. Eventually, it is hoped that software designs for large systems can proceed directly from a specifications language to the implementation of programs.

During the past year, computer operating systems have undergone some dramatic developments. There has been progress in reducing the overhead associated with handling simultaneous users. Although there have been no public announcements, observers find that the IBM system 370 overhead is drastically reduced, compared with that of system 360. Very secure operating systems are needed for such applications as electric utility and nuclear reactor control. Such systems are not vulnerable to sabotage, and will perform only those functions for which they have been designed. A provably secure system is being designed at Stanford Research Institute under the leadership of Peter Neumann. Similar work is underway at the Army Ballistic Missile Defense Advanced Technology Center under Mr. Vick. Under contract from the British Post Office, Plessey has designed a hardware system that includes many different protective features that act against both internal malfunctions and external tampering.

Extensible languages

With the proliferation of minicomputers, the need has grown for languages that can readily be altered and easily moved from one machine to another. Extensible computer languages are now appearing. These allow changes in language syntax, and in vocabulary, as well as the addition of new operations, by users. With these languages, moderate changes can be made with very little corresponding change in the language compilers. This capability gives the users added flexibility and also extends the useful life of the language. The most prominent of these extensible languages are Pascal, (especially for data-type extensibility) developed by Nicholas Wirth at the Swiss Federal Institute, and EL1, developed at Harvard.

Universal compilers (sometimes called meta compilers) map high-level language programs into programs for any of the many existing minicomputers. With such a compiler, a variety of minicomputers can be conveniently used and the cost of developing a separate compiler for each minicomputer is largely avoided. Such a compiler has been developed for the National Aeronautics and Space Administration by the McDonnel-Douglas Corp.

Very-high-level languages, directed to specific applications, continued to appear last year. For example, the Pearl process-control language was developed by Rudolph Lauber at the University of Stuttgart.

Computer network shakeout

The realities of competition in the computer network marketplace have produced a major casualty with the demise of Packet Communications, Inc., the first value-added carrier to receive Federal Communication Commission (FCC) approval in 1973. Left in the value-added battlefield are Telenet, Inc. (Washington, D.C.), which began actual operations during the summer of 1975, and Graphnet (Englewood, N.J.), which has not yet made a substantial appearance in the marketplace although it has received FCC authorization. On another front, Timeshare, a remote computing organization, has begun offering value-added services through its TYMNET without FCC authorization, and there has been no action on the part of the FCC to intervene. However, recently Telenet has asked the FCC to rule on the matter.

Value-added carriers

The FCC itself is now working on Docket 20097, a rule-making inquiry into resale and shared systems. The major issue is whether the resale of communications and transmission channels should be regulated. Many large organizations such as General Electric are thought to be waiting on the sidelines for a determination as to whether value-added carriers will be regulated or unregulated. If unregulated, it is expected that numerous new organizations will enter the field with a blossoming of new services oriented toward computer-communic ,n user needs.

The pricing battle between the Bell System and the specialized common carriers continues, with issues revolving primarily around the question of whether Bell is cross-subsidizing its data services. Technical cost questions involved are so complex that the controversy can be expected to continue for quite some time. Until then, the FCC is in effect allocating a large part of the market to the specialized carriers by limiting AT&T's attempts to lower tariffs.

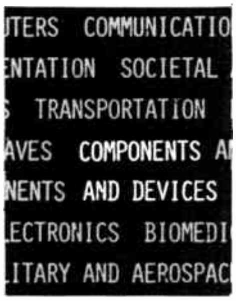
Extensible languages

In the international public network arena, the most significant announcement during the year was that of the Datapac packet switching network to be developed by the Trans-Canada Telephone System. Packet switching network technology is being rapidly adopted by many organizations in many countries.

In the standards area, IBM has followed up the introduction of its Synchronous Data Link Control (SDLC), a bit-oriented data-link control protocol, with a set of systems network architecture (SNA) conventions. SNA adds up to a complete restructuring of teleprocessing architecture. It standardizes the division of functions between the central processor, network devices, and terminals. This new architectural approach will allow various processing functions associated with a particular application to take place at points distributed throughout the network. A similar kind of architecture was announced by Digital Equipment Corporation with their new DECNET protocols. DECNET follows the lead of SNA and similar approaches that develop standard interfaces between the different levels of network functions. Standards efforts on line control procedures seem to be rapidly moving toward completion, while U.S. and international standards organizations are now turning their attention to packet-switching network standards. International Telegraph and Telephone Consultative Committee (CCITT) activities in new data networks—which originally were focused on circuit switch standards for new common carrier systems—are now dominated by packet-switching network standards activity. ◆

System network architecture (SNA)

Information for this article came from many sources. Major contributors were Daniel Siewiorek (Carnegie-Mellon Univ., Pittsburgh, Pa.), Jack E. Shemer (Xerox Corp., El Segundo, Calif.), David Hsiao (Ohio State Univ., Columbus, Ohio), Arthur Pohm (Iowa State Univ., Ames, Iowa), William J. Dejka (Naval Electronics Lab., San Diego, Calif.), C. V. Ramamoorthy (Univ. of California, Berkeley), and Lynn Hopewell (Network Analysis Corp., Vienna, Va.). Stephen S. Yau, Past President of the IEEE Computer Society, provided invaluable organizational assistance.



Components: microprocessors galore

Advances in logic, memories, microprocessors, and linear ICs give new capabilities to device users

Progress in device and component technologies continued through 1975. While no one device or component type dominated, advances were more dynamic in some areas than others. For example, digital ICs such as logic and memory devices advanced in performance at a faster rate than many linear ICs, as has been traditional due to the greater demand for digital ICs. Highlights of these developments follow:

- The preponderance of semiconductor companies making the new 4-kb RAMs during 1975 has pushed the industry to talk of introducing 8-kb and 16-kb RAMs by this year or next. CCD memories for bulk storage made their debut in the commercial market. And silicon-on-sapphire (SOS) ICs in the form of RAMs also became commercially available for low-power applications.
- LEDs continue to be found in more and more display applications, thanks to improvements in efficiency, color, availability, and power dissipation. But gas-discharge and liquid-crystal displays have hardly been dormant, having undergone significant advances in reliability and operating lifetimes.
- The newest look in low-to-moderate-power IC devices is the plastic package, making for lower-cost parts. In high-power ICs, bigger thyristor and rectifier devices (up to 77 mm in diameter for commercially available devices) with multi-kVA ratings are being produced to handle the large industrial jobs at record-breaking switching speeds of several kHz.
- The number of available microprocessors more than doubled last year, with just about every semiconductor manufacturer marketing one or more models. Even some national distributors have gotten into the act, selling the newest concept, a low-cost microprocessor kit. Many microprocessor manufacturers are now concentrating on adding interace devices to the basic CPU chips to expand the microprocessor's capabilities.
- Although digital ICs tend to be cited more often for progress in performance, linear ICs have made some notable advances. Newest of the linear IC products are 8- and 10-bit CMOS D/A converters, higher-performance FET-input op amps, versatile voltage regulators, low-cost voltage-to-frequency (V/F) converters, and gyrator circuits for active-filter networks.
- Hybrid circuits continue to be in demand. For nearly every monolithic IC function available (e.g., op amp, converter, multiplier), a hybrid circuit that uses such an IC as a building block is available for even higher performance. Modular hybrid products such as op amps, and V/F, A/D, and D/A converters with performances pushing technology limits, were introduced last year. Hybrid thick- and thin-film resistor-network packages are increasingly common in circuit design. These high-performance film network packages are making a bid to replace many older and less accurate

Roger Allan Associate Editor

Processing—the key to device advancement

Progress continued in pattern-generation technology—the key to making higher-performance and lower-cost IC devices—in projection printing, proximity printing, electron-beam lithography, and X-ray lithography.

One-to-one scanning projection printing, in which a limited area of an almost-perfect photomask is imaged onto the corresponding area of a wafer, and the wafer and mask are scanned in synchronism to expose the entire wafer, gained rapidly in commercial acceptance. The Perkin-Elmer Micralign system is a commercially available example of this approach and is in wide use by a number of semiconductor IC manufacturers to produce critical LSI devices, such as MOS random-access memories.

Proximity printing has also seen greater application. Along with one-to-one scanning projection printing, it sharply reduces mask damage making it economically feasible, in many cases, to use high-quality step-and-repeat photomask masters directly as working plates. Continuation of this trend could have a major long-term impact on the mask business, sharply reducing the need for the large numbers of low-cost copies now gobbled up by the contact-printing process.

As predicted by processing specialists, electron-beam pattern generation has indeed emerged from the laboratory, and at least one major in-house mask-making facility (Bell Telephone Laboratories, Murray Hill, N.J.) has an electron-beam exposure system (EBES) in routine use for master photomask production. The use of electron-beam systems for direct patterning of resist-coated silicon wafers is widespread, but still generally limited to the laboratory. The potential of this technology to produce specialized small-feature devices—such as microwave transistors with high yield and performance—has been clearly demonstrated, but the long-term applicability to high-volume LSI remains open to debate.

X-ray lithography

Significant advances have been made in the use of X-ray lithography for the definition of feature sizes in the vicinity of 1 μm, especially for magnetic-bubble circuits, but the technique is still very definitely in the exploratory phases. Substantial disagreement still exists among the various development groups on such fundamental system parameters as what is the optimum wavelength range, and which mask technology to use.

discrete components, although at slightly higher prices.

A wider choice of logic families

The trend in digital IC logic has been to LSI complexity (Fig. 1), with some non-LSI logic families being fabricated using LSI methods. The new high-speed Schottky TTL and low-power Schottky TTL standard logic families, along with new I²L and CMOS logic ICs, have given the logic designer the widest choice ever.

Two of the most important performance parameters of a low-cost LSI logic element are its operating speed and power dissipation, usually expressed as speed–power product in picojoules (pJ). Until the introduction last year of I²L ICs with pJ products of 1 or less, standard silicon-gate NMOS and low-power Schottky TTL ICs had been the low-cost contenders, with pJ products of 10 to 20 (CMOS has pJ products of 4 to 5 but is more expensive).

I²L logic

I²L logic products were introduced last year by Motorola Semiconductor—the Megalogic programmable logic family. In addition, Texas Instruments and Fairchild Semiconductor introduced an I²L microprocessor chip and a 4-kb RAM, respectively. At Bell Telephone Laboratories, I²L LSI ICs were used in telephone circuits for the first time. Several manufacturers of low-power Schottky TTL ICs are offering fairly complex computer-oriented components (e.g., Fairchild's Macrologic ICs, and Monolithic Memories', Advanced Micro Devices', and Intel's bit slices), and are planning to upgrade their logic lines by offering even faster operating speeds and more device drive capability.

In SSI and MSI complexities, Fairchild introduced an advanced line of ECL ICs during 1975 with subnanosecond speeds. The F100k family includes SSI ICs with 0.75-ns gate propagation delays, and MSI elements with 0.5-ns gate delays. Speed–power products are in the 2- to 3-pJ range. The F100k family of logic elements operates from supply levels of −4.5 volts.

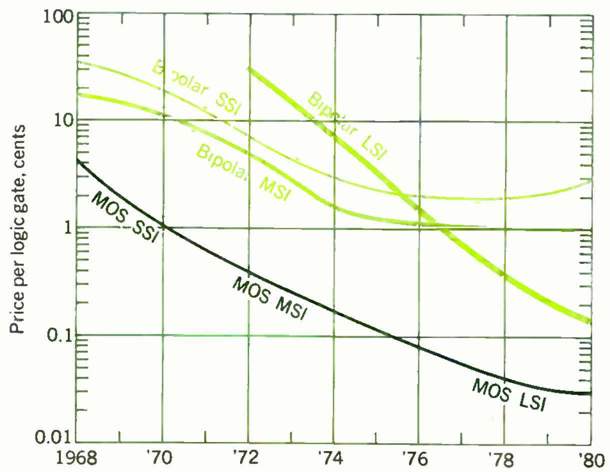
Which way the 4k?

4-kb RAMs

With designers still reeling from the impact of the new 4-kb NMOS RAMs on their memory circuits, the semiconductor industry is talking of getting ready for newer 16-kb RAMs (or 8-kb RAMs that some industry spokesmen argue is the next logical step) within one to two years. However, it is clear from user experiences that MOS RAM technology is far ahead of itself with its leapfrogging developments. Too many users are complaining of a lack of confidence in 4-kb MOS RAM reliability and testability, which, while improving with time, must be proven in the field before the users are ready for even bigger RAMs.

The driving force toward even denser memory chips is the lower cost per bit the user enjoys as a result of the traditional semiconductor learning curve. Already, some 4-kb RAMS are being quoted for long-term delivery at less than \$5, in large quantities (at about 0.1¢ to 0.15¢ per bit). This rivals core-memory prices at the component level.

[1] Bipolar LSI such as I²L is fast proving itself the least expensive high-performance technology, in price per logic gate. Note that while MOS LSI is less expensive (at lower performance levels), bipolar LSI will be closing the logic-gate price gap, and should be selling at close to 0.1¢ per gate by 1980.



Activity in active filters

Active RC filters can be built to outperform equivalent- and larger-size LC filters, and at lower prices, for audio-frequency circuits. Advancements in monolithic op amps as well as hybrid thick- and thin-film resistor and capacitor technologies have been the leading reasons.

Reporting in the *IEEE Journal of Solid State Circuits* (vol. SC-10, no. 4, Aug. 1975), W. B. Mikhael of Bell Northern Research, Ottawa, Canada, shows how cascaded RC active-filter sections, thick- and thin-film hybrid technologies, and functional tuning techniques are combined to produce standardizable low-pass voice-band hybrid filters for PCM communication systems.

In the *Bell System Technical Journal* (vol. 54, no. 3, Mar. 1975), R. A. Friedenson, R. W. Daniels, R. J. Dow, and P. H. McDonald of Bell Telephone Laboratories, North Andover, Mass., report on the first single-substrate RC active filters using thin-film tantalum RC and silicon IC technology, now produced on a large scale by Western Electric for the Bell System's D3 type PCM channel bank.

Active RC filters

There have been advances in active filters for small-scale productions as well. J. J. Friend, C. A. Harris, and D. Hilberman of Bell Telephone Laboratories, Holmdel, N.J., developed STAR (standard tantalum active resonator), an active biquadratic filter section. The thin-film hybrid IC network consists of an RC network with one op amp. The STAR circuit is described in the *IEEE Transactions on Circuits and Systems* (vol. CAS-22, no. 2, Feb. 1975).

To date, most engineers designing active RC filters have done so by building cascading filter sections. However, it has been shown that multiple-loop feedback techniques have better sensitivity performance than those of cascaded filter designs. Among the better known multiple loop techniques are the leapfrog, LF (*Wireless World,* Part 13–14, July, Sept., and Oct. 1970), and the follow-the-leader feedback, FLF configuration (*IEEE Transactions on Circuits and Systems*, vol. CAS-21, March 1974 and Nov. 1974). Another school of thought on designing such filters has been the generalized impedance converter (GIC) approach, such as the gyrator, which generally requires a two-amplifier (and hence higher-priced) configuration. But C. E. Schmidt and M. S. Lee of GTE Lenkurt, Inc., San Carlos, Calif., have discovered that a multipurpose simulation network (now in production), consisting of a single op amp, one or two capacitors, and several resistors, can be connected to form one of several frequency-dependent negative-resistance circuits or GICs (*Electronics Letters*, vol. 11, no. 1, Jan. 9, 1975).

Confusion over which type of 4-kb RAM package to use (16-, 18-, and 22-pin DIPs are available) still exists. However, it appears that more users are favoring the 16- and 18-pin designs, particularly for micro- and minicomputer applications, opting for higher density levels on the board. The 16-pin design will probably become the favorite in the future. The 22-pin design with generally better performance is being used mostly in large-computer mainframe applications.

Last year's 4-kb NMOS RAM developments emphasized faster access. Fairchild Semiconductor introduced a 4-kb 16-pin NMOS dynamic RAM (model 40963) with 250-ns access time at a surprisingly low power dissipation level of 250 mW maximum (typical active access power dissipation of 120 mW). An even faster 4-kb NMOS dynamic RAM was Intel's 2107B. This 22-pin memory is reported to have a 200-ns worst-case access time. But the fastest access time for a 4-kb NMOS dynamic RAM is provided by the μPD411D-3 from NEC Microcomputers, Lexington, Mass., the North American marketing arm of the Japanese Nippon Electric Co. This aluminum-gate, 22-pin RAM has a 150-ns access time.

CMOS RAMs

New 1-kb CMOS RAMs have begun to appear with power-dissipation levels so low that they are attractive choices for nonvolatile memories via battery backup (Fig. 2). Intersil introduced a 1-kb CMOS RAM (1024 by 1) with 0.5 mW of standby and 10 mW of active power dissipation at 1 MHz. The model IM6508 with a 250-ns access time was followed by 1-kb 256-by-4 versions (models 6551/6561). Intel's model P5101-8, a 256-by-4, 5-volt, CMOS RAM, priced at 1¢/bit in OEM quantities, dissipates just 0.25 mW of standby power. RCA has made available several 1-kb CMOS/SOS RAMs with extremely low power-dissipation levels: model MWS5040 (265 by 4), a 5-volt, 150-ns-access RAM with 0.1 mW of standby and 4 mW of active power dissipation; model MWS5501 (1024 by 1), a 10-volt, 90-ns-access RAM with 2.5 mW of standby and 20 mW of active power dissipation; model MWS5001 (1024 by 1), a 5-volt, 150-ns-access RAM with 0.1 mW of standby and 4 mW of active power dissipation; and developmental model TA6852 (256 by 4), a 10-volt, 120-ns-access RAM with 1 mW of standby and 20 mW of active power dissipation.

SOS memories

Another company active in SOS work, Solid State Scientific, introduced a 256-bit SOS RAM last year with a 10-ns access time (at 10 volts). Its model SCM5520S dissipates 5 mW in the active state at 1 MHz and 10 volts and works from a 2-volt battery. The company is also ready to introduce a 1-kb SOS RAM.

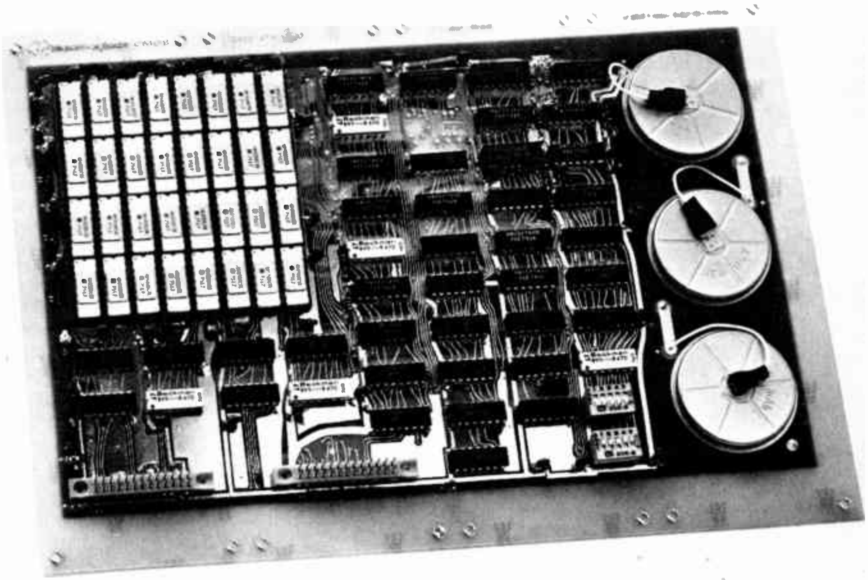
Other companies known to be active in SOS RAM work are Bell Northern Research (Ottawa, Canada), Rockwell International, Siemens, and Hewlett-Packard, all of whom are known to be actively working on 1-kb SOS RAMs (Rockwell is working on a 576-bit SOS RAM).

The major CMOS/SOS technology developments in the last year have been the development of ion-implantation techniques for enhancement-mode devices, and the development of a deep-depletion process to replace the earlier double-epitaxial process. Progress has been reported in controlling leakage currents at substrate edges and at the silicon–sapphire interface.

Erasable PROMs

Progress in semiconductor memories was not restricted to RAMs. Larger-capacity ROMs, PROMs, and electrically programmable ROMs (EPROMs) continued to evolve. Recently, Intel introduced an 8-kb EPROM (model 2709) with a 500-ns worst-case access time. NEC Microcomputers introduced a 2-kb PROM (model μPD454D) that can be erased as well as programmed electrically. The nonvolatile NMOS PROM has an 800-ns maximum access time. Harris Semiconductor, a leading manufacturer and the original developer of the PROM, has taken a step toward standardizing bipolar PROM dc and ac programming parameters with the introduction of a family of 2-kb bipolar PROMs with identical programming requirements, I/O characteristics, fuse geometries and technology, and circuit configuration.

Field-programmable logic arrays (FPLAs)—essentially PROMs with multiple interconnecting diodes, in matrices, performing AND and OR logic functions—are becoming available as memory-element replace-



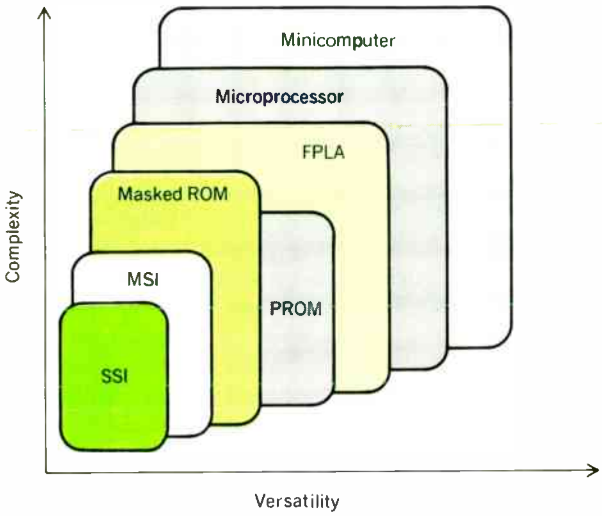
[2] Designed around a 1024-by-1 CMOS static RAM, the Monostore 1X/Planar memory system from Monolithic Systems Corp. incorporates up to 4k-by-8 of memory on a single board for nonvolatile-memory applications (the batteries are on the board's right side). A single 4k-by-8 board requires just 5 volts (at 1.8 amperes) of operating power, and +3.25 volts (at 120 μA) of standby power, making battery backup possible.

ments for nonstandard logic functions in microprocessor and large-computer systems (Fig. 3 and Table I). Such FPLAs as Intersil's IM5200 and Signetics' 825100/101, introduced recently, are examples.

Other memory technologies

CCDs as memories have arrived in the form of 16-kb units introduced by Fairchild Semiconductor and Intel. CCD memories are serial-access devices that can be accessed by line or block format. These mass-storage elements have much faster access times than disk and drum memories (although more expensive on a per-bit basis) and lower per-bit costs than MOS RAMs (while not as fast). Solid-state memories—MOS RAMs and CCD memories—are replacing electromechanical disk and drum memories. The question is: How much less will CCD memory per-bit prices be than MOS RAM prices, which are at the moment lower by factors ranging from 2 to 4? Per-bit CCD memory prices are now at about 0.1¢ or less, compared with about 0.01¢ for disks and drums.

CCD memories



[3] Hardware versatility of ICs as a function of their complexities. In terms of user device cost, flexibility, and complexity, the gap that existed between ROMs/PROMs and microprocessors has been filled with lower-cost FPLAs. (Source: Gene Miles, Intersil, Inc.)

As if to underscore the determination of CCD memory manufacturers to compete with drum and disk-memory systems, Intel introduced a 1.1-Mb CCD memory system designated as the BORAM (block-addressable RAM) in-65 with a latency time (the worst-case access time to any random memory address) of 193 μs. The expandable system, which uses Intel's new 16-kb CCD memories, has operating speeds that are orders-of-magnitude faster than equivalent-capacity disk-memory systems. Per-bit pricing for this memory-on-the-card system is around 0.2¢.

CCD line arrays

Fairchild Semiconductor's answer to the relatively slow access time of CCD memories (compared with MOS RAMs) is the LARAM (line-addressable RAM) concept, which allows access times anywhere from 80 ns (for the first accessed bit in a selected 128-bit string) to 25 μs (for the last bit).

Last year, Bell Northern Research of Ottawa, Canada, developed (in the laboratory) a 16-kb CCD memory on a chip only 137 by 167 mils—dimensions that are considerably smaller than those of other 16-kb CCD designs, and comparable to those of newer 4-kb NMOS dynamic RAM chips.

In addition to its 16-kb CCD memory, Fairchild introduced a 4-kb I^2L RAM, the first of its type, with access times considerably faster than competitive NMOS RAMs. Fairchild refers to its 100-ns-access RAM as a

I. Characteristics of available programmable-logic alternatives*

Devices	Speed	Volume Cost/Function	Device Reliability	Programming Method
Random logic	0.7–200 ns	2–50¢/gate	Very high	Wire interconnects
PLA	50 ns	$25	High	Masks
FPLA	50 ns	$30	Medium	Fusible links
ROMs	20–3000 ns	0.1–1¢/bit	High	Masks
PROMs	20–1500 ns	0.25–3¢/bit	Medium	Fusible links
EAROMs	450–3000 ns	1–2¢/bit	Medium	Trapped charges
RAMs	2–3000 ns	0.2–5¢/bit	Medium	Writing
CAMs	30–1000 ns	15¢/bit	Medium	Writing
Microprocessors	55–250 ns	15–$40/chip	High	Any or all of the above elements

Systems	Speed	Price	Reliability	Program Methods
Microcomputers	2–20 μs/instruction	20–$300	Very high	Assembly language; medium-level languages
Programmable calculators	2–200 μs/instruction	195–$11 000	Medium	Key-stroke/memory; assembly language; Basic
Minicomputers	0.6–4 μs/instruction	2500–$40 000	Medium	Microassemblers; assembly language; system programming languages; most high-level languages; operating systems
Large-scale computers	0.1–2 μs	>$40 000	Low	Assembly language; system programming languages; all high-level languages; operating systems

* Source: Robert J. Frankenberg, Hewlett-Packard Co.

RAM made from an I^3L proprietary process—Isoplanar I^2L—and says it has samples for evaluation.

BEAMOS memory

BEAMOS, for beam-addressed MOS, is a new memory technology that became available from General Electric. BEAMOS makes use of electron beams for accessing memory by bombarding CRT silicon targets. It is capable of storing trillions of bits in small CRTs at very low per-bit prices, potentially the lowest of any high-performance mass-memory technology. While the BEAMOS system was developed for military applications (other principals such as Stanford Research Institute and Micro-Bit Corp. are investigating this technology), it is projected by General Electric to be in the 0.001¢/bit range by 1980.

