VOLUME 12 ☐ NUMBER 10 OCTOBER 1975

IEEE spectrum

articles

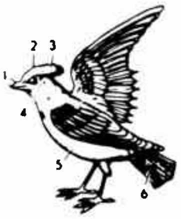
departments

the cover

The subject of our special report, EEs' Tools and Toys, beginning on page 38, is reflected in Art Director Herb Taylor's cover design depicting engineers' pursuits in both business and pleasure.

bird (bûrd) *n.* 1. Any member of the class Aves, which includes warm-blooded, egg-laying, feathered vertebrates with forelimbs modified to form wings. 2. A bird hunted as game. 3. *Aerospace Slang.* A rocket or guided missile. 4. A target; a **clay pigeon** (see). 5. The feather-tipped object used in playing badminton; a **shuttlecock** (see). 6. *Slang.* One who is odd or remarkable. 7. *British Slang.* A young woman. 8. *Slang.* A derisive sound of disapproval or derision. Used chiefly in the expression *give (someone) the bird.* —**for the birds.** *Slang.* Objectionable or worthless. —*intr.v.* **birded, birding, birds.** 1. To observe and identify birds in their natural surroundings. 2. To trap, shoot, or catch birds. [Middle English *bird, brid,* young bird, Old English *bridd.*]

a thousand words



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World Radio History

IEEE spectrum OCTOBER VOLUME 12 □ NUMBER 10

spectral lines

Hardware, software, and mushware

Huge piles of garbage lie rotting in the streets of New York City as we write this message. Meanwhile, elsewhere, urban technologists are meeting to discuss highly efficient systems to remove refuse regularly and inconspicuously from metropolitan streets. The two images are incongruous. The New York rubbish heaps may be partly due to work slowdowns resulting from layoff threats by a City administration in severe financial straits, but an executive of the Sanitation Department insists it is simply a matter of the difficulty in redeploying a somewhat reduced sanitation force—the workers are presumably willing but confused.

This problem calls to mind another, somewhat parallel, incident. It relates to the recent noontime bombing of historic Fraunces Tavern, in downtown New York, in which scores of diners were maimed. The City's Emergency Control Board has a well-defined set of regulations specifying that victims from a disaster are to be moved by ambulance only. Yet after the blast, 60 victims were found in the Beekman-Downtown Hospital—too many for one hospital to handle. Evidently, well-meaning police and fire department personnel, as well as the general public, had acted on their own, despite the fact that within minutes ambulances from 15 hospitals were on the scene.

Perhaps these two illustrations are good examples of "mushware," a term coined by the writer to describe that portion of a system that is not hardware, nor even software. Rather, it can be thought of as that part of a system that is ill defined—the part that requires actions by humans to close the loop, or to make the system work. Sometimes, particularly in sophisticated systems, it represents the segment of the loop in which "fine-tuning" is accomplished with more finesse than can be provided by a machine program. But too often it is a gray area characterized by too many options for "us humans." The result: we are very likely to make the wrong choice.

A danger inherent in the mushware segment of a system is that a neophyte operator (or a careless or disinterested one) might attach too little importance to it since it is the only segment not automated. This form of reverse thinking may or may not have been present at the crash of the ill-fated Trans World Airlines' flight just outside Dulles International Airport. In that case, a veteran air traffic controller testified that Federal landing procedures did not require him to monitor the aircraft continuously over mountainous terrain, and that his radar was not designed to be continuously reliable in monitoring the altitude of an aircraft. Therefore, although he knew the minimum safe altitude over the mountainous approach was 3400 feet, he took no action when he noticed the aircraft's altitude to be 2000 feet, and the aircraft plunged into terrain short of the airport.

Not all actions in the mushware area lead to disaster and loss of life. Some are merely disconcerting. The other day the telephone company installed new instruments on the desks of all members of *Spectrum's* staff, to accompany a new Centrex system at the United Engineering Center where *Spectrum* is headquartered. After the installers left, some staffers discovered the empty instrument boxes in their trash baskets, and, inside each box, a handsome 8-page instruction booklet describing the instrument and its features. It is not clear whether the booklets are inaccurate or obsolete, or whether a verbal briefing by the telephone company (some of the staff were traveling that day) was intended to substitute for the booklets.

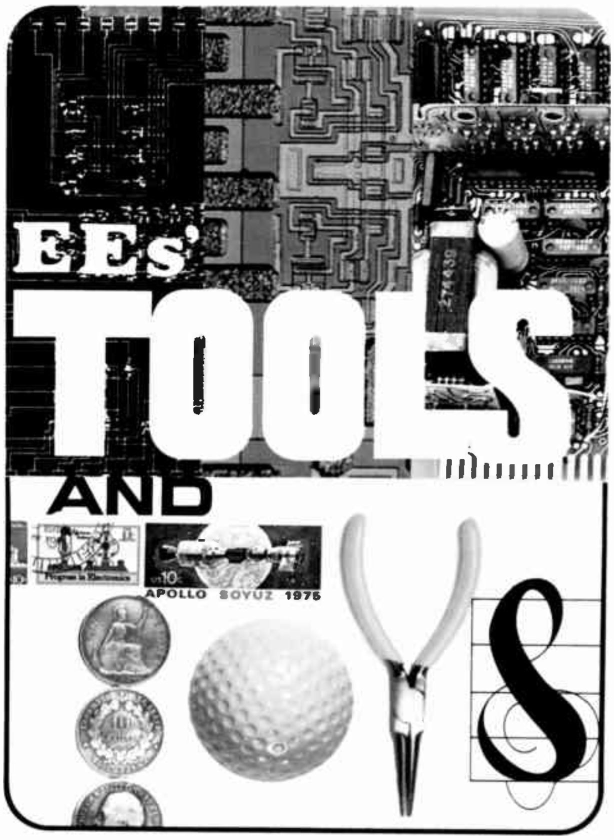
The most important observation affecting mushware may well be that the path of our highly-developed technological society is irreversible. That is, the trend to compressing mushware into a smaller and smaller segment of any system's cycle will probably continue—indeed, it is probably desirable.

But as this trend continues, the problems in the mushware segment may not decrease as we would hope, but actually rise. This may be explained partly by the inverted axiom, "lack of practice makes imperfect," so that humans become "rusty," unaccustomed to reacting quickly and intelligently to problems occurring in the shrinking mushware area. For example, in the earlier days of railroading, employees were well versed in the "rule book," taking great pride in being able to respond to real or invented complex and hazardous operating situations. Today, with the enhancement of rail automation, an operational glitch throws the system into a "frantic" mode, and illuminates the ignorance of most operating personnel about safe, manual procedures.

A complicating factor may relate to society's greater reliance on large institutions (the Federal government or private corporations) to assume the role of Big Brother in the mushware arena. Thus, we expect less and less of the small businessman (in repairs, for example) and more frequently embrace the philosophy that "it's Detroit's fault,"—or General Electric's, or the telephone company's. This genre of thinking helps us put the blame on everyone else. (Personnel of FAA and the Port Authority each blamed the other for failing to close down the fatal runway in the recent disaster at Kennedy International Airport.)

Mushware, almost by definition, is the area that engineers are affecting least. Is it not possible that, in our quest for greater professionalism, progress made by individual engineers in "hardening" mushware could constitute one of the more significant contributions to society?

Donald Christiansen, Editor



A Spectrum special report

Donald Christiansen Editor

Certain concerns of engineers overarch all their special skills, efforts, and knowledge. On the one hand, there are "tools" of the electrical engineering trade: those general design techniques and methods of information-gathering that make all engineering design tasks feasible. On the other hand, there are avocational activities: the "toys" that can give added meaning to the engineer's life whether he is actively working or in retirement.

This issue of *Spectrum* includes three groups of articles, designed to explore several different facets of both "tools" and "toys." Computer design techniques first take the spotlight in two articles that explore current techniques for computer-aided design of circuits and power systems as well as the use of computers to design other computers.

Computer is king

The computer has become the overriding extension of the engineer's "right hand," as well as his brain. It is employed in advanced circuit analysis programs—the successors of "pioneer" general-purpose computer-aided design programs like IBM's ECAP. Among the tasks upon which CAD can now be brought to bear are dc and transient analysis, sensitivity analysis, Monte Carlo analysis, component tolerance studies, and design centering. In an article by Gadi Kaplan, these techniques are reviewed briefly and a tabulation is provided of 28 CAD programs in which features such as input and output versatility and format, program capability, and source and program availability are identified. The key to useful CAD programs resides principally in the accurate modeling of its active circuit devices; the author explains, briefly, some of the problems involved and how macromodeling—the modeling of more complex devices—may be exploited in the future.

The computer is also used extensively for component positioning and circuit layout, wire routing, and the generation of artwork required to produce complex devices and equipment. It is also employed to design and execute testing programs for complex circuits and systems. Since the computer can be employed to a greater or lesser extent at nearly every phase of designing and producing a given circuit or piece of equipment, the usefulness of a common data base that may be shared by each of the programs (e.g., wire routing, logic testing, etc.) becomes obvious. A discussion of the techniques of design automation, as the overall process is frequently labeled, is provided in the article "Designing for production," by Howard Falk.

The article following these two includes a compilation of design books generated by Roger Allan in consultation with experts in several technical areas. For convenience, Mr. Allan has divided the "bookshelf" into five segments: computer-aided design and modeling; design automation; general systems design techniques; microwave design techniques; and, far from least, power systems design and planning techniques. The engineer's kit contains some esoteric tools that are occasionally, but not frequently, brought to bear on everyday problems: decision analysis, cost/benefit analysis, pattern matching, and the like. Some of these topics, too, are covered by the books listed.

Finding it fast

Knowing where to find information quickly and in a form that is easily usable is often half the battle for the EE embarked on a new project. Thus, the second group of "tools" articles concerns information retrieval. The first is a guide to upcoming short courses about microprocessors. In it, Howard Falk has compiled a list of about 25 such courses to be given at a wide variety of geographical locations from Hollywood, Fla., to Osaka, Japan. These courses vary in length from one day to two weeks and the tuition ranges from $25 to $750.

To cut the flood of paper that can inundate the engineer engaged in researching a topic, the micrographics industry provides easy-to-use reader/printers and a variety of new storage media, such as cassettes, cards, and computer output microfilm—the last eliminating manual drawings and photo reduction. Don Mennie reviews the state of this art in the article "Engineering micrographics," which includes a discussion of the features of new equipment now available on the market.

The computer reenters the picture once again in Oscar Firschein's article describing on-line information retrieval systems. Those he describes provide the user not with answers to specific questions but, rather, refer him to documents wherein the answer may reside. The key to the usefulness of such systems is in the completeness of their data base. Mr. Firschein includes a table that summarizes data bases of value to the EE, the organizations that offer these bases, and their prices.

A principal task of certain organizations is to provide help to members of the engineering profession, often simply by getting them "pointed in the right direction." Evelyn Tucker began with a list of such organizations issued by Engineers Joint Council ("Guide to engineering information sources"), then modified and added to it to generate the "Engineer's source guide," a list of 36 major sources.

The "toys" of the EE range from sports in which he participates through crafts, hobbies, and other avocations (some quite individualistic). The results of an open-ended questionnaire *Spectrum* sent to 1000 randomly selected U.S. member-readers included not merely obvious leisure-time activities, but many productive avocations that show how at least some members share a kinship with the "Renaissance man," as broad contributors to profession, family, and society.

The EE at leisure

Ellis Rubinstein summarizes the results of this mini-survey in the article, "The EE at leisure," replete with charts revealing the interest profile of the respondents as a group.

One of the avocations listed by readers is amateur ("ham") radio, a hobby long identified with the EE community. To probe the present status of that hobby, *Spectrum* engaged Contributing Editor Alex McKenzie (WAIRGP/W2SOU), Judith Gorski, a staff member of *QST* magazine, and A. Prose Walker, FCC's chief of its amateur and citizens division, who, together, produced the article "Inside amateur radio."

Collecting, particularly of old electronics gear and components, is a pastime engaged in by a significant number of EEs. On the other hand, many simply like to visit technical museums to retrace the history of developments in communications, transportation, and the like. Ms. Tucker assembled the impressive list of museums and private collections that encompass a range of artifacts from classic vacuum tubes to old trolley cars that still run.

Finally, *Spectrum* enlisted the aid of editors from leading craft and hobby magazines to produce "The leisure bookshelf." Ellis Rubinstein and Barbara Gail Music selected over 50 books and other publications from among the many suggested in these areas: photography, gardening, reading, tennis, golf, fishing, camping, skiing, bicycling, and home repairs.

◆

Computer-aided design

No longer a mere infant, CAD now offers more sophisticated programs with Monte Carlo computations and tolerance assignment

The main thrust of computer-aided design (CAD) is to solve problems that cannot be readily or quickly solved on a bench in the lab. In its broad sense, CAD includes analysis, design, and evaluation of the performance of electrical circuits by using a computer to simulate these circuits.

It is often that, when other design techniques fail, engineers try CAD. A typical case in point is the breadboard that does not properly account for those parasitics that often dominate circuit performance. Similarly, unipolar circuit breadboards do not usually incorporate the parasitic capacitance or leakage that are predominant factors in such circuits. CAD simulation can include these parasitic effects and speed the design process.

A second application of CAD simulation is to help the designer understand the performance of a complex digital circuit, as well as to test and verify that performance. Other motivations for using CAD include the wish to acquire confidence in a design that was accomplished by other means, and, not least in importance, a sense of curiosity or perhaps a desire to discover the unexpected.

The increasing interest in CAD is attributable to the fact that it is becoming ever more powerful in simulating circuit performance. New areas like optimization of nonlinear circuits and elaborate statistical analysis are opening up to it, and it is implemented to assign tolerances to components in discrete circuits, while new concepts such as design centering have been evolving for applying CAD techniques to integrated circuit designs.

From the user's point of view, CAD presents a number of problems. The documentation associated with CAD programs, although plentiful, often fails to meet the user's needs; a "universal" program that suits all potential users has not been generated yet, and may never be; and the costs of programs and their execution times are sometimes prohibitive, particularly to small users. In spite of such difficulties, computer-aided design is used by many, and it is not only justified but, very often, also essential for acceptable design standards.

CAD programs are available to perform frequency analysis of linear circuits and time-domain analyses (both transient and steady-state) of linear and nonlinear circuits. In the time domain, just a few years ago CAD programs were very expensive for analyzing periodic steady-state circuits, such as oscillators. The reason was that it took a long time for most programs to run until initial transients died down so that the periodic variation could be seen. Specialized techniques have been developed to avoid this, particularly for the design of many communications-type circuits like frequency doublers and oscillators. Even more significant is a recent advance in computational methods, introduced in so-called "third-generation" programs (see Table I), which provides a much more economical analysis of nonlinear circuits than that obtained by previous methods. In the frequency-domain analysis of linear circuits, CAD has advanced more rapidly than in time-domain analysis, and optimization is one area where this is well demonstrated.