LEDs dominate displays

LED displays continue to dominate the digital readout market, with 1-in- (2.54-cm-) high digits available from Fairchild Semiconductor, Litronix, and IEE. The availability of LEDs in several different colors (red, orange, yellow, and green), improvements in efficiency, and lower drive-current requirements (from a few milliamperes down to 0.1 to 0.5 mA per segment) have contributed to their increasing popularity, particularly in instruments, watches, and calculators. The switch to vapor-phase nitrogen doping of gallium-arsenide-phosphide (GaAsP) epitaxial layers has been a factor in performance inprovements.

A trend in LED displays is the increasing number of LED arrays available commercially. Up to seven 0.5-in- (1.27-cm-) high LEDs may now be purchased in a single package. And with increasing LED efficiencies, it will soon be possible to drive them directly from MOS circuits without special driver ICs.

Liquid crystals

The biggest improvements in digital displays have been with liquid-crystal types, where progress has been made in better lifetime figures—operating lifetimes of up to 50 000 hours are now possible, contrasted with 15 000 to 20 000 hours of operation possible one to two years ago, over 0 to +50°C.

The largest advantage of liquid-crystal displays is their ultralow power-dissipation level, which has progressed from a few microwatts to 200 to 300 nW for a typical 0.25-in (0.68-cm) 3½-digit display, of the field-effect type. Improvements in fabrication techniques and materials have been largely responsible.

A noticeable trend has been to larger-size liquid-crystal displays (up to several centimeters high) made possible by means of improvements in the liquid-crystal material's response time to an excitation voltage. A notion also arises of using larger-size liquid-crystal displays in competition with CRT and plasma-panel displays, where the liquid crystal's low cost per digit would be an asset.

LEDs

Burroughs Corp. recently announced an improvement in the density of plasma-panel or gas-discharge displays with the Self-Scan II family of alphanumeric displays, principally for the point-of-sale and large-scale audience information systems. The modular (5- by 7-dot matrix) display line can be configured anywhere from 20 to 1920 characters, or more, in slim packages that are highly readable beyond 15 meters. The panels are designed to be stacked vertically and are joinable side-by-side for up to 24 80-character lines in a 1.2- by-1.5-meter frame that is only a few centimeters deep, and which includes all the drive electronics.

Superfast electrons?

By using laser light beams to start and stop an electrical signal, research scientist David Auston of Bell Telephone Laboratories has produced one of the fastest electronic switches yet devised. In experiments performed at Bell Laboratories, Auston has achieved measured switching times as short as 10 ps. Only one other type of device—a Josephson-junction device—is known to be capable of such speeds.

This is 10 to 100 times faster than conventional semiconductor switches, such as transistors, and the limit has not yet been reached, Auston notes. The device should work as fast as one picosecond, or less, he observes, and the switching speeds attained are limited by the duration of the optical pulses.

Beams of laser light focused on a piece of light-sensitive silicon cause the semiconductor to act like a switch in the manipulation of electrical signals. Pulses of two different colors—one to turn the switch on, the other to turn it off—were used in Auston's experiments. By the proper timing and location of the two optical pulses, electrical signals can be turned on and off in the crystal with a time precision of only a few picoseconds.

Since there is no conventional instrument capable of measuring electronic switching times this fast, it was necessary to devise a special technique to determine just how fast the switching occurs. To do this, Auston used two switches connected in tandem, the second one being used to measure the electrical signal produced by the first one. The experiment is reported in the February 1 issue of *Applied Physics Letters*.

Power chips—packing more wallop

Two concurrent developments highlight the power IC field: larger-diameter thyristor and rectifier devices are being made to handle multi-kVA industrial jobs at microsecond switching speeds; and lower-power thyristor, rectifier, and transistor chips are increasingly being put into plastic packages, with improving hermetic-performance levels at very low prices, for consumer applications.

An advanced high-power IC last year was International Rectifier's new SCR, rated at 600 volts and 500 amperes, and capable of switching at up to 10 kHz with only a 1.3-volt forward drop. It is part of a line of SCRs that includes devices handling 1200 volts and 500 amperes up to 5 kHz.

New types of power devices have become available. These include the reverse blocking thyristor from Westinghouse Semiconductor to replace more expensive and bulkier ignitron and thyratron vacuum tubes; a symmetrical, bidirectional thyristor SCR to replace triacs from Hutson Industries; and the gate-turnoff (GTO) thyristor from RCA Semiconductor with low gate-turnoff voltages and currents.

Darlingtons

International Rectifier Corp. now utilizes a hard-glass passivation technique that allows better surface stabilities in high-voltage semiconductor devices to produce a high-performance Darlington for ac motor drives. The device features a record-breaking sustaining voltage of 900 volts at a collector current of 2 amperes. It also features an I_{cbo} of 0.5 mA at 1000 volts, and a gain of about 10 minimum at 15 amperes of collector current and 5 volts.

Triple- and four-stage Darlington transistors for automotive-ignition and TV applications are under development by several semiconductor manufacturers. In 1975, RCA Semiconductor brought out developmental samples of a triple-stage Darlington with 10-ampere, 1000-volt ratings, a 1.5-μs switching time, and current gain of 500.

Power transistors have been increasing in switching speeds as well as high-voltage ratings, with some reaching 200-ns speeds and up to 3-kV voltage ratings.

The trend to plastic packaging for lower-cost devices accelerated last year with RCA's Tri-metal process that made possible plastic-packaged power devices with better hermeticity. Texas Instruments, earlier in the year, developed higher-power plastic-packaged transistors and thyristors capable of dissipating 65 watts at 100°C case temperatures.

The key to higher performance and lower-cost packaging of power ICs has been processing refinements. The use of ion-implantation and neutron-irradiation techniques, along with the use of epitaxial and glass-passivation methods, have been largely responsible. Electron-beam irradiation such as done by Westinghouse Semiconductor provides power ICs with fast switching speeds at no voltage degradation.

Westinghouse Semiconductor developed a rectifier made of a 3-in- (77-mm-) diameter silicon wafer to handle 10 MW of power, through better alloying of the silicon wafer and its molybdenum backing, accomplished in a hydrogen atmosphere. Siemens AG of West Germany successfully employed neutron irradiation of the silicon wafer to produce 50-mm-diameter SCRs that handle 800 amperes at 3200 volts of peak reverse voltage. The SCRs were designed for HVDC applications. Last year, Solid State Devices employed ion implantation to produce 100-ns thyristors and rectifiers, handling hundreds of amperes and volts, at very small forward voltages drops (under 1 volt).

Microprocessors—a whole new ballgame

Circuit/systems designers had much to choose from last year with a wide variety of microprocessors on the market, each with different capabilities. Several 16-bit units became available, and some 8-bit MOS designs were upgraded to offer even faster instruction execution times. Low-power CMOS and CMOS/SOS microprocessors became available. Bipolar microprocessors were introduced with high instruction speeds of 100 ns and faster. The results has been a new circuit-design direction: the microprocessor offers the designer of inexpensive systems the computational power of the computer functioning as a component.

Even minicomputers made use of the microprocessor's power. Last year, Digital Equipment Corp. showed off its LSI-11 16-bit microcomputer, a machine with 4096 words of memory on a single PC board using four NMOS LSI chips and compatible with the manufacturer's PDP-11 minicomputer.

New MOS microprocessors include RCA's 8-bit microprocessor that operates with Digital Equipments Corp.'s PDP/8A software and Solid State Scientific's samples of an 8-bit CMOS/SOS microprocessor.

Many microprocessor manufacturers are in the process of adding interface peripherals to their basic processor chips to do more functions. Work is also going on in software support and prototype development systems such as Intel's Intellec MDS (microcomputer development system) to help users of the firm's 8080 MOS and 3000 bipolar processor chips. For ease of circuit prototyping, the Intellec MDS has an in-circuit emulator module that can be plugged into the socket that will eventually house the final microprocessor.

Because of the many types of microprocessors available with differing languages and instructions, a ground swell of demand is emerging from manufacturers of microprocessor systems and end users for more standardization.

Linear ICs progress

Without much fanfare, linear ICs of all functions continued to be made into higher-performance and lower-cost devices. This includes monolithic A/D and D/A converters, op amps, voltage regulators, V/F converters, and many other linear functions.

A trend in monolithic linear ICs has been to reduce device costs by incorporating multiple functions on a chip, such as quad op amps and comparators. Another cost-reducing method has been to reduce the chip die size by ion implantation. Several versions of available 741-type op amps with ion-implanted resistors feature 5- to 10-percent smaller dice.

In monolithic voltage regulators, Fairchild Semiconductor pioneered a four-terminal device through inexpensive packaging. The four-terminal design, an improvement over older three-terminal designs, allows the adjustment of the output voltage over 5 to 30 volts. Older three-terminal designs required an additional external op amp and several components to do the same thing. The Fairchild four-terminal voltage regulators are available in TO-3 packages for hermetic applications and four-lead TO-202 packages for conventional applications.

In monolithic converters, Analog Devices introduced the first monolithic CMOS 10-bit A/D converter last year. Such converters had been until then multichip devices. The successive-approximation, microprocessor-compatible AD7570 dissipates just 20 mW of quiescent power, and has a 20-μs conversion time and a 50-kHz throughput rate. The company also introduced a double-buffered monolithic CMOS 10-bit D/A converter that was also microprocessor compatible.

Teledyne Semiconductor introduced the 8700 series of 8-, 10-, and 12-bit monolithic A/D converters, which drift less than ±10 ppm/°C in zero offset and ±30 μV/°C in gain over −40 to +85°C.

Monolithic converters are not only smaller in size than their modular counterparts, but are less expensive, although offering less stable performance. An example of low cost is Precision Monolithics' new 8-bit multiplying D/A converter with an 85-ns settling time that sells for as little as $6.50 each in OEM quantities.

More stability, lower noise, and higher slew rates marked the advances in monolithic op amps last year. Typical were National Semiconductor's LH0044 with less than 0.7 μV of peak-to-peak noise over 0.1 to 10 Hz, and Teledyne Semiconductor's 844 series (as a 741-type replacement) with internal compensation, a 1-V/μs slew rate, 75 MΩ of input impedance, and a 2.8-μV noise figure. Harris Semiconductor introduced a monolithic dual op amp that is optimized for both ac and dc characteristics. Its HA-2650 offers internal compensation, 5-V/μs slewing, an 8-MHz bandwidth, just 35-nA of bias current, and an average offset drift of 8 μV/°C. In monolithic instrumentation amplifiers,

Plastic power ICs

Four-terminal voltage regulators

CMOS A/D and D/A converters

Micro-processors

JFET/bipolar op amps

National Semiconductor's LH0036G, for precision battery-powered differential-signal processing, offers advanced performance parameters such as a 0.3-percent gain deviation and 100 dB of common-mode rejection.

A significant op amp development came from National Semiconductor with its series 155/156/157 internally compensated op amps combining JFET and bipolar technologies for advanced performance. The 741-pin-compatible op amps with ion-implanted resistors feature state-of-the-art performance parameters such as 30-pA bias current, 3-pA offset current, 1-mV offset voltage, 3-μV/°C offset-voltage drift, and 10^{12}-Ω input impedance. Bandwidth is up to 20 MHz and slew rate is up to 50 V/μs.

The industry's first monolithic V/F converter was Raytheon's model 4151 with a significant degree of accuracy over 10 to 100 kHz (linearity varying from +0.05 to +1 percent depending on whether or not an external integrator is used).

CCD analog delay lines

Other recent and notable linear-IC products, representing state-of-the-art performance levels, include a low-cost ($49 in OEM quantities) CCD analog delay line from Fairchild Semiconductor (model CCD311), and a bucket-brigade analog delay line from Reticon with a 75-dB dynamic range (model SAD-1024); a phase-locked loop from Exar Integrated Systems that allows operation at narrow 1-percent bandwidths (model XR-2211); and a solid-state 20-MHz image sensor from Reticon featuring 1872 elements on 15-micrometer centers in a 2.8-cm row of diodes.

There were also developments last year in CCD imagers. Three companies, RCA, Fairchild, and General Electric, are actively producing commercially available products. Fairchild, most recently, updated its 244-by-190 matrix array of CCD image sensors with a 488-by-380 array. RCA also introduced a large array—512 by 320—while General Electric introduced a CID (charge-injection device) imager array of 250 by 200 points. Fairchild also introduced a large (1728-element) CCD line array. Interest also continues in using CCDs for analog signal processing.

Modular/hybrid elements push performance

While monolithic ICs keep chipping away at modular and hybrid linear functional elements—getting closer in performance and lower in price—these very ICs are being used as building blocks for making even higher-performance hybrid and modular components. Modular op amps and converters, while more expensive, generally exceed the stability and accuracy levels of their monolithic counterparts, despite the fact that the performance gap is narrowing.

Advanced-performance modular hybrid op amps introduced recently include Burr-Brown's model 3452 "Iso-Op-Amp" with ±1200-volt isolation, and Analog Devices' model 285 isolation amplifier with record-breaking performance for the industrial and instrumentation markets: 3 kV rms of isolation, 115 dB of minimum CMRR at 60 Hz, and linearity within 0.03 percent. The company has also made available its model 235 chopper-stabilizer op amp with 5-μV/year offset voltage drift for long-term no-trim stability.

In A/D and D/A converters, last year's push was either to drive down prices or to hike performance levels. For example, Datel Systems introduced a pair of 12-bit D/A and A/D converters (models DAC-HY12 and ADC-HY12B) with good performance levels at respective single-lot prices of only $29 and $79 each. Analog Devices, the first to offer 16-bit modular converters, led the industry with its DAC-16QM and ADC-16Q D/A and A/D converters. Analogic's 12-bit MP2712 A/D converter with superior thermal stability, and 16-bit MP8116 D/A converter with state-of-the-art accuracy, linearity, and stability, were high-performance examples.

Modular data-acquisition systems were improved to enhance the designer's arsenal of components. Micro Networks Corp. developed a miniature 12-bit 16-channel system (model 7000) with dimensions that allow a 40-percent reduction in on-board mounting space. Analogic Corp. also developed a 12-bit 16-channel data-acquisition system for OEMs that reduces data-acquisition costs considerably. The company's model MP6812 was priced at $180 each in 100 quantities.

Analog Devices optimized modular V/F converter price/performance last year with its model 450K. Selling at $59, the 10-kHz converter is specified to operate at the best maximum nonlinearity level available yet—0.005 percent of full scale, half that of other high-performance V/F converters.

Gyrators

A hybrid IC introduced last year that seems destined to have a considerable impact on active-filter circuits was Amperex Electronic Corp.'s model ATF431 gyrator—a generalized-impedance converter for audio frequencies. In combination with external capacitors, the ATF431 can be substituted for a conventional grounded inductor, or become a frequency-dependent negative-resistance element.

Discrete components: alive and well

In discrete resistor, capacitor, and inductor components, the trend has been and continues to be better performance and better quality at the same or lower prices. The carbon-composition resistor, for example, is fast being replaced by higher-performance film, and metal glaze resistors, at the same price.

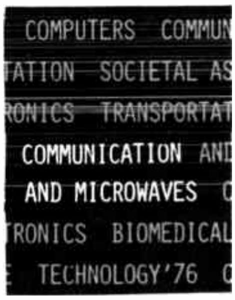
Reversing an earlier trend toward greater miniaturization, most discrete components are now being made in physical sizes small enough to be used with IC networks, but not so small as to increase their prices and reduce the reliability of the total circuit in which they are used. The exception to this is the discrete for such things as heart pacemakers, pocket radios, and watches, where microminiaturization is necessary, or at least highly desirable.

Thick-film networks

Thick-film-component networks (resistor–capacitor packages), on the other hand, are shrinking in size. The trend is to place greater numbers of thick-film resistor/capacitor combinations in small dual-in-line and single-in-line packages.

An additional trend is a requirement for use of flame-retarding materials on many discrete components. With equipment designers becoming more conscious of product safety and liability factors, flame-retarding and burn-resistant discretes are being demanded at no increase in price. ◆

Information for this article came from many sources. Major contributors were: Larry Anderson, Bell Telephone Laboratories; Glenn Carter, Dale Electronics; Dan Hilberman, Bell Telephone Laboratories; Walter Kosonocky, RCA Laboratories; Frank Micheletti, Rockwell International; and Fred Pouliot, Analog Devices.



Communications: electronics and optics, too

Solid-state lasers, optical waveguide, and digital techniques for TV broadcasting come on line

The important progress in communications and microwave hardware observed by *Spectrum* during 1975 consisted largely of refinements in existing equipment or new applications of proven techniques—including commercially available solid-state lasers and optical waveguides, a computer-controlled customer-premises private branch exchange, new channel assignments and equipment for mobile telephones, digital techniques as applied to commercial television broadcasting, and design refinements in microwave antennas for communications, radar, and satellite applications. However, there was at least one noteworthy exception to the emphasis on the practical. This was the "optical transistor," the direct amplification of laser beam signals, described by Bell Laboratories' Samuel L. McCall during the annual meeting of the Optical Society of America held in Boston this past October. So far, the effect has been demonstrated only with extensive laboratory equipment.

Fibers for hire

News of the Bell Labs development also brightens prospects for another important area where products are now becoming available after years of research effort—the field of optical communications. Last May, Corning Glass Works of Corning, N.Y., announced the availability of Corguide®, a six-fiber optical cable with losses initially specified at 20 dB/km at a wavelength of 820 nm (each fiber). Improvements introduced since that time have reduced losses to 10 dB/km, and Corguide cable lengths have increased from 500 meters to 1 km. Corguide differs significantly from previously available optical cable "bundles" in that each fiber is a distinct and separate communications channel.

In addition to the step-index fiber cable announced last spring, Corning has also supplied a graded-index version of Corguide to three customers. The advantage of graded-index fibers is that pulse spreading—a blurring of individual data bits during optical transmission—is reduced. (Pulse spreading is caused by slight differences in the speed of light within a single fiber, depending on its exact path length and number of internal reflections.) Whereas step-index fibers transmit a maximum data rate of 30 MHz/km, graded-index fibers can handle up to 500 MHz/km. Corguide cables feature an optical isolation of 80 dB between fibers, and a tensile strength of 50 kg, and are priced at $13.50/m (this applies to 20-dB-loss cable).

Corning also anticipates that low-loss connectors for Corguide will be available soon, making assembly and modification of extended optical circuits practical. Unlike the grinding, polishing, and gluing techniques used on loosely packed fiber-bundle-type optical cables, the Corguide "overlap connector" allows precise alignment between individual fibers.

Optical connectors

After preparation in a machine that stresses and then breaks the fiber tips, exposing a clean mirror-finish, the strands are placed in a mechanical mounting (much like an electrical connector) that can be easily manipulated to make or break the junction whenever required. Insertion loss in any *one* fiber channel is less than 1 dB across the new connector. This can be further reduced to about 0.5 dB by using special oils that match the refractive index across the glass/glass fiber butt. Laboratory models of the connector were exhibited in August 1975. Development of fully engineered field-deployable connectors is being handled by a major producer of electronic connectors, the Deutsch Electronic Components Division, Banning, Calif.

Another key component of any optical communica-

Sharper images are being obtained from television cameras designed around charge-coupled devices. Fairchild Camera and Instrument Corporation's MV-201 announced in October has 244-line resolution and a bandwidth of 1.86 MHz. Sensitive to as little as 0.000125 footcandle and selling for $4500, the MV-201 is intended for military and industrial low-light applications. Earlier last year, RCA announced availability of its TC1150 and TC1155 CCD cameras featuring 512-line resolution, 3.05-MHz bandwidth, and a $3000–$3800 price tag. RCA has been shipping since July.

Don Mennie Associate Editor

broadcasters whose multikilowatt signals beam forth from every significant population center are taking a strong interest in recently introduced digital hardware. Such new products include digital time-base-error correctors (DTBC) for use with both portable and studio video tape recorders (VTRs), and standards converters able to convert 525-line/60-Hz NTSC color programs originating in the U.S. to 625-line/50-Hz PAL programs for European consumption, and vice versa. These needs are not new to television broadcasters, and have often been implemented in analog circuits. Where time-base error is concerned, analog designs could correct a relatively small range of video instability (termed "narrow window").

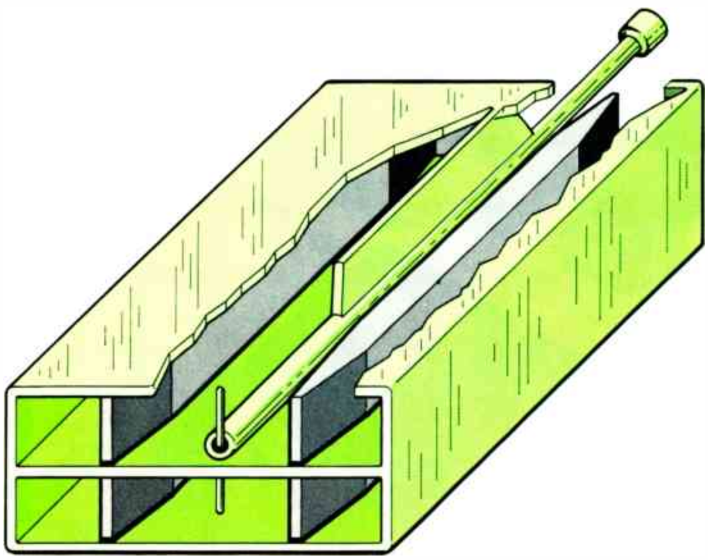
Digital time-base-error correction

Development of the digital time-base-error corrector is of special significance because it allows TV news teams to take a lightweight helical VTR into the field instead of a camera and film. The resulting video tape—although never equaling the visual quality (bandwidth) obtained on large floor-model quadruplex machines—can be quickly processed through a DTBC, dubbed to a studio VTR, edited, and/or played over the air. The digitally corrected color signal is compatible with broadcast industry stability standards.

One company devoted to DTBC product development is Television Microtime, Inc., Bloomfield, Conn. In 1974, the Microtime 640 was introduced, featuring a "wide window" input (ability to accept and correct gross timing errors in VTR signals), made possible by a high-speed bipolar semiconductor memory. The 640 is compatible with a variety of VTRs (portable and studio units), including machines from Ampex, IVC, JVC, Panasonic, and Sony. It can process nonstandard signals from line-lock machines as well as signals from capstan-servo'd and professional H-lock VTRs.

Another DTBC compatible with many different VTRs is the model TBC-800 from the Ampex Corporation, Redwood City, Calif. This is a rack-mount or table-top unit, and is designed specifically for use with available electronic news-gathering systems. Prices for the TBC-800 begin at $12 800.

[2] Intended for aircraft antennas that must simultaneously operate microwave communications, navigation, and landing systems during flight, this dual-band array element operates efficiently at two bands an octave apart. The U.S. Air Force Cambridge Research Laboratories sponsored development.



Based on experimental designs perfected by British engineers in the early 1970s, Marconi Electronics Inc., Northvale, N.J., will bring to market its digital intercontinental conversion equipment (DICE) during mid-1976. DICE is a field rate converter able to handle NTSC/PAL or PAL/NTSC operation. The equipment is priced at $400 000–$450 000 and is of primary interest to television networks that intend to market video tapes internationally or to broadcast via satellite between the U.S. and Europe. The DICE equipment operates in real time, and can be used for tape dubbing or during live intercontinental broadcasts. Marconi engineers claim that picture quality deterioration introduced by DICE is barely perceptible, a significant improvement over analog field rate converters.

Solid-state muscle, automated measure

Bipolar X-band transistors

With some impressive laboratory results to back them up, semiconductor manufacturers in the U.S. (RCA, Texas Instruments), France (Thomson-CSF), and Japan (Fujitsu, NEC) expect that many traveling-wave-tube amplifiers will turn solid-state in the next few years. Power gallium arsenide FETs have already been demonstrated that deliver over a watt of power in X-band, and similar devices with 5- or 10-watt outputs are expected soon. And recent activity at Texas Instruments, Dallas, Tex., has also pushed bipolar technology into the X-band arena. TI has developed a bipolar transistor with a 0.5-μm emitter width capable of delivering one watt in X-band, significantly extending the useful frequency range normally associated with bipolar devices.

Though output power remains an important objective, so does broad bandwidth, and getting both together requires using "lumped" matching elements (MOS capacitors, wirebond inductors) close to the microwave transistor junctions. A 5-watt transistor (50 ohms in, 50 ohms out) operating from 3.7 to 4.2 GHz is available from the Microwave Semiconductor Corporation, Somerset, N.J. TRW's Semiconductor Division in Los Angeles, Calif., has also done much work recently on broadband microwave power semiconductors.

Boulder, Colo., was the scene of recent work to simplify and improve the accuracy of automated measurements. The U.S. National Bureau of Standards (NBS) is constructing six-port reflectometers operating from 1 to 26 GHz for measuring net power and complex reflection coefficients in terms of four power measurements made on four arms of a six-port junction. A recent paper entitled "Using six-port junctions to measure active and passive circuit parameters" is available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. Its author, Cletus A. Hoer, is the principal NBS investigator working on the application of six-port junctions to automated microwave testing.

Satellites and antennas

Communications systems based on geostationary satellites to relay messages typically have been characterized by large costly ground stations. The cryogenically cooled amplifiers, 30-meter dish antennas, and extensive ground interconnections to serve the user do not come cheap (see *Spectrum*, Sept. 1975, pp. 36–40). However, the greater flexibility of digital data (as opposed to voice and/or video signals), coupled with more closely defined user requirements for communications service, have opened the door for the customer-located earth station.

Presently at work on a dedicated broadcast network for Dow Jones that will allow digital broadcast of *The Wall Street Journal* to remote printing plants, the American Satellite Corporation has already installed five dedicated-user earth stations for the U.S. Government. When completed, the Dow Jones hookup will permit newsprint transmission at 3 minutes per page (150 000 bits/s), with provisions eventually to provide one-minute transmission (1.344 Mb/s).

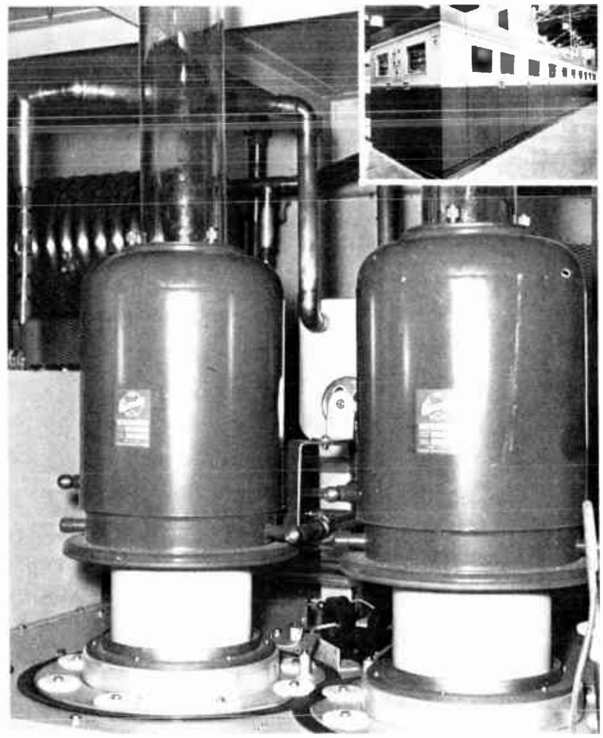
NASA's SESAT program for monitoring ocean currents and temperatures from space emphasizes a low profile concerning its technology. However, *Spectrum* contacted Calvin T. Smith of the NASA Langley Research Center in Virginia, and he pointed out several "technology items" (hardware undergoing further development based on published performance goals) related to the SEASAT-A satellite. For example, the sensors on board SEASAT-A all require antennas of significant size (i.e., scatterometer, 2.7-meter stick array; imaging radar, 14- by 2-meter array; microwave radiometer, 0.8-meter dish). Although the size of the radiometer dish is not spectacular, the feed must accomodate five frequencies while exhibiting low ohmic losses. The imaging radar requires a data rate of 15–24 Mb/s, necessitating an improved digital data processor on the ground, as well as on-board processors for future SEASATS.

An important part of SEASAT's mission is measuring the geoid (surface within or around the earth everywhere normal to the direction of gravity and coinciding with mean sea level in the oceans) with an altimeter measurement accuracy of ±20 cm. Translated into the time domain, this indicates that radar pulses of 1–10 ns will be required. Improved pulse-compression technology is implied for the driver circuits. And earth surface temperature measurements are expected to be the most precise yet achieved by a satellite system (absolute accuracy of 1.5K—thermal noise at microwave frequencies).

For a synopsis of antenna developments through 1975, *Spectrum* contacted Allan C. Schell at the Air Force Cambridge Research Laboratories, Cambridge, Mass. Dr. Schell reports that during the past year there has been a strong effort on limited-scan antennas. This type of design limits angular scan range, reducing both the number and complexity of antenna elements and control devices.

Of particular note is a technique developed by Raymond Tang and N. Wong of Hughes Ground Systems Group, Fullerton, Calif. Their device uses a feed array, a spherical constrained lens, and a parabolic reflector to generate a series of uniformly spaced overlapped virtual subarrays on the aperture surface. A paper on this approach, along with several other discussions of limited-scan antennas, was presented at the June 1975 IEEE Antennas and Propagation Society International Symposium held in Urbana, Ill.

Robert J. Mailloux, a co-worker of Dr. Schell's, is credited with the design of a dual-band array element capable of operating at two frequency bands an octave apart. The element's chief advantage is the high aperture efficiency displayed in both bands. A coaxially driven dipole excites the low frequency, while at the high band waveguide inputs coupled to dielectric slabs are used to confine the fields appropriately (Fig. 2).



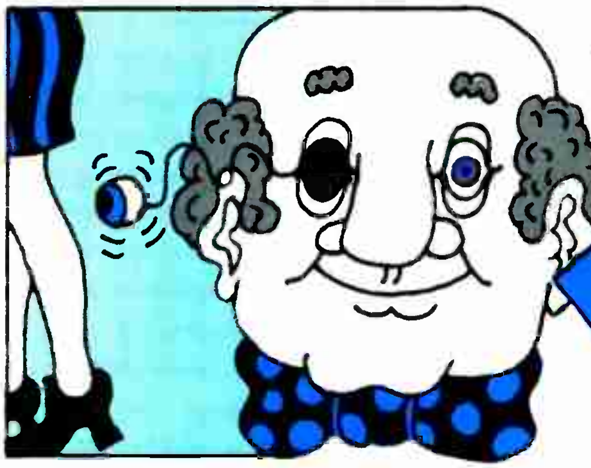
Late in 1975, the Radio Broadcasting Service of Radiotelevizija, Belgrade, Yugoslavia, took delivery of a 2-MW AM transmitter from Continental Electronics Manufacturing Company, Dallas, Tex. Termed the world's most powerful transmitter for 535–1620-kHz operation, the final RF amplifier uses eight Eimac 4CV250,000A tetrodes (two are shown here). Full modulation is achieved with a combination of screen and impedance modulation patented by Continental. Parallel triodes are used in the cathode-follower screen modulator. Any that develop faults are automatically disconnected, so transmitter operation can continue without immediate tube replacement.

Limited-scan antennas

Another of Dr. Mailloux's projects is the control of sidelobes outside the scan range of microwave antennas with dielectric filters. By using several spaced layers of dielectric, electromagnetic-wave transmission is controlled as a function of angle. Within a designated central region, the signal is not attenuated; but outside the angular "passband," transmission through the filter is low. By appropriate choice of filter parameters, a Chebyshev-type response is obtained, giving good rejection in both the E and H planes with low cross-polarization. A full treatment of this development is scheduled for publication in the *IEEE Transactions on Antennas and Propagation* for March 1976.

Spectrum has also learned that a successful prototype of the TPS-59 solid-state L-band surveillance radar has been developed by the General Electric Electronic Systems Division, Syracuse, N.Y., for the U.S. Marine Corps. The antenna is a 54- by 24-column array of solid-state modules. Azimuth scanning is by mechanical rotation, and elevation scanning is by electronic control of the diode phase shifters. ◆

Information for this article came from many sources. Major contributors not acknowledged in text were: Adam Lender, GTE Lenkurt, San Carlos, Calif.; and Harold Sobol, Collins Radio Group, Dallas, Tex.



The fleeting glance

Anything fleeting—any transient phenomenon—is meat for Biomation's waveform recorders. If you've got a sensor to sense it, we've got the recorder to catch it and play it back for the kind of close scrutiny most fleeting glances never get and probably don't deserve.

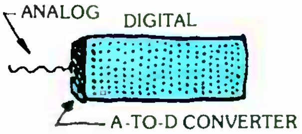
Catch a falling star

Q-switch a laser. Snap an electronic shutter. Plot the gurgles and whistles of underwater mammals. Shoot a 9-pound chicken into a 747 to simulate a chance encounter with a flying fowl. IF YOU CAN OPERATE A SCOPE (and find a 9-pound chicken), you can do all these fun things on a waveform recorder. They're very versatile. And the nice thing about our recorders is that *you can't miss*. If your event takes place, our recorder will catch it.

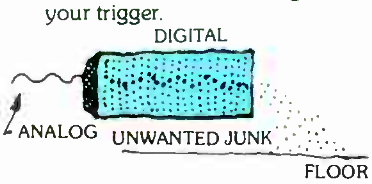
The Pre-Trigger Recording REASON

1 This is a somewhat simplified diagram of a semiconductor memory. It's currently OFF.

2 Now the power is on and stuff is starting to march through at, say, 5MHz.



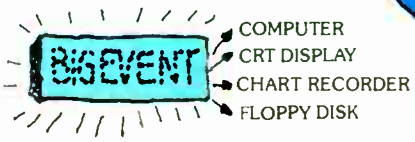
3 Now it's humming. Data is pouring through and dumping out onto the floor, waiting for your trigger.

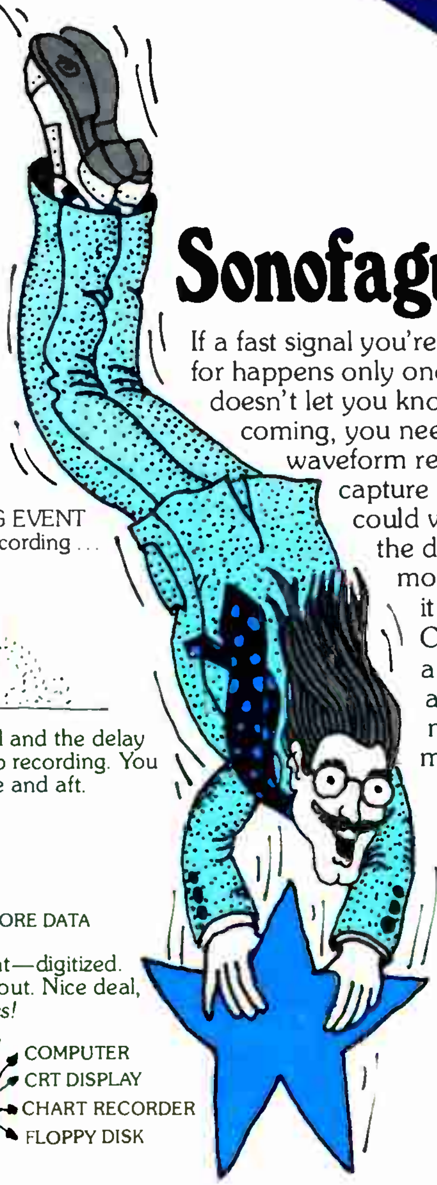


4 Here comes your BIG EVENT and you're already recording . . .

5 Trigger on your signal and the delay tells you when to stop recording. You have caught data fore and aft.

6 Here's your Big Event—digitized. Now you can play it out. Nice deal, right? *No more misses!*





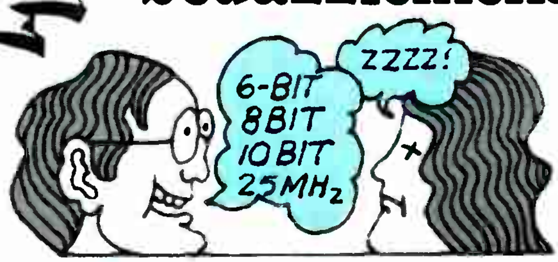
Sonofagun!

If a fast signal you're looking for happens only once and doesn't let you know when it's coming, you need a Biomation waveform recorder. You'll capture it more surely than you could with scope cameras, and the digitized data is infinitely more useful; you can play it out onto a flicker free CRT screen, write it on a recorder, or feed it to a computer for all manner of wonderful manipulations.

Greased lightning

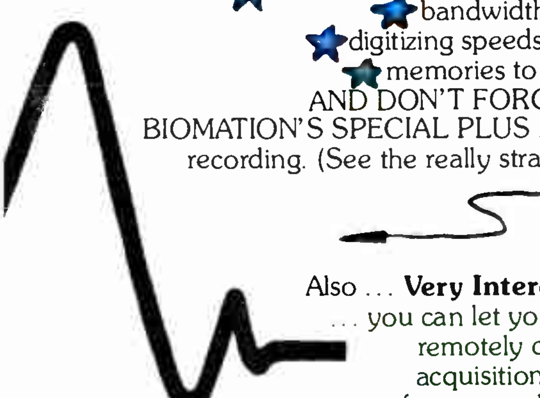
If what turns you on is an electrical quickie, grasp it with a Biomation waveform recorder. Your UHV transient is just another fast analog waveform to us. We'll digitize it at speeds up to 100MHz. That should effectively degrease your problem lightning.

SPECS for your bedazzlement



- 6-bit, 8-bit, 10-bit A/D conversion
- time resolution to 1 point in 4000
- bandwidths to 25MHz
- digitizing speeds to 100MHz
- memories to 4000 words

AND DON'T FORGET, FOLKS, BIOMATION'S SPECIAL PLUS ... pretrigger recording. (See the really strange diagram over there



Also ... **Very Interesting Idea** ... you can let your computer remotely control signal acquisition of our 8100 waveform recorder through a full digital interface. Let your mind wander over that one for a moment.

THEN ACT!

There's a ton more we can tell you about putting a Biomation Waveform Recorder to work for your unique one-of-a-kind set-up. **The idea's not new. Neither are we.** Thousands of Biomation recorders are doing it all over the world.

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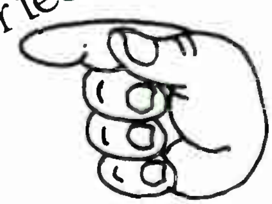
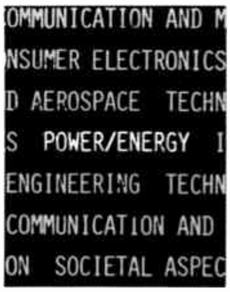


Circle No. 52 on Reader Service Card



Power: problems and progress

Despite difficulties, advances were notable in UHV and ac transmission, and energy-storage devices

During the past year, one got the feeling of *déja vu;* we had seen all this at least once before, hadn't we? But of course—the twin, interrelated energy–power pinch that hit us like an avalanche during the Arab oil embargo and its aftermath was still with us; only, perhaps now, a bit more intensified since OPEC raised the price of a barrel of crude about 15 percent last September. And the financial crunch being experienced by the power industry was quite thoroughly chronicled and documented in the March, April, and May issues of *IEEE Spectrum.* As Shakespeare put it in *Macbeth:* "Troubles come not as single spies, but in battalions." Or so it seemed in view of some of the other developments.

ERDA on LMFBR

For example, last July, Robert C. Seamans, Jr., Administrator of the Energy Research and Development Administration (ERDA), announced that R&D efforts on the liquid-metal fast-breeder reactor (LMFBR) "should move forward," but that any decision on widespread commercial use must await the resolution of "several significant issues." Dr. Seamans' rather inconclusive conclusion further stipulated that a review of ERDA's final environmental impact statement amply demonstrates the need to continue the LMFBR demonstration program. However, *that* technology is not the only one that "holds the promise of an essentially inexhaustible source of energy"—nevertheless, uncertainties concerning the timely availability of solar and fusion energy "make it risky" and imprudent to discard the fast-breeder program.

ERDA: esoteric—and enigmatic

In the latter part of 1975, ERDA published vols. 1 and 2 of *A National Plan for Energy Research, Development & Demonstration,* in which the agency states flat out its preference for the LMFBR program over all of the competitive fast-breeder schemes. Even though the gas-cooled fast reactor (GCFR) and the molten-salt breeder reactor (MSBR) technologies are mentioned in the document, the conclusions could not have been encouraging to the advocates of these systems.

The breeder program has been a political football in the U.S. for many years. Although Russia, France, and the U.K. already have LMFBR demonstration plants on the line, the U.S. program was detoured into the Fast Flux Test Facility (FFTF) at Hanford, Wash., as a proving ground for components before construction could commence on the Clinch River demonstration plant—now rescheduled for operation in 1983. However, Clinch River is presently only in the initial stages of construction application review. It will not be until mid-1977 that a final decision on the scope of construction is made.

Gordon D. Friedlander Senior Editor

To put it mildly, ERDA's shifting position on *any* breeder scheme has been a bit muddled to date. For instance, in early 1975, it reduced its appropriation request for Clinch River—and there was speculation that breeders might be scratched entirely. But vol. 1 of the just-mentioned ERDA plan seemed to defer breeders to a 21st century operation, together with solar and fusion. Now, however, in an apparent switch of signals, commercial LMFBRs seem to be targeted for commercial use before 2000—and will form the nucleus of a major energy source beyond that date. Another ERDA interpretation is that GCFR and MSBR will be put on a "back burner" with far lower priorities for development.

Is nuclear bombing out?

Higher power plant prices

All of these policy shifts have raised ancillary speculation, and a question that looms large: Is nuclear becoming too costly? Zooming construction costs, plus unpredictable demand and growth patterns in the use of electric energy, slowed nuclear power development last year in a totally unexpected way. As an example of the escalation in nuclear costs (according to a Bonneville Power Administration appraisal), nuclear plants, announced in 1965 for completion by 1967–71, were expected to average about \$125/kW. However, when these plants were actually completed in 1970–73, the average had climbed to \$200/kW. Nuclear plants announced in 1968 for completion by 1973–77 were expected to average \$170/kW; but 1974 cost estimates of these plants (whose completion schedules have slipped to the 1974–81 time frame) are expected to average about \$410/kW. The average cost of plants announced in 1974 for completion by 1982–86 is about \$560/kW and, if past experience is any guide, these plants could cost \$1000 to \$2000 per kilowatt when they are completed by 1983–1990.

But while nuclear costs may be soaring, increasingly stringent air- and water-pollution-control regulations are upping the price tags of coal-fired plants, which are currently about 70–80 percent of the nuclear plant costs.

In the absence of a clear cost/benefit comparison between coal and nuclear, some major utilities throughout the U.S. that had large-scale nuclear plants either on their drawing boards or actually under construction in 1975, have revised their completion schedules. One investor-owned utility, Con Edison, is selling its two newest nuclear plants—and a fossil-fuel station—to the state power authority (an action made necessary by the recent "cash crunch" that adversely affected many utilities); other utilities, however, are urging the public to become part owners in nuclear power ventures.

The nuclear plant suppliers have also hit upon hard times: at Westinghouse (one of the largest in the business), there has been a deferral of 70 percent in back orders; and General Electric experienced a similar slump during 1975.

This reverse shift in emphasis—plus the "on-again, off-again" policies of the Federal government—has some Midwestern utilities eyeing the coal fields of Wyoming and other western states and making cost-comparison studies on the transportation of coal vs. that of the complete nuclear package.

A look on the brighter side

Despite the disappointments and difficulties of the past year, there have been some notable and solid accomplishments: the first stage of the 1400-km-long (870-mi) Cabora Bassa ±533-kV HVDC project in Mozambique, involving the construction of a hydropower plant with an ultimate output of 2000 MW on the Zambesi River, was completed in mid-year when three turbogenerator sets and four converter groups were made ready for commercial operation. And the 1700-km-long (1050-mi) ±500-kV HVDC transmission of the Inga-Shaba complex (*Spectrum*, Dec. 1975, pp. 40–45) in Zaire is well on its way toward completion. When finished, these African developments will be the world's two longest HVDC transmission systems.

The recent installation of phase-angle regulators on certain key high-voltage lines has provided improved utilization of transmission facilities. With their reliability to "buck or boost" the power flow on a given line, they have increased the capacity of the existing transmission networks by shifting power flows to otherwise lightly loaded lines. The use of phase-angle regulators has increased significantly in recent years in the vicinity of New York City, Philadelphia, and Washington, D.C.

Progress on the $6 billion trans-Alaska pipeline construction proceeded at an accelerated pace as more and more essential construction material reached the remote sites, either by overland transport or by ship across the Beaufort Sea "Northwest Passage." The pipeline's completion will ensure an uninterrupted flow of vital fuel oil to meet a small portion of the power generation needs of the contiguous 48 states for a number of years.

Power goes underground

Underground transmission became an integral, albeit small, part of the Bonnevile Power Administration's (BPA) network with the energization last summer of a 187-meter (630-foot) complex of gas-insulated conductors and associated control equipment.

The installation, near Ellensburg, Wash., represents the world's first compressed-gas-insulated transmission system (CGITS) carrying load at a level of 500 kV in an operational network. The sulfur hexafluoride (SF_6) system, built by High Voltage Power Corp., replaces that portion of BPA's overhead 500-kV Sickler–Raver No. 1 line at a crossing location of five lines of a major trans-Cascade transmission corridor. A broken conductor on the highest line could result in the loss of all lower circuits.

The CGITS trench was left open for ready access; however, the trench will soon be backfilled and operating experience with the underground line will be obtained, with the original overhead line remaining in place as a precautionary backup for at least a year.

Advances in UHV

UHV test lines

In Lenox, Mass., GE's "Project UHV," which has been a center of UHV ac overhead transmission-line research since 1967, was expanded last year from single-phase to three-phase. The project is operated by GE for the Electric Power Research Institute (EPRI). The 400-meter-long three-phase test line can be operated up to 1500 kV; it has been energized since January 1975.

The first line configuration tested used three bundles of eight conductors (each conductor being 3.3 cm in diameter), with a bundle diameter of one meter.

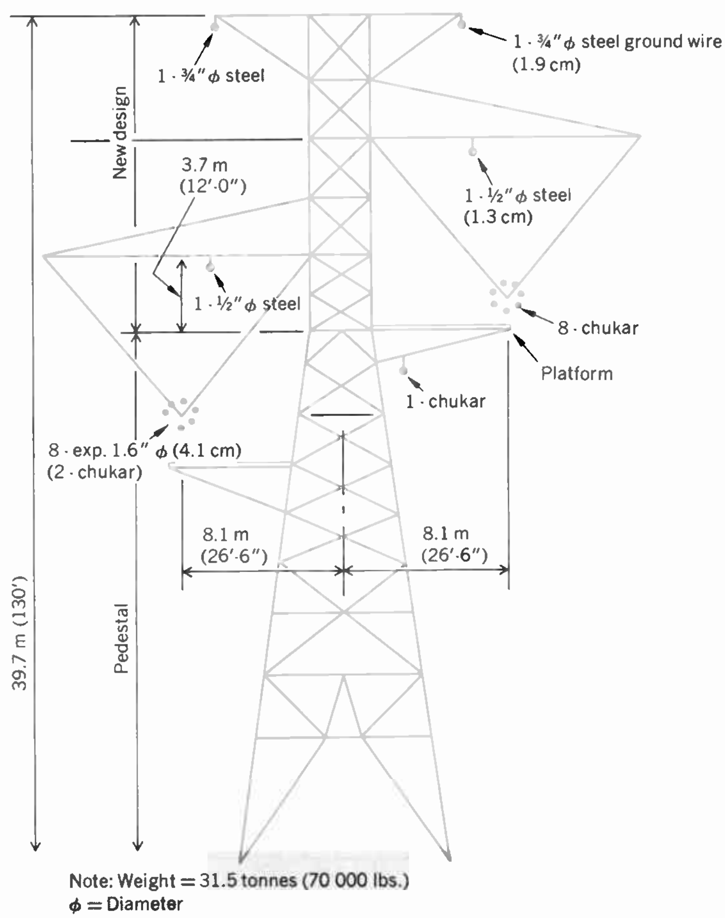
HVDC on the move

The most important issue investigated in connection with full-scale three-phase line testing is the audible noise generated by corona in foul weather and the effects of the electric field generated by the transmission line. The tests on various line configurations energized at different voltages are in progress. In addition to tests on the line, contamination flashover tests on long insulator strings are being conducted using the 1500-kV generating facilities.

A 1100-kV transmission-line prototype

BPA has also advised us that an 1100-kV UHV overhead prototype transmission line will be constructed

1100-kV test line tower configuration that is under construction in the BPA service area.



this year. The reason for proceeding with this project is the fact that long-range transmission planning for the Pacific Northwest indicates that UHV transmission may be required by the late 1980s.

The prototype project involves the construction of:

• A 2.1-km (1.3-mi) 1100-kV line on an existing 230-kV right-of-way, near Lyons, Oreg.

• A 1.6-km-long (1-mi) mechanical test facility near Moro, Oreg.

• Terminal facilities that include three single-phase 50-MVA 1100/230-kV test transformers, one 230-kV terminal, and associated ancillary facilities.

The initial construction funding for the first year is $5.5 million; the total construction cost will be $10.6 million.

The sketch on p. 65 shows a typical suspension tower structure, at the Moro facility, on which there will be three different conductor combinations strung for testing and study. The plan is to subject all conductor configurations to the same environmental conditions to obtain a realistic comparison of mechanical performances.

Energy-storage advances

Information derived from the Lyons and Moro test facilities will have both immediate and long-range benefit to BPA and every large utility in the U.S.—especially those that have already introduced 500 kV on their systems. BPA believes that the most logical next higher voltage for those systems is 1100 kV. The BPA prototype construction should provide not only design information, but also data on the total system performance of UHV transmission. It will enable Bonneville to optimize the 1100-kV design before the first projected 280-km (175-mi) UHV trans-Cascade line is built.

Big thyristors, compact dc terminals, etc.

Big thyristors, compact terminals

The Electric Power Research Institute reports that the largest thyristor, to date, with a cell size of 50 mm, is available and is being used in converter valves on all four HVDC projects presently under construction in the U.S. EPRI expects that, by this year, 70-mm thyristors will become available for commercial applications.

Also, a start was made on the EPRI project "Prototype DC Link" for development of compact dc terminals. As a result of the R&D efforts on this scheme conducted in 1974–75, it was determined that compact dc terminals are feasible; and the design of a gas-insulated dc bus was achieved for the first time in the U.S. (This was previously achieved at Volgograd in the U.S.S.R.) Another first in this area was the development of a gas-insulated valve. In general, EPRI's development work over the past two years has definitely established that dc terminals can be made far more compact than those previously available.

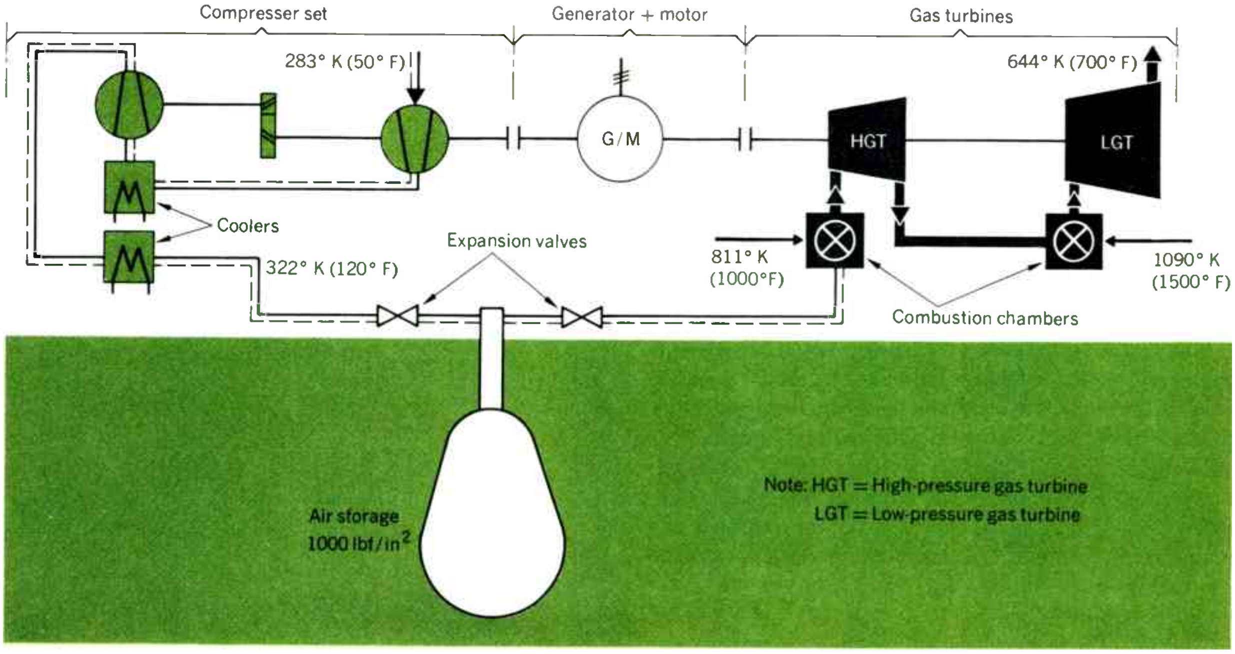
In addition, EPRI reports that a laboratory prototype of a dc circuit breaker (1000 kV peak, 1000 amperes peak rating, developed by Hughes Research Laboratories) was tested on the Pacific Intertie HVDC system for the first time last year. The tests proved that dc breakers can be satisfactorily used in HVDC systems. Therefore, further development work has been initiated on these devices to make them commercially acceptable to the power industry.