Gadi Kaplan Associate Editor

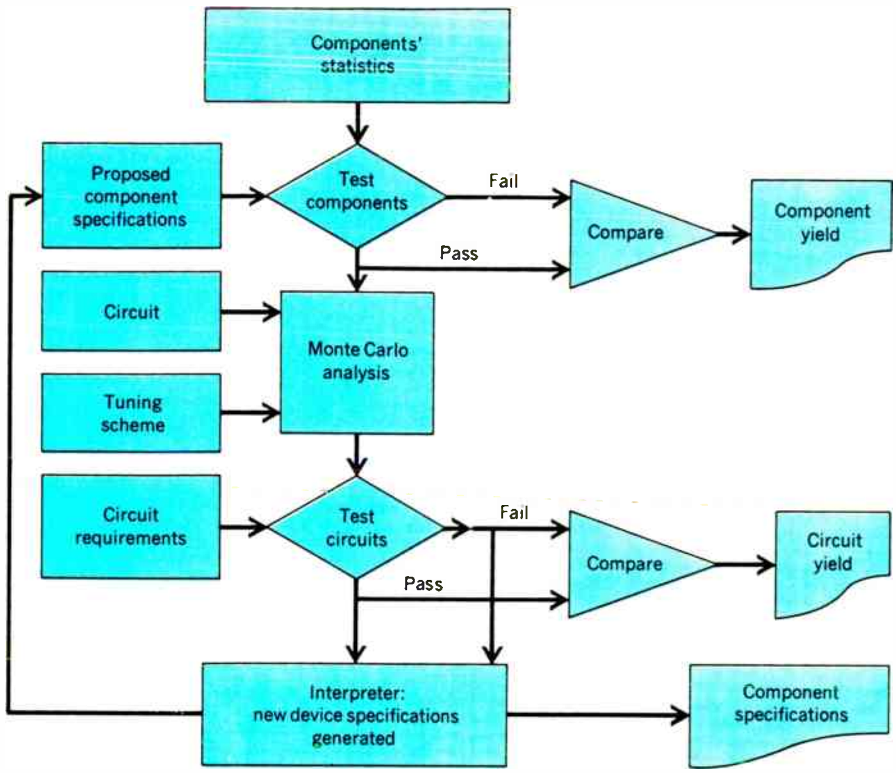
Optimizing circuit designs

What is the thrust of optimization in circuit design? Stephen Director, of the University of Florida, Gainsville, Fla., indicates that in order to use an optimization program effectively, one should be able to state all design objectives, or performance functions, of a proposed circuit and cast them in some sort of a mathematical expression that can be used to measure how well the circuit is doing. But can one really pin down all design objectives, many of which are intuitive?

Dr. Director believes that the use of optimization programs for designing different classes of circuits will enhance the development of suitable performance functions. For example, in the case of frequency-domain analysis of linear circuits, a weighted "least squares" function has been found to be adequate, and this function is built into existing frequency-domain optimization programs.

Once a suitable performance function has been found, it can be used for other circuits in the same class. Initial development of optimization routines for a new class of circuit designs can be expensive, but this initial investment may pay off handsomely as more and more designs in that class are optimized. For widely used classes, such as the frequency-domain design of linear circuits, optimization has been found very useful in arriving at practical designs. For example, at Zenith Radio Corp., Chicago, Ill., optimization has been employed to zero in on practical filter designs using finite Q values for the coils, as opposed to the infinite Qs assumed in many design handbooks.

How well is optimization accepted by engineers? Although firmly established in the frequency-domain analysis of linear circuits, optimization has been less enthusiastically received in the nonlinear circuit area. One reason for this chilly reception seems to be that, in this latter area, considerable effort on the user's part is required to learn how to apply optimization. Users have to become familiar with some unfamiliar concepts—for example, the specification of a suitable performance function. And there are other hurdles: Optimization programs of nonlinear circuits are lengthy and expensive, and until recently have not been generally available. Attempts have been made to convert one widely used CAD program, SPICE 1, for optimiza-



[1] **TOLERATE, a computer program that identifies the tolerances of passive components and transistors which maximize *circuit yield* is depicted in block diagram form. Recently developed in Bell Laboratories, Holmdel, N.J., this proprietary program is centered around a conventional Monte Carlo analysis, performed on a random sample of several hundred circuits. In the analysis, *circuit yield* is computed as the fraction of circuits that meet all requirements. The Monte Carlo analysis thus maps component specifications into circuit performance. TOLERATE, in turn, maps, via the interpreter, the circuit performance data into revised component specification. The entire process repeats until either 100-percent circuit yield is realized or until the circuit yield surpasses some predetermined level.**

tion. In the frequency domain, the successful use of optimization for more than seven years encourages new efforts. One new program in this area—EXHOPT—was recently written at Columbia University, New York, N.Y. (See tables.)

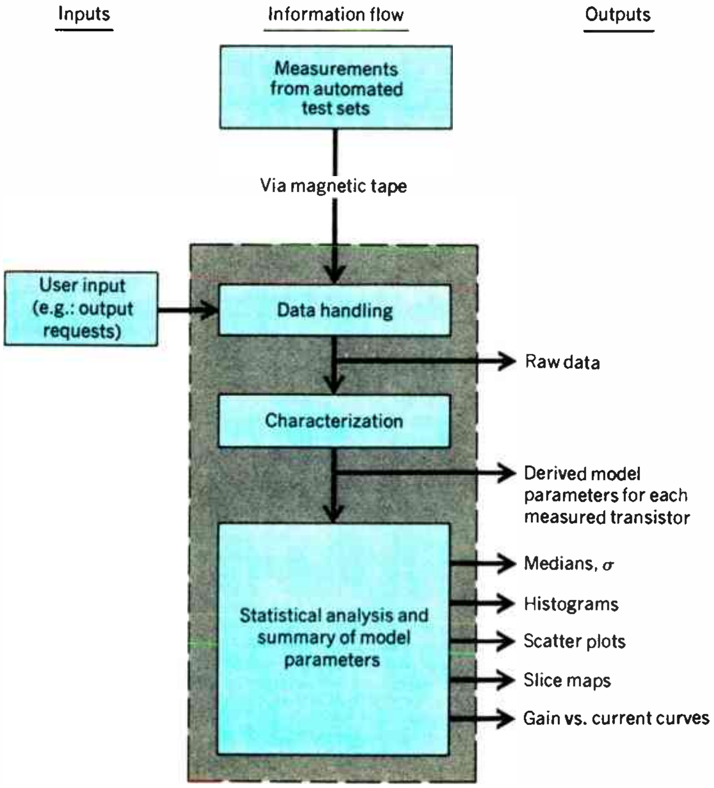
Tolerance assignment

In addition to establishing nominal element values in circuit designs, CAD has an important function in evaluating the effectiveness of a circuit design. One area where this is demonstrated is called tolerance assignment. The term relates to a typical problem facing a designer of electronic circuits—variation in circuit performance resulting from statistical variations in the values of characteristics of components used in the circuit or those of input parameters. The problem is: Given the constraints on the circuit's output, how large can the maximum tolerances on its components be? From the practical viewpoint, the tolerance assignment question relates to circuit yield—that is, the percentage of the manufactured circuits that perform according to specifications. Recently, advances have been made in solving the tolerance assignment problem; however, a truly general and realistic procedure has yet to be developed. Much of the work that has been done is limited to linear, discrete-component circuits such as filters.

Apart from its limitation to discrete-component circuits, tolerance assignment has, at present, a major economic drawback in the eyes of the majority of CAD users—its use is expensive in that a lot of computer time is needed to run tolerance assignment programs. But tolerance assignment is constantly being developed. Disclosures at the 1975 International Symposium on Circuits and Systems, for example, indicate an ability in tolerance assignment hitherto not anticipated.

But is tolerance assignment at all practicable with

[2] **To obtain statistical information about dc bipolar transistor models, which is essential for a successful Monte Carlo analysis in circuit designs where such models are used, a population of nominally similar transistors is automatically measured. According to the portrayed procedure, developed at Bell Laboratories, Holmdel, N.J., for this purpose, the measured information is processed on an IBM 370/168 computer, and the outputs include the statistical summary of the measurements. The procedure is believed to be general enough to be directly applicable to any bipolar device type, and it is also very fast—about 24 seconds of the computer's central processing unit is required for the derivation and complete statistical summary of all dc model parameters for 100 transistors.**



I. Major computer-aided circuit design programs—general information[1]

	Type of Analysis		Approx. No. of Statements (X 1000)	Core Requirements (k bytes)	Time in Use (years)	Topological Limits[2]	Program Availability
Program Name	Linear	Nonlinear					
ADA 74	X	X	4	64	9.5	m	Commerc available
ANP 3	X		4	80–135	3	100 b, 40 n	Handling charges[3]
ASTAP	X	X	60	200	5.5	m	Commercially available
BELAC	X		10	120	6.5	m	Handling charges
CIRCUS 2[4]	X	X	18	180, 400, 600	4.5	m	Handling charges[3,16]
COMPACT	X		2.5	96	4	1-, 2-, 3-p, 150 n	Commercially available[3]
CORNAP	X		3	80–110	7.5	30–70 e	Handling charges[3]
ECAP 2[4]	X	X	25	200–300	4	m	Commercially available
EXHOPT[5]	X		1.5	250	3	40 n	Handling charges
IMAG 2	X	X	10	100	4.5	m	Commercially available[3]
ISPICE	X	X	25	330[6]	2	m	Commercially available[7]
ITRAC 3	X	X	7	120	5	100 n, 200 b	Commercially available[3]
LISA	X		17	140	6.5	125 e, 50 n	Handling charges
MARTHA	X			32	5	2-p	Commercially available[3]
MOFRAN	X		4	156	1.5	50 ccs, 256 e, 25 sn (limits of a main circuit subnetwork)	Handling charge
NAP 2[8,9]	X	X	6.5	104 or 250	2	200 b, 50 n, or 1500 b, 500 n	Handling charges[3]
NET 2[4]	X	X		70[6]	6	m	Classified
NICAP		X	10	300–350	5	m	No charge[10]
PTNA	X		1.5	64	3.5	30 e, 20 n (adjustable)	Handling charges[3]
SCAP	X		1.4	12	2.0	200 n, 500 b, 100 ce	Handling charges
SCEPTRE	X	X	30	228	2	300 e	No charge[3,11]
SLIC	X	X	10	200	3	100 n	Handling charges[3,12]
SNAP	X		1.5	26	5	35 n, 100 b	Handling charges
SPICE 1	X	X	10	184	3	400 n, 200 e	Handling charges[3,12]
SPICE 2	X	X	13	135 up	0.5	m	Handling charges[3,12]
SUPER SCEPTRE	X	X	40	238	2	300 n	Handling charges[3]
SYSCAP 2[4]	X	X	20	155[13] 60[14]	1.5	255 n	Commercially available[7]

Notes: 1. A survey and an evaluation of third-generation computer-aided design programs—most of which are mentioned in the tables in this article—is underway at the University of South Florida, College of Engineering, Department of Electrical and Electronic Systems. The final report of this CAD survey is expected in January, at which time copies should be obtainable through Phillip C. Harren, Jr., AFAPL/TOD-1, Wright-Patterson Air Force Base, Ohio 45433. 2. Legend: b = branches, ccs = controlled current sources, ce = coupled elements, e = elements, m = limited by computer memory size only, n = nodes, p = port, sn = subnetworks. 3. Versions available for more than one computer brand. 4. Original version

Program Features	Source
.mized for most efficient use of CPU time and memory	J. Watson, General Electric, Schenectady, N.Y. 12345
Excellent teaching program written in Fortran and Algol	Dr. E. Lindberg, Technical University of Denmark, Lyngby, Denmark
Statistical transient analysis	F. L. Wise, IBM., Dept. 1E9, Building 414–700, Hopewell Junction, N.Y. 12533
Available on time-share, batch, and remote batch	J. R. Greenbaum, GE, Philadelphia, Pa. 19101 C. A. George, GE, Utica, N.Y. 13503;
Convolution integral modeling of linear systems, third-generation features	A. S. Bushkin, Boeing Computer Systems, P.O. Box 24346, Seattle, Wash. 98124
Microwave design and optimization, using fine (gradient) search; coarse (vicinity) search is optional. Available on time-sharing[15]	L. Besser, 1651 Jolly Ct., Los Altos, Calif. 94022
State-equation oriented; written in ANSI Fortran 4	Prof. C. Pottle, School of Electrical Engineering, Cornell University, Ithaca, N.Y. 14853
Nesting of models and subcircuits; recursive modeling; capability for rerun with modified topology; interactive (one version only)	Any IBM branch office
Use of Hessian matrix; least-square approximation	Prof. O Wing, Columbia University, Dept. of EE and Computer Science, New York, N.Y. 10020
Third-generation features	C. Masson, Honeywell-Bull, 94 Avenue Gambetta, Paris-20^e, France
Completely interactive or batch (at user's option)	Alan Schwartz, ISPICE Product Manager, National CSS, Norwalk, Conn. 06851
Interactive	S. Bernstein, Berne Electronics, White Plains, N.Y. 10605
Provides poles and zeros and block diagram	E.T. Johnson, IBM. GPD, R64/282 5600 Cottle Rd., San Jose, Calif. 95193
Suits microwaves and low frequency; built-in transistor and microwave models, and response functions; good for synthesis	Prof. P. Penfield, Jr., M.I.T., Combridge, Mass. 02139
Recursive use of subnetworks; in ANSI Fortran 4	Dr. E. Lindberg (see ANP3)
Third-generation features, well suited for stiff systems	Dr. E. Lindberg (see ANP3)
Hierarchy ("nesting") of subcircuits, up to 16 levels; built-in transistor and diode models; automatic parameter extraction for modeling from curves	M. A. Espig, P.O. Drawer QQ, General Electric Tempo, Santa Barbara, Calif. 93102
Built-in models and a model library	I. A. Cermak, Bell Laboratories, Holmdel, N.J. 07733
Educational aid for modern network analysis studies; completely topological approach	Prof. R. Priemer, Univ. of Illinois, College of Engineering, Chicago Circle, Chicago, Ill. 60680
Response evaluated by loopless code	Prof. O. Wing (see EXHOPT)
Run controls in transient analysis—start, stop, step size, number of points	SCEPTRE Project Officer, att., B. White, A.F.W.L., Kirkland AFB, N. Mex., 87117; J. R. Greenbaum (see BELAC)
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Symbolic network function	Prof. P. M. Lin, School of EE, Purdue Univ., Lafayette, Ind. 47907
Built-in models for bipolar junction transistor, diode, junction FET, MOSFET	Prof. D. O. Pederson (see SLIC)
Built-in models for bipolar junction transistor, diode, junction FET, MOSFET; dynamic memory	Prof. D. O. Pederson (see SLIC)
SCEPTRE features plus mechanical and control systems, digital and nonlinear mechanical models	Prof. J. C. Bowers, College of Engineering, Univ. of South Fla., Tampa, Fla. 33620
Circuit failure simulation and stress analysis	J. D. Bastian, Rockwell International, 3370 Miraloma Ave., Anaheim, Calif. 92803

believed obsolete. 5. Incomplete documentation. 6. K words, not k bytes; larger memory requirements depend on problem. 7. Mainly in time-sharing systems, but sale or lease of program is possible. 8. Not completely debugged. 9. Documentation includes users' and programmers' manuals, and theoretical and application notes. 10. Available to universities only, for educational purposes. 11. One version available for use through a commercial time-sharing service. 12. One version only. 13. Batch version for CDC 6600. 14. Interactive version for CDC 6400. 15. Documentation includes users' manual, application notes, and reprints of articles. 16. Commercial versions also available.