Energy-storage devices

The most promising near-term advanced energy-storage concept is the electric storage battery. Conventional lead-acid batteries are being improved and several advanced types of battery—including sodium–sulfur, zinc–chloride, and lithium–sulfur—are under active development. ERDA and EPRI have been supporting battery research programs in cooperation with private industry.

"Turnaround" efficiencies for advanced batteries are predicted to lie in the range of 70–87 percent (with 70 percent considered typical for early installations). The lithium alloy/metal-sulfide and sodium–sulfur batteries appear to be the most promising at the present time. Sodium–sulfur batteries may offer the best long-term potential if the properties and life of the solid electrolyte can be guaranteed—and the con-

Features of a 290-MW air-storage/gas-turbine combination plant that is being built in West Germany.



tainment material for the sulfur electrode can be developed.

The zinc–chloride battery has been demonstrated in electric vehicles and offers the potential for scaling to substation-size systems, with storage capacity in the range of 50 to 500 MWh.

Several manufacturers have been actively designing large-scale batteries and modules for testing in the Battery Energy Storage Test (BEST) Facility. These prototype batteries are to be tested in a utility system environment. The first phase of a program to implement the BEST Facility was successfully completed last July, with the report by a project team composed of representatives of EPRI, ERDA, and the electric utility companies. The BEST Facility will be built at a utility substation so that battery system performance can be tested and characterized on complete systems in a user environment (after extensive battery system component testing at the developers).

Thermal energy storage also has the potential for near-term development as both a domestic heating appliance, and, on a larger scale, for supplementing feedwater heating of once-through utility boilers at nuclear plants. The application of thermal storage systems was advanced with the letting of contracts by ERDA to prepare designs for these systems. The primary purpose of the system is to "levelize" the thermal input to a furnace, or a nuclear reactor, while having the capability to vary the electric output for load following.

In addition to the advances in these areas, there has also been significant progress in long-term energy-storage devices, including the design of flywheels that use exotic materials in their construction.

gas-turbine/air-storage peaking plant

Gas-turbine "combo" plant

Last year witnessed the implementation of an order for a 290-MW combination air-storage and gas-turbine generating station to be built at Huntorf, Germany (in the Bremen/Oldenburg area). The block diagram on p. 66 shows the operational features of this plant.

In the gas-turbine/compressed-air storage cycle, an inherent characteristic of the gas turbine is that two thirds of its generating power is consumed internally and can be utilized for the compression of its cycled air. In this plant, used for air storage for peaking applications, the compression will be done during off-peak hours. As shown in the diagram, the ambient air is compressed by an axial-flow compressor, intercooled, and the pressure further boosted in a high-speed centrifugal blower to 1000 lbf/in^2 for storage in the underground reservoir. (Note that during the compression cycle, the generator is used as a motor.) For peaking service, the air is led from the storage reservoir through an expansion valve, where the pressure is reduced to 650 lbf/in^2 before reaching the high-pressure combustion chamber. Here, it is heated to 811K (1000°F). After passing through the high-pressure gas turbine, the gases are reheated to 1090K (1500°F), and finally introduced to the low-pressure gas turbine. The exhaust gases leave this turbine at 644K (700°F).

A principal advantage of this configuration is the rapid start-up time; it takes only 11 minutes from initial start to full-load generation (in emergency situations, this time can be reduced to six minutes; however, four minutes is the time required in the U.S. for many similar installations). There will be a high-voltage transmission line built between the Huntorf plant and a 52-MW gas-turbine plant in Emden, about 100 km (60 mi) distant. The units of the two plants will be electrically interlocked and brought up, by frequency regulation, to synchronous speed.

Lightweight, high-strength insulator

New EHV insulator

A new transmission suspension insulator, that its manufacturers claim has four times the working strength and only 5 percent of the weight of conventional porcelain insulators, has been successfully tested in trial installations by 30 U.S. and Canadian utilities. Under field development since 1971 by The Ohio Brass Company, the insulator features polymer skirts mounted on a fiberglass rod of unusually high mechanical and dielectric strength (100 kV per inch and 100 000 lbf/in^2 in tension, compression, and flexural loading). The high strength-to-weight ratio of the insulator may remove many limitations in UHV construction; new concepts can be used in tower design, and the need for multiple insulator strings is eliminated. Initially, the insulator will be furnished, starting this year, for voltages up to 800 kV.

An advanced industrial gas turbine

Industrial gas turbine

During 1975, work proceeded on Florida Power and Light Company's "FT50 Power Pac," a new gas turbine for electric power generation that is being built and installed at the Fort Meyers Power Plant. The FT50 is a high-pressure ratio, high-performance, 100-MW industrial gas turbine that features modular components for easy maintenance and ready replacement. This gas turbine is designed for high burner exit temperature. The combustion section consists of eight reverse-flow combustion chambers arranged inside a cylindrical burner case. Each chamber is of multifuel nozzle design similar to those used sucessfully in aircraft engines. The combustors are louver-type, fully shrouded for accurate control of combustion air and uniform distribution of wall cooling air. Long service life is achieved by maintaining relatively low nominal metal temperatures and holding peak "hot-spot" temperatures under 1144K (1600°F). Each burner has its own igniter and ignition-sensing thermocouples.

Good thermal efficiency is achieved by a combination of high turbine inlet temperatures (in excess of 1365K, or 2000°F). Long life is attained by using the most advanced aircraft gas turbine cooling techniques, coupled with the best available materials for both the high- and low-pressure turbine vanes and blades.

Of the total net generating capacity of 1368 MW at Fort Myers, 828 MW are provided by gas turbines. Florida Power and Light Co. presently has a net generating capacity (system-wide) of 9517 MW, of which 2340 MW are provided by gas turbines, and 1428 MW are generated at nuclear plants.

Dc/ac power conversion

United Technologies' Power Systems Division is developing low-cost, high-efficiency dc to ac power conversion equipment for fuel cell power plants to be used in two different commercial applications: (1) for on-site power generation in the range of 10 to 500 kW, and (2) for dispersed electric utility power generation in substations at a 26-MW power level. ◆

Information for this article came from many sources: Major contributors were PES, ERDA, NRC, and representatives of the electrical supply and power industries.

Instrumentation: smaller and smarter

Performance is up and prices are down as advances in ICs and clever packaging techniques abound

Prices of test and measurement instruments continue to drop, with the microprocessor IC greatly increasing instrument dollar value by providing more measurement power for the same purchase dollar. And the trend extending instrument frequency ranges and increasing measurement accuracies, as well as features, for the same or less cost also continues. Digital multimeters are now available that provide field accuracies under 100 ppm. And frequency counters that reach into the GHz region are also available at attractive prices, usually at a few hundred dollars.

Computational capability

However, along with cost reductions and increasing performance, user complaints regarding reliability have proliferated, generally relating to newly introduced products that utilize advanced-design ICs such as microprocessors and semiconductor memories. These ICs have, in turn, increased the need for automatic, high-speed, accurate, and reliable test systems, and increased "system orientation" for designers.

Summarizing last year's developments:

- More instruments using microprocessors became available, for a wider range of measurement capabilities. As a result, the emphasis by instrument manufacturers (particularly those of systems instruments), and users, is shifting from hardware to software utilization, to take advantage of the microprocessor's capabilities.

Software emphasis

- Flexibility in reducing instrument prices through improved circuit designs declined for the instrument manufacturer. This was because large-function, small-size, and low-cost LSI ICs made some instrument manufacturers, particularly those of the simpler designs, more dependent on IC manufacturers. In fact, one large semiconductor-device manufacturer, Fairchild Semiconductor, even entered the instrument business itself by introducing a DPM (digital panel meter). To offset this trend, more emphasis is now being placed on clever packaging to reduce instrument prices.

Clever packaging

- The microprocessor made instrument interfacing simpler and less costly. And the new IEEE Standard 488 for digital interfacing of programmable instruments was enthusiastically embraced by a number of instrument manufacturers.
- In automatic test equipment (ATE), efforts continued to improve system throughputs and flexibilities through software and hardware developments.

Low-cost intelligence with microprocessors

Microprocessor intelligence

Until the advent of the microprocessor IC, improvements in instrument performance tended to be evolutionary. This reflected the progress of IC components from SSI and MSI to LSI levels, with manufacturers of instruments generally adding a range here, a decade there, to achieve better performance levels. Either custom LSI chips or costly discrete component assemblies were usually necessary to get a higher instrument performance level, and the result was higher priced instruments. Where complex instrument operation is required, the microprocessor has made possible instrument intelligence at low cost.

As more types of instruments become available with microprocessors, the user benefits from added measurement and interface flexibility, as well as improved instrument capability and reliability. The microprocessor's computational capability allows automatic conversion of measured electrical parameters such as volts, amperes, and ohms, into engineering units representing force, rotation, temperature rate, etc. With a microprocessor, an instrument can be commanded to store and to recall various front-panel control settings at the touch of a button. For example, a voltage offset can be stored and recalled at a later date, either alone or in a desired combination with another value (product, ratio, etc.). In production-line testing of narrow band filters, the ability to store and recall several fr quency settings from a signal source, by push buttons, can greatly simplify and speed up the testing process, particularly for unsophisticated instrument operators.

Roger Allan Associate Editor

Some notable microprocessor instruments

Recent outstanding microprocessor-based instruments include Dana Laboratories' Series 9000 timer/counter (see illustration), Ballantine Laboratories' model 5500B universal counter/timer, Boonton Electronics' model 76A capacitance bridge, Systron-Donner's model 7115 digital multimeter, Norland Instrument's model NI-2001 digital oscilloscope, and John Fluke Mfg.'s models 6010A and 6011A signal generators.

Dana Laboratories' Series 9000 microprocessor-based 11-digit timer/counter (two models covering 100 and 512 MHz) features a calculator-type keyboard (the keyboard slides in and out of the timer/counter like a drawer) for function control, instead of the traditional knobs, buttons, and switches. The microprocessor, an Intel 4-bit 4004, permits the selection of conventional or reciprocal measurements with a single key depression; assures minimum possible triggering error by automatically scanning a signal and setting the trigger level at the mean; automatically calculates rise and fall times and pulse widths (with an option) at the traditional 10- and 90-percent points; and allows manual keyboard programming of the trigger level. Interface flexibility is enhanced by allowing a choice of a general-purpose interface bus (GPIB), parallel BCD, serial ASCII, and a "do-it-yourself" option for very high speeds for custom requirements.

Ballantine Laboratories' model 5500B universal c /timer with automatic microprocessor-controlled circuitry is an intelligent instrument that provides ten modes of operation in-

In fact, microprocessor-based instruments are expected to make their greatest inroads in areas where lack of operator sophistication has traditionally made instrument use more costly.

Most instruments have made use of microprocessors in such a way that they are inaccessible to the user. The instrument's computing function has generally been restricted to control of internal elements, with few or no facilities allowing the user to alter details of the microprocessor's stored program.

Lack of these facilities stems partly from the novelty of extensive digital processing capacity in traditionally "unintelligent" instrument products. In addition, suitable low-cost peripheral devices for man–machine interface and bulk storage (such as the Hewlett-Packard magnetic-strip reader/writer) had to be developed. Some sophisticated applications now make use of external processors that can be interfaced to an "unintelligent" instrument. It should be kept in mind that, because of the microprocessor's serial oriented input/output capability, interfacing it to external circuitry can require hardware that may offset its cost advantage.

Instrument types now using microprocessors include multimeters, oscilloscopes, frequency counters, signal sources, spectrum analyzers, and impedance instruments (see box below). Automatic test systems are also finding uses for microprocessors. General Radio is considering the use of microprocessors in its sound-measuring instruments, particularly for noise analysis.

In some instrument designs, a standard calculator chip, which is more cost effective than a microprocessor, is used for enhanced measurement capability. An example is Keithley Instruments' System 1, a family of calculator-based data-acquisition, control, and measurement instruments, that can be configured to suit a variety of requirements. California Instrument Co., offers a calculating processor instrument, designed around a calculator chip. Its model CP70 converts digital data to engineering units, directly.

Clever packaging reduces cost

Lower prices

Clever packaging techniques now rival innovative circuit design as a means of lowering the price of an instrument. This is particularly so in such low-priced dedicated instruments as digital panel meters (DPMs), where a handful of IC chips often makes up the instrument's entire circuit and miniaturization becomes more challenging. Clever packaging also involves optimizing the number of PC boards used; employing less-expensive single-sided PC boards instead of double-sided ones wherever possible; reducing the amount of point-to-point wiring; and using fewer sockets, connectors, and switches. Instrument manufacturers who have long been known for providing "top of the line" advanced products at generally top prices are having to scale down their designs by providing alternate product lines of lower-cost instruments without too many "extras." They are accomplishing this primarily through redesign of the instrument's case and mechanical hardware.

Tektronix's new T900 line of single- and dual-trace oscilloscopes is a good example. By redesigning its higher-performance and higher-priced models' internal as well as external mechanical hardware (instrument case, PC boards, switches, etc.), Tektronix has been able to offer oscilloscopes with up to 35-MHz bandwidths, and 2-mV sensitivities, in a price range of $695 to $1250.

Calculator chips

Another example is Data Precision's new 4½-digit systems/laboratory digital multimeter that is optimized for mechanical and electrical parts count, and retails for just $795. Usually, the basic instrument includes dc-voltage and perhaps ratio measurements and additional ac-voltage and resistance measurements are

Microprocessor instruments

cluding frequency measurement capability up to 118 MHz. The unit is an extension of the company's Autometronic Series of counter/timers. The 5500B's automatic resolution and autoranging features make it particularly suited to use in ATE systems. The ROM used in the instrument's self-programming circuitry greatly simplifies and reduces the number of control lines and commands needed from an ATE system controller. Featured on the front panel is a "resolution" control that guarantees full use of the most significant digit in any measurement, insuring against overflow or loss of data. When the "resolution" control is set to the full number of digits needed in the final readout, the model 5500B automatically (and concurrently with the measuring process) selects the time base or gate required; positions the decimal; sets the dimension annunciator; and displays the answer to the exact number of places called for by the "resolution" knob. This performance is provided for single-shot and repetitive signals.

In Boonton's model 76A 1-MHz capacitance bridge, the microprocessor allows automatic bridge balancing for parallel-capacitance and conductance measurements, internal data processing, and data display of equivalent series capacitance and resistance, dissipation, and Q, all at the touch of a button.

Systron-Donner's model 7115 multimeter is one of the most advanced microprocessor-based instruments of its type. It features automatic zeroing and self-calibration, linearizes and normalizes displayed data, can perform comparisons on high and low readings, multiplies data by a programmed constant, and averages out a selected number of readings. A built-in failure-detection feature allows the microprocessor to detect an out-of-limit condition beyond the microprocessor's self-adjusting range (due to an outright component failure or tolerance drift), and to display a "FAIL" indication. A series of LED lamps inside the 7115, in conjunction with a troubleshooting chart, direct the user to the malfunctioning or defective circuit, or even actual component.

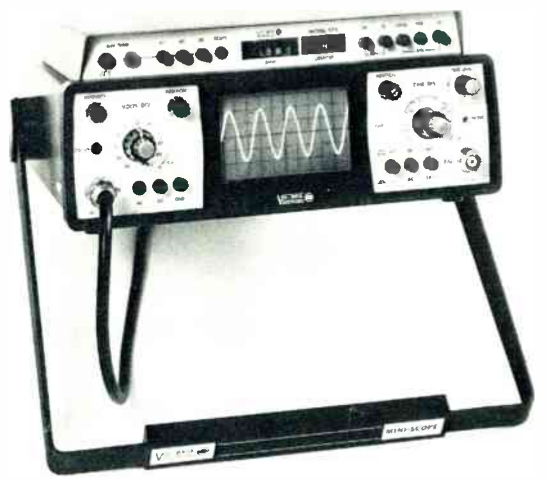
For the scientific and industrial user in need of rapid and accurate manipulation of complex data, Norland Instrument's model NI-2001 programmable calculating oscilloscope combines digital-oscilloscope and microprocessor capabilities in a single instrument. Preprogrammed fixed-function keyboard buttons on this real-time, data-storage instrument permit exact calculations of waveform rise times, integrals, differentials, peak areas, rms values, peak-to-peak values, n-point averages, frequency values, and square-root values.

Intel's 4004 microprocessor is also used in John Fluke Mfg.'s model 6010A synthesized signal generator for a high degree of automation. Local and remote programming of frequency (over 10 Hz to 11 MHz) and output amplitude (0.25 mV to 5 volts rms, into 50Ω) are possible. As many as ten preset frequencies, modulation settings, and output amplitudes can be stored and recalled through the 6010A's keyboard. A more advanced version, model 6011A, is also available.

Multifunction instruments

optional. The model 3400, however, incorporates all of these functions in one case (thereby reducing PC-board, connector, and socket parts count). The 3400 is completely and independently programmable from its rear-terminal digital interface for both range and function. It provides 100-percent overranging (20 000 counts), a basic dc-voltage accuracy of ±0.007 percent of reading, ±1 LSD for six months, and can measure over 10 μV to 1 kV dc (to 750 volts ac rms). The dc-resistance range is from 10 mΩ to 20 MΩ, and the ac/dc and dc/dc voltage ratio range extends from 0.01000/1 to 100.00/1, with a denominator range of +1 to +11 volts dc, and a numerator range of 10 μV to 1 kV dc or peak ac. The output BCD is in parallel format, and the conversion rate is 12 readings per second (externally triggered), and three readings per second (internally triggered).

Microprocessor interfacing



[1] Three instruments in one: An oscilloscope, digital multimeter, and frequency counter are contained in this small (6.35 by 21.59 by 33.02 cm) and lightweight (4.5 kg) package. This Vu-Data instrument includes a single-trace, triggered-sweep, 20-MHz oscilloscope with 10-mV/div. sensitivity (0.635 cm per div.); an autoranging, 3½-digit, three-function digital multimeter; and a four-digit, 20-MHz counter.

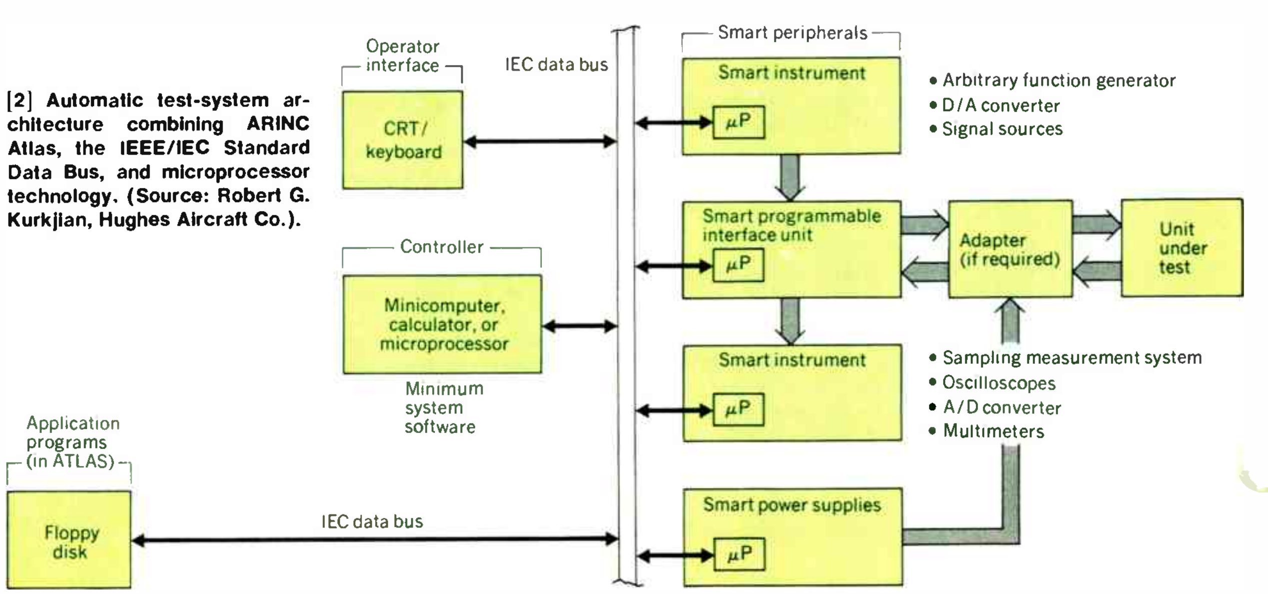
Innovative packaging often involves more than just putting one instrument function in a case. Vu-Data managed to package three instrument functions in one portable case with its model PS915/975 (Fig. 1). This small (6.35 by 21.59 by 33.02 cm) and lightweight (4.5 kg) instrument is actually three instruments in one: single-trace, triggered-sweep oscilloscope with 20-MHz bandwidth, 10-mV/division vertical sensitivity (0.25 in or 0.635 cm per division), 100-ns/division sweep rate, ×5 magnifier, and a 6- by 10-division CRT; a 3½-digit autoranging digital multimeter that measures dc and ac rms voltages up to 1 kV (in five ranges each) to within 0.5 percent of reading, and dc resistance to 2 MΩ in four ranges; and a 20-MHz, 4-digit frequency counter. The PS915/975 can operate from a battery.

Of course, technological advancements in circuit components still contribute heavily in lowering instrument prices. An example of this is in Hewlett-Packard's model 3476A 3½-digit fully autoranging multimeter. This portable benchtop instrument (battery-powered version also available) for just $225 offers the following combination of measurement features: ±100 μV to ±1 kV dc (±300 μV to ±700 volts rms), 100 μA to 1.1 amperes dc (from 300 μA ac), and 1 ohm to 11 MΩ. Autozero, autopolarity, and autoranging are built-in features. By developing fine-line, tantalum-nitride resistors to eliminate more costly and bulkier discrete resistors, Hewlett-Packard was able to offer this compact instrument at an unusually low price.

Interfacing with microprocessors

While not necessarily the fastest operating interface method, the microprocessor used as an interface permits low-cost and simpler designs. Microprocessor use is also helping to popularize the new IEEE Standard 488 for digital interfacing of programmable instruments, a concept orginated by the Hewlett-Packard Co. and pending approval by the International Electrotechnical Commission. The list of instrument companies embracing IEEE Standard 488 continues to grow, and now includes Hewlett-Packard, Dana Laboratories, John Fluke Mfg., Wavetek, Exact Electronics, Rohde & Schwarz, Siemens, and Tektronix.

Microprocessor-based instruments are finding easier



[2] Automatic test-system architecture combining ARINC Atlas, the IEEE/IEC Standard Data Bus, and microprocessor technology. (Source: Robert G. Kurkjian, Hughes Aircraft Co.).

A "hardware" review

While it would be difficult to review all specific instrument developments last year, within the few pages of this report, some are worthy of mention. Following is a list of these developments, in order of instrument system function:

Digital panel meters (DPMs). Smaller physical sizes and lower prices were the trends. The use of MOS LSI ICs were a large factor, as shown in Analog Devices' second-generation family of DPMs. This includes the model AD2021, a 5-volt-powered, 3½-digit unit with 13-mm-high LEDs, selling for $128 (1 to 9 units) and consuming just 1.45 watts; the model AD2027, a 5-volt-powered, 4½-digit unit with 10.9-mm-high LEDs, selling for $197 (1 to 9 units) and consuming 3.75 watts; and the model AD2024, an ac-line-powered, 4½-digit unit with 10.9-mm-high LEDs, selling for $207 (1 to 9 units) and consuming 4 watts. These units reflect improvements in prices (up to 37 percent less), power consumption (up to 46 percent less), and increased display height size (up to 85 percent more) over their predecessor first-generation family of DPMs. California Instruments, San Diego, Calif., produced a 5-digit DPM for dc/dc ratios (the Cimron Model DRM51) with a measurement range of 0.000001:1 to 0.99999:1, for inputs over 0 to +11 volts, and a reference input from +1 to +11 volts. The unit, which provides a host of high-performance features, sells for $695. Low power consumption was the highlight of Datascan's (Van Nuys, Calif.) model 820, a 3½-digit battery-powered DPM that consumes less than 100 mW and operates for over 600 hours on 4 D-cell batteries. For sheer size reduction, Datel Systems, Canton, Mass., produced the model DM-2115, a 3½-digit, ac-line-powered DPM with 11-mm-high LEDs and dimensions of just 7.6 by 4.4 by 5.7 cm.

Frequency counters/timers. Several low-cost counter/timers became available last year. Data Precision, Wakefield, Mass., introduced the model 5740, a 7-digit, 100-MHz counter/timer that measures frequency, period, period average, elapsed time, and total events for a very low price of $295. Hewlett-Packard, Palo Alto, Calif., unveiled a direct-counting 520-MHz 9-digit laboratory counter for just $795, with the model 5383A. The company also introduced the model 5328A universal counter, a modular design with a choice of options. The simplest version with no options permits: 100-MHz performance; 100-ns single-shot time-interval resolution (time-interval averaging allows 10-ps resolution for repetitive signals); measurement of period, period average, and frequency ratio; totalization; and input scaling—all for $1300. Logic Technology, Mountain View, Calif., unveiled a pocket counter that measures up to 10 MHz for just $189. The 7-digit hand-held Pocket Counter II operates from four size AA rechargeable Ni-Cd batteries and has dimensions of 19.8 by 10.2 by 4.3 cm.

Frequency sources. These include function, pulse, and signal generators, and frequency sweepers and synthesizers. In function generators, the trend was toward lower prices. Exact Electronics, Hillsboro, Oreg., introduced several low-cost units: a $525 11-MHz voltage-controlled unit with sine, square, and triangular waves (model 513); a $275 sweep/function unit with 2-MHz sine, square, and triangular waves, and variable time symmetry of all waveforms for ramp and pulse operation (model 121); and a $245 2.2-MHz voltage-controlled unit with sine, square, and triangular waveforms, and variable time symmetry for all waveforms for ramp and pulse operation (model 119). Interstate Electronics, Anaheim, Calif., reduced prices on its Series 70 units with its $895 model F72 true pulse/function generator. The 20-MHz unit is designed for digital users and offers variable rise/fall pulses to 15 ns, with width setability over 30 ns to 1 second. Systron-Donner's (Concord, Calif.) model 405 is an 11-MHz sweep/function generator with sine, square, and triangular waveforms selling for $495.

In pulse generators, E-H Research Laboratories, Oakland, Calif., introduced its model 137A with a repetition rate of 10 Hz to 125 MHz and variable rise and fall times of less than 2 ns to 160 μs. From T.R.I., Sunnyvale, Calif., came the 4220-4230 500-MHz pulse-generator system with 13 plug-ins that allow rise and fall times down to 500 ps.

In signal generators, Boonton Electronics, Parsippany, N.J., used a phase-locked loop in its model 102B that locks the FM/AM generator's 4.3- to 520-MHz frequency to a crystal reference for better than 0.05-ppm/hour stability.

In microwave sweepers, developments included two 18-GHz units: Systron-Donner's model 540A mainframe

interfacing in bus-oriented systems, where the microprocessor's serial input/output capability (most microprocessors transmit data in a narrow word-serial format, in some multiple of 4 bits) does not necessitate a large number of additional ICs for multiplexing and distributing data. For those instruments with random-logic controllers, a price must be paid for use of the IEEE Standard 488 bus, due to the need for additional interfacing ICs.

Interface translators

Some companies, like Dana Laboratories and Rohde & Schwarz, are offering microprocessor-based modules that act as translators between the IEEE Standard 488 and their instruments with parallel digital output formats. Dana's model 55 GPIB (General Purpose Interface Bus), which is the same as Hewlett-Packard's HP-IB or the IEEE Standard 488, is designed to interface to its model 5000 and 5900 digital multimeters, and its model 6900 precision voltmeter.

Wanted: low-cost testers for complex ICs

The testing requirements for today's complex ICs are more complex, and the need grows for high-throughput and low-cost automatic test equipment (ATE) systems. Efforts are underway to make cost-effective ATE systems by tuning up both software and hardware capabilities as in the RCA EQUATE system and the General Dynamics SCATE system. Fairchild Systems Technology's new Sentry II computer-controlled test system for microprocessors, memories, and other complex ICs is another example. It makes use of multiprocessor techniques to minimize hardware and software costs. Another approach is to bring down system cost by building dedicated computer-controlled systems that fill the gap between slow-speed and low-cost benchtop testers, and high-speed but very expensive (over $100 000) systems. General Radio Co. plans to introduce such a system this year. The model 2230, designed for passive-component testing, will be priced under $20 000. It is microprocessor-based and allows high-level keyboard programming.

Low-cost systems instruments

A big problem in ATE is controlling software costs, particularly for users of maintainance test systems for large fleet operations involving taxies, buses, truck lines, airlines, military vehicles, etc. As newer, more advanced ATE systems evolve to solve the testing problems of newer devices, older software programs with model 572A-17 plug-in covers 2 to 18 GHz with +7 dBm minimum leveled output power; and Weinschel Engineering's (Gaithersburg, Md.) model 4310A/K-P with four plug-ins covers 0.01 to 18 GHz with +25 mW of output power level within ±1 dB. Wiltron, Palo Alto, Calif., has available a three-plug-in sweeper system that ranges over 10 MHz to 40 GHz (model 610D basic system with models 6247/6136C-1/6140C-1 plug-ins).

In frequency synthesizers, Adret, Lancaster, Pa., introduced a pair of programmable units: Series 2400 covering 300 Hz to 14 MHz with 0.05-dB output-level stability; and Series 3300 50-MHz unit with 8- or 9-digit resolution, 200-μs switching speed, and search, AM, and FM capabilities. Comstron, Richmond Hill, N.Y., made available a $1595 5-digit LED-display unit (model 1013) that covers the frequency range of 0.1 Hz to 13 MHz. Ailtech, Farmingdale, N.Y., introduced its model 360, a direct-frequency synthesizer that combines high-performance advantages of low phase noise, low non-harmonic spurious outputs, and fast switching speeds, over 10 kHz to 180 MHz (to 1.4 GHz with plug ins).

Logic analyzers. The first digital logic recorder for serial data was announced by Biomation, Cupertino, Calif. The firm's model 110-D was designed for monitoring, storing, and displaying synchronous and asynchronous data to 10 MHz. BP Instruments, Cupertino, Calif., introduced the model 20D Logiscope, a compact analyzer that simultanesously records up to eight different data channels for display on an oscilloscope. Tektronix, Beaverton, Oreg., introduced the model LA501 logic analyzer for its TM500 line of plug-in modules. The unit displays up to 16 data channels in timing-diagram format and provides 4096 bits of data storage for display on any monitor or oscilloscope with X–Y capability and at least 500-kHz bandwidth. Sampling rate of the LA501 is 50 MHz (100 MHz in the 4-channel by 1024-word mode).

Multimeters. With the exception of frequency counters, digital multimeter prices have been falling more rapidly than any other instrument type. Examples included a 3-digit, five-function (ac and dc volts and amperes and dc resistance), hand-held, portable (battery and ac power) digital multimeter with LED displays from B&K Div. of Dynascan, Chicago, Ill. (model 280), selling for $99.95; model 1455 4½-digit bench/portable (battery and ac powered) multimeter with five-function capability from Data Precision, Wakefield, Mass. for $355; and from Hewlett-Packard, Palo Alto, Calif., model 3465A, a 4½-digit five-function bench/field digital multimeter for $425, and offering dc-voltage accuracy of 0.02 percent of reading plus 0.01 percent of range. Of further note: the model 334 from Hickok Electrical Instruments, Cleveland, Ohio, is a 3½-digit multimeter with five-function capability for just $229; Sencore, Sioux Falls, S.Dak., made available a five-function 3½-digit multimeter with 0.1-percent basic dc-voltage accuracy for $295; and one of the lowest-priced multimeters was the model 464 from Simpson Electric, Elgin, Ill., a 3½-digit five-function unit for only $210.

Other digital multimeter developments included the Fluke model 8000A/MTR, a 3½-digit five-function instrument with additional analog peaking and dipping capabilities using an analog meter. Systron-Donner provided the model 7003, a high-performance 3½-digit multimeter with true-rms, overload-protection, and five-function capabilities. Combining a 27-MHz frequency counter with its 4½-digit five-function model 4440 multimeter was Valhalla Scientific, San Diego, Calif. And Yokogawa Corp. of America (YEW), Elmsford, N.Y., introduced a 600-volt ac digital multimeter with true rms, current, and wattage measurement capabilities.

Oscilloscopes. For $495, B&K Div. of Dynascan, Chicago, Ill., made available a 10-MHz dual-trace, triggered-sweep oscilloscope with 10-mV/cm sensitivity (model 1471). Tektronix, the world oscilloscope leader, had two important developments: its model 335, a portable 35-MHz dual-trace delayed-sweep oscilloscope with 1-mV/cm sensitivity was made available in a portable (11.2 by 23.6 by 34.7 cm) case with a mere 4.7 kg of weight. In the miniscope class, the model 213, which weighs less than 1.8 kg in a miniature hand-held package of 7.6 by 13.3 by 22.9 cm, includes a digital multimeter with true-rms capability in addition to the 1-MHz 20-mV/cm oscilloscope. The 3½-digit multimeter has five-function measurement capability. Another miniscope, the model PS121A from Vu-Data, San Diego, Calif., at a price of $495, is the lowest priced, single-trace, 5-MHz, triggered-sweep 50-mV/div. (0.5 cm/div.) miniscope available.

Analog simulation

have to be changed. Often, as in military ATE systems, at least 20 percent of the hardware system unit-cost must be paid for with each new test program.

Most ATE advancements have tended to be for digital-device testing. For analog circuits, device simulation by computers is under investigation by a number of automatic systems manufacturers.

Atlas

For the most part, however, instrument test systems aimed at broad analog test problems continue to employ distinct and separate subsystems: a stored-program digital computer, an instrument-to-computer digital interface, conventional test and measurement instruments, an analog switch matrix, and the UUT (unit under test) interface. There is an evolutionary trend toward combining several subsystems, such as the digital processor, digital memory, and digital interfaces, in the same "card cage" and tying them together electrically onto a common bus structure. Stimulus for this trend stems from the availability of the microprocessors and competitively priced semiconductor memories.

Optical and magnetic coupling

Integrating precision analog and digital circuit functions physically into the same test-system enclosure can be a difficult problem, and internal electrical isolation is frequently the solution. Both optical and magnetic isolation are viable candidates, with cost favoring magnetic isolation when speed is essential. Nevertheless, isolation has a finite impact on both system operating speed and analog performance, often introducing time delays along the data bus.

ARINC Atlas software language implementations for commercial automated test systems were evident last year (Fig. 2). This test-procedure-oriented test language has continued to grow in popularity because it relates so directly to the testing functions of the system. The trend to test programs written in Atlas may be roughly likened to the slow, but evolutionary development of Fortran as a universal scientific programming language. There is a strong move in military programs to require Atlas for test system and software procurement. ◆

Material for this article came from many sources. Major contributors were: John Fluke, Jr., John Fluke Mfg.; Harold Goldberg, Data Precision Corp.; Fred Liguori, U.S. Naval Air Engineering Center; and members of the engineering staff of the General Radio Corp.

Transportation: year of travail

Although some projects were halted or delayed, new urban and mainline systems are proceeding

Continuing adverse economic conditions in much of the world have hindered, if not crippled, advances in all forms of transportation. United States airline schedules have been drastically curtailed, the huge Boeing 747s that were often flying with much less than half their passenger capacity were virtually eliminated from U.S. domestic flight schedules, and passenger fares have been steadily increasing to cover sharply rising operating expenditures.

On the oceans, things are no better: many of the great liners are in dry dock because their owners are economically at sea. The Italian ships, *Rafaello* and *Michelangelo*, for example, were indefinitely withdrawn from service in the wake of the layup of the behemoth *S.S. France*. The Swedish–American Line is presently negotiating the sale of its transatlantic twins, *Kungsholm* and *Gripsholm*. The Incres and Home Lines have given up the ghost. The reason: the exorbitant costs of fuel oil, maintenance, and labor.

And on land, rail and road transport have shown no special immunity to the effects of inflation. While AMTRAK, the huge U.S. interurban rail agency, continues to employ deficit financing as its operations dip ever further into the red, the National Association of Motor Bus Owners—who apparently feel AMTRAK is both an unfair and unworthy competitor—recently took out a full-page ad in *The New York Times* alleging that:

- Only 19 million passengers (less than 10 percent of the population) rode on AMTRAK trains in 1975; these passengers paid $233 million for the trip, but the other 194 million tax payers who did not ride paid $250 million for the privilege of staying at home.
- By contrast, the U.S. intercity buses paid almost $90 million in taxes instead of collecting $250 million, as did AMTRAK, in subsidies.
- Question: Which would you say is the better way to travel—via a tax-eating AMTRAK system that serves only 457 destinations, or a tax-paying bus system that serves 15 000 communities coast-to-coast?

Transportation retrenchment

AMTRAK

Suffering perhaps the most, however, is urban mass transit. In the U.S., the Washington, D.C., Metro line was originally projected to cost about $1.6 billion for what is to be a 157-route-kilometer (98-route-mile) network. This year, revised cost estimates have passed the $4.6 billion mark and are still climbing. The Atlanta, Ga., Metropolitan Atlanta Rapid Transit Authority (MARTA) has run into similar financial snags. New York City's extensive Second Avenue subway line construction has been abandoned (after an expenditure of untold millions) because of that city's fiscal plight. And in London, England, the new 4.4-km (2.7-mile) Fleet Line of London Transport's Underground complex, under construction since 1972, will be retarded at least a year because of the economic recession in the United Kingdom.

Nevertheless, despite the severe problems just enumerated, advances in transportation are being made—and on a number of fronts. Even some of the hardest hit urban mass transit systems have managed a limping progress in construction. Thus, for example, London's 5.6-km (3.5-mi) extension of the Piccadilly Line from Hounslow West to Heathrow Airport is proceeding apace. The Washington, D.C., Metro, for all its problems, is, at time of writing, about to inaugurate limited revenue service over a 7.4-km (4.6-mi) route in

Transit overseas

Gordon D. Friedlander Senior Editor

Two-car Washington Metro train shown approaching Rhode Island Avenue station in test run along overhead section. U.S. Capitol may be seen in center background.

Electronics aids the 'biomedics'

Imaging systems, prostheses, electric stimulators, and aids for the blind move ahead

In an evolutionary biomedical engineering year, notable more for refinements than for breakthroughs, noninvasive medical imaging techniques were at the fore. Diagnostic instruments known as computerized axial tomographic X-ray scanners, previously available for scanning the human brain, came on the market for clinical evaluation in whole body scanning. Impressive gains were made, once again, in ultrasonic diagnostic imaging. And, in fields other than imaging, progress was noteworthy in prosthetic devices and in electric stimulation devices both for the control of pain and for muscle activation.

X-ray scanners

Whole body X-ray scanners

A new era opened in medical diagnosis in 1972 when EMI Limited of Hayes, Middlesex, England, introduced to the world market a computer-aided axial tomographic X-ray system for scanning the human brain. Called the EMI-Scanner, it proved to be useful in diagnosing brain tumors, blood clots, cysts, hemorrhages, and other physical abnormalities of the brain, while, at the same time, eliminating the need for potentially dangerous invasive techniques such as injecting dyes, air, or gas into the brain and exploratory surgery. To date, EMI has either sold or received orders for over 340 scanners and, not surprisingly, other manufacturers have similar units on the market and in use.

Tomography

The EMI-Scanner and its competitive instruments combine known tomographic X-ray techniques with modern computer technology. Prior to the advent of these new instruments, a tomograph was produced by moving an X-ray source in one direction during an exposure while the X-ray film was moved in the opposite direction. In the resulting projected image, only one plane (hence the name tomograph) in the body remains stationary with respect to the moving film and all other planes are blurred. By passing the X rays through the patient's body in parallel rays as the patient is rotated in steps around a single axis (with the patient's body perpendicular to the axis of rotation), and by making a photographic image at each step, structures in the body are recorded as a single, one-dimensional line. Measuring the X-ray density along that line on each image isolates the information from the desired plane. A single, two-dimensional plane can then be reconstructed. Stacking a sequence of such planes gives a three-dimensional picture.

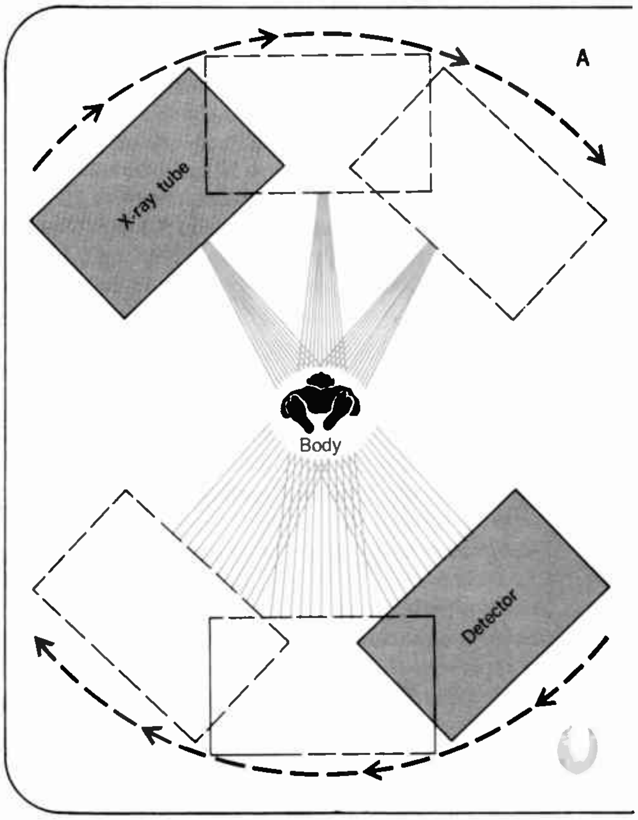
The EMI-Scanner and its counterparts operate on these same basic principles of tomography. But they carry it several steps further. Total time that a patient is exposed to X rays is only 20 seconds in the EMI-Scanner. During those 20 seconds, the X-ray tube and a detector on the opposite side of the patient rotate through 180 degrees, stopping every 1 degree to "take" a total of 18 000 X-ray absorption values. When the 20-second scan is completed, a digital computer cross-correlates all the absorption values to produce absorption values for 80 000 points. The points make up the resolution in a picture matrix of 320 by 320 elements. The absorption values show whether a point consists of bone, tissue, or an organ.

It is too early to know whether or not the body scanners made by EMI, Pfizer Medical Systems, Inc., Ohio Nuclear, Inc., and other manufacturers will prove to be as useful as the brain scanners, but hopes are high.

Ronald K. Jurgen Managing Editor

Three examples of modern imaging techniques

Whole body scanner (A) sends fanned beams of X rays through a patient's body as the X-ray tube and detector are rotated through 180 degrees around the body. X-ray absorption valu[es] massaged by a digital computer, are used to reconstruct [im]ages for portrayal on a TV screen. EMI, Ltd.'s scanner pr[...]



(There are reservations because organs within the body move on their own and can cause blurring. For example, intestines churn around during a 20-second interval. The brain, however, sits relatively still.) With prices of the scanners ranging from about $300 000 to $500 000 per unit, a lack of real-world clinical usefulness for the scanners would be an extremely expensive failure. Among others, the Mayo Clinic, Rochester, Minnesota; the Mallinckrodt Institute of Radiology, St. Louis, Missouri; and Northwick Park Hospital, Harrow, Middlesex, England, are now evaluating body scanners. The results of their experience will be crucial in determining the future role of these instruments.

Ultrasonic imaging moves forward

Ultrasonic noninvasive diagnostic procedures are finding clinical acceptance in a wide variety of applications such as echocardiography, echoencephalography, blood flow detectors, etc. And in some clinical applications, such as obstetrics, the use of ultrasonics has even become required procedure.

Although 1975 was a year of increasing availability of U.S.-made ultrasonic diagnostic equipment of high quality, a problem still remains in many applications in that ultrasonic images are difficult to read and interpret correctly. It takes a lot of experience to be good at it and, for this reason among others, researchers are constantly looking for ways to make the ultrasonic pictures clearer and less subject to wrong judgments.

One answer to the problem may lie in work that was initiated at The National Bureau of Standards in Gaithersburg, Maryland, this past May. A seminar was held on the subject of ultrasonic tissue characterization. Cosponsored by NBS, NSF, and the National Institutes of Health, the seminar chose as one of its goals to review the current status of tissue identification using ultrasound, looking toward the development of a tissue signature library. Such a library would contain imaging tissue identifiers, or signatures, based on the parameters of ultrasonic returns from those tissues such as phase angle or attenuation. Ultrasonic signatures would differentiate between diseased and normal tissue. The tissue signature library approach is one step toward making ultrasonic diagnosis more foolproof, but work has just begun.

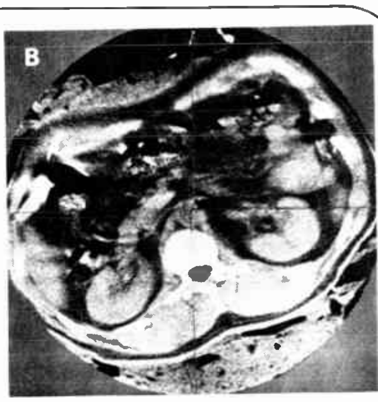
Tissue signatures

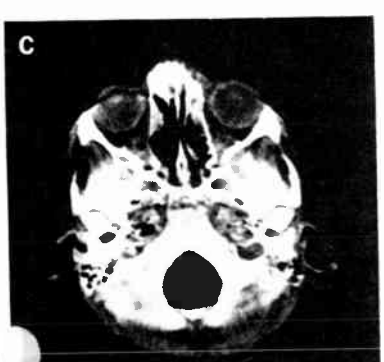
Ultrasonic diagnosis

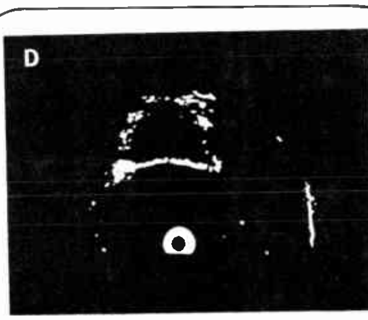
A typical example of the evolutionary development of ultrasonic products is a transrectal probe incorporating a barium–titanate disk that is driven at 3.5 MHz. An ultrasonic beam at this frequency is emitted at right angles to the probe and echoes are received by the same disk. Echoes are displayed on a CRT by intensity modulation.

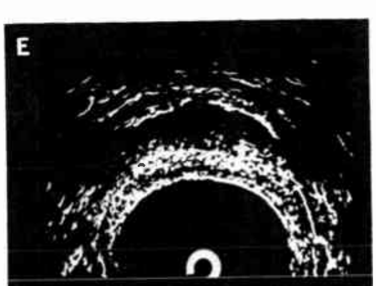
Transrectal probe

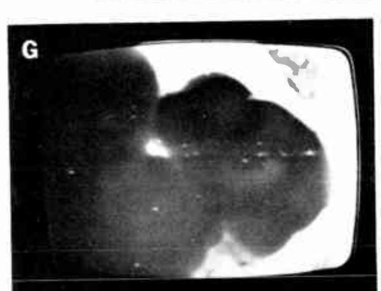
duced the X-ray picture (looking up the body from the feet toward the head) of a cross section through the body (B) showing, at bottom center, vertebra with spinal cord; on either side of the vertebra the ys can be seen. The spongy layer around the picture is a padoand used to position the patient. Another EMI picture (C) was taken by the brain-scanning version of the equipment. Taken through the base of the skull, the picture shows the eyes (upper left and right) between which are the nasal septum and nasal cavity. The foramen magnum is at lower center and the pinna of the ear at lower left and right. Figure D shows a normal prostate as viewed on a CRT. The picture was produced by an ultrasonic transrectal probe under continuing development at the Bowman Gray School of Medicine of Wake Forest University. Figure E shows a prostate with carcinoma as depicted by the same equipment. In Fig. F, an acoustic micrograph of a 10½-day mouse embryo (equivalent to a 26-day human fetus) is shown as imaged by the Sonomicroscope, an ultrasonic microscope marketed by Sonoscan, Inc. Figure G shows an optical image (100 X) for comparison.

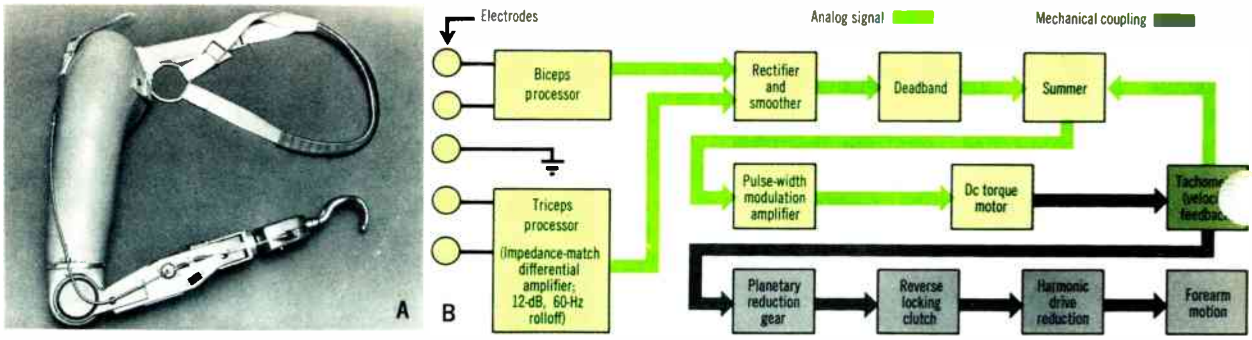












The "Boston Arm," an above-elbow prosthesis (A) uses the major electronic and mechanical components shown in (B). The electrodes are located in the upper arm socket and a nickel–cadmium battery pack is placed in the forearm of the prosthesis. Developed at Liberty Mutual Insurance Company's Research Center, the arm is controlled by myoelectricity (electricity from human muscles). The myoelectric signals are generated from the severed bicep and tricep muscles in the amputee's stump. The deadband activates the motor only when a muscle signal is greater than a preset amplitude.

The method was first developed in Japan by H. Watanabe about eight years ago. Since that time, it has been under continuous refinement. Recently, gray-scale imaging was added, providing nine shades of gray for aid in diagnosis. In experiments at the Bowman Gray School of Medicine of Wake Forest University in Winston-Salem, North Carolina, where much of the recent developmental work has been done, the probe has proved useful in diagnosing carcinomas and other abnormalities of the prostate as well as tumors in the bladder.

Acoustic microscope

In another ultrasonic development, the first commercially available acoustic microscope using ultrasound was marketed last year. The "Sonomicroscope" is manufactured by Sonoscan, Inc., of Bensenville, Illinois, under an exclusive license from Zenith Radio Corporation to Lawrence W. Kessler, the president of Sonoscan and one of the coinventors of the microscope. The first unit has been installed at the Indianapolis Center for Advanced Research, Indiana University Medical School, where it is being used in research focusing on the effects of various drugs on the beating of heart muscles in living embryos.

The Sonomicroscope uses sound waves at 100 MHz. A high-resolution scanning laser beam pickup relays ultrasonic information to a TV screen to produce a visible image. The acoustic picture provides a view of the material structure being examined that is substantially different from other viewing techniques. For this reason, an optical image of the specimen for comparison purposes is simultaneously displayed on a separate TV screen.

The "Boston Arm"

Boston Arm

The longest period in the development of a product may be after its designers feel they have solved all the design problems. Such was the case with the "Boston Arm," an above-elbow prosthetic device. More than 13 years ago, research to help the above-the-elbow amputee was begun by M.I.T., Harvard Medical School, and the Massachusetts General Hospital. This work led to a practical device developed at the Research Center of Liberty Mutual Insurance Company in Hopkinton, Massachusetts. A number of elbows were fitted to patients and they didn't wear them. The reasons became obvious *after* the clinical trials. Batteries were too heavy (1.8 kg), it was inconvenient to tape electrodes in place each morning, it was annoying to have to continually switch the device on and off, and the noise was objectionable.

Pain relief

Some of the problems were easy to solve. Others required a systems approach. One key element in a basically electric device turned out to be mechanical. A reverse locking clutch now holds the arm whenever the amputee is not voluntarily moving it. With low-current op amps and with power usage reduced by the locking clutch strategy, the rechargeable nickel–cadmium battery now weighs only 235 grams, an eightfold reduction. In fact, the entire elbow–forearm assembly weighs just slightly over one kilogram.