II. Analysis and input details of computer-aided circuit design programs

	Analysis Details										Elements		
Program Name	AC	DC	Sensitivity	Worst Case	Monte Carlo	Time	Optimization	Fourier Analysis	FFT[1]	Other	Active	Passive	Controlled Sources
ADA 74	X	X	X				X						
ANP 3	X	X[2]	X[3]	X[3]		X				Semisymbolic[4]	X	X	X
ASTAP	X	X			X	X					X	X	X
BELAC	X	X[2]	X	X	X	X	X			LaPlace equations	X	X	X
CIRCUS 2		X				X					X	X	X
COMPACT	X		X		X		X			Noise figure; stability factor	X	X	X
CORNAP	X					X					X	X	X
ECAP 2		X				X					X	X	X
EXHOPT	X						X				X	X	X
IMAG 2	X	X					X				X	X	X
ISPICE	X	X	X[8]	X[8]		X		X		Temperature analysis	X	X	X[9]
ITRAC 3	X	X	X	X	X	X					X	X	X
LISA	X	X	X			X				Root locus	X	X	X
MARTHA	X	X						X			X	X	X
MOFRAN	X										X	X	X
NAP 2	X	X	X	X		X	X	X		Tolerance	X	X	X
NET 2	X	X			X	X	X			X[11,12]	X	X	X
NICAP		X				X			X		X	X	X
PTNA	X	X								Topological		X	
SCAP	X	X									X	X	X
SCEPTRE		X				X			X		X	X	X
SLIC	X	X	X			X[14]	X[14]			Pole-zero; delay	X	X	X[15]
SNAP										Symbolic[3]	X	X	X
SPICE 1	X	X	X[15]			X		X		Noise	X	X	X[9]
SPICE 2	X	X	X[15]			X		X		Noise	X	X	X
SUPER SCEPTRE	X[17]	X	X[17]	X	X[17]	X	X[17]				X	X	X
SYSCAP	X	X	X	X	X	X		X		Failure, stress analysis	X	X	[illegible]

Notes: 1. Fast Fourier transform. 2. Frequency = 0 Hz. 3. Only in a special version called ANPS. 4. Results given in mathematical symbols. 5. Equations for signals: polynomials, poles, zeros, LaPlace transform of input signals, Fortran subroutines. 6. Transistor *S* and *Y* parameter values; noise defined according to program rules. 7. Arbitrary parameter values in functions. 8. To be available shortly. 9. Only voltage-controlled current sources. 10. Equations for elements, built-in, or user specified—values are a function of time, frequency, circuit signals, or other element tracking. 11. Mathematical functions. 12. Nesting of subcircuits. 13. Photo current sources for radiation effects. 14. Transistor *S*, *Y*, *Z*, and *H* parameter values, but not available on all versions. 15. In dc only. 16. Subcircuits: user-defined elements allowed provided they are legal in SPICE.

integrated circuits? Apparently not. The reason is that while building an IC, one doesn't really have much control over tolerances. A typical manufacturing line for integrated circuits can realize transistor betas, for example, somewhere within 20 to 50 percent. But one does not have control over *individual* parameters, as is the case in hybrid or discrete components (resistors, for instance), which can be obtained at 10-percent, 5-percent, or other tolerance values.

A new concept, called *design centering*, has been introduced in relation to integrated circuit design. The basic idea in design centering is to achieve the same circuit performance with larger element tolerances, by appropriately shifting the nominal design values. The design center is not necessarily going to be the optimum design with regard to best circuit performance. The reason is that, when applying optimization, the designer lists all his design objectives, with the aim of coming as close to satisfying all of them as possible. He may never achieve that aim, but he may succeed in satisfying some objective functions. When doing design centering, however, the designer specifies all constraints that *must* be satisfied by a circuit's performance and tries to find a design that is, in some sense, in the center of the region defined by these constraints. In this manner, he may have the best design with regard to parameter tolerances.

Monte Carlo analysis

For circuits that are to be manufactured in large quantities, statistical analysis during the design stage has become extremely important. Well-written computer programs for statistical analysis can be invaluable to designers of such circuits. Typically, such a Monte Carlo analysis program may offer a capability that is equivalent to selecting randomly, say, 500 circuits from a large production run and making extensive measurements on them.

For statistical analysis of linear circuits, relatively little computer time is required and the running costs are accordingly moderate. One 100-run Monte Carlo analysis of a linear circuit that included 21 operational amplifiers and about 250 other components lasted about 15 minutes at $100 (about one dollar a run). But for nonlinear circuits, statistical analyses are very costly—a typical run time for Monte Carlo analysis of such a circuit on a large computer may be measured in hours. Edward Nowak of Zenith, a major user of

Input Details					
Eq[illegible]ons	Library Elements	Tables	Transmission Lines	Arbitrary Input Signal	Other
X	X				
X[5]		X		X	
X	X	X		X	
X[5]	X	X			
X	X	X		X	
	X	X	X		S, Y; noise[6]
X	X	X		X	X[7]
X	X	X		X	
X	X	X		X	
X	X	X	X	X	
				X[19]	X[20]
X	X	X	X	X	Waveguides
X[5,10]	X	X		X	
X	X	X	X	X	X[13]
	X	X		X	
			X		
X	X	X			X[13]
		X[14]	X[14]	X	S, Y, Z, H[14]
	X			X	X[16]
				X	X[16]
X	X	X	X	X	X[18]
	X			X	X[13]

17. One version only. 18. Fortran function capability. 19. Combination of signals like steps and vamps for transient analysis. 20. Transfer function (poles and zeros); polynomial matrix; simple block diagram.

Modeling . . .

Probably the biggest single factor in successful circuit simulations is modeling. If the circuit devices can be properly and accurately modeled, the right answers may be found; if not, then the entire CAD effort is likely to be a waste of time.

For accurate modeling, there must be accurate measurements of device parameters, not only of nominal values, but of distributions as well. Unfortunately, device manufacturers do not usually provide these data, so the user often has to measure them. Relatively inexpensive equipment and techniques for obtaining transistor parameters are available. Nevertheless, there are circumstances—perhaps because one may not have the right equipment for measuring certain parameters—wherein a good model of the device, including all of the strays and third-order effects, is unobtainable. If these parameters are important in the circuit, a simulation of that circuit on the computer without them will be deficient. In such a situation, the computer can only give a starting point, a ball-park result, and the rest has to be done on the bench by trimming and tweaking.

As semiconductor technology develops, new devices continue to appear, and these require new types of models. For example, I^2L device modeling is just getting underway. Often, there is poor communication between model developers and users of semiconductor device models. The former are mainly physics-oriented and try to model everything that is taking place, physically, in the device. Much of that may not be important for the understanding of circuit behavior—the main interest of the model users.

. . . and macromodeling

Once the modeling problem of a single electronic device, like a bipolar transitor, has been settled, a second modeling question poses itself and that is, how can the modeling of large, nonlinear, circuits, which include many individual devices—for example, an entire calculator chip—be economically yet adequately handled? Specifically, how many of the fine details should be included in such a model? Usually, one does not need the full complexity of a device model to describe a logic gate. What matters for a delay calculation might be summarized by just a few parameters. The question is, however: Which parameters are the important ones?

The answers may well be provided by *macromodeling*, a new modeling approach for large circuits. Instead of modeling individual devices, which may lead to too complex overall circuit models that are prohibitively expensive to compute with, macromodeling summarizes the *external* behavior of large *chunks*, or subcircuits, of the entire circuit. These subcircuits can be selected according to function, for example, with their appropriate macromodel accounting for the performance at their terminals. A macromodel for an integrated-circuit operational amplifier that performs satisfactorily both in linear and nonlinear circuit simulations is described in the *IEEE Journal of Solid-State Circuits*, December 1974.

Monte Carlo analysis programs, observes that to rectify this situation faster algorithms and faster computers are required, along with more interactive programs. There have been recent attempts at decreasing the cost of Monte Carlo analysis by carefully selecting parameter values of circuits that are to be simulated, as opposed to using a large random selection of parameter values, which is the normal practice. If these attempts prove successful, they will greatly encourage the use of Monte Carlo methods.

Another hurdle in the use of statistical analysis programs is prohibitively high costs of the program themselves. One extremely good program, ASTAP by IBM (see tables), is priced in the range of $34 000. So, in spite of its apparent merits—flexibility as well as speed when compared with SCEPTRE, an alternate choice (see tables)—ASTAP was not chosen by a potential user for his statistical analysis purposes.

Circuit sensitivity analyzed

In contrast to statistical analysis methods, where a few circuit parameters, according to needs, are simultaneously perturbed by random amounts, CAD sensitivity analysis is based on slightly varying only *one* circuit parameter at a time, and observing the effects of these variations on predetermined performance criteria of the design. Sensitivity analysis is regarded as one of the key assets of CAD, and as one of the most powerful design tools available to the engineer.

To a limited extent, sensitivity analysis schemes are employed by engineers at the lab bench, under the title of "trial and error." In that case, changes in performance with potentiometer adjustments or insertion of "worst-case" components into a circuit are observed. The sensitivity analysis that can be performed by a computer is, obviously, a totally different animal, since

III. Output details and formats of computer-aided circuit design programs

	Output Details											
Program Name	Element Volts	Node Volts	Element Current	Voltage Differences	Poles and Zeros	Transfer Function	Gain	Driving Point Function	Group Delay	Phase	User Specified	LaPlace Equation	e
ADA 74											X		
ANP 3					X	X	X	X	X	X			
ASTAP	X	X	X	X	X	X	X	X			X		
BELAC	X	X	X	X	X	X	X	X	X	X	X	X	
CIRCUS 2	X	X	X	X							X		
COMPACT						X	X	X		X	X[2]		
CORNAP	X	X	X	X	X	X	X	X	X	X			
ECAP 2	X	X	X	X							X		X
EXHOPT	X	X	X	X			X	X		X			
IMAG 2	X	X		X		X	X			X	X		
ISPICE	X	X[6]	X	X		X	X			X	X[7]		
ITRAC 3	X	X	X								X		
LISA	X	X	X	X	X	X	X	X	X		X[19]		
MARTHA	X	X	X	X		X	X	X		X	X[9]		
MOFRAN	X	X	X	X		X	X	X		X			
NAP 2	X	X	X	X		X	X	X		X	X		
NET 2	X	X	X			X	X	X		X	X[12]		
NICAP	X	X	X				X						
PTNA	X	X	X			X	X				X		X
SCAP	X	X	X	X									
SCEPTRE	X		X								X	X	X
SLIC		X	X[15]		X	X	X	X		X			
SNAP		X		X		X		X					
SPICE 1		X	X[16]	X		X	X	X		X			
SPICE 2		X	X[16]	X		X	X	X		X			
SUPER SCEPTRE	X	X	X	X									
SYSCAP	X	X	X	X			X			X	X[18]		

Notes: 1. Two-dimensional error contour. 2. *S* or *Y* parameters, voltage standing-wave ratio, reflection coefficients, noise figure. 3. Not on all versions. 4. Up to eight variables simultaneously. 5. Compatible with Tektronix's graphic terminal 4012. 6. Magnitude and phase, real and imaginary parts. 7. Any function parameter, in ac analysis. 8. Smith charts. 9. The network definition can also be provided as an output. 10. Of Fourier analysis only. 11. Nyquist plots; linear—linear, linear—logarithmic, log.—lin., log.—log. plots; superimposed plots in time or frequency domain. 12. Power dissipation (resistors), energy storage (inductors and capacitors). 13. Regular plots (obtained from a Tektronix terminal). 14. Up to nine different outputs

the range of possibilities that is available with CAD is vast. In some cases, CAD is the only realistic means to gain sensitivity information. A case in point is the determination of the effect of changes in the gain-bandwidth product of a transistor upon circuit response. Through CAD, this parameter can be changed independently; whereas the exchange of transistors on the breadboard will usually result in simultaneous change in other parameters.

Although only a few existing CAD programs include sensitivity analysis, more undoubtedly will be included in future programs. Low cost is a potential asset. Efficient sensitivity analysis methods are known to exist that require only about two complete iterations for a sensitivity picture of a selected current or voltage in a circuit, with respect to all circuit parameters.

Simulation tools

A designer is often faced with the basic question: Is the design feasible? And when testing a design breadboard at the bench, he must also explain various phenomena that take place. For these purposes, two major subcategories of simulation are available through CAD: circuit and logic simulation—the former tells the user about the dynamics of the problem, and the latter, restricted to digital circuits, of course, deals only with gate-level logic. The simulation itself is based on modeling electronic devices as well as large circuits and systems (see box on p. 47).

By playing with parameters employed in the simulation model, a puzzling phenomenon in a tested breadboard may be duplicated and explained through simulation. For example, in circuit simulation, the effect of a collector-base feedback capacitor can be examined by inserting and then removing it from the simulation model. In another case that has occurred in an industrial environment, introduction of Early voltage, a second-order effect, into the model of a simulated circuit resulted in similar performances of the breadboard and the simulated circuit. (Early voltage is defined as the voltage value at the intersection of the extrapolated transistor collector characteristic curves, which are sloping slightly, with the negative axis of collector-emitter voltage.)

It is believed that dedicated electronic simulators will eventually be available, like other electronic instruments, to perform specific design tasks. In the meantime, though, a fair amount of effort is still required to make simulators a truly practical tool for cutting design costs.

Users' problems

Users often approach CAD with the idea that they can let the computer do some of their design thinking for them. In fact, CAD may help the engineer get more accurate and rapid results, but achieving these results often requires *more* design thinking, not less.

First of all, the user needs a thorough understanding of computer modeling techniques for the devices in his (or her) designs (see box on pp. 45). He also needs to

	Output Data Format				
s	Printer Plots	Histograms	Scatter Plots	Envelope Plots	Misc.
X	X				
X	X				
X	X	X	X	X	
X	X	X			
X	X				
X	X				X^{1}
X	X^{3}				
X	X				
X					
X	X	X			
X	X^{4}				X^{5}
X	X				
X	X				X^{20}
X	X				X^{8}
X	X				
X	X	X^{10}			
X	X	X			X^{11}
X	X				X^{13}
X	X				
X	X				
X	X				X^{14}
X	X				
X	X				
X	X				
X	X				
X	X				
X	X	X			X^{17}

simultaneously. 15. For resistors and active devices only. 16. Only voltage-source currents. 17. Nichols (gain vs. phase) plots. 18. Including output voltage versus component failure; one variable vs. another; overstress tables for devices. 19. Root locus; sensitivity. 20. Smooth curve (by using a digital plotter).