Another power-saving strategy is a deadband used so that the motor is only activated when the amputee makes a muscle signal large enough to indicate that motion is really desired. Another use of the deadband is to reduce the need for clever processing of low-level myographic signals from the muscles. However, it is the low end of the scale that normal people use for most of their activities, so that even though six man-years of clinical trials prove that the new Boston Arm is worn and used by amputees, work still remains to be done.

With the new arm, an amputee can perform delicate work such as soldering a circuit board, but considerable mental effort is required. Further improvement in EMG processing strategy should reduce this effort and make the arm respond more naturally and with less effort.

Other future work will further reduce the size of the electronic hardware so that other functions such as wrist rotation and grip can be added. These additional degrees of freedom lack control sites in an above-elbow amputee so another Liberty Mutual project is to develop an implantable nerve electrode array with which a prosthesis can be controlled directly by the central nervous system. Work on this project is well along with rabbits and will shortly be shifted to primates.

Several manufacturers have indicated interest in the improved Boston Arm. As a result, it may be commercially available to amputees sometime this year.

Electric stimulation devices

The first applications of electric energy to relieve pain took place a long time ago but, with the advent of drugs and surgery for pain control, electrical techniques became less popular. Now, once again, the electric method of pain control has taken hold. In some instances where drugs, surgery, and even psychiatry have failed, electrical techniques have not only succeeded but have done so without any serious side effects or complications.

Charles D. Ray, in a guest editorial for a special issue of *Medical Instrumentation* on electrical neutralization of pain (Sept.-Oct. 1975), said this about electrical pain control: "It works with some astonishing results when it works; it's much, much cheaper in dollars and family sanity than drug control; if it doesn't work, then one can still go ahead with those other ways and means, and nothing important has been lost. A few coulombs applied to the right spot may do more to control pain than many other well-established methods."

One method of electrical pain control uses implanted devices for electronic augmentation of nervous system function. Electronic augmentation systems (cerebral, cortical, intracerebral, cerebellar, spinal cord, peripheral nerve, and neuromuscular) have been used, in addition to pain relief, for visual augmentation, auditory augmentation, and muscle activation for treatment of epilepsy, cerebral palsy, certain aspects of paralysis and stroke, spastic bladders, scoliosis of the spine, certain symptoms of multiple sclerosis, and other malfunctions, as well as for activation and feedback of limb and extremity prostheses.

Other than the cardiac pacemaker with approximately 150 000 implanted units and 100 000 external units in use worldwide, perhaps the best known and most widely used neuroaugmentive device is the dorsal column neurostimulator. Electrical stimulation of the dorsal column has been used as a mode of therapy for intractable pain, to stimulate the bladder, and for control of spasticity.

Results reported for use of neurostimulation devices vary widely. Some are dramatic. Effective relief of abdominal pain lasting from 2 hours to 25 days was achieved in eight patients by neurostimulation of the celiac plexus. Electrostimulation of peripheral nerves, used in patients to relieve chronic pain due to nerve injury, resulted in most patients exhibiting some degree of pain alleviation even after periods of 6 to 48 months.

As Dr. Ray concludes in his editorial, "This new area of practical, clinical engineering will doubtlessly develop dramatic new applications each succeeding year, as the field emerges."

Aids for the blind

To its ever-expanding inventory of aids and appliances for the blind, the American Foundation for the Blind in New York City has just added three new electronic devices to expand educational and vocational opportunities for blind and visually handicapped persons. The new devices are a braille electronic calculator, an audible calculator, and a combination paper money identifier and light detector.

The braille calculator was adapted by the Foundation's engineering division from a standard portable calculator. The braille version is a five-function unit (addition, subtraction, multiplication, division, and percentage) with floating decimal point. The calculator is mounted in a box and is equipped with a single braille cell. The cell, which uses four dots out of the basic six-dot braille notation to represent the numerals zero through nine, is activated by depressing a "read" button on the front panel of the calculator. The digits and decimal point displayed on the visual readout are then presented in sequence in the form of small pins that pop up to form a braille digit. The sequence goes from left to right. The braille notation can be read at a variable speed of up to four braille digits per second, adjustable by turning a speed control on the calculator case. Reading capacity is eight digits and the calculator is priced at $345. It has self-contained, rechargeable batteries.

Neurostimulators

The Speech Plus audible calculator was developed by Telesensory Systems, Palo Alto, California. Priced at $395, it has a 24-word vocabulary that announces every entry and result. It has six basic functions (including square root and percentage), accumulating memory, automatic constant, change of sign key, floating decimal point, and an eight-digit visual display. The speech key can be pressed repeatedly to announce what is on display without initiating further calculations. The loudspeaker in the calculator provides sound of sufficient volume for small classrooms. An earphone is included with the calculator for private listening.

Audible calculator

Implants

The paper money identifier was originally produced with the support of the NASA-sponsored Biomedical Application Program and is now manufactured by EMR, Ltd., Los Angeles, California. With about four to six hours of training, an operator can learn to identify the unique tone patterns generated by different values of paper currency (because of the differences in light and dark areas on the bills). A simple switch change converts the money identifier into a light detector. It is sensitive enough to detect lights that blink on multiple button phones, to determine whether or not a coffee pot's ready light is on, or even to operate a PBX switchboard. Room lights (including fluorescents) can also be detected. The device is about the size of a pack of cigarettes and is priced at $125 including a recharger and cassette instructions.

Paper money identifier

Light detector

Medical device law in '76?

Legislation amending the Food and Drug Act to give the Food and Drug Administration legal backup for regulating medical devices has received U.S. Senate approval. And, at the time of this writing, the House Health Subcommittee was at work writing its version of the bill.

The long-pending legislation could mean a whole new ball game for manufacturers of medical devices of all types once the FDA begins exercising its authority under the legislation to require premarket clearance of selected medical devices. An FDA study estimates that premarket approval for prosthetic heart valves, for example, will cost $225 000 and arrhythmia detectors and alarms, $10 000 to $160 000. ◆

Information for this article came from many sources. Major contributors were: John Busser, Alliance for Engineering in Medicine and Biology; Thelma Estrin, University of California; Melvin Linzer, National Bureau of Standards; Hun Sun, Drexel University; Cedric Walker, Duke University; John Webster, University of Wisconsin; Leon H. Wheeless, Jr., University of Rochester Medical Center; James Willard, Bowman Gray School of Medicine; and T. Walley Williams, III, Liberty Mutual Research Center.

Braille calculator

Military and aerospace

Work progresses on space shuttles, air cushion landing systems, earth resources programs, and controls

With Federal R&D budgets now at their highest in over a decade, the United States seems firmly committed to a continuance of its technological superiority despite the ravages of inflation and the public clamor to cut spending in every sector of the economy. Budget increases for military, aerospace, and energy research were particularly high last year, with development of new weapon systems, the space shuttle, and new sources of power having the highest priorities.

Although 1975 heralded the close of manned space flight in this decade, there is new excitement in the aerospace arena as man turns his attention toward solving some of the problems encountered in his struggle to survive in an earthbound environment. To help in finding adequate solutions, there is continuing use of such sophisticated methodologies as control theory (see box, p. 82). In addition, there is a continuing emphasis on applying solutions obtained from the military/aerospace fields to everyday problems.

Landsat

Military priorities

The Air Force has given top priority to advanced ICBM technology, antisubmarine warfare surveillance systems, the air combat fighter (F-16) and B-1 advanced bomber, and the close-support weapons system. Although the Navy is heavily committed to its Trident submarine-launched missile system, other priorities include the fleet ballistic missile system, the sea-launched cruise missile, the Navy version of the air combat fighter, the antisubmarine warfare system, and mine systems. Army increases will go for the short-range air defense missile system and SAM-D, the XM-1 tank, and improved mine systems, with development continuing on the UTTAS logistic helicopter and advanced attack helicopter.

F-16 fighter

B-1 bomber

Trident sub

SAM-D

One military development, the *remotely piloted vehicle* (RPV)—an aircraft used for electronic espionage and ground attack as well as missile decoys and target markers—has already added a new dimension to warfare. According to the 1975–1976 edition of *Jane's All The World's Aircraft*, the U.S. leads the world in the development of these robot planes with 100; the Soviet Union is reported to have two.

Remotely piloted aircraft

United States military commitments have also heavily influenced international political relationships. With the partial dismantling of the nation's only Safeguard antiballistic missile site at Grand Forks, N.Dak., almost ensured by Congressional approval (*Spectrum*, Jan. 1975, p. 87), the newest bargaining weapon in U.S.–U.S.S.R. arms-limitation talks seems to be the *cruise missile*—an extremely thin, long-range, terrain-following projectile that would be almost impossible to detect in time for adequate defense, and capable of being launched from land, air, or sea. At the heart of this new low-altitude missile is a unique guidance system with a preprogrammed memory of the terrain over which it will travel.

Safeguard

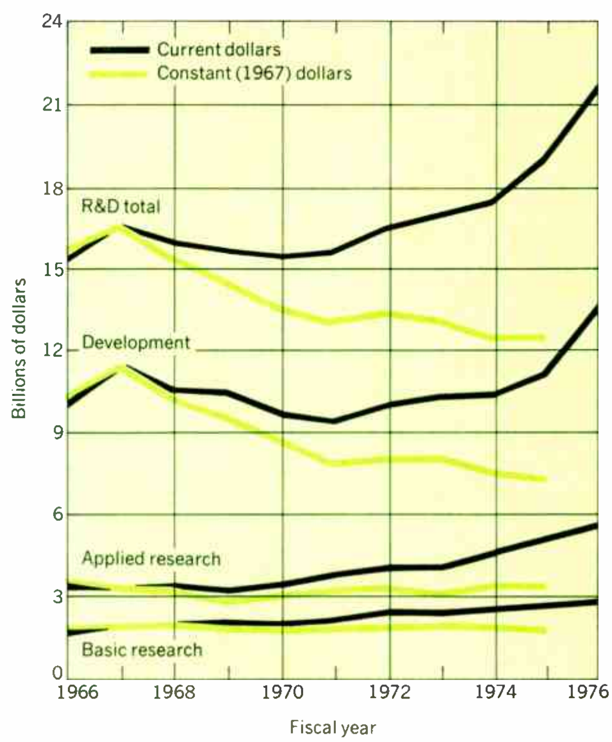
Cruise missile

A return to earth

Popular concern with depleting natural resources, diminishing food supplies, and debilitating environment, has fostered an enlivened appreciation of earth-oriented technologies. It is significant that the next U.S. manned space project will not be consummated until another half decade, and even then will be in earth-bound orbit; further, more than two thirds of all NASA mission launches during 1975 dealt with some aspect of the earth's environment (resources, communications, meteorology, or purely scientific).

Earth resources programs, such as Landsat, are beginning to provide mountains of image data about the world. Fortunately, such information lends itself to computer processing and considerable activity is underway to develop appropriate software. (One example of this is the LARS project at Purdue University.) The need for scientists from differing disciplines to interact with these data at the processing stage has created

[1] Federal R&D obligations. (Courtesy NSF)



Marce Eleccion Associate Editor

problems, however. Consequently, considerable effort has been devoted to combining the computer with high-resolution color television displays and supporting software for more sophisticated interactive display systems (e.g., General Electric's Image 100)—a definite trend of the future.

There is another problem in actually obtaining data from the environment. In the past, major emphasis in earth observation satellites has been on sensors that operate in the visible spectrum, severely restricting operation over cloud cover. During 1975, increased attention was given to developing active and passive microwave sensors for earth observations. The Seasat satellite, scheduled for launch in 1978, will carry an altimeter, a radar scatterometer, a side-looking imaging radar, and a multifrequency microwave radiometer; construction of these sensors will begin in 1976. In addition, preliminary design has been completed on a high-resolution, dual-frequency (X- and L-band), synthetic-aperture imaging radar to be carried on the space shuttle in 1981. This sensor package has the potential of providing "cloud-free" images of the earth comparable in information content to visual systems such as those carried in Landsat.

One significant mission begun by NASA during 1975 was that of Viking 1 and 2. The most ambitious unmanned planetary exploration ever attempted, the two spacecraft—representing the most sophisticated instrument package launched to date (*Spectrum*, Oct. 1974, pp. 42–50)—will have traveled 460 million miles in 11 months before reaching Mars. Once there, the Orbiter portion of each spacecraft will survey selected landing sites prior to separation from the Lander, which will land with the majority of the instruments while Orbiter continues to orbit the planet, serving as both an instrument platform and a communications link with earth. The Orbiters are designed to operate for approximately 144 days in orbit and the Landers to operate serially for 125 days on the surface. During this mission, particular emphasis will be placed on obtaining biological, chemical, and environmental data relevant to the existence of life on Mars—whether in the past, at present, or if ever possible at some future time.

Microwave sensors

Where the R&D dollar is going

DOD

Trying hard to keep pace with the nation's inflationary spiral, both the U.S. Department of Defense (DOD) and National Aeronautics and Space Administration (NASA) budgets reflected increases of approximately 10 percent for fiscal year (FY) 1976—DOD with a Congressional appropriation of $90.7 billion (compared with $82.7 billion in FY 1975), and NASA with a request of $3.5 billion for FY 1976 (Congress's

Viking

Landing on air!

Not only is the U.S. Air Force flying on air, but it's landing on air as well! Sponsored jointly by the Air Force Systems Command's Flight Dynamics Laboratory (Wright-Patterson AFB, Ohio) and the Canadian Department of Industry, Trade, and Commerce, the *air cushion landing system* (ACLS) is an advanced development program to demonstrate the feasibility of using an air cushion as a landing system on large transport aircraft. And from the initial successful demonstrations this writer has seen, the idea looks like a good one.

The first takeoffs and landings of the ACLS took place in March and April of last year. Using the Air Force STOL XC-8A, a modified CC-115 "Buffalo" Canadian aircraft, as the testbed for ACLS, the Air Force's Aeronautical Systems Division at Wright-Patterson installed twin auxiliary air-supply engines beneath the XC-8A wings to generate a constantly flowing cushion of air, which is forced out through 6800 holes in the bottom of a rubber and nylon trunk below the aircraft fuselage. The highly elastic trunk, which resembles an upside-down life raft about 32 feet long and 14 feet wide, folds to fit snugly against the fuselage when the plane is in flight.

Perhaps the most startling fact about ACLS is that the Air Force plans to use it to completely replace the conventional landing-gear system—as a primary system rather than a backup emergency system. In reality, ACLS operation is simplicity itself. As the aircraft lands, the pilot starts his auxiliary engines to pump air into the trunk, which then pops out (see photograph) into a landing configuration. Because an extremely small amount of pressure per square inch is exerted on the landing surface compared with conventional landing gears, the result is an extremely safe as well as bumpless landing. Once landed, braking is accomplished through six rubber pads on the bottom of the trunk, each of which resembles a section of heavy-duty tire tread, activated by the pilot much like an emergency brake. Stopping distance is comparable to that of conventional brake systems, and each brake pad is attached to the trunk by screws for easy replacement. Once the aircraft has been maneuvered into docking position via the XC-8A's variable-pitch propellers (which can be made to reverse instantly), the exit holes of the trunk are blocked off and auxiliary engines turned off, leaving the plane to rest on its inflated trunk.

Certainly the major advantage of ACLS is that it can land on virtually any surface—mud, sand, water, snow, ice, or even extremely rough terrain (it can traverse 2-foot ditches or obstructions). Compared with conventional landing-gear systems, the ACLS is simpler to deploy, requires fewer moving parts, and is ideal for crosswind landings and takeoffs.

In addition to obvious military applications, one use of ACLS would be as an intercity transport—landing on water in an uncongested area, taxiing to a small transition ramp onto shore, loading or unloading cargo or passengers, and reversing the procedure before takeoff to the next destination. Considering the congested air traffic anticipated over the next decade, this may be one Air Force project with very important impact on the civilian economy.

appropriation in FY 1975 was $3.2 billion).

Federal R&D

Actual Federal R&D obligations, representing their largest relative gains in the last ten years, rose to $21.7 billion in FY 1976 from $17.4 billion in FY 1974 and $18.9 billion in FY 1975. The primary stimulus to R&D growth in 1976 comes from defense and space programs, which show a greater relative increase over other programs for the first time in a decade. All areas of R&D experienced some growth (see Fig. 1), but only the development increase is of sufficient size to allow for expanded performance in real terms. If one looks at total R&D in terms of 1967 dollars, however, there has been a decided decrease in real purchasing power for almost a decade.

Although the R&D programs of most Federal agencies are experiencing a general growth trend for 1976, only DOD, NASA, and the Energy Research and Development Administration (ERDA), the Government's new energy agency, reflect important constant-dollar increases. It is interesting to note that for the first time since 1971, engineering will be the leading field of science in Federal R&D.

At DOD, R&D spending has been increased over 1975 by $1.776 billion, almost two thirds of the total Federal R&D increase. DOD alone, with a total of $10.6 billion, accounts for almost half of the total R&D budget, and with all three services planning expansions, DOD will need all it can get.

NASA

Space shuttle

At NASA, the space shuttle continues to be the prime project, with $1.2 billion allocated for R&D and $47 million for facilities during 1976, representing more than a third of the entire NASA budget. During 1975, fabrication of a subsystem test bed for the main shuttle engine was completed by the Rocketdyne Division of Rockwell International, and the first set of shuttle wings (which one day will travel at 17 500 mi/h in earth orbit) were delivered by Grumman Aerospace Corp. to the orbiter's final assembly site at Palmdale, Calif., along with aft-mid-forward sections built by other contractors. NASA's budget itself is due for a $365 million increase in 1976; other projects of high priority include the lunar and planetary, physics and astronomy, aeronautical research and technology, and earth resources satellite programs. With the completion of the Apollo–Soyuz Test Project (ASTP) in 1975, manned extraterrestrial activities were curtailed for at

Control theory—the key to application

With the increased use of more sophisticated defense systems and space vehicles, modern control theory is one of the more important areas of engineering application in the military/aerospace fields. Control applications have begun to impact other areas as well, however, notably transportation, power systems, and economics.

In *aerospace and defense* systems, prime areas of concern have been the identification of aircraft parameters, adaptive control for aircraft, jet engine control, radar tracking, man–machine systems, nonlinear stochastic control for tactical missiles, precision telescope pointing and tracking, and ride-quality control. Other areas include self-test and failure-detection techniques, gyro caging loop design, and reduced-order estimators.

Developments in transportation include both air traffic control and ground systems. In *air traffic control*, modern control theoretic ideas—including differential games—have been used to define strategies for horizontal collision avoidance by a research team at Systems Control, Inc. In the near terminal area, optimum control of both conventional and STOL aircraft has been studied at NASA Ames and M.I.T.'s Electronic Systems Laboratory.

During the past year, *ground system* activity has included a class of problems arising from the control of long freight trains traveling over mountainous terrain. At Queen's University, a team has been studying the accelerations/decelerations of several engines to minimize the stresses created in linkages connecting the freight cars. Using modern control and estimation ideas, several researchers (at IBM, Systems Development Corp., the University of California, Berkeley, Polytechnic Institute of N.Y., Sperry, and the M.I.T. Electronic Systems Laboratory) have studied the problem of controlling freeway traffic flow, signal intersections, tunnels, etc.

The interaction between control scientists and *economists* has increased significantly over the past year, and may continue well into the future. The reason for this, advanced by Michael Athans, director of the M.I.T. Electronic Systems Laboratory and president of the IEEE Control Systems Society, is that economists now realize that theoretical and algorithmic advances in stochastic and adaptive control present a useful and flexible conceptual approach to the development of coordinated monetary and fiscal policies for the U.S. economy.

Military/aerospace. The following are included among the many areas of modern applications:

- NASA is now using the *F*-8 digital fly-by-wire aircraft to test several advanced concepts on adaptive control and system reliability; flight testing will continue for the next several years.
- During the past several years, it has been recognized that traditional servomechanism techniques are not suitable for designing high-performance jet engines. Over the last two years, preliminary designs using modern control theory were carried out at NASA Lewis Research Center, Honeywell, United Aircraft, and Systems Control, Inc., where initial efforts have shown a high degree of promise.
- One of the most complicated control theory applications is that of tracking a reentry vehicle so that discrimination and impact-point prediction can be accurately obtained. At M.I.T. Lincoln Laboratory, the extended Kalman-filter algorithm has been refined to include problems of false radar measurements as well as ballistic reentry vehicle (MIRV) tracking.
- In a tracking control task, there are two fundamental points of view concerning the human mathematical model. The traditional view models the human as a transfer function whose parameters are then identified using input–output data. The more modern approach (pioneered by Bolt Beranek and Newman) is based on linear-quadratic-Gaussian control theory. Since the latter can be easily adapted to nonstationary situations, it has gained in popularity, with increased application to such problems as pilot performance, cockpit displays, and remotely piloted vehicles.
- In designing control systems for the space shuttle, C-5A, B-52, and other high-performance aircraft, load alleviation and mode stabilization control systems are of critical importance. Several contributions to this area have been made by research groups at NASA Johnson Space Center, Honeywell, Rockwell International, Wright-Patterson Air Force Base, Lockheed-Georgia, Boeing, and NASA Langley Research Center.
- At one aerospace company (TASC), several space shuttle landing navigation systems have been evaluated using convariance analysis methods.

I. 1975 NASA mission launches

Date	Name*	Launch Vehicle	Test Range†	Mission
Jan. 22	Landsat-B	Delta 107	WTR	Formerly ERTS; to conduct earth resources experiments
Feb. 6	SMS-B	Delta	ETR	Geostationary environmental satellite; visible and IR spectrum
Feb. 20	Intelsat IV	Atlas/Centaur	ETR	Unsuccessful; first stage destroyed
Apr. 9	GEOS-C	Delta	WTR	To demonstrate precise instrument calibration and tracking
May 7	SAS-C (Explorer 53)	Scout	SM	Third in a series of small astronomy satellites
May 7	Telesat-C	Delta	ETR	Third in a series of Canadian communications satellites
May 22	Intelsat IV	Altas/Centaur	ETR	Global ITSC synchronous communications satellite
June 12	Nimbus F	Delta	WTR	Experimental meteorological satellite; atmospheric sensing
June 21	OSO-8	Delta	ETR	Scientific satellite to explore features of the sun
July 15	Apollo-Soyuz Test Project	Saturn 1B	ETR	U.S.–Soviet manned-spacecraft rendezvous to test new docking system and conduct experiments
Aug. 8	ESRO COS-B	Delta	WTR	European study of extraterrestrial gamma radiation
Aug. 20	Viking-A	Titan/Centaur	ETR	Planetary mission to explore Mars both from orbit (Orbiter) and from the surface (Lander)
Aug. 26	Symphonie-B	Delta	ETR	Second French–German experimental communications satellite
Sept. 9	Viking-B	Titan/Centaur	ETR	Same as Viking-A
Sept. 25	Intelsat IVA-F1	Atlas/Centaur	ETR	First of a series of satellites with twice the present communications capacity
Oct. 6	Atmosphere-D (Explorer 54)	Delta	WTR	To study atmospheric chemical processes and energy transfer
Oct. 16	SMS-C (GOES-A)	Delta	ETR	First operational synchronous meteorological satellite of the National Weather Service
Nov. 19	Atmosphere-E	Delta	ETR	Same as Atmosphere-D
Nov. 26	U.S.S.R. Cosmos	—	—	Contains United States bio-payload
Nov. ‡	ITOS-E2	Delta	WTR	Meteorological satellite of the National Weather Service
Dec. 3	Dual Air Density	Scout	WTR	Two scientific spacecraft to study composition of upper and lower atmospheres
Dec. ‡	RCA-A	Delta	ETR	First of a series of RCA domestic communications satellites

*For NASA spacecraft, suffix letters indicate prelaunch nomenclature, becoming numerals after launching.
†ETR = Eastern Test Range (Kennedy Space Center, Fla.); SM = San Marco (Indian Ocean) platform; WTR = Western Test Range (Vandenberg Air Force Base, Calif.).
‡Scheduled.

least another half decade. Other NASA space missions are described in Table I.

Inheriting its many energy roles from the now-defunct Atomic Energy Commission and the National Science Foundation, ERDA's $2.4 billion FY 1976 budget is $476 million greater than last year's, with its efforts accounting for 11 percent of all Federal R&D. Responsible for nuclear, fossil, solar, geothermal, and advanced energy systems research as well as nuclear weapons activity, ERDA has its greatest dollar increase in the multifaceted coal-utilization area, with other increases planned for nuclear fission power, weapons R&D and testing, solar energy development, and fusion power R&D. Although solar energy will receive the largest relative increase of all ERDA programs, petroleum and natural gas, geothermal energy, and advanced energy systems are also scheduled for growth.

Dropping $78 million from its 1975 R&D budget, the Department of Health, Education, and Welfare is scheduled to receive $2.3 billion for FY 1976, a result of declining funds for the National Institutes of Health (NIH). The National Science Foundation, on the other hand, has increased its R&D support by $58 million in 1976, to a total of $678 million. The program scheduled to receive the largest allocation of NSF funding is Scientific Research Project Support, which includes expanded help toward finding long-term solutions for food and energy problems; next largest support areas are National and Special Research Programs and RANN (Research Applied to National Needs). ◆

ERDA

NSF

RANN

Information for this article came from many sources. Major contributors were: the National Science Foundation, the Department of Defense, Donald L. Zylstra of NASA Headquarters, Sajjad Durrani of Goddard Space Flight Center, Michael Athans of the M.I.T. Electronic Systems Laboratory, A. Gelb of The Analytic Sciences Corp., and J. W. Rouse, Jr., of the Remote Sensing Center, Texas A.&M. University.

Consumer electronics: fun and function

John Q. Public goes digital with calculators, watches, sewing machines, and air conditioners

The spark and crackle typically associated with new consumer electronics were subdued during 1975. Though the spotlight played briefly on video disks, little hardware is yet available—excitement dissipated quickly, awaiting the "big push" still scheduled for late this year when MCA/Philips and RCA start marketing players in the United States. Calculators were personal, portable, and plentiful this past year, with new entries by Hewlett-Packard and Texas Instruments leading the pack. And jewelers, accustomed to the familiar tick of mechanical timepieces, had to adjust to the silence of the digital watch—which, as prices tumble, is showing up in chain store windows as well as posh display cases. Here, the technology tug-of-war revolves around readouts: light-emitting diodes (LEDs) vs. liquid crystal displays (LCDs).

Meanwhile, on other fronts: more top-of-the-line TV sets now offer digital LSI tuning, and RCA has designed its latest color consoles with 95-percent dc restoration, significantly improving contrast; microprocessors are showing up in gas pumps, sewing machines, and air conditioners; and a college professor has designed and marketed a $20 RF leak detector for microwave ovens.

Video disk doings

Video disk home players

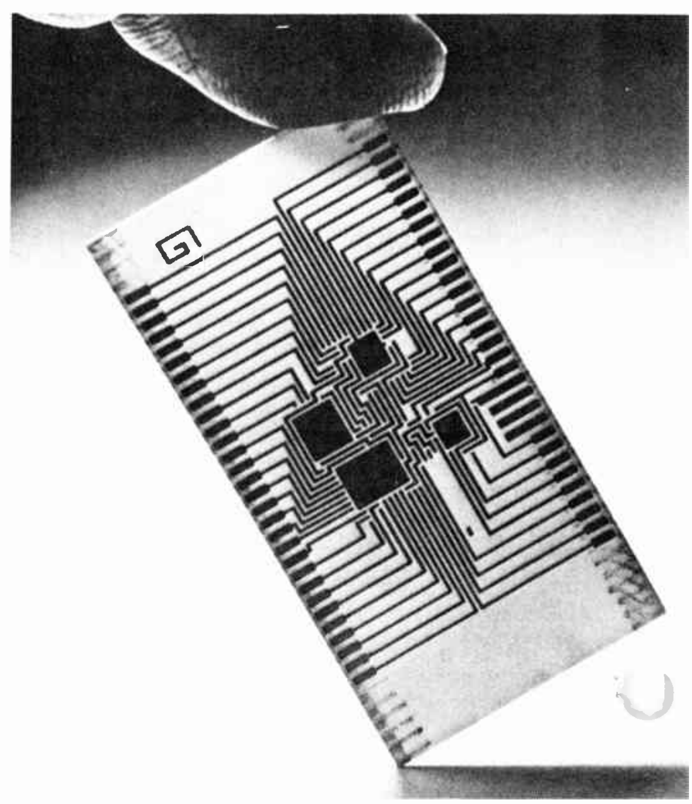
Ostensibly because of the stakes involved, manufacturers with announced intentions involving video disk products have had little more to say officially since holding interesting, impressive demonstrations early last year (see *Spectrum*, Aug. 1975, pp. 34–39). *Spectrum*'s most recent soundings at both Philips/MCA (laser beam optical pickup) and RCA (capacitance-sensing mechanical stylus) show that limited introduction is still projected for late 1976. However, Philips Laboratories president Donald D. King, in a November talk to the National Association of Educational Broadcasters, made mention of an advanced video disk player being developed for educational and industrial use. An important feature of the advanced player would be automatic access to each individual picture frame simply by keying a number (00 000 to 54 000 for a half-hour NTSC disk) into a built-in computer. Dr. King explained that full compatability would be maintained between the home player already demonstrated and any advanced design. All Philips/MCA disks could be played satisfactorily on either type of machine.

Meanwhile, it is known that RCA is retooling a former audio products plant in Indianapolis, Ind., to handle production of video players and disks. RCA has also confirmed that field tests of SelectaVision among a scientific sampling of several hundred "typical" consumers has been underway since the last weeks of 1975. This program will test the handleability of SelectaVision's disk and stylus.

RCA expects to have 500 SelectaVision programs available by the time of formal product introduction late this year. Announcement of the titles will be made about two months before players are marketed.

Perhaps the most sensitive area among the major developers of video disks is the maneuvering for licensing agreements with other interested manufacturers. Informal technical agreement has been reached to minimize the differences between existing and proposed optical players (Zenith, Thomson-CSF), while five Japanese TV set producers have signed licensing agreements with RCA. (They can produce a SelectaVision-type product, but are also free to abandon or change plans as future market conditions dictate.) The sudden departure of Robert Sarnoff as RCA's chief executive in November has invited much industry speculation about the priority and funding that new-tech-

[1] Project Omega, General Instrument's all-electronic TV tuning system, consists of four semiconductor chips. Most important is a nonvolatile memory that retains channel setting and fine tuning, even if the set is unplugged for years.



Don Mennie Associate Editor

nology products will enjoy under the realignment of RCA's top management.

Priming the top end

What RCA has actively been promoting recently is its new group of ten XL-100 ColorTrak television receivers. Unveiled in October, and priced from $509.95 to $1095, these "top end" color sets all feature automatic adjustment of brightness, color, and contrast; and an improved picture tube made with phosphors that reduce reflection from external ambient light. As demonstrated by RCA during the official introduction of ColorTrak, a considerable improvement in picture contrast (better white-to-black dynamic range) is evident in the new sets when compared with RCA's previous XL-100 models. This is attributed to 95-percent dc restoration incorporated in ColorTrak's video circuits.

Solid-state tuning has become a major selling point with top-line color sets. RCA's ColorTrak uses varactor tuning throughout, but only the remote-controlled models have full channel selection (the others require shop setup, allowing local UHF reception).

During June last year, the General Instrument Corp. announced a four-chip all-electronic color television tuning system called Project Omega (Fig. 1). Intended for the OEM market, Omega's unique property is a nonvolatile semiconductor memory. This allows users of Omega-equipped sets to fine-tune all channels once and never retune, even after the power has been interrupted. Such a set could be unplugged for ten years (or more) and, when turned back on, would show the last channel watched with the fine-tuning undisturbed. The nonvolatile memory is an original NCR Corp. design that General Instrument adapted as part of its Omega system.

[2] The PC-100 print cradle for Texas Instruments' SR-52 programmable calculator will be available early in 1976, retailing for $300–$400. It can print answers, audit trails, or trace all calculations in a running program.

Microcircuits for the mind and body

Although solid-state convenience options may help move some premium-grade color TV sets, microelectronics' primary influence on consumer spending still involves two products first introduced less than five years ago: calculators and digital watches. Particularly active this past year with new calculator products for the engineering community were Hewlett-Packard, Texas Instruments, Casio, and Sinclair. Prices are still declining on many calculator models, but not at the incredible rate recorded during 1974.

Programmable calculators

New entries produced by HP during the past 12 months include the HP-22 business management calculator at $165, the HP-25 programmable scientific calculator at $195, and the HP-21 scientific calculator at $100. The HP-25 has a program memory of 49 steps and includes a pause feature that momentarily interrupts program execution, giving the operator a chance to review and write down intermediate results. Retired from HP's calculator lineup last year was the original HP-35, essentally replaced by the more versatile and lower-cost HP-21.

Color TV tuning

The big news from Texas Instruments during 1975 was the SR-52 magnetic-card programmable calculator listing at $395 (see *Spectrum* Nov. 1975, p. 57). Since then, TI has brought out the PC-100 print cradle, available as an add-on feature for the SR-52 (Fig. 2). The TI printer uses sensitized paper and a special thermal print element to generate hard-copy records of problem solutions and intermediate calculations.

Since last summer, Casio Inc. has brought out better than a half-dozen portable calculators. Of particular note is the FX-101 ten-digit scientific model listing at $69.95. Included are scientific notation, logarithms, trigonometrics, and a four-key memory system.

Calculation sequences of up to 24 steps can be stored in the Sinclair Scientific Programmable first marketed in July 1975 by Sinclair Radionics Inc. Answers appear in a five-digit mantissa/two-digit exponent format implemented in a bright green display. Sold by mail order at $79.95, the Sinclair Scientific Programmable is the lowest-cost programmable calculator presently available. Price restructuring announced by Sinclair in November did not affect this original figure, but did reduce the two-year-old Sinclair Scientific to an all-time low of $29.95.

Digital watches

Large, expensive, and not particularly reliable or attractive when first introduced several years back, the digital watch finally found favor with consumers during 1975. Not surprisingly, this enthusiasm paralleled the introduction of $40 and $50 digital timepieces. And again, as was the case with calculators, semiconductor manufacturers who produce watch electronics while also marketing a finished product are surviving the price wars and making the profits.

Most digital watch modules are hybrid circuits implemented in CMOS, a semiconductor technology noted for the low power consumption vital to practical watch design. An important exception is Texas Instruments' application of integrated injection logic (I^2L) to watch-module design. TI's digital watch uses isolated I^2L, allowing the crystal oscillator (32 768 Hz), current regulator, and output multiplexer (capable of sinking

60 mA for display LEDs) to occupy the same chip with 500+ gates of logic. Total current drain for this I^2L watch circuitry is also low, permitting about one year's operation with two easily replaceable, inexpensive silver-oxide batteries.

Perhaps the main confusion surrounding digital watches concerns the readout: liquid-crystal display (LCD) vs. light-emitting diode (LED). LCDs can run continuously, but cannot be seen in the dark without outside illumination, whereas LEDs are bold and bright, but would run down any watch battery with a few hours' steady use. As a result, LED watches have push buttons that illuminate the display briefly for time checks (some advanced models now feature an inertia switch so the LEDs can be activated "no hands").

No better example of this problem—and the lengths gone to solve it—can be found than the Chronosplit combination watch/stopwatch introduced by Heuer-Leonidas. This Swiss-based watchmaker produces the $395 Chronosplit in conjunction with Integrated Display Systems, Inc., in the U.S. The display actually contains an LCD for standard hours/minutes timekeeping, an LED for stopwatch functions, and a wheat-grain incandescent lamp to make the LCD visible at night!

Of minicomputers and microwave ovens

Advanced technology also awaits gasoline customers at service stations in the Los Angeles area. Fully automated computer-controlled self-service pumps were opened at several ARCO (Atlantic Richfield) stations this past year. The system, controlled by a Computer Automation Naked Mini® minicomputer, handles all credit-card or cash sales, dispensing of fuel, and printing of receipts.

Closer to home, microprocessors are showing up in sewing machines (Singer Corp.'s Athena 2000 with 25 stitch patterns contained in a ROM), air conditioners (Heil-Quaker Corp.'s central air conditioner has a diagnostic monitor that shuts down equipment and alerts the homeowner to problems), and oven controls such as the defrost-cook feature on some microwave ranges.

Microwave leakage

Homemakers who like the speed and convenience of microwave cooking, but worry about possible RF leakage, are now offered an inexpensive radiation detector that quickly finds any such trouble. The hand-held device, consisting of LED indicators and pickup circuits tuned to 2450 MHz (FCC-mandated operating frequency for most microwave ovens), was developed by Walter L. Weeks, professor of electrical engineering at Purdue University, West Lafayette, Ind. (Fig. 3). The various models of his detector sell between $20 and $40, and none have batteries or other service-prone components. All energy needed to power the LEDs is derived from the detected microwave field.

[3] Radiation intensity around a microwave oven door seal is indicated by a new, low-cost detector ($20). Three or more LEDs provide the readout. A single diode lamp starts glowing when a nearby 2450-MHz field intensity reaches 0.05–0.1 mW/cm², other lamps indicate somewhat higher levels, and all reach equal brightness at 8–10 mW/cm² (or above). Operation is demonstrated by inventor Walter L. Weeks.

Moving and storage

Where batteries are needed is in electric-vehicle development. *Spectrum* contacted a number of organizations involved in designing electric cars—McKee Engineering, Palatine, Ill.; Copper Development Association, New York, N.Y.; and Sebring Vanguard Inc., Sebring, Fla. (virtually the only quantity producer of electric vehicles in the U.S.)—and all expressed a need for better storage batteries.

Development work on high-energy batteries seems to fall into two depressing categories: those built with expensive materials that "do the job" but have no prospect for mass production, and those built with (relatively) common ingredients that cannot be charged and discharged repeatedly without deteriorating.

A possible exception is the almost forgotten nickel–iron Edison battery, long used in railroad cars to power overhead lamps, and famous for its year-in, year-out dependability. However, its energy/weight ratio is nothing spectacular, and it does not promise to provide performance comparable to gasoline-powered cars.

An intensive and continuous program on an advanced Edison-type cell (now termed the iron–nickel battery to differentiate it from older designs) has been in effect at the Westinghouse Research and Development Center in Pittsburgh, Pa., since 1967. *Spectrum* has learned that this effort has resulted in finished cells and battery systems delivering 44.1–55.1 watt-hours/kilogram at 110.2 W/kg (almost double the rating on a good lead-acid battery). Cells are said to demonstrate a life capability well in excess of 1000 fast-charge/deep-discharge cycles with less than a 20-percent loss in rated capacity.

Battery systems sized for electric vehicle use (96 volts, 16 kWh) have been produced in prototype quantities at the Westinghouse pilot plant facility in Pittsburgh. This iron–nickel battery system is ready for limited electric vehicle demonstration field trials, and Westinghouse is seeking other applications that could eventually support a major investment in iron–nickel battery production. ◆

Industrial electronics: to boost productivity

Microprocessors and minicomputers take over; "efficiency first" dictates other developments

Recession, curtailment in natural gas and oil supplies, and increased pressures for improving productivity characterized the general industrial activity in the U.S. in 1975, and were accordingly reflected in the industrial electronics field. For example, motor-drive manufacturers have emphasized more efficient drives. And another area, computer-aided manufacturing (CAM), also has attracted attention in the U.S. as the ultimate means of attaining increased productivity goals (although the rate of increase of production in industrial electronics was down in 1975, as indicated in the table below). In the meantime, the microprocessor has been penetrating almost every area of industrial application, and computer numerical control (CNC), a powerful production automation tool, is being implemented on a wide scale, improved both in hardware and software. Successful industrial application of systems that recognize spoken commands by a human voice has brought a new dimension into man–machine communication. In metalworking, high reliability and precision have been demonstrated through use of a new, powerful gas laser. And the implementation of optical fibers, along with sophisticated coding methods, has opened new avenues for industrial application of infrared radiometry.

Microprocessors as building blocks

The best exploited component in 1975 in industrial control and instrumentation was the microprocessor, which enables a higher degree of sophistication and greater accuracy than had been available prior to its introduction. In addition, the microprocessor permits consolidation of many functions at a high reliability. Moreover, it is easily replaceable, at a relatively low cost.

Evolving from a component intended for devices like calculators and point-of-sale terminals, the microprocessor has emerged as a useful building block in systems, in such roles as programmable controllers and dedicated processors (that is, processors used only in conjunction with specific tasks), and as an element in distributed processing systems. An example is a family of three microprocessor-based controllers, the EPTAK family, manufactured by Eagle Signal, Davenport, Iowa. EPTAK includes: a programmable logic controller (PLC), available as of November 1975, for metalworking and machining, materials handling, and measuring and gauging; a process controller for chemical, petrochemical, food, pulp and paper, and other industries; and a dedicated machine controller for specific tasks like plastics injection molding or load-level demand, with the last two expected to be available later in 1976.

Often, by employing microprocessors that are assigned to specific tasks, much analog control equipment, like summing units or multiplexors, can be eliminated. (The analog equipment functions often can be implemented by software modules.) But there is a price to pay for microprocessor application—the designer of control equipment that employs them must be familiar with hardware (digital logic design) and software (real-time systems programming), and how the two interact.

Microprocessor software

The advent of more powerful microprocessors, although the most heralded, is not the most significant work of the past year. Much work by manufacturers of microprocessors such as Intel and National Semiconductor has been in software development—in attempts to introduce a uniform language to the user.

More computer numerical control (CNC)

An area of growing importance in machine tools is computer numerical control (CNC)—automatic control (of a machine tool) by a powerful, industrial-type minicomputer or microprocessor that is an integral part of the machine. While conventional, "hardwired" controllers are characterized by their fixed logic, CNC offers flexibility in machine-tool controllers, in that the same basic controller hardware can be used by entirely different types of machine tools. CNC also opens up new functional capabilities that were not practical with hardwired controllers. Especially effective are

Recent and projected total production of electronic equipment for industry applications in the U.S., Canada, Western Europe, Japan, Australia, and South America, as broken down into its various categories (in millions of dollars). The "industrial electronics" area is represented mainly by the process control and the instrumentation fields.*

Category	Year 1972	1973	1974	1975	1976	1980
Total	34 025	40 810	50 327	57 293	65 172	115 195
Telecommunications	14 391	17 176	20 852	23 790	27 102	45 994
Data processing and business equipment	9 960	12 112	15 540	17 899	20 608	38 023
Medical electronics	1 828	2 198	2 645	3 051	3 526	6 893
Process control	1 825	2 108	2 622	2 940	3 280	5 825
Instrumentation	2 647	3 142	3 825	4 146	4 429	7 112
Vehicle electronics	2 531	3 069	3 711	4 239	4 905	9 553
Navigational aids (except U.S. Government)	843	1 005	1 132	1 228	1 322	1 795

*Data provided by Darling, Paterson & Salzer, Los Angeles, Calif.

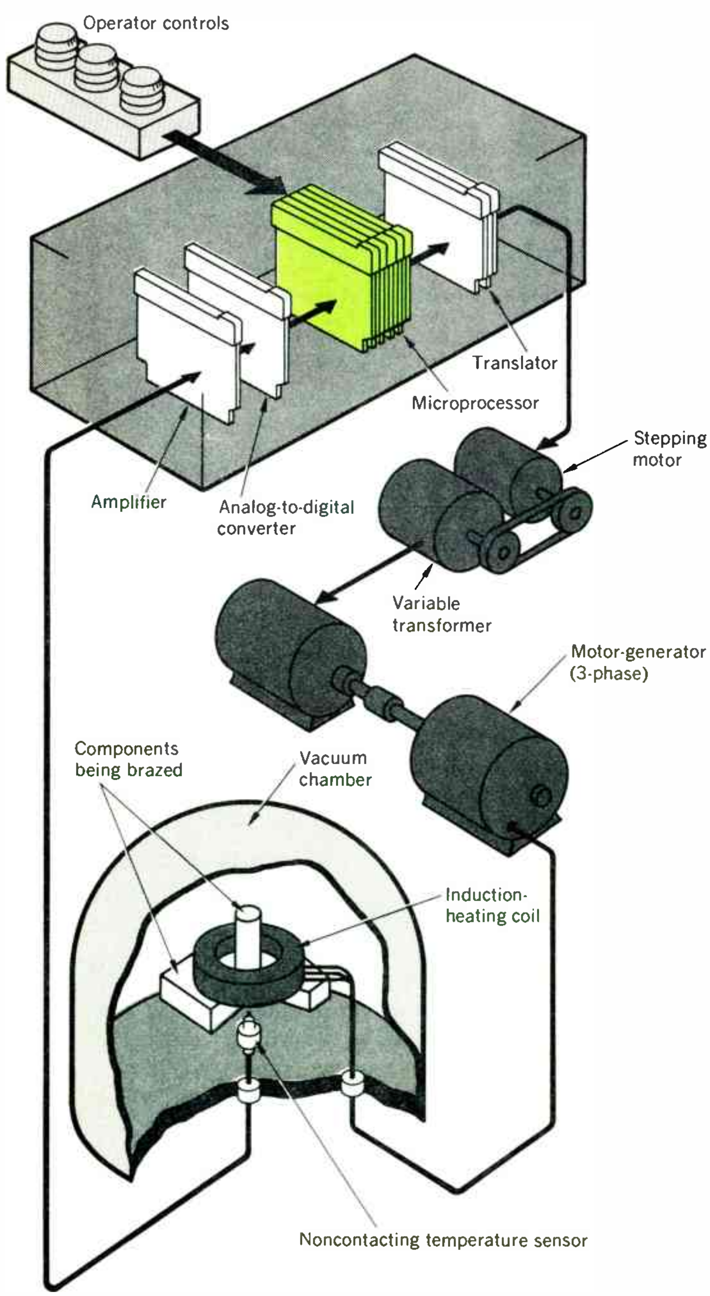
Gadi Kaplan Associate Editor

compensation error-correcting methods, editing, and storage techniques. CNC has also made a big step forward by being introduced on a large scale into metal cutting and punch press equipment.

Static logic

Much attention was focused last year on the extension of automatic diagnostic software programs. One of the major technical sessions at the IEEE Machine Tools Industry Conference, held in Milwaukee in October, was devoted to computer diagnostic techniques.

An Intel 8008 microprocessor is incorporated in the control loop of this automatic braze control system, employed at Batelle's Pacific Laboratories, Richland, Wash. Prior to brazing, a rod-shaped component is placed in a hole of its mating part along with a ring of a brazing compound. An induction heating coil positioned over the rod heats the parts to brazing temperature. This entire apparatus, along with a specially developed noncontacting temperature sensor that provides the feedback signal, is placed in a vacuum chamber. The process is actuated by adjusting the field voltage of the motor generator used to power the heating coil. This is done using a variable transformer driven by a stepping motor.



New minicomputer hardware techniques, such as self-correcting and fault-indicating semiconductor memory boards (now utilized by Pratt & Whitney, West Hartford, Conn., in all of the CNCs manufactured by the company), were also introduced into CNC in 1975.

In addition to CNC, a wide spectrum of logic circuits, programmable controllers, and even dedicated computers is being increasingly applied, within the metal industry, to replace the electromechanical relays that experience considerable wear and tear due to their moving parts (contacts, armatures). Termed "static logic" by the industry, these logic "components" serve both in sequential logic as well as regulator switching functions. The use of dedicated computers has been enabled by the increased computer reliability achieved in recent years (computers are among the most reliable components in the metal industry today). And stemming from the overriding need to reduce overall energy consumption, further progress in digital, programmable, and computer-controlled applications in the metal industry is projected in connection with requirements for optimized use of heating for forging, rolling, heat treatment, and melting.

Voice commands recognized by machines

One relatively new area, with potential applications in many industrial as well as nonindustrial uses, is speech recognition—a process whereby spoken commands from, or words of, a human operator are identified and interpreted by an automatic speech recognition system. These spoken commands can then be translated into a compatible computer code.

Various systems based on speech recognition have been manufactured by Threshold Technology, Delran, N.J., since the company's inception about five years ago. Applications areas include quality control and inspection, automated material-handling systems, direct voice input to computers, voice control of machines, and voice programming of machines. In September 1975, Threshold Technology introduced a new voice data entry terminal, Threshold 500, which, the company claims, is a direct replacement for a standard keyboard computer terminal. Earlier last year, in May, Threshold Technology introduced a voice programming system, the VNC-100, for numerical control parts programming. The system deciphers the operator's spoken commands, decodes the information into a machine-compatible format, and punches the numerical control (NC) tape.

For motor drives, a range of applications

In the metal industry, large motors are being used in applications traditionally driven by mechanical drive steam turbines to minimize the effects of the fuel crunch. Motors are being used to drive blast furnace blowers to release valuable by-product fuels (such as coke-oven gas) and scarce natural gas for use in other processes within the plant.

In a power range a few orders of magnitudes below the thousands of horsepowers needed for the above-mentioned use, ac and dc drives using Darlington-connected transistors are now available in large quantities. Potential user industries include glass manufacturing, food machinery, textiles, wood processing, and machine tools. If and when the recession ends, manufacturers of motor drives are expected to start introducing more low-horsepower ac equipment to replace dc equipment in some applications. With the substitution of Darlington-connected transistors for SCRs in motor drives, the ac motor drive may become cost-competitive with its dc counterpart, depending on the nature of the requirement. It is anticipated that the cost gap between the two types of motor drives will close over the next year, especially for low- and even medium-horsepower applications.

Switching regulator power supplies

In the field of power supplies, a trend has continued toward the use of switching regulator power supplies. While some major industrial manufacturers tend to design and build the supplies themselves, increasing numbers of manufacturers are now ordering them from power supply houses. In addition to their smaller size when compared with other types of power supplies, the switching power supplies are likely, due to their improved efficiency, to consume less energy, thereby enabling their users not only to reduce their operating costs but also to further the national energy conservation effort.

Meanwhile, within the steel industry interest has been stimulated in equipment for correcting the generally poor power factor and for filtering out the harmonic currents generated by the more powerful, thyristor power supplies that are widely used in the industry. This power-correcting and filtering equipment usually takes the form of variable reactances connected in parallel with inductor–capacitor networks that filter the high-frequency harmonics and correct power factor at the fundamental frequency. Reactance variation may be obtained by a controlled saturating winding arrangement or may consist of thyristor-switched reactors. Some consideration has also been given to thyristor switching of capacitors.

Dielectric-, induction-heating power grows

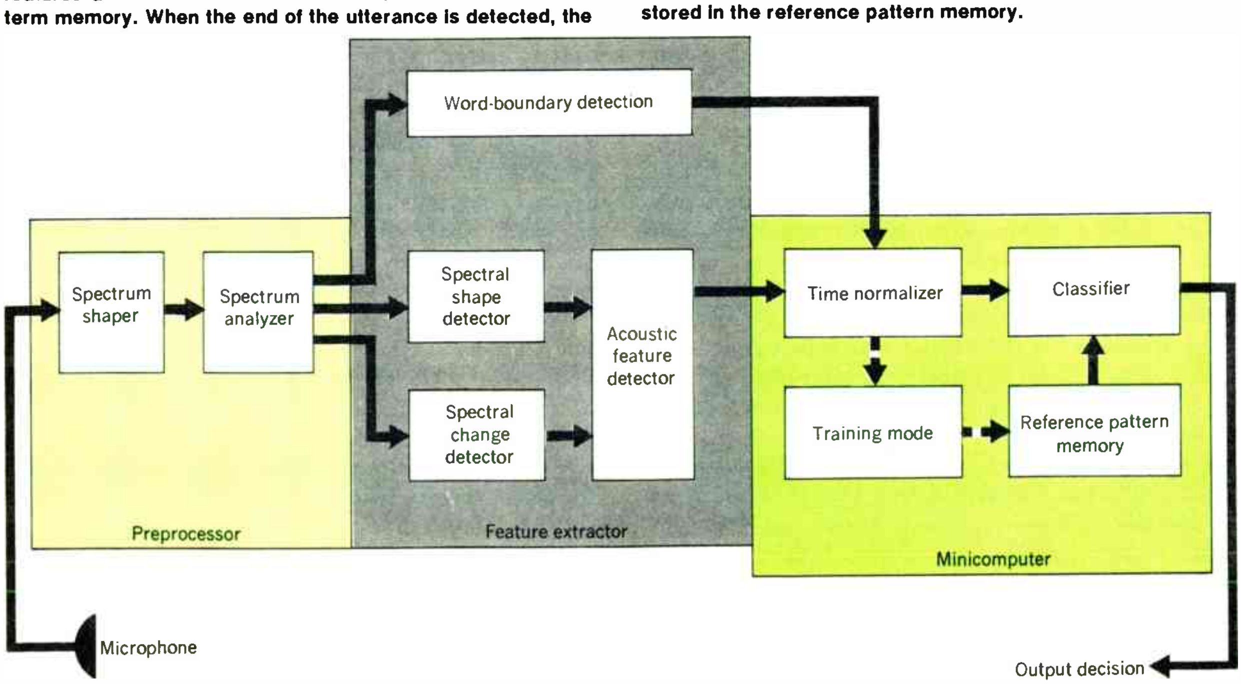
Vacuum-tube supplies

While improvements in power utilization characterize the present status of power supply in the steel industry, increased power range is anticipated in power supplies for vacuum-tube oscillators associated with dielectric heating, operating in the 1- to 50-MHz range. (The choice of frequency of these oscillators is usually determined by the geometrical dimensions of the material to be treated.) The power supplies for these oscillators are expected to reach the 2000- to 2500-kW range. This will be dictated by growth in applications such as continuous paper, textile, and wood product curing lines, which involve heavy energy consumption.