Computer program library includes CAD programs

A useful service to users of CAD programs is available from COSMIC library of the National Aeronautics and Space Administration (NASA), at the University of Georgia, Athens, Ga. The library contains over 40 programs—for circuit analysis, design of printed circuit boards, logical design of digital circuits, automatic wiring (to minimize wiring lengths), performance and transients of integrated circuits, and some specialized areas like analysis of transmission-line systems, design of total electric systems in ships and aircraft, and a simulation program for power systems of spacecraft. Programs can be purchased from the library at a charge that is higher than the nominal handling fee required by some universities for these services, but is substantially lower than many commercial program fees (average program cost last year was $375 and the prices run between $25 to $3000, depending on the program). The charges are said to be set with the aim to recover operating costs of this Government-operated center. Documentation of programs can be purchased separately, at processing costs between $10 and $50. The user can call COSMIC for information, and programs can be ordered directly from the library. The full program inventory is described in NASA's official publication, *Computer Programs Abstracts Journal*, available on a subscription basis from the U.S. Government Printing Office, Superintendent of Documents, Washington, D.C. 20420.

know something about computer programming. Many organizations using CAD programs feel that an engineer using the computer benefits from getting more involved and from actually doing some programming himself, such as writing a special subroutine or even creating a new model for his own needs. In some cases, knowledge of a programming language is recommended. In other situations, like interactive computing, understanding the users' manual of a program may prove quite adequate.

CAD programs often spew forth too much data for the user to digest. The user wants to get an answer that is specific to his design, but he finds he can get out only what the program allows. For example, one academic CAD expert has observed that all frequency analysis programs known to him do not enable the user to take selected output results and operate on them for other purposes—the example mentioned was the evaluation of narrow-band amplifier stability. To get the necessary data for such a calculation, it was argued, the user must either modify an existing program, or write a separate program for these purposes.

It is often asked whether a universal and, at the same time, an efficient CAD program could be generated. Apparently this is not likely to happen. Experts indicate that although basic CAD techniques apply to most problems, many areas require additional, specialized techniques. To be most efficient and economic, one expert observed, both simulation and optimization programs must be tailored to the specific problem, say, a communication circuit or a switching circuit design.

Documentation of CAD programs is of key importance for the user. The documents include users' manuals, application notes, theoretical notes, reprints of articles, and even examples of actual program runs. Although such documentation is generally comprehensive, it is often inadequate. According to one CAD expert, even when the user's computer is the one for which the program is intended, difficulties are often encountered in the program's implementation.

In terms of the practical availability of CAD techniques, there is a tremendous difference between the possibilities available to large and small companies. The former can hire staff to write programs for them (although management is often reluctant to fund such activity). They also often have in-house experts—fondly labeled "gurus"—who know how to get inside the programs and turn them around to give the users what they need in any special situation. Zenith, for example, is now attempting to write its own, substantially modified version of ISPICE, a proprietary conversational version of SPICE 1 (see tables), which was adapted for time sharing.

What about the little man? Small organizations are in a much more difficult position in that they have neither the expertise in CAD programs, nor the necessary funding to hire outside programmers. But manual design is costly, too, and at least one expert believes that there must be some sort of crossover point at which a certain amount of CAD will be cost-effective, even to a small company. ◆

The author is grateful to John Golembeski of Bell Labs, Holmdel, N.J., and John Greenbaum of General Electric, Philadelphia, Pa., for their advice. The tables in this article are based on similar tables by Mr. Greenbaum, published in the IEEE Circuits and Systems "newsletters," vol. 7, no. 1, Feb. 1974.

Design for production

The computer steps in to automate physical design and testing of computers and other electronic equipment

Born in the weaving patterns of component wiring interconnections, computer-based design automation has grown to provide tools for many aspects of digital system engineering. In the more traditional areas, automation of the physical design of computer boards and integrated circuit chips now permits automatic placement of components and devices so they will operate correctly and can be properly interconnected, and automatic routing of connections between these devices and components has been developed to the point where few connections need be made manually. Design automation systems also routinely generate necessary artwork for these physical designs and produce documentation needed for design, manufacturing, and maintainance activities.

Branching out from these basic tasks, automated techniques are being extended into such areas as checking and verifying the correctness of logic designs. As design automation techniques mature, centralized data systems are being developed to bring the various design functions into efficient cooperation. In these systems, the programs for performing each of the design automation functions all share a common information store.

Diagnosis and testing has become a separate, and very important, area of design automation. Automatic diagnostic programs are now available to tell whether or not a digital system is faulty and, if faulty, to indicate which unit to replace. Until recently, that unit has usually been a circuit pack; now it is likely to be a microprocessor or a single-chip peripheral device controller. Fault simulators are used to help produce and evaluate these diagnostic programs. However, new semiconductor technologies are posing new problems in simulating possible circuit faults. Despite considerable production experience, there is little public knowledge about the failure modes of large-scale integrated circuits, and such knowledge is a prerequisite to the task of fault simulation.

Test patterns for diagnosis of logic circuits are being generated automatically for circuits containing a few hundred—even a few thousand—gates. For still larger circuits, and for those involving complex sequential logic, the most promising approach has been to design logic circuits that are easily testable, and computer manufacturers are investing substantial amounts of added hardware to guarantee improved testability.

Finally, simulation techniques have become an increasingly important design automation tool. With many systems, increased assurance of design correctness *before* the manufacturing process begins is an economic necessity. Simulators become indispensible when circuit prototypes are very expensive, as is the case with large-scale integration (LSI) and when design turnaround time must be rapid. In addition, simulators are increasingly used to aid in system diagnosis and automatic test generation. At the highest levels of simulation—like those afforded by microprocessor simulators—the system designer can evaluate the usefulness of one set of software and hardware compared to that of another, for fulfilling his particular requirements.

Simulation and functional models

LSI has made digital logic plentifully available at costs that could not be dreamed of in the days of wired discrete components, but LSI has also brought difficult new problems of design verification and parts testing that design automation is helping to solve. Photolithographic masks for LSI production can cost as much as $50 000 to $100 000 apiece, and a single logic design error can be a dramatic problem at those prices. Shaking down the LSI design and getting the parts correct before they are released to manufacturing are therefore steps worthy of considerable design attention. In addition, fast design turnaround is often essential in the competitive world of computers and integrated circuits, creating a need for such time-savers as simulation.

Until recently, design automation programs used logic gates, like ANDs and ORs, to model and simulate everything—even flip-flops were modeled by collections of gates. Today, the trend is to model complete functions like counters and registers as units. For example, we know that if a "1" is inserted at the input of a 32-bit shift register and the circuit is clocked 32 times, a "1" should appear at the output. That is a basic functional characteristic of the shift register, and it is relatively easy to express in the form of a computer program subroutine. In contrast, it would take a long time to simulate—in computer program form—a collection of gates to perform the 32-bit shift register function (like a shift register counter or decoder) with a single specific software routine.

Most digital systems now consist of interconnected functions, each of which is, more often than not, physically embodied on an integrated circuit chip. There are decoders feeding multiplexers that, in turn, feed adders or shifters. System designers think in terms of complete functions—and the functional approach is currently being used in some of the newer design automation, simulation, and test generation programs.

Microprocessor simulation technique

Programs to simulate the functions of a given computer are widely used to aid system designers, and to give programmers a head start in writing software for systems even before they are completely available in hardware form. Some of the most widely used func-

Howard Falk Senior Editor

tional simulators are those made available by microprocessor manufacturers. Each of these simulator programs is designed to describe the operation of a specific microprocessor chip. They are useful to the manufacturer when the overall architecture of a new microprocessor is being designed and checked. But these simulators may be even more useful to the microprocessor user. For the engineer planning to use a microprocessor, they offer the opportunity to try out his design ideas on two, three, or four different processor chips. Most simulators are publicly available through time-sharing systems, so this trial process can be relatively simple to arrange.

Choosing the right microprocessor is a process necessarily dependent on intuition as well as on hard facts. After system designers consider things like data rates, they still have to decide whether they like that processor as a means of solving their particular problem, so an opportunity to try out key program segments on several different microprocessors can be important. Of course, this means someone must take the time to rewrite trial programs for each of the processors.

Microprocessors initially needed a great deal of custom interfacing circuitry to attach memories and peripheral devices. Today, there are an increasing number of standard interface chips available that can be used as standard building blocks. And the new generation of microprocessor simulators, soon to be publicly available, will handle peripheral components—even multiprocessor systems—allowing the system designer to get much closer to his final design before he decides which functions to cast in hardware form and which to cast in software. All this will make microcomputer system design a simpler and more accessible process than ever, and the consequences will probably be that increasing numbers of nonelectronic engineers and scientists will be designing systems using microprocessors for their own applications on a do-it-yourself basis.

Special-purpose simulators, like those used for microcomputers, are difficult and expensive to write. When thousands of identical microprocessors are to be produced, simulator programming cost can be easily justified, but for large computer systems—often produced only by the dozens—such simulation remains a largely academic pursuit, not yet economically feasible.

High-level simulators of the future

There is a possible route to more economic, large-system, high-level simulation: through the use of register-transfer languages (RTLs). Using a standardized RTL—see Fig. 2 for an RTL description of a typical central processor operation—a universal simulator could be written to describe the program operation of a number of large computers. Feeding an RTL description of a new computer into such a simulator would allow it to be simulated at relatively low cost, in much the same way that Fortran allows new programs to be easily written and run.

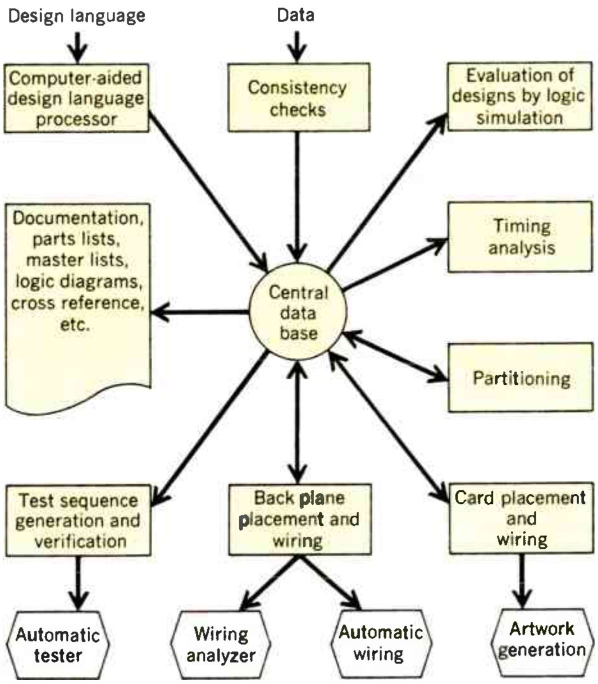
Despite these advantages, companies making logic products have not yet made practical use of RTL languages. The main reason for this seems to be that the design and manufacturing dollars spent on new systems, particularly in the pre-LSI days, went mainly into packaging and testing rather than into design of system logic functions.

RTL critics point out that these languages have mainly ignored physical packaging constraints, that most RTLs are not suited for actual design use, and that gross inefficiencies have been observed in the results obtained in some of the attempts to use these languages. In addition, there are very few useful software tools designed to be driven by RTL inputs.

Higher speed needed at the gate

Despite the growing importance of higher-level, functional representations of digital systems, most of the bread-and-butter work of simulation for design automation continues to be done using logic gates as the basic elements.

The main reason for modeling gates, rather then individual transistors, is to achieve fast computation. Also, gates can be fairly well characterized as black boxes. Gate-level simulators exist that can successfully handle over 50 000 gates. They have proven very valuable in digital system design and are continually being improved. But speed continues to be a limitation on gate-level digital logic simulation, particularly when logic failure modes are included. It takes considerable



[1] Unified data base system. Many of the functions performed by design automation techniques appear in this block diagram of a design system organized around a central data base. In such a unified system, the working programs (rectangular boxes) communicate with each other, as necessary, via the central data base.

[2] RTL description of a processor instruction fetch.

MAR ← (PC)	Contents of program counter to memory address register (MAR)
PC ← (PC) + 1	Increment program counter
MDR ← MEMORY (MAR)	Read memory at address specified by MAR to memory data register (MDR)
IR ← MDR [a:b]	Instruction bits to instruction register

time to simulate a large system, and computer time costs money. In fact, about two thirds of current research in gate-level simulation go into making the simulators faster; only a third of the effort is directed to more accurate simulation.

Comparing the speed of one gate-level logic simulator to another can be confusing because different systems quote their speeds differently—while some don't quote them at all. Actually, simulator run-time is very difficult to pin down. A simulation of a circuit containing 1000 gates may run very fast if the circuit is combinational, but will run much slower if it is a complex sequential one. Some types of faults are expensive to simulate—for instance, faults in clock circuits—while others are relatively cheap. Similarly, some input vectors may cause a lot of simulation activity and involve long run times, while other vectors may run quickly, with little or no activity. To give an idea of current gate-level simulation speeds, a recently designed, rather detailed simulator for MOS integrated circuits takes about two seconds of real time for each nanosecond time advancement of a 1000-gate logic circuit (using a single input vector, and no fault simulation).

In the area of improving simulation accuracy, representations of gate delay have been getting more sophisticated. For early simulators, all gates were assumed to impose no delay at all on the signals passing through them. Later, unit delays were introduced; some gates could be assigned a single, fixed delay while others could have zero delay. With integrated circuit technology, actual gate delays are somewhat variable. For example, they might run between 4 and 8 ns for a given circuit chip, depending on such factors as the manufacturing batch and the operating temperature. Simulators are now incorporating timing features like minimum and maximum rise delay and fall delay, so each simulated gate can be assigned four delay parameters. Also being considered is integration of the input signal—over time—to produce the output.

Coping with bigger and better faults

Gate-level simulation provides a means to shape and check logic designs, but it also has another important use, in connection with system testing. With automatic testing now a practical necessity for many complex digital systems, reliability and correctness of diagnostic programs have become important concerns, and a simulator capable of representing faulty logic can be used to verify a diagnostic program. If the diagnostic program is known to be correct because it has been verified by simulation, system checkout and debugging can be approached with much greater confidence. The basic question the fault simulator can answer is: If the logic is bad or goes bad, will the diagnostic program discover that something is wrong and can it identify what should be replaced?

Digital logic can become defective in many different ways, but only a few of these are usually simulated. Design automation experience is said to indicate that a good test for single failures will also detect most of the multiple failures. However, it appears that it is very difficult to *locate* multiple faults, based on single-failure tests. At one large aerospace company, a fine dictionary was generated that allowed the user to interpret incorrect digital system logic outputs in order to identify faulty components. Unfortunately, this dictionary was compiled under the assumption that there were only single faults in the system. Later, Navy inspectors came in to see how good the diagnostic test was. They removed the power lead from one of the IC chips. This was not one of the faults the diagnostic program had anticipated; the effect was a massive multiple logic failure, with *all* the gates on the chip malfunctioning at the same time. Test results indicated that something was wrong on a logic board, but the dictionary gave no definite indication of which chip was involved.

A limitation of most existing fault simulators is that they deal only with the so-called classical faults: gate input or output stuck at *one* or stuck at *zero*. These are obviously not the only types of faults that can occur in real circuits, but they seem to describe most of the problems in discrete component circuits. Unfortunately, little is known about the failure modes of integrated circuits, and particularly of LSI circuits. Large-scale testing to get these failure data is so costly that it has not been undertaken. Consequently, engineers concerned with design automation are not sure what types of logic faults to anticipate. This lack of information may provide a convenient reason for failing to tackle some very difficult fault-modeling problems. In any case, little has been done to model nonclassical faults in most fault simulators.

One fault that *is* known to occur frequently in LSI circuits—but is ignored by fault simulators—is the delay fault. When LSI masks are not precisely aligned, or contain imperfections, the propagation delay of the logic gates is likely to vary widely. All gates may function logically as they should, but the delay through some of them may be three times as long as would normally be expected. Pattern-sensitive faults are also known to occur in LSI devices.

Probing the limits of automatic tests

Several different kinds of tests are used to check digital logic. Functional tests check to see if the overall system actually performs to specification. Parametric tests examine specific voltages and current levels to uncover such obvious faults as shorts and opens. Classical fault tests check the logic for gate input or output stuck at 1, or stuck at 0.

Despite the limitations of classical fault tests, they are widely used in automatic test procedures for digital systems. Such procedures are produced by test generators, which are computer programs into which descriptions of logic circuits can be entered. Program output consists of a set of tests supposedly adequate to meet the necessary testing goals.

For circuits that are strictly combinational—those that contain no memory devices like flip-flops or registers and are moderately sized—complete tests can be generated by exact, analytic techniques. Unfortunately, there are very few strictly combinational circuits in the real world. At the present state of the art, automatic test generation for circuits with a few hundred gates usually works; it occasionally works for circuits with a few thousand gates; it seldom or never works for circuits with tens of thousands of gates.

Automatic techniques don't work with very large and complex circuits because test generation is inherently mathematically intractable. Test generation problems appear to be exponentially bounded—thus,

Interactive graphics—expensive but promising

Although techniques have been demonstrated and used since the mid-1960s, design automation using interactive CRT displays has not become the predominant practice in most companies. Instead, hard-copy plots are generally used to output and display artwork such as routing information, while graphical digitizing techniques or manual encoding are used to input changes.

In some organizations, there is considerable skepticism about the future usefulness of interactive graphics in design automation, but many others see it as the practical way to go for the present. At Bell Laboratories, for instance, users have found that interactive systems help dramatically to reduce design turnaround time while they increase the effective use of the design specialist's efforts.

Interactive graphics systems can be thought of as divided into two general types: first-generation systems, used simply to manipulate graphics, and second-generation systems, which "understand" the design problem, at least to some extent. For example, a second-generation system would be able to translate readily from interconnection descriptions into graphics, automatically applying all the appropriate rules and constraints.

Recent studies have shown that, for first-generation systems, savings over manual digitizing techniques can pay for the system within a year. In some cases, second-generation systems have allowed cost reduction of over 50 percent, compared to manual methods, and have been shown to reduce the design time by factors of 3 to 5. At least one design group found substantial gains in going from first-generation to second-generation systems; the group experienced a 3-to-1 difference in cost on difficult circuit boards (those with about 0.7 in^2 per integrated circuit package) and a 2-to-1 difference in the cost of designing moderately difficult boards (those with about 1 to 1.2 in^2 per package).

High-quality, refreshed CRT displays, the kind needed for precise layout work, are quite expensive—costing $10 000 or more. However, many design automation problems are now being solved using interactive systems with storage-type CRT displays. These can be implemented for under $5000.

Some interactive CRT display systems can be used on a rental basis; these cost $50 or more an hour for the privilege of sitting in front of their tube, not to speak of computer use charges. In contrast, hard-copy equipment for graphical output and input is currently available at rental costs of only a few hundred dollars per month.

Here an interactive plotter/digitizer and an interactive CRT terminal, both products of Computer-vision Corp., Bedford, Mass., are shown.

as circuit count increases, computer run time to generate the desired tests appears to rise exponentially—and they are members of a large class of problems called NP-complete problems, for which it appears more reasonable to use approximate solution techniques rather than to search for exact analytical techniques.

Consequently, heuristic cut-and-try techniques have been devised and applied to generate test patterns for sequential circuits. Since these tests do not guarantee that all faults have been detected, manually generated tests are used to bring the test coverage up to desired levels.

The problem of finding which faults have been detected, and which missed, is the simulation problem, discussed earlier in this article. This problem is solvable for large systems, with reasonable computer run times, provided the faults considered are limited to the classical "stuck-at" faults.

Among the unresolved problems related to automatic test generation is the initialization problem. When the power goes on, in most digital systems, the initial state of the flip-flops is unknown. However, to run a test program, the initial flip-flop states must be well-defined. The notion that a carefully designed sequence of input signals might drive the system to a known state is appealing; unfortunately, no one has yet discovered how to find these sequences easily.

A simple initialization solution—widely practiced in the early years of computer design—is to provide a system reset line to drive all flip-flops to the zero state. However, this feature adds cost to the system hardware. Clever logic designers have long noted that many parts of their system will function regardless of initial states. These designers are seldom responsible for system testing. They don't understand it and don't care about it. Testing is not in their budget. Yet, where substantial production quantities are involved, money invested in producing more-testable logic designs can pay off handsomely.

Bringing the circuit to the test

Because of the difficulty in testing large circuits, the idea of designing testable logic circuits seems to be gaining momentum. It may no longer be feasible, in many systems, to let the logic designers do anything they want, and then later try to cook up test procedures to cope with their results.

Actually, testable logic circuit design has been practiced by several computer manufacturers for years—Burroughs, Honeywell, Xerox, and IBM all use it—and its use appears to be on the increase. In many computer systems, there is a designed increase of from 15 to 25 percent in system hardware to provide improved testability. This is showing up, in the first place, on the production lines, where more easily testable circuit cards are found. It is also showing up in overall system testing, with increasing use of techniques by which the system performs maintenance checks on itself without using any external test equipment. In effect, this allows a computer to give itself some homework problems. Then, if it finds the correct answers, it tells itself that it is feeling fine.

At the Design Automation Conference in Boston in June 1975, a speaker from Nippon Electric gave a talk on testing of integrated circuit cards containing 1000–2000 gates by using the Scan-Path method. The technique hooks storage elements together to form shift registers for test generation. The storage elements are easily controllable and observable from outside the card, and the method allows sequential circuits to be converted to combinational ones for testing purposes, thus permitting 100-percent fault coverage. This approach requires 10–30 percent more gates than the design without scan, but the cost trade-off seems a reasonable one.

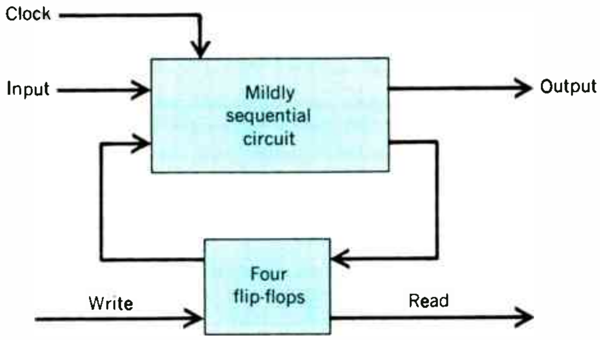
Testable logic-design techniques are used widely with integrated circuit logic gates but when it comes to microprocessor chips, the picture is very different. At present, such chips are usually functionally tested by manually generated programs. The specified functions of a particular chip are known; programs are written to perform these functions and, if the programs execute correctly, the chip is assumed to be good. But this too is changing. Some microprocessors, like Texas Instruments' TMS-1000, now provide added circuitry on the chip, for testing purposes, along with external test pins.

Building boards and chips

Since the inception of design automation, its bread and butter has been, first, in the production of printed circuit board designs and, later, in integrated circuit chip designs.

The physical design of a board or chip for a digital system involves, at the outset, determining what logic will be included in the design. This is the system partitioning problem. The objectives of partitioning include: limiting the number of terminals and interconnections, using as many standard parts as possible, and satisfying signal propagation requirements, among other things.

There has been progress, in recent years, in developing computer techniques for partitioning, using boards and chips containing as many as 5000 to 10 000 gates. Highly automated partitioning solutions, based on computer algorithms, have been found to be at least as satisfactory as manual solutions and less costly to obtain for a limited objective such as minimizing chip count. However, no one algorithm—or set of algorithms, for that matter—has been developed that can take into account all of the desirable partitioning objectives. For this reason, partitioning programs have not found very much use in practice.



[3] Easily testable circuit. The circuit represented here is a 1000-gate, 11-state sequencer whose current state is stored in four flip-flops. It is usually necessary to step a sequencer through several intermediate states to reach the desired state. With its built-in read/write access, this sequencer can be directly written into the desired state. Thus, the read/write access makes it much easier to test this circuit.

Using this read/write access feature, the Bell Laboratories LAMP-ATG system was able to generate 750 input test vectors which detected 95 percent of the classical faults for this circuit in 800 seconds of IBM 360 Model 67 computer time. Without the read/write access feature, such performance would not have been possible.

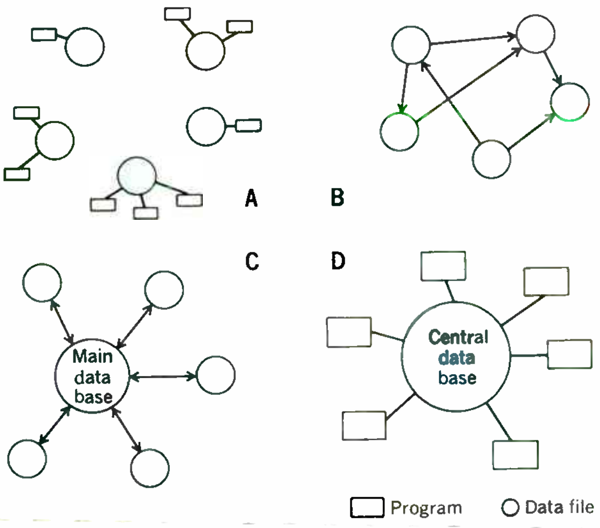
On the circuit board itself, the designer faces the problem of properly placing components. Usually, the objective is to minimize the total interconnecting distance between them, in order to ease the problem of completing the wire-routing and, also, to help satisfy other constraints such as signal delay and crosstalk. Recent work in this area has been concerned with developing new computer algorithms for solving the placement problem.

Once the components are placed, they must be properly interconnected. This is the problem of routing. Over the last few years many successful automated routing systems have been developed. They have included systems for routing discrete wires for back panels, as well as those for routing multilayer etched conductors for ICs, MSI and LSI circuit cards, and LSI chips.

Man wanted: to complete the design

For many years, the thrust of the routing effort was to develop systems that would allow the designer to enter his basic data and then push a button. The design automation system was supposed to churn until it produced the desired circuit board or chip layout with all connections property routed. This approach worked very well for relatively simple and regular layouts but as components and devices were packed more closely, fewer automatic routing procedures were able to reach 100-percent completion. When a router hasn't completed a design, the user of automated design software is faced with a difficult problem: to complete the few wires that remain. Usually, this is solved by having one of the designers sit down, look at the nearly completed design, and use human insight to move and add connections so as to complete the design. Bringing the human designer back into the picture is becoming increasingly popular, because experience is proving that a talented designer can rapidly complete routing problems that would be very expensive to finish using completely automatic techniques.

In fact, at Bell Laboratories, as in several other com-



[4] **Evolution of a data base system. Design automation efforts at a given company are likely to start with separate programs for placement, routing, artwork, generation, etc., each having its own, unique data file (A). As the need for interchanging data increases, programs are written to map all or part of the data from one certain file into another and a data-file network develops (B). Later, a main data base serves as the vehicle for interchanges between data files (C). Finally, in the ultimate system, the programs themselves operate directly from the single, central data base (D).**

panies, it has been found that complete automatic routers are not practical, at present, for printed wiring board designs because of the wide variety of these designs. As a result, interactive systems, like one at Bell Labs called NOMAD, have been developed to combine the judgment of a human specialist with computation power in solving the printed wiring board routing problems.

As an example, a design normally originates in the form of a rough schematic drawing and stocklist. The first activity in Bell Labs' NOMAD is to verify that all required components exist in its computer-stored library. Some new components may have to be entered during this first activity. Input data are then entered into NOMAD and an automatic placement is completed, the results of which may be reviewed so that manual adjustments can be made where desirable. Interconnection routing may then be done using a combination of automatic, semiautomatic, and manual techniques. Through the routing section, adjustments to the placement of the components and their relative orientations may be made continually. As the layout progresses, updates are usually made to the original circuit definition, and these updates are easily reflected in the NOMAD design data base. Upon completion, the design documentation may be obtained and printed circuit board fabrication can take place.

In addition to interactive techniques and manual intervention, various techniques for wirability *analysis* are being used to get around the computational difficulties of routing. The idea is to estimate the chances of automatically completing a given routing job before it is actually run. The concept is not a new one, but it has received a lot of attention in several companies during the past two years.

Continuing difficulties with completely automatic routing programs stem from the same basic cause as problems with programs that generate tests automatically. For routing, the computation time increases as some polynomial related to the circuit complexity. Specifically, the polynomial is related to maximum possible wiring density. For example, consider two 4-in by 6-in printed wiring boards; if one uses 25-mil center-to-center spacing and the other uses 50-mil spacing, the first will take about four times longer to route. The more perfect routing program would have both a look-ahead feature and a rearranging feature. This type of router is expected to become a reality in the near future, but will probably have to wait for practical implementation on fast low-cost and large memories based on bubble or charge-coupled device technologies.

Putting it all together

Design automation is an evolving, growing art. Within any company, it usually starts with programs written for partitioning and placement of components and routing of interconnections; then other programs may be added. Each of these programs may be written by a different group of people using different data descriptions. As these activities grow, pressures for bringing them together into a single system tend to increase. One design automation expert described the process in these terms: "Programmer **A** writes the placement program; programmer **B**, the router. **A** and **B** agree to the information that is to be passed between them. Programmer **C** is added to provide partitioning—he agrees with **A** about what information to pass. **A** now has responsibility for two interface programs. Later, **D** adds a program for schematic drawings and he makes agreements with **A** and **C**. Then, **E** writes one for automatic artwork; he makes an agreement with **A, B, C,** and **D**.

"Then it happens that **B** is killed in an auto accident and the project is paralyzed. The software can't grow and it can't be debugged. An agreement is then made that no two programmers may talk to each other; they may talk only to a pool of data that might as well be called a central data base."

The process of creating and implementing a central data base is an expensive one. A company may spend several hundred thousand dollars to get such a data base, but it won't solve any problems, do any routing or placement. With the data base, these functions may be carried out more easily and smoothly, but management may not feel that this is a convincing reason to make a substantial investment.

Overall, the experience of design automation groups seems to indicate that the centralized data base *is* a money-saving proposition. Most experts feel it is a necessity.

Obviously, centralized data bases are only feasible for relatively large companies with extensive design automation activities. For smaller operations, automatic test generators and simulators are available on time-sharing facilities. Unfortunately, these are likely to be of little value unless someone in the company has experience with design automation techniques. ◆

Material for this article was received from many sources. Major contributors were: Melvin A. Breuer, Southern California University, Los Angeles, Calif.; Stephen G. Chappell, Bell Laboratories, Naperville, Ill.; Edwin B. Hassler, Texas Instruments Inc., Dallas, Tex.; Roy L. Russo, IBM Corp., Yorktown Heights, N.Y.

Designer's bookshelf

The experts' choices in five major categories: CAD, design automation, and design techniques for microwave, power, and general systems

Roger Allan Associate Editor

With thousands of design books available, covering all the electrical and electronics fields of interest, *Spectrum* decided to identify some of the top books. The list on these pages is limited to five design areas, chosen because they are related to other articles in this issue. The books were recommended after consultation with experts in computer-aided design and modeling, design automation, general systems design techniques, microwave design techniques, and power systems design techniques and planning. Books in these areas cover (and often overlap) such disciplines as decision review, decision analysis, and pattern matching.

The total cost of the recommended books in any one of the five areas is about $100 or less. While many of these books are new, a few have been available for years, but are still considered valuable today. For each listed book, a short critique is given.

Computer-aided design and modeling

- *Circuit Theory: A Computational Approach.* Director, S.—John Wiley & Sons, Inc., New York, 1975, 679 pp., $18.95.
- *Introduction to Modern Circuit Analysis.* Calahan, D., *et al.*—Holt, Rinehart & Winston, New York, 1974, 448 pp., $16.95.

Both these books treat nonlinear and linear circuits on an introductory level. Both introduce numerical integration and the general nodal-analysis approach to circuit simulation. A number of simple computer programs are included.

- *Computer Aided Network Design.*Calahan, D. A.—McGraw-Hill Book Co., New York, 1968, 298 pp., $16.50.

The only textbook-oriented, general-purpose, computer-aided-design book available. Lacks some detail in certain areas of discussion.

- *Computer Aided Circuit Design, Simulation and Optimization.* Director, S. W.—Dowden, Hutchinson & Ross, Stroudsburg, Pa., 1974, 400 pp., $20.00.

A compilation of benchmark papers in computer-aided design with running commentary. Papers were collected from a variety of sources, including the IEEE and ACM.

- *Modern Filter Design.* Ed. by Mitra, S. K., and Temes, G. C.—Wiley-Interscience, New York, 1973, 566 pp., $27.50.

Provides a new look at filter design with computational methods.

Design automation

- *Design Automation of Digital Systems.* Breuer, M.—Prentice-Hall, Inc., Englewood Cliffs, N.J., 1972, 420 pp., $18.50.
- *Digital System Design Automation: Languages, Simulation and Data Base.* Ed. by Breuer, M.—Computer Science Press, Inc., Woodland Hills, Calif., 1975, 430 pp., $17.95.

These two books give a comprehensive view of digital system design automation. Ten chapters treat design automation applications for digital system design; one deals with the concept of the data base.

- *Fault Detection in Digital Circuits.* Friedman, A. S., and Menon, P. R.—Prentice-Hall, Inc., Englewood Cliffs, N.J., 1971, 220 pp., $17.95.

Presents basic methods for deriving tests to detect faults in combinational and sequential circuits. Information is complete and concise, and very easy to read.

- *Fault Diagnosis of Digital Systems.* Chang, H., Manning, E., and Metze, G.—Robert E. Krieger Publishing Co., Huntington, N.Y., reprinted 1974, 176 pp., $10.95.

A detailed description of pre-1968 test-generation methods for combinational and sequential circuits. Tutorial-like discussion on digital fault diagnosis.

General systems design techniques

- *Systems Engineering Handbook.* Ed. by Machol, R.—McGraw-Hill Book Co., New York, 1965, approx. 1100 pp., $36.75.

An excellent collection of systems engineering and design tools from many well-known contributors.

- *A Methodology for System Engineering.* Hall, A. D.—Van Nostrand Rheinhold Co., New York. Out of print.

A classic book reflecting practices, methodology, and systems engineering education at Bell Telephone Laboratories

- *The Design Method.* Ed. by Gregory, S. A.—Plenum Press Publishers, New York. Out of print.

A British book that stresses design of hardware systems, builds on the foundations laid by the Hall book (above), and further extends these foundations.

- *A Unified Systems Engineering Concept.* Warfield, J. M., and Hill, J. D.—Battelle Memorial Institute, 1972, 124 pp. Out of print, but available through University Microfilm, 300 N. Zeeb Rd., Ann Arbor, Mich. 48100. Cloth, $10.00; paper, $12.50; and microfilm, $5.00.

Extends methodology of system engineering to innovative application of functional modeling techniques in program planning.

Microwave design techniques

- *Foundations for Microwave Engineering.* Collin, R. E.—McGraw-Hill Book Co., New York, 1966, 589 pp., $19.50.

Provides the basics of electromagnetic field theory for microwave devices. Strong on waveguides. Covers a good range of topics.

- *Microwave Filters, Impedance Matching Networks, and Coupling Structures.* Matthei, G., Young, L., and Jones, E. M. T.—McGraw-Hill Book Co., New York, 1964, 1096 pp., $29.75.

Considered a "bible" of microwave circuitry. Includes a tremendous amount of "how to" information and examples of designs. Although not quite up to date, still a *must* for every bookshelf.

- *Microwave Filters and Circuits, Contribution from Japan.* Ed. by Matsumoto, A.—Academic Press, 1970, 349 pp., $25.00.

Includes many microwave advances and is a good supplement to the previous book. Very mathematical in treatment, without being strong on examples.

- *Stripline Circuit Design.* Howe, H.—Artech House, Dedham, Mass., 1974, 360 pp., $33.50.

A compendium of design charts and information for the application and design of stripline components. This is the first such book of its type. The drawback is that the necessary background information is missing.

- *Advances in Microwaves, Vol. 8.* Ed. by Young, L., and Sobol, H.—Academic Press, New York, 1974, 420 pp., $35.00.

The first book devoted to microwave ICs. A good overview of the field, but may lack some depth and is perhaps a little too mathematical in some areas.

- *Microwave Semiconductor Devices and Their Circuit Applications.* Ed. by Watson, H. A.—McGraw-Hill Book Co., New York, 1969, 617 pp., $27.00.

A good overview of microwave semiconductor devices. Gives some flavor of the problems in using these devices. Not deep enough in any one area.

- Selected reprint books of the M.I.T. Radiation Laboratory series of books (originals by McGraw-Hill), from Dover Publications, Inc., over the last five years.

Great fundamental books. In many cases, no better job has been done.

Power system design techniques and planning

- *Circuit Analysis of AC Power Systems.* Clarke, E.—Out of print, but available through H. M. Rustebakke, General Electric Co., 1 River Rd., Schenectady, N.Y. 12345. Volume I, $8.00. Volume II, $6.50. Both in paperback form.

Good for basic power-system calculations in the steady state, both balanced and unbalanced conditions. Covers transmission circuits, transformers, transmission lines, induction, and synchronous machines. Introduces system protection.

- *Synchronous Machines—Theory and Performance.* Concordia, C.—John Wiley & Sons, Inc., New York, 1951, 224 pp. Out of print, but available through H. M. Rustebakke, General Electric Co., 1 River Rd., Schenectady, N.Y. 12345. Paperback, $6.00.

Mathematical description of synchronous machines, treats steady-state and transient operation for both balanced and unbalanced operation. Concludes with calculation procedures for determining short-circuit torques, starting torque, and voltage dip.

- *Transmission Line Reference Book—345 kV and Above.* Electric Power Research Institute—Distributed by Fred Weidner & Sons, New York, 1975, 393 pp., $25.50.

A "must" for the design of high-voltage transmission lines. Contains most up-to-date data available.

kins, B.—Chapman & Hall, London, 1957, 236 pp., no price available.

A concise reference which contains an excellent coverage of synchronous machines.

- *Stability of Large Electric Power Systems.* Ed. by Byerly, R. T., and Kimbark, E. W.—IEEE Press, New York, 1974, 584 pp. Cloth, $11.95; paper, $8.00.

A valuable compendium of 59 technical papers with accompanying commentaries. Provides the experienced power system analyst with a variety of viewpoints and experiences.

- *Electric Power Systems, 2e.* Weedy, B. M.—John Wiley & Sons, Inc., New York, 1972, 501 pp., $17.25.

Good up-to-date coverage of basic power system elements, how they are interconnected, how the system performs, and how it is analyzed. Author reflects both British and North American practices.

- *Power Systems Engineering and Mathematics.* Knight, U. G.—Pergamon Press, Oxford, England, 1972, 274 pp., no price available.

Excellent book by a practicing engineer. Special emphasis on planning and security.

- *Electrical Transients in Power Systems.* Greenwood, A.—Wiley-Interscience, New York, 1971, 544 pp., $29.95.

A modern treatment of electrical transients and their effect on power system components. Contains many practical examples.

- *Power System Reliability Evaluation.* Billinton, R.—Gordon & Breach Science Publishers, New York, 1970, 310 pp., $27.00.

The first book on power-system reliability written by a well-known authority in the field. Treats the full spectrum of applications.

- *Insulation Co-ordination in High Voltage Electric Power Systems.* Diesendorf, W.—Crane Russak & Co., Inc., New York, 1974, 132 pp., $11.75.

The only textbook with an adequate coverage of insulation coordination.

- *Electric Power Transmission Systems.* Eaton, J. R.—Prentice-Hall, Inc., Englewood Cliffs, N.J., 1972, 365 pp., $15.95.

A practical handbook giving data and applications for circuits, power limits, faults, interrupting devices, instruments, relays, insulation, and grounding.

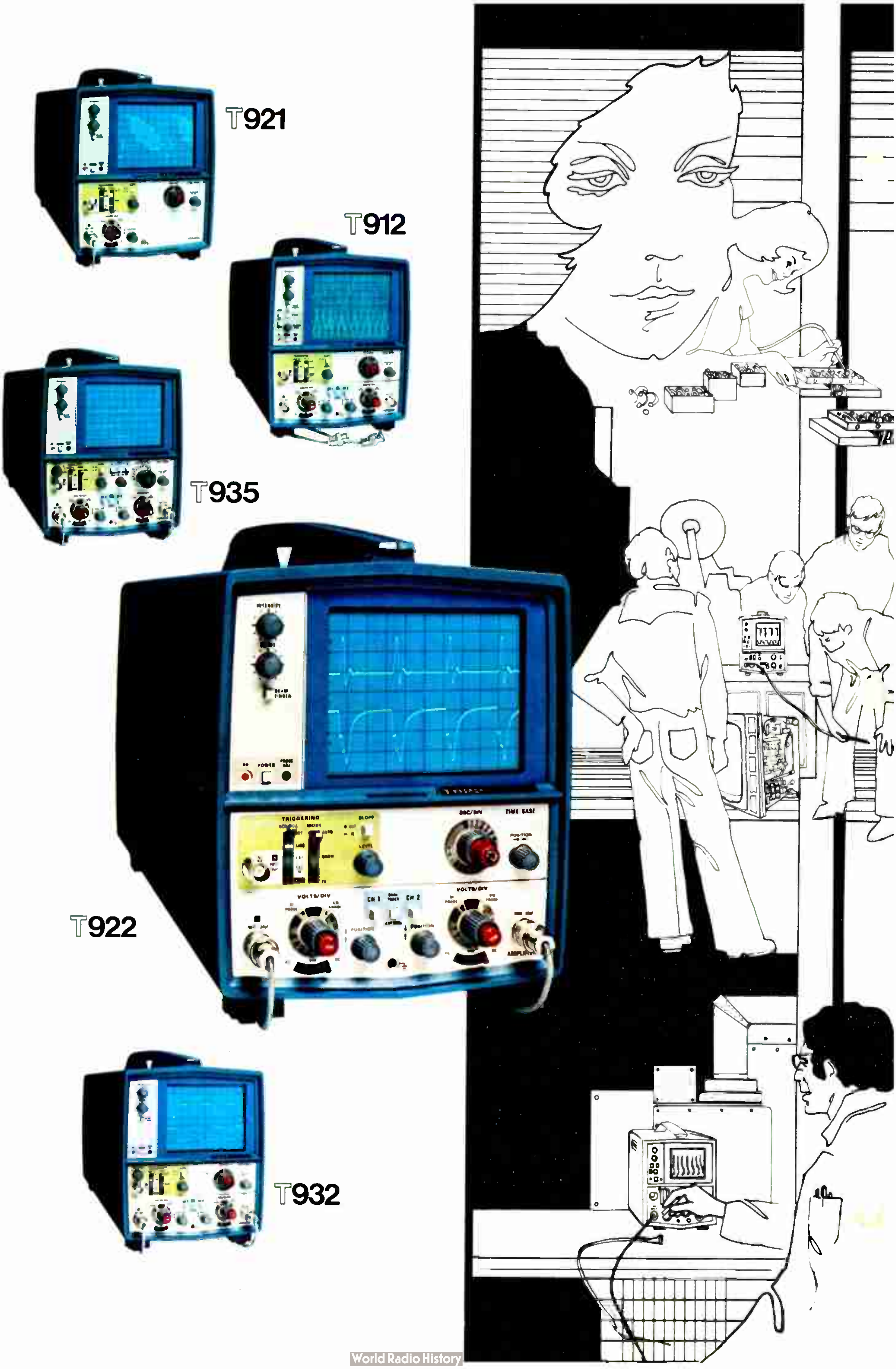
- *Analysis of Faulted Power Systems.* Anderson, P. M.—The Iowa State University Press, Ames, Iowa, 1973, 513 pp., $27.50.

Steady-state fault condition analyzed for a wide range of network conditions. Contains analytical development in matrix form, with examples.

- *Traveling Waves on Transmission Systems.* Bewley, L. V.—Dover Publications Inc., New York, 1963, 543 pp., $3.00. Out of print.

An outstanding treatise on classical theory of traveling waves and transients. ◆

The following individuals recommended and evaluated the aforementioned books: Stephen Director and Roy Russo, IBM's Thomas Watson Research Center; John Golembeski, Bell Telephone Laboratories; William H. Von Alven, Federal Communications Commission; Fred Rosenbaum, Washington University; Charles Falcone, American Electric Power; and Donald Ewert, Paul Albrecht, Gordon Carter, Charles Concordia, Leonard Garver, Carl Grund, Harvey Happ, Leon Kirchmayer, Einar Larson, Richard Schulz, and Homer M. Rustebakke, General Electric.


T921
T912
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Microprocessor short courses

A sampling of courses, ranging from one day to two weeks, and priced from $25 to $750, is provided

With microprocessor technology developing at a faster pace than most design engineers can follow, the need for special forms of education—to prepare engineers to evaluate and use these new systems-on-a-chip—has become evident. Responding to this need, conferences and publications concerned with conveying knowledge and up-to-date information about microprocessors have mushroomed.

For EEs who have never had practical experience with computer programming, and who are unfamiliar with the basic ideas underlying computer system operation, the learning process is often accompanied by considerable anxiety. In such a situation, direct educational experience offered by a short course can be a powerful confidence-builder. A sampling of available short courses covering microprocessor topics is presented in the table below.

Howard Falk Senior Editor

These courses are offered by microprocessor chip manufacturers, microcomputer system vendors, universities, and others; they run from one day to two weeks in length. To attend the average three-day course, participants will pay about $250 for travel and lodgings. Their organizations usually pay their salary and overhead expenses for those days—about $500. In addition, since the engineer attending a course would presumably have made money for his company had he stayed on the job, we will estimate "lost opportunity" cost at about $1000. So, before considering the course fee, attendance at a three-day course is likely to cost about $1800. The fees themselves vary from $25 to $750.

On the benefits side, the techniques learned in these courses are likely to pay off handsomely for the attendees' companies: microprocessors can be substituted for existing logic, and new microprocessor-based products and services can be designed.

Spectrum asked engineers who had attended these

Microprocessor courses currently offered

This list includes a number of short courses covering microprocessor topics. All the listed courses are to be offered during the coming year.

Course	Description
ACS Microprocessors and minicomputers—interfacing and applications, a hands-on course	This five-day course is designed for engineers and scientists, as well as for managers, who wish to use microcomputer systems in their work. From the first laboratory session, the students have hands-on contact with the I/O bus of a microcomputer. A PROM-based program called OPERATE, and an editor/assembler called TEACH, running on a host minicomputer, are used. Basic operating principles are reviewed. Advanced hardware experiments and intermediate-level software challenges are available for those with previous experience. Enrollment is limited to 24. The course is oriented toward microprocessor applications in chemical and process instrumentation.
Integrated Computer Systems (seven courses available)	1. Motorola's 6800 vs. Intel's 8080, a side-by-side comparison. This one-day course covers factors influencing performance development and production. Facts, figures, schematics, benchmark programs, and documentation are provided. 2. Military microprocessor systems. This two-and-a-half-day course is directed to evaluation of the feasibility of using microprocessors, as well as availability selection and development techniques. 3. Software development and applications techniques for microcomputers. This two-day course develops, in detail, the principles and techniques of microcomputer programming. 4. Microcomputer applications techniques. A two-day course designed to provide insight into techniques for applying microcomputers; geared for project engineers, electronic design engineers, and computer programmers. 5. Minicomputer/microcomputer real-time software system techniques and applications. A two-day course that focuses on real-time systems requirements and operating systems. 6. A manager-level overview of microprocessors, microcomputers, and minicomputers. A one-day course covering key management decisions related to developing micro- and minicomputer applications. 7. Microprogramming techniques—applications in microprocessors, minicomputers, and digital systems. This one-day course stresses implementation techniques, illustrated by specific case studies.
IEEE Microprocessor short course	This one-day course gives a basic introduction to microprocessors, and covers industrial applications, system development techniques, and testing methods.

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courses what use they had made of their experience. Some of the most important practical benefits seem to have come in the form of increased confidence about and familiarity with microprocessors. After taking a general-coverage course, one attendee said, "Now I can talk knowledgeably to various manufacturers about the specifics"; another attendee came back from his course to set up a microprocessor development center in his company. Still another designed a microprocessor-based system after his course and felt "more comfortable about trying something I had familiarity with."

Through the attendees' eyes

In discussing course experiences with a number of former attendees, *Spectrum* found almost all were well-satisfied with what they had learned. Some attendees praised courses for their generality. The NEC Microcomputer Institute was cited by one as giving a good overview, and by another for the up-to-date material it offered. Other attendees felt that specific detailed information was what they wanted and got. For example, the National Semiconductor courses were cited for taking up "real problems." Instructors were also felt to be an important factor. Commenting on the ACS course on microprocessors and minicomputers, a former attendee said the instructors showed "tremendous enthusiasm and desire to help. They worked their britches off."

Perhaps the most pervasive "complaint" by the attendees was that *they* worked too hard. At the Massachusetts Institute of Technology's course on the mighty mini, for example, one attendee felt he had "more studying than I could handle. No regular college course is as hard as this one." Among hardware-oriented engineers, there were some misgivings about the level of software instruction offered at some courses. For instance, an attendee at the Microcomputer Technique course on how to design with microprocessors felt that the software people probably benefited more from the course than those with primarily hardware backgrounds.

Spectrum's editors attended courses offered by Motorola and National Semiconductor. The success of both courses seemed limited only by the instructors' capacity to help their students understand microcomputer software. Further, as an important confidence builder, there seemed to be no substitute for hands-on programming experience.

From the relatively few attendee comments *Spectrum* received, it is impossible to evaluate meaningfully the quality of any of these courses. However, careful examination of the information listed in the accompanying table should give the reader an idea of the range of microprocessor courses currently offered, and of the kind of people who are teaching these courses. The listing is not intended to be complete since it only includes information received by *Spectrum* on course offerings of which our editorial staff had previously been made aware.

Dates/Locations	Fee	Contact	Instructors
Dec. 14–19, Mar. 14–19 June 6–11, Aug. 30–Sept. 3. All courses given at Blacksburg, Va.	$325 for ACS members $360 for nonmembers	Course registration: Harold Walsh, American Chemical Society, 1155 Sixteenth St., NW, Washington, D.C. (202) 872-4507 Technical Information: Raymond E. Dessy, Virginia Polytechnic Institute, Blacksburg, Va. (703) 951-5394	Raymond E. Dessy, Ph.D., Prof., chemistry Peter Janse, Ph.D., Asst. Prof., chemistry Isabel B. Starling, Asst. Prof., physical chemistry
1. To be announced 2. Nov. 12–14, Dallas, Tex. Nov. 25–27, Ottawa, Canada Dec. 3–5, Los Angeles, Calif. 3. Dec. 8–9, Sydney, Australia Dec. 15–16, Tokyo, Japan Dec. 22–23, Osaka, Japan 4. Dec. 10–11, Sydney, Australia Dec. 17–18, Tokyo, Japan Dec. 24–25, Osaka, Japan 5. To be announced 6. To be announced 7. To be announced	$135 for one-day courses $365 for two-day courses $395 for two-and-a-half-day courses	Julie Schneider, Integrated Computer Systems, P. O. Box 2368, Culver City, Calif. 90230 (213) 559-9265	*Regular lecturers* David C. Collins, Ph.D., computers and control theory Eric R. Garen, M.S.E.E., logic design S. Brannan, B.Sc.E.E., avionics *Added lecturers* Branko Soucek, Ph.D., Prof., computer science Granino Arthur Korn, Ph.D., Prof., computer control James D. Schoeffler, Ph.D., Prof., computer control M. R. Lemas, B.S. computer systems Michael T. Gray, B.Sc., microprocessor consultant
N[illegible], Pittsburgh, Pa. Dec. 6, Charleston, S.C.	IEEE members, $55 Nonmembers, $70 Students, $25	IEEE Educational Registrar, 445 Hoes Lane, Piscataway, N.J. 08854 (201) 981-0060, ext. 175	Ronald H. Temple, Ph.D., control applications of minicomputers and microcomputers

(continued on next page)

Microprocessor courses currently offered (*continued*)

Course	Description
Intel Microcomputer workshops (three courses available)	1. MCS-80 workshop. This three-day workshop covers procedures required to design and develop systems using the Intel 8080 microprocessor. It includes laboratory "hands-on" experience with the Intellec MDS-800 development syster 2. PL/M workshop. This three-day workshop covers elements and procedures required for writing and debugging PL/M programs. It includes laboratory "hands-on" experience in operating PL/M interactively from a high-speed, time-shared computer terminal. 3. MCS-40 workshop. This three-day workshop covers the procedures required to design and develop systems using the Intel 4040 and 4004. It includes laboratory "hands-on" experience with the Intellec 4 MOD 40 development system.
NEC Microcomputer institute (three courses)	1. Microcomputers: basic concepts and applications. This four-day course covers computer arithmetic and logic, fundamentals of digital computers, basic concepts of microcomputers, fundamentals of microcomputer software, assembly-level programming of microcomputers, and microcomputer applications. 2. Microcomputers: architecture, software, and systems. This four-day course covers microcomputer architecture, comparison of commercially available microcomputers, advanced software concepts, microprogramming, memory and interface considerations, microcomputer economics, microcomputer future trends, and system design using microcomputers. 3. System design using micro/mini computers:. This four-day course covers design philosophy, software development, testing techniques, and design principles for interfaces. Management techniques found sucessful in micro/mini computer development projects will be emphasized. Designers will describe their experiences, emphasizing problems and solutions.
Pro-Log How to design with programmed logic	A three-day course devoted to "hands-on" experience for the design engineer, to help develop the needed basic skills for using a microprocessor as a design tool. Emphasis is on developing programs using programmable read-only memory (PROM) and PROM programmers as well as learning how to interface, debug, and maintain PROM-based microprocessor systems.
M.I.T. The mighty mini—a close look at minicomputers/microprocessors and their applications	This two-week course covers small computers and microprocessors from both the hardware and software viewpoints, including extensive "hands-on" experience on several minicomputers and microprocessor systems. Modular microprocessor building blocks are used to demonstrate applications to industrial problems.
Microcomputer technique How to design with microprocessors	Aimed at engineers, this three-day course is designed to show how to exploit the features of the popular processors 't pitfalls there are, and how to avoid them.
Motorola M6800 Microprocessor training course	A three-day course detailing the operation and utilization of the M6800 Microprocessor System. Extensive "hands-on" training is provided to acquaint the student with the system. In addition, an advanced software course and a course covering support hardware are to be offered, with dates to be announced.
National Semiconductor (five courses)	1. Microprocessor fundamentals. This four-day course covers basic concepts of programmable systems for engineers, managers, and technicians who have never worked with microprocessors or minicomputers. The course includes stored program concepts, I/O control principles, use of standard software packages, and a guide to microprocessor selection. 2. IMP 16/PACE applications. This is a four-day detailed study of systems design using IMP-16 and PACE microprocessors. Covers microprocessor architecture, designing with chip sets and applications cards, use of prototyping systems, and use of standard software. Lab time is emphasized to reinforce lectures. 3. Advanced programming. This four-day course is a study of real-time programming techniques as they apply to microprocessors. It is designed for engineers who will write complex applications software. IMP-16 and PACE microprocessors are used as training machines. 4. Microprogramming. This four-day course covers the use of National's Microprogram Development System in developing custom instruction sets for National's IMP series microprocessors. Attendance is limited to experienced programmers and computer engineers. 5. SCAMP applications. This is a four-day detailed study of systems design using SCAMP microprocessors. It covers architecture, designing with chip sets, use of prototyping systems and standard software. Lab work is emphasized.
Texas Instruments Microprocessor design workshop	This two-day program includes eight hours of color videotape instruction in English, French, or German, amplified more than six hours of discussion led by a technically competent moderator. The presentation is supported by a lesson summary that covers the videotape. The videotape course is available for purchase in English at $3850. Multilingual course prices available upon request.

Dates/Location	Fee	Contact	Instructors
1. Nov. 10–12, Dec. 8–10 2 [illegible]. 13–15, Dec. 11–13 3. Nov. 17–19, Dec. 15–17 All courses are held both at Santa Clara, Calif., and at Boston, Mass.	$350 per workshop	MCS Workshops, Intel Corp., 3065 Bowers Ave., Santa Clara, Calif. 95051 (408) 246-7501	
All courses given Nov. 2–7 at St. Charles, Ill.	$595 per course	R. J. Napolitan, General Manager, National Engineering Consortium, Inc., 1301 W. 22nd St., Oak Brook, Ill. 60521 (312) 325-5700	Andre G. Vacroux, Ph.D., microprocessors in communications C. Dennis Weiss, Ph.D., microprocessors in communications LeRoy H. Anderson, Ph.D., microprocessor-based control systems James D. Schoeffler, Ph.D., Prof., computer control Charles Popper, Ph.D., microcomputer programming
Nov. 11–13, Knoxville, Tenn. Nov. 18–20, Denver, Colo. Dec. 1–5, Monterey, Calif. Dec. 9–11, Philadelphia, Pa. Jan. 13–15, No. N.J. Jan. 20–22, Los Angeles, Calif. Jan. 27–29, Vancouver, B.C., Can. Feb. 3–5, Washington, D.C.	$300	Pro-Log Corp., 852 Airport Rd., Monterey, Calif. 93940 (408) 372-4593	J. McDonald, E. Whitaker, R. Grant. All three have engineering and teaching backgrounds
Jan. 1976 (tentative), and June 1976, in Boston, Mass.	$750	Hoo-min D. Toong, 38-641, M.I.T., 77 Massachusetts Ave., Cambridge, Mass. 02139	Hoo-min D. Toong, Ph.D., Prof., EE and computer science (also, instructors from M.I.T. and industry)
N[illegible]–7, Cleveland, Ohio N[illegible]2–14, Palo Alto, Calif. Nov. 19–21, Long Island, N.Y. Dec. 3–5, Philadelphia, Pa. Dec. 10–12, Denver, Colo. Jan. 14–16, Seattle, Wash. Jan. 21–23, Hollywood, Fla. Jan. 28–30, Boston, Mass. Feb. 4–6, Toronto, Ont., Canada Feb. 11–13, Raleigh, N.C. Feb. 25–27, Minneapolis, Minn.	$395	Registrar, Microcomputer Technique, Inc., 11227 Handlebar Rd., Reston, Va. 22091	Richard G. Cooper, microprocessor system design James W. Gault, Ph.D., digital system design Scott McPhillips, microcomputers Jerry L. Ogdin, data communications
Nov. 11–13, Dec. 9–11, in Phoenix, Ariz. Other dates and locations to be announced	$375 in Phoenix $430 elsewhere	R. Bishop, Motorola Inc., Semiconductor Products Div., 5005 E. McDowell Rd., Mail Drop BB102, Phoenix, Ariz. 85008 (602) 962-2345	James Bainter David Hyder Ray Vasquez Francis Christian Michael Shotey Edward Neil
Course locations are Miami, Fla., Dallas, Tex., and Santa Clara, Calif. Microprocessor fundamentals, IMP 16/PACE applications, and advanced programming now scheduled at all three locations for Nov. 1975 through June 1976. Microprogramming, Mar. 29–Apr. 1 at Miami, Fla. SCAMP applications, at all three locations, March through June 1976.	$395 per course	W. Harding, National Semiconductor Corp., 2900 Semiconductor Dr., Santa Clara, Calif. 95051 (408) 732-500, ext. 7183	W. Harding, field engineering T. Harper, microprocessor systems D. Grove, M.S., systems analysis Ira McComic, systems analysis Georgia Marszalek, M.S., systems analysis George Goode, M.S., Prof., computer sciences T. Malone, software
N[illegible]S. courses are planned, but courses will be scheduled in several European cities during the next four months.		James B. Allen, Texas Instruments Learning Center, P. O. Box 5012, M/S 54, Dallas, Tex. 75222 (214) 238-3894	

Engineering micrographics

Reduced from hand-made originals or prepared directly by computer, microfilm data files claim size, access, and integrity advantages

Proposal work, documentation, drafting activities, and spec writing all contribute mightily to the flow of paper circulating throughout any sizable technical organization. Perceiving this hard-copy addiction, more than one observant engineer has characterized his work environment as "the Paper Mill Playhouse." While it's always been possible to stem part of the tide and save space too by stashing little-used drawings and reports on microfilm, keeping active files under control presents a more serious challenge.

The micrographics industry claims to have some of the answers—better reader/printers, improved film, a variety of formats (roll film, jackets, microfiche, aperture cards), and, in the past few years, computer-output microfilm (COM). This last development allows direct production of microfilm from recorded instructions, eliminating hand-drawing and photoreduction. Indeed, the promise of micrographics for paper-intensive engineering activities is said to include a 96–98-percent savings of storage space, reduced retrieval/reproduction expenses for hard copies, improved file integrity, and vault protection of original films.

Microfilm, of course, is the granddaddy of micrographics (the concept dates back to photography's infancy). Continuous roll film is still in wide use for archival storage where updating single images (pages) is essentially nonexistant, and it is also practical for engineering drawing files where frequent changes affecting many individual prints make periodic refilming of the entire collection economically worthwhile. Aperture cards (IBM-type keypunch cards with 35-mm film "windows") are the natural choice for storing large drawing files where only a small percentage of the documents are undergoing constant revision. Vendor catalog data, spec sheets, and parts lists are conveniently retained on roll film, microfiche, or jackets.

Outright technical improvements—fine-grain film coupled with better optics—now provide crisp blowback at more than 90X reduction, allowing thousands of images to be stored on a single 105- by 148-mm "ultrafiche." While even finer reductions have been achieved, film contamination from dust and tiny scratches sets a practical limit on recoverable detail. Ultrafiche is primarily a read-only medium, since the mechanical vibrations associated with automated hard-copy generation (or nearby machinery) easily disrupt image stability.

Computers have also increasingly figured into the micrographics story over the past several years. Computer-output microfilm (COM) systems can completely eliminate typed or hand-drawn originals (and the photoreduction of such documents), producing first-generation microfilm from taped instructions. A cathode-ray-tube image is reduced by a lens system, put directly on film, and developed, saving weeks of drafting time.

Getting ready to roll, reel, or fiche

Microform formats divide down into about six easily identified subgroups consisting of either continuous roll film, individual transparencies, or cards. An awareness of the cross section available is important, since readers and reader/printers are typically designed to accept just one specific microform variety.

- *Microfilm reels* provide a high measure of file integrity and prove desirable where information is added sequentially and updating is infrequent. The 16-mm reels are primarily used for correspondence, checks, and similar information, and 35-mm reels for graphics (engineering drawings, X-rays, and newspapers).
- *Microfilm cassettes* each contain two film cores—the feed and the take-up. There is no need to rewind a cassette when it is removed from the reader. Any frame may be held in position for later reference.
- *Microfilm cartridges* function as "convenience packaging" for rolls of microfilm. The self-threading cartridges are well protected, and not subject to fingerprints and other possible sources of damage.
- *Microfiche,* or "fiche," are sheets of film containing multiple microimages in a grid pattern. They usually contain identification information that can be read without magnification. Available in a variety of styles, microfiche generally permit unitized data storage and updating. They are easily duplicated for mailing, security, or reference purposes. Microfiche may contain from a few to several hundred images in a reduction range of 18X to 48X. Ultrafiche contain images reduced more than 90X.
- *Jackets* are plastic carriers with single or multiple sleeves or channels designed to accept strips of 16-mm or 35-mm film. Jackets both protect the microfilm and also facilitate organization of material.
- *Aperture cards* combine key-punched data and access information with microfilm. They may contain a single image, or up to eight page-size images on one 35-mm frame.

After selecting a format, the next step is obtaining reader and reader/printer equipment. Prices range from less than $100 for a portable pocket reader to $50 000 (or more) for sophisticated copying systems that can duplicate and collate hard copies from fiche in just a few minutes. A Xerox spokesman and micrographics specialist told *Spectrum* that reading and printing needs are best met with separate machines. Expensive, high-speed duplicating equipment should earn its keep running copies, while low-cost desktop readers ($200–$600) provide everyone else with eyeball access to the microform files.

Conversion costs are another big variable to consider when shopping for micrographics. Some smaller com-

Don Mennie Associate Editor

panies will want to farm out the camera work, developing, and mounting to an outside service bureau. Large outfits generating around 10 000 (or more) prints per month can benefit by starting an in-plant micrographics department. Xerox explains that this latter mode can easily take six months to get fully underway. When set-up involves transferring old, brittle, and deteriorating drawings to film, much time is lost repairing aged originals and experimenting with backlighting and other techniques to retain detail and improve contrast. A careful treatment of this subject, entitled *1860 Drafting Practices*, is available free from Xerox. While the booklet is specifically geared to users of the Xerox 1860 Printer, it contains considerable discussion on methods of enhancing old sepia and blueline prints for eventual microfilming.

The promise and the product

Micrographics is still in the process of proving itself to potential customers. Those with unpleasant past experiences—reading machines of poor mechanical design; scratched, broken, or smudged film; eyestrain from low-quality optics—are less than enthusiastic. Others simply like tactile involvement with wads of paper, and will settle for nothing less than a hard copy. But the document flow in many engineering departments does present several challenges suitable to micrographic solution:

- Wasted engineering time. When an engineer needs a drawing, he must wait while drafting hunts up the original drawing and runs a copy. Satellite readers eliminate this delay.
- Wear and tear on originals. When an original is used for making copies, a certain amount of deterioration is inevitable. Original microfilm stays in a vault while duplicate film handles routine access needs.
- Disasters. Fires and floods do occur, and the cost of remaking hundreds of drawings can be tremendous. Again, vault storage of compact microfilm originals minimizes the risk.
- Distribution time and costs. When prints are distributed, they must be produced from the originals, inventoried, folded, packed, and mailed—all of which costs time and money. Microfilm duplicates can be produced and mailed at a fraction of the hard-copy costs.
- Reproduction costs. Often, requested copies are unnecessary. If an engineer only wants to confirm a specific dimension or specification, looking up the needed data on a satellite reader is sufficient.
- Misfiling, mislaying. The retrieval and filing of large originals is cumbersome. Microfilm is easy to handle, and, in the case of roll film, file integrity is guaranteed unless the whole reel is mislaid.

At the 3M Company, St. Paul, Minn., a complete system (consisting of a processor–camera, film copier, and choice of printer or reader/printer) has been developed for handling engineering drawings. And that system can be tailored to meet the needs of small and medium-size companies, as well as very large firms. In all cases, documents are processed in similar fashion. The original drawing is taken to a 3M2000E processor–camera. At the push of a button, the camera produces a finished microfilm aperture card. These cards are all the same size, regardless of the original document's physical dimensions.

The master aperture card can then be inserted into a card-to-card copier, where duplicates are reproduced, in seconds, in whatever quantity needed for in-plant or other satellite locations. The master card is consigned to a security file, while the duplicates become the working copies.

Now, it is a simple job to put the card into the reader–printer and obtain large-screen viewing or get hard copies at the push of a button (Fig. 1). Sharp, clear copies are delivered at sizes up to 46 by 61 cm.

The economy of such a micrographics system really proves itself when mail distribution is necessary. A total of 1000 aperture cards, which are themselves reproducible, weighs 36 kg *less* than the same number of full-size copies.

During January of this year, Xerox began shipping its 970 Microfiche Printing System (Fig. 2). The high-speed equipment makes positive copies from negative microfiche at 3300 pages per hour on unsensitized bond paper. A frame selection keyboard allows the 970 operator to program for printing any frame sequence *within* a given fiche should only a portion be needed in hard copy. Quantity selector dials, similar to those found on Xerox office copiers, permit up to 499 automatically collated sets per run.

Small world semantics

The micrographics industry has borrowed liberally from the photographer's lexicon, while going on to create a language of its own. The summary of key terms defined here is based on the *Glossary of Micrographics*, NMA MS100, available from the National Micrographics Association, Silver Spring, Md.

Blowback—An easily readable, magnified image (or hard copy) produced by a film reader (or reader/printer), not necessarily to full scale. Hard copies are also called printbacks.

COM—Computer output microfilm: microfilm containing data produced by a recorder from computer-generated electric signals.

Diazo material—A slow print film or paper, sensitized by means of diazonium salts, which, subsequent to exposure to light strong in the blue to ultraviolet spectrum and development, forms an image.

Frame (film frame)—The area of film exposed to light in a camera during one exposure, regardless of whether or not this area is filled by the document image.

Generation—A measure of the remoteness of a particular copy from the original material.

Hard copy—An enlarged copy, usually on paper.

Microform—A generic term for any form, either film or paper, which contains microimages.

Micrographics—The art, science, and technology that reduces information to a microform medium.

Microimage—A unit of information (page of text) too small to be read without magnification.

Reduction—A measure of the number of times a given linear dimension of an object is reduced when photographed, expressed as 16X, 24X, etc.

Resolution—The ability of optical systems and photomaterials to render visible fine detail of an object—expressed in lines per millimeter.

Vesicular film—Film that has the light-sensitive element suspended in a plastic layer and that, upon exposure, creates strains within the layer. The latent image is made visual by heating the plastic layer, resulting in the formation of minute bubbles or vesicles.

The 970 will *not* handle every existing combination of fiche reduction and page layout. The three models that are available accept input formats of 24X, 98 pages; 20X, 60 pages; and 24X, 63 pages, respectively. Printback magnification obtained with the first two formats is 10 percent less than reduction, and 30 percent less with the third format. Minimum rental is $1500 per month including 50 000 A-size prints.

For aperture card users, Xerox produces the model 600 Microfilm Enlarger Printer. Introduced in 1971, the 600 MEP automatically handles up to 200 microfilm aperture cards, producing one to 99 copies of each at the rate of ten prints per minute. Rental on this equipment currently runs a minimum of $550 per month including 4300 B-size prints (note: the 600 MEP has three paper trays and can make A-, B-, or C-size copies, with different "per-print" charges applying to each). The 600 MEP may also be purchased for $40 000.

Also intended for volume production of technical drawings from 35-mm film (aperture cards, rolls, or strips) are the Océ 3780/3781 automatic production printers. Listing at $39 950 each from Océ Industries, Chicago, Ill., these models handle four different sizes of precut sensitized paper and yield four to 12 copies per minute, depending on the paper size involved. Enlargement factors are infinitely variable: 6.5× to 24× on the 3780, 6.5× to 26× on the 3781. For one aperture card various number of copies can be made in different sizes, either manually or automatically (e.g., five C-size prints, three B-size prints, four A-size prints).

Such high-speed printback systems, complete with a five-figure price tag, are the exception among micrographic equipment. Those who can forego paper copies completely will find a wide selection of sturdy desktop readers available at moderate cost. Perhaps typical of these is the Mini-Cat I front-projection microfiche reader developed by Washington Scientific Industries, Long Lake, Minn. (Fig. 3). This reader, suitable for aperture cards, is one of the three commercial Mini-Cat models introduced since WSI's original design was developed under contract with the U.S. Department of Defense in 1973. Two versions of the Mini-Cat I are available: a single-lens (12× or 21×) model for $229, and a dual-lens (12×/21×) model for $289. WSI also makes Mini-Cats for Xerox, where they are relabeled and sold to micrographic printer customers who also need dependable satellite readers.

Spectrum questioned a number of micrographics users regarding reader quality and performance. Only inexpensive hand-held portable reading equipment was singled out for serious complaint. Portables presently on the market are said to suffer from illumination problems and optical distortion.

Data by subscription

One obvious way micrographics can help many engineering departments is by condensing all the needed reference material to a compact file. Information Handling Services, Englewood, Colo. has built a thriving business around this theme by offering vendor catalogs, product literature, military documents, industry standards, and—since July 1975—metric product data in microfilm cartridge and/or microfiche format.

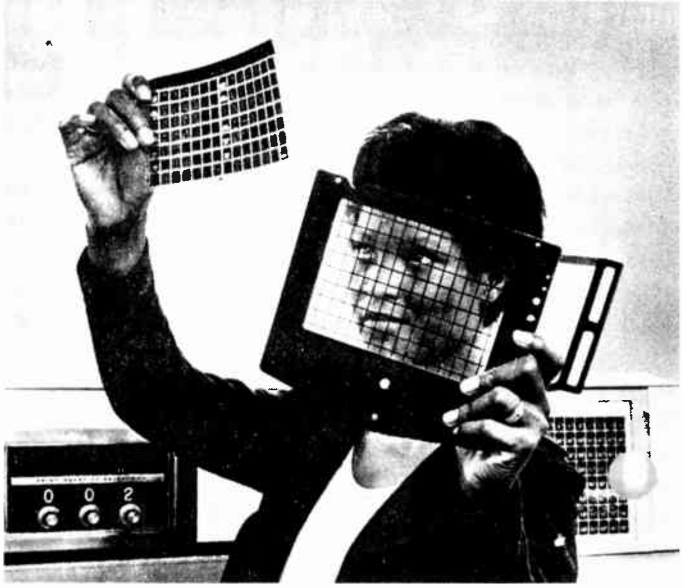
The IHS "product" is its broad range of over 30 VSMF® (visual search microfilm files) information systems containing technical data. These information collections are used in data centers consisting of a reader/printer, satellite reader, film storage rack, microfilm library, and indexes (reading equipment may be owned or leased—not necessarily through IHS).

Updated microfilm arrives every 15, 30, 60, or 90 days (depending on the particular VSMF subscription involved). For example, IHS's Metric Design Service for U.S. engineers is offered on 8-mm cassettes or 16-mm cartridges and is refreshed every 60 days at an annual cost of $1850.

VSMF data systems are available in 13 distinct engi-

[1] The 3M Quantimatic printer can handle up to 200 aperture cards at one time with an individual copy quantity for each (1 to 99) dialed in. Dry copies are produced at the rate of ten per minute on plain bond paper. The Quantimatic has a suggested retail price of $50 000, with rental or leasing available.

[2] The microfiche sheet contains 98 images of letter-size documents that can be reproduced on plain paper in original size by the Xerox 970 microfiche printing system. The empty frame (left hand) holds the fiche in proper alignment during the printback process.



neering categories (plus the new metric service). The microfilm selection covering industry standards, for example, includes all of the standards published by IEEE. Engineering product data are indexed by *product*, alphabetically, and by *supplier*, alphabetically. Vendor catalogs are microfilmed with similar items side-by-side for easy comparison of specifications.

What COMes next?

There are even more sophisticated extensions of micrographics, especially as microfilm and computers draw closer together in what has been described as a "marriage" of the two technologies. For example, computer-output microfilm permits the instant production of microfilm from computer data. Generating text is the simplest application, but there are COM programs and devices that can produce flow charts from mathematical computations, and other similar graphics (Fig. 4). For the most part, these sophistications are practical in large industries and research organizations; they are not yet typical for traditional engineering applications.

Over the past five years, COM's most widespread success has been with frequently updated texts (inventories, personnel files, customer lists, etc.) that require repeated access and wide distribution