Power-factor correction

For example, 1.6-MW-output dielectric-heating equipment operating at about 4 MHz, manufactured by the Votator division of Chemetron Corp. at Louisville, Ky., is ready to start operation at the Holly Hill Lumber Corp. in Holly Hill, S.C. While the oscillator of this unit is, by necessity, a vacuum-tube type, exten-

The key processing function in a speech recognition system (see p. 88), like the one portrayed here, is the *feature extractor,* whose inputs consist of signals derived, in real time, through spectral analysis by a *preprocessor* from the voice input. In the feature extraction process, the spectral shape and its changes with time are continuously measured over the frequency range of interest. Combinations and sequences of these measurements are processed to produce a set of significant acoustic features, one of which is the initial estimate of word boundary. The classification (or decision) process as to which word was uttered is performed in software using a *minicomputer.* For each spoken word, the encoded features and their time of occurrence are stored in a short-term memory. When the end of the utterance is detected, the duration of the word is divided into time segments and the features are reconstructed into a normalized time base. A pattern-matching logic subsequently compares these feature-occurrence patterns to stored reference patterns for the various vocabulary words and determines the "best fit" for a word decision. Typically, a total of 512 bits of information (32 features mapped into 16 time segments) are required to store the feature map of each utterance or reference pattern. In a special "training" mode, designed to enable the voice recognition system to adapt itself to individual talkers and/or words, the system automatically extracts a time-normalized feature matrix for each repetition of a given word. A consistent feature repetition is required before the features are stored in the reference pattern memory.



sive use is made of solid-state devices in the dc power supply circuit.

Similar strides have been made in the field of induction heating, prompted largely by industry demands for large power capability equipment of the utmost reliability. The use of solid-state devices in induction heating actually revolutionized the field by replacing, in many cases, both motor—generators and vacuum-tube equipment. Most of the high-power, solid-state induction-heating generators are built for purposes of forging and melting. The Pillar Corporation of Milwaukee, Wis., recently delivered a solid-state 1.5-MW induction heating generator operating at 180 Hz to Taiwan.

Lasers for metalworking and testing

Various types of solid-state, semiconductor, liquid, and gas lasers have been employed for a variety of processing applications. More recently, expansion has been in the 10-kW range using CO_2 lasers for high-production applications involving welding, cutting, surface transformation hardening, and surface alloying. For example, Avco Everett Research Laboratory Inc., in Everett, Mass., now has on demonstration a unit called the HPL Industrial Laser, which is based on a CO_2 laser capable of delivering 15 kW continuous power (20 kW for short periods). The unit has two work stations that use the laser beam on a time-share basis. Three similar units have been delivered to manufacturers and are being used in process development, and an additional unit is used by Avco, itself.

Current gas lasers operate, however, at relatively low efficiencies—in the range of 10–15 percent. Future technology development for these applications will probably focus on more efficient gas lasers (although a theoretical limit of about 40 percent exists), and on longer-life and more reliable optical systems for beam splitting and directing. Development of other gas lasers such as CO, chemical, nuclear-pumped, X-ray, and metal vapor lasers has great potential. Also, new laser applications are being identified. An application of a helium-neon laser to explore nondestructively the electrical characteristics of semiconductor devices on a point-by-point basis was recently demonstrated by the Institute for Applied Technology at the National Bureau of Standards, Washington, D.C.

Optical fibers help infrared radiometry

Discharge lamps

The entrance of infrared (IR) technology into industry, as both a testing and a process control tool, marks a turning point in this technology. In particular, Vanzetti Infrared and Computer Systems, Canton, Mass., has developed a line of thermal monitors that employ optical fibers between sensed object and detector, instead of conventional optical systems, to transmit IR signals. This transmission method enables IR radiometry to tackle thermal problems that could not be resolved before.

Prior to the introduction of fiber optics, IR detectors could only sense radiation within their field of view. Optical fibers, however, due to their flexibility and small diameter, extend the viewing capabilities. For example, sensing of radiation from objects enclosed in ovens, or hidden around corners, or surrounded by "hostile" atmospheres like vapor, gas, dust, or smoke, is possible. And optical fibers can be useful in monitoring processes like those that take place within a combustion chamber of an engine.

One new application of fiber optics in IR technology is in the control of critical thermal processes that determine metal hardness in steel mills and other metal manufacturing plants. Other uses include the control of electromagnetic field power in induction or microwave ovens for treating metals or for processing semiconductors.

Research and development programs have already proved the feasibility of infrared fiber optics techniques for controlling spot-welding processes in real time, or for monitoring the tool temperature in a metalworking machine. And IR monitoring systems, using fiber optics, are already being applied in manufacturing processes of plastics such as injection molding or extrusion.

Another innovation involves hybrid IR systems using lasers as thermal sources. In a joint effort by the Hamilton Standard Division of United Technologies, Windsor Locks, Conn., and Vanzetti, a hybrid IR system has been successfully tried to detect hidden defects in multilayer electronic boards.

Remote IR sensing also made a big stride in 1975, as demonstrated by the Hadamard Imaging Spectrometer (HADIS), conceived and designed by Spectral Imaging, Concord, Mass., and manufactured by American Science and Engineering, Cambridge, Mass. New methods of coding and multiplexing the input from a remotely sensed object, and numerical manipulations performed by a computer on the coded data, yield an improved signal-to-noise ratio compared with that offered by other infrared spectral imaging techniques. HADIS has already been demonstrated as a viable aerospace research tool and it has potential for industrial applications—for example, in detecting pollutants in an industrial atmosphere or in monitoring electronic microcircuit structures.

Lighting efficiencies increase

Due to rising energy costs, lamp and lighting equipment manufacturers as well as lighting designers and specifiers are being pressured to come up with more efficient systems and to do more coordination between lighting and other energy uses in buildings (see *Spectrum*, Dec. 1975, pp. 28–34 for more information). Fortunately, the process of transforming electric energy into visible light has become much more efficient with discharge sources now being used for most general lighting systems. High-pressure sodium and metal-halide lamps continue to develop as the most efficient generators of light suitable for a wide variety of lighting applications.

New versions of the modern, high-pressure sodium lamps (identified as "Penning start" lamps) were introduced in 1975, approximately doubling the luminous efficacy (lumens/watt) of standard mercury lamps. They work with many types of existing ballasting (current limiting) systems for mercury lamps. Solid-state components became more widely used in 1975, in fluorescent lamp ballasting systems in transportation and emergency lighting systems, to replace bulky core and coil units, and 1976 will probably see the introduction of solid-state ballast designs for entire commercial and industrial fluorescent lighting systems intended for use at standard voltage. ◆

Satellites, sensors, and society

Interface topics are: satellite broadcasting, sensors in the Middle East, and energy legislation

Arnold Toynbee, the English historian whose distinguished career ended with his death in October of last year, once wrote: "Technology is, of course, only a long Greek name for a bag of tools; and we have to ask ourselves: What are the tools that count in this competition in the use of tools as means to power?"

Historians have the benefit of decades, even centuries, of retrospection in sorting out the "tools that counted" from those that were peripheral to a society's development. Chroniclers can do little more than thrash about in the overstocked hardware stores of their own time. This chronicler's thrashing has tipped two items from the 1975–1976 shelf: one is the broadcast satellite; the other is the unattended ground sensor. Worlds apart in terms of technological sophistication, both seem to be having great societal impact.

Of even greater impact is, and has been, the present energy crisis. During the last several years in the United States, thousands of articles have been written on this topic of immediate concern. But during the same period, little legislation of any consequence has been enacted to resolve the issues the crisis has raised.

Ellis Rubinstein Associate Editor

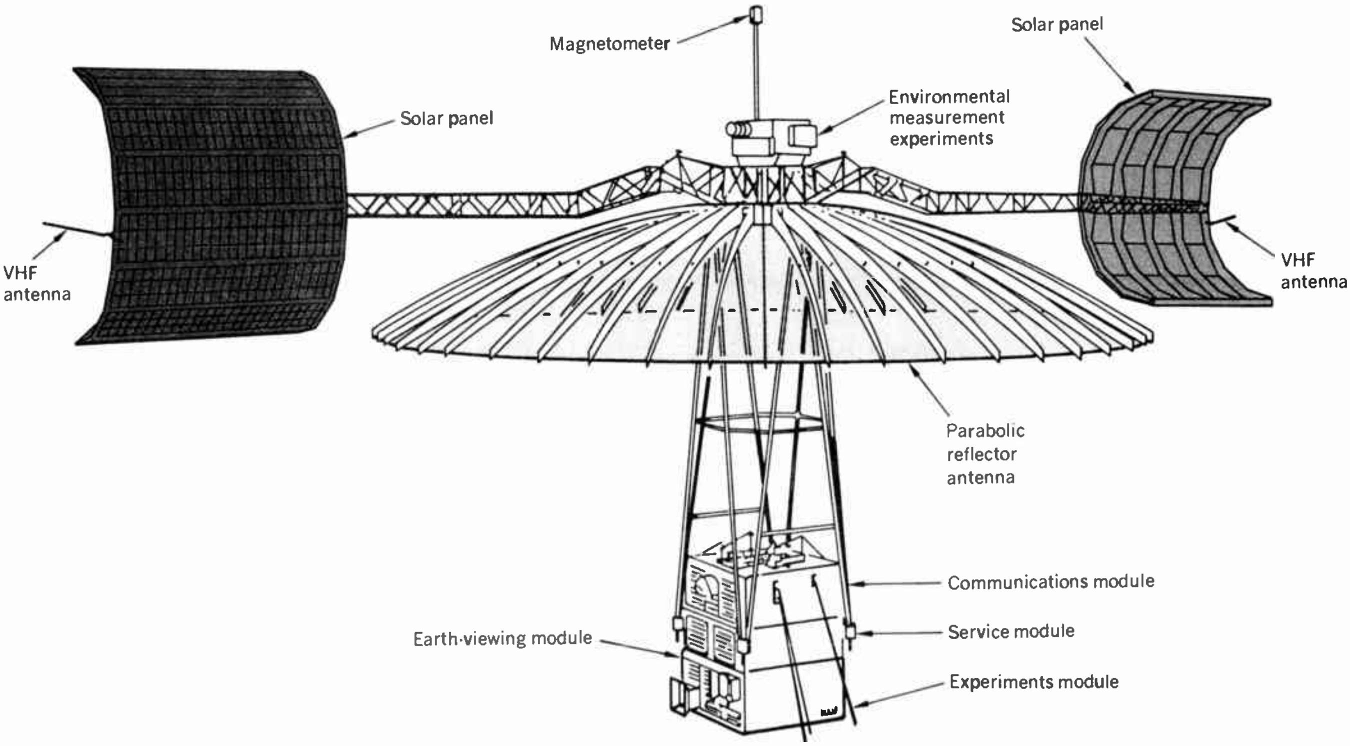
In addition to the broadcast satellite and the ground sensor—two "tools that seem to count"—*Spectrum* will take up in this article the "toolful but toothless" topic of U.S. energy legislation, bearing in mind that many *Spectrum* readers are very much concerned with political decision-making in our society.

Satellites for health and education

Applications Technology Satellite VI

In June 1969, the National Aeronautics and Space Administration invited interested users to employ the experimental capabilities of any of NASA's applications satellites once NASA's own program objectives had been met. Six and one-half years and two launches later, that challenge has been answered. Presently in use for the benefit of the people of India, the Applications Technology Satellite VI (ATS-6)—NASA's most recent launch—has already performed a spectrum of significant social experiments in education and health-care services within the geographical

[1] The Applications Technology Satellite VI (ATS-6) represents the space segment of a new concept in satellite broadcasting systems in that its earth receiver terminals need not be expensive (under $5000). It measures 8.51 meters (28 ft) from top to bottom and 16 meters (52 ft) from the end of one solar panel to the end of the other. The two VHF antennas provide telemetry and command for the satellite, while the large 9-meter- (30-ft-) diameter parabolic reflector antenna beams a signal that is sufficiently strong to be clearly received by unsophisticated ground terminals.



boundaries of the U.S. Scheduled for launch this month, the Communications Technology Satellite (CTS), a cooperative effort of the Canadian Department of Communications and NASA, will "expand on" ATS-6—both in geographical coverage in the U.S. and Canada and in broadcast capabilities.

ATS-6

Eight years of design and development went into ATS-6 (see Fig. 1), which was launched on May 30, 1974, and has been operating successfully ever since. The primary sociotechnical goal of ATS-6 was to demonstrate that a new era was at hand in the field of communications satellites. For the first time, the costly complexities of a satellite communications system would be built into the satellite itself, rather than into that satellite's ground receiver stations. In fact, with ATS-6 the receiver stations would be cheap enough to be bought in quantity by school systems and hospitals, and by developing nations, and the technology of those stations would be simple enough to be operated by technologically "naive" users.

Cheap ground stations

Within these general parameters, ATS-6 was designed to perform a variety of experiments of a pioneering nature. These have included community TV health and education experiments, satellite air traffic control, tracking and data relay applications, and a series of advanced applications experiments in, for example, millimeter-wave propagation, radio-frequency interference, and meteorological measuring.

Intra-Alaska networks

Measures of success

In its first year and a half of operation, ATS-6 has fulfilled nearly all its design goals. The primary objectives of economy and simplicity of ground stations have been made possible through the use of a high-gain 9.1-meter-diameter parabolic antenna. With antenna gains of from 34 dB up to more than 50 dB over the range of UHF to C-band, relatively conventional satellite transponder performance parameters have been able to achieve unconventional results. In consequence, the ATS-6 earth stations, emplaced and operating, cost less than $5000 each (in 1973 dollars) when purchased in a lot quantity of 130. It was precisely this relatively inexpensive ground station cost that permitted the U.S. Department of Health, Education, and Welfare (HEW) and the Veterans Administration to sponsor and fund the most ambitious, and successful, of the ATS-6 experiments—the Health/Education Telecommunications Experiment (HET).

Health/ education broadcasting

HET consisted of six experiments in three geographical regions of the United States—Appalachia, the Rocky Mountain states, and the Northwest and Alaska—where existing terrestrial TV networks have not reached. The basic earth stations (there were 120 distributed throughout these remote regions) were receive-only terminals (ROTs), capable of receiving and demodulating a single color TV signal and four associated audio channels that were transmitted on subcarriers above the video spectrum. When summed, the composite spectrum was transmitted as a wide-band FM signal.

In addition to the ROTs, there were a number of "intensive terminals" (ITs). Each consisted of an ROT and a VHF transmitter and receiver permitting interactive exchange of audio and/or data via the previously launched ATS-1 or ATS-3 satellites (ATS-6 was originally designed for interactive voice/data transmissions, but, because of restrictions on certain of its frequency bands, this capability could not be utilized for HET). Lastly, there were two types of "comprehensive terminals" that operated at either C- or S-band frequencies and permitted remote video origination.

From one operational control center and one network coordination center, the HET experiment was carried out via ATS-6 to clusters of ground stations in each of the three remote U.S. regions. In Appalachia, graduate-level college-credit courses were beamed to some 1200 teachers, while interactive teleconsultative projects were carried out by the Veterans Administration between a TV studio in Denver and ten of the VA's hospitals in the Appalachian region. In the Rocky Mountain experiment, the beneficiaries of ATS-6 capabilities included 2500 students at 56 different junior high schools, about half of which were equipped with ITs while the remainder were equipped with ROTs (interaction at these was accomplished by telephone). In addition, another 12 500 students were involved in the experiment via 12 Public Broadcasting Service stations that picked up the ATS-6 feed and retransmitted it over the normal TV channels. A third series of experiments worthy of mention linked the Universities of Washington at Seattle and Alaska at Fairbanks for the benefit of medical students. And a fourth involved two intra-Alaskan networks linking large-city hospitals with remote clinics and providing primary- and secondary-school educational programming and community services.

The remote terminals proved easy to use, their picture quality was equal to that achieved in a television studio and 20 percent better than that of the typical private-home TV receiver, and, last but not least, the participants were generally enthusiastic about the programs or capabilities offered them.

If the sociotechnical significance of ATS-6 remains in doubt in regard to developing countries, it should be noted that ATS-6 has been operating over India with similar success for more than a half year. Some 5000 villages (2400 of which have been equipped with receiver terminals) are presently receiving educational programming—beamed to them by the Indian Space Research Organization ground station at Ahmedabad, north of Bombay—directed toward family planning, basic hygiene, basic literacy, improved agricultural techniques, and national integration. One of the tremendous advantages of the ATS-6 is that its two audio channels permit these broadcasts to be made in as many as four different Indian languages. And, of course, the overriding plus of the ATS-6 is that it demonstrates an economy of cost. Richard Marsten, currently dean of engineering at the City College of New York but formerly NASA's director of Communications Programs overseeing the development of ATS-6, feels "a savings by a factor of perhaps three for setting up an educational broadcasting delivery system in a developing country" is possible.

And what of the future?

In autumn of this year, the ATS-6 will be returned to its position over the United States, where it will continue to provide a variety of social services during the life of the satellite. Meanwhile, its successes have encouraged the formation of the Public Service Satellite Consortium, a corporation that is to be dedicated to providing similar services in the future. India, for its part, is expected to develop a long-term program of its own, dependent upon national budgetary constraints, and Japan will shortly become the first nation in the world to have an operational satellite broadcasting system, the JBS, whose satellites are being built by General Electric.

U.S./Canada satellite

As for the United States, its only other currently planned effort is the previously mentioned Communications Technology Satellite (CTS), developed by Canada and the U.S. as a joint effort. CTS deserves some mention because it has several clear advantages over the ATS-6. While much of the programming could be similar to that afforded via ATS-6, CTS will demonstrate that a satellite with a much wider coverage pattern need not require expensive receiver terminals. This is due, of course, to the greatly enhanced power of the CTS compared with the ATS-6.

Although ATS-6 achieves its broadcasting capability with a very large antenna, its transmitter power of 15 watts per channel is still quite moderate. Increasing the transmitter power substantially would permit an equivalent reduction in antenna gain while maintaining the necessary flux density at the earth stations, thereby increasing the coverage area.

CTS embodies this approach, but in the 12-GHz band. Since the capability of broadcasting to small, low-cost ground stations was already established in the ITFS band through ATS-6, and since the 12-GHz band was allocated to the satellite broadcasting service without flux density limitations, it was thought appropriate to demonstrate high-power, wide-area coverage with CTS in the latter band. The CTS will fly a new kind of satellite transmitter, having 200 watts of power in a single channel and a major improvement in efficiency. With the gain needed at 12 GHz, the antenna is sized for a 2.5-degree beam rather than the 0.8-degree of ATS-6. From synchronous orbit, a 2.5-degree beam can cover one third of the continental United States, or about a million square miles.

The peace-seeking ground sensors

In late 1975, the Middle Eastern tinderbox was at least temporarily dampened by the signing of an Egypto–Israeli agreement that both sides hope will be a steppingstone to a permanent peace. This agreement, which at time of writing has been only partially implemented, depends for its very existence on a U.S. promise to provide and man a trio of "watch" stations equipped with a variety of electronic devices—devices that, with the kind of irony characteristic of history, were developed for war but are now to be used to maintain a peace. Though the electronics involved is not highly sophisticated, it illustrates how, increasingly in today's world, technology impacts on society . . . in this case, for the better. As stated in *Isaiah*: "They shall beat their swords into plowshares, and their spears into pruning hooks."

Electronic swords and spears

While new geographical boundaries have been drawn—and mutual troop relocations have been effected—in accordance with this latest Israeli–Egyptian pact, the United States, for its part, has not made public all the details of its Sinai role. Shortly before this article went into print, the Administration announced that the Department of State would award private concerns the contracts for the construction of the three U.S.-sponsored watch stations and the hiring of personnel (expected to number about 200 civilians). However, the precise nature of the electronics hardware that will be required has yet to be specified and may remain classified for some time to come.

[2] This soldier is in the process of implanting an unattended ground sensor.

Sinai watch stations

Nevertheless, conversations with officials at the Department of Defense, as well as with civilian engineers who participated in projects developing prototype equipment for use in Vietnam, indicate that the state of the art in electronic early-warning gear (sensors and radars) has not evolved so rapidly as to prevent informed guesses about what will eventually be deployed in the Middle East. In fact, compared with the sophisticated and proliferating hardware—laser-guided bombs, electrooptical weapons, electronic jamming pods and warfare decoys, and advanced digital processors—that has been gobbling up ever-larger chunks of the big powers' military budgets, unattended ground sensors and antipersonnel radars constitute little more than the swords and spears of today's military arsenals. As such, they are less likely than their complex cousins to become quickly obsolete.

Unattended ground sensors

Essentially, ground sensors have utilized the following physical phenomena: magnetic, seismic, infrared radiation, pressure, strain, electromagnetic, and acoustic. The sensors can be deployed (see Fig. 2) in combination and in diverse patterns either above or below ground. Within the range of the particular type of sensor, activity can be recorded and electronic logic can determine whether, based on characteristics of amplitude, timing, and frequency of the disturbance, a target is present. If so, the sensor "decides" to transmit an RF message to the so-called display site. Then, at the display site, a read-out will provide a pattern of activated sensors that can describe the number of targets present, their nature (e.g., tanks or infantry), their direction of movement, and their speed. Such assessments can be performed both by human reader and by computer. Although "nuisance" alarms, triggered by anything from meteorological conditions to animals or even innocent human intruders, can increase the difficulty of evaluating the ground-sensor data, acceptable accuracy rates can be achieved by certain types of sensors within their ranges (for example, certain seismic sensors, under the proper geological conditions, can detect and report passing jeeps within 100 meters and passing soldiers within 30 meters).

Where technology ends and diplomacy begins

The best guess of *Spectrum*'s DOD and civilian sources is that, in the Middle East (specifically, in the Mitla and Gidi Passes that divide the Sinai and are to separate Egyptian and Israeli forces), the 200 U.S. civilians will be operating a combination of seismic and acoustic sensors at the east and west entrances to each pass. Although intended to warn of "any movement of armed forces, other than the UNEF [United Nations Emergency Forces], into either pass and any observed preparations for such movement" [Article IV, Section 2, Paragraph B], these sensors are likely to be more symbolic than practical. According to the treaty, the U.S. technicians are to contact the Egyptians, Israelis, and U.N. forces immediately if an intrusion is imminent. But would U.S. citizens have been committed to a position of vulnerability? That is, would either Egypt or Israel dare to overrun a U.S. installation?

Omnibus energy bill

For all their mutual distrust, it is apparent that both Egypt and Israel feel the other side will respect a U.S. presence. Otherwise, that presence would not have been, as Secretary of State Henry Kissinger has claimed in Congressional testimony, insisted upon by both parties as vital to the pact. Thus, both technology and technicians are symbolic pawns in a diplomatic chess game—not true watchdogs of a peace. And this being the case, why should watch stations at a cost of hundreds of thousands of dollars and fields of unattended sensors (less expensive, but requiring the costly presence of technicians) have been necessary? Wouldn't it have been just as effective merely to have stationed a few U.S. citizens between the opposing armies to be, in effect, the hostages they will be, sensors or not?

Electronic and human pawns

Apparently, electronics has so come of age in today's world that, for better or worse, the human presence is insufficient.

Energy and the law

It has been more than two years since the United States, *en masse*, faced the fact that it was in the midst of a serious energy crisis. This writer's article in *Spectrum*'s January 1974 "Technology Review" special issue was only one of many in the technical and lay press detailing the need for a national energy policy—one that was already long overdue as witness the unheeded warnings of many in the technical community. It is now 1976. How far has the U.S. come in its efforts to formulate a coherent energy policy?

National energy policy

During 1975, two relatively minor energy-related bills were passed by Congress and signed into law by President Ford. These were the repeal of the oil depletion allowance, now Public Law 94-12, and H.R. 9524, known as the Oil Pricing Controls Bill, which extended controls through November 1975. Both of these bills had previously been vetoed before being resubmitted and signed. A third piece of legislation called the Coal Conversion Act Extension contained three separate bills, each of which was vetoed by the President. But of the Presidential vetoes, certainly the most important in terms of the need for a national energy policy was the one that killed the controversial Strip Mining Bill (officially, H.R. 25). The heart of this legislative effort—those sections applying to the strip-mining of Federal lands—was immediately repassed in the Senate as S. 391, but it will be some time before it reaches the Executive Office.

Until recently, the picture was no brighter in terms of petroleum. No fewer than three bills are currently in Senate/House conference. In the Senate alone, nine more bills are either on the calendar, in hearings, being debated on the floor, awaiting a vote, or passed and awaiting action by the House. Not all of the bills relate directly to petroleum, but many have been stalled pending the outcome of a protracted battle over the most important energy legislation ever written, the Energy Policy and Conservation Act.

This omnibus bill, though silent on coal, represents the closest thing to a national energy policy bill ever attempted. In essence, it grants wide authorities to the President to (1) control domestic oil prices within Congressionally set limits, (2) allocate materials and equipment in the face of a shortage, (3) set up and direct a Federal energy conservation plan and foster State conservation plans, (4) issue coal conversion orders to electric utilities, and (5) promulgate guidelines for industrial energy conservation.

In addition, the bill sets up strict provisions regarding motor vehicle gas consumption standards, provides for the disclosure of energy use and costs associated with major household products and automobiles, and provides for the creation of national and regional fuel reserves to offset any interruption in supplies.

While most of these provisions have always been acceptable to the Administration, Congress's insistence on an oil price roll-back brought the threat of a Presidential veto, thus creating a test of wills that logjammed almost all energy legislation in 1975. Only on November 12 did this logjam begin to break up. On that day, the House-Senate Conference agreed upon a compromise version of the bill that won the acceptance of FEA-head, and Presidential advisor, Frank Zarb.

But, despite the advice of Mr. Zarb, the President remained noncommittal through November. The decision point came just as this article went to press. The logjam has finally been broken and the United States is at last on its way to a national energy policy . . . for better or worse. ◆

Information for this article came from many sources. Major contributors included: Richard Grundy, U.S. Senate Committee on Interior and Insular Affairs; Wasyl Lew, NASA; Richard Marsten, City College of New York; and Donald Wakefield, Department of Defense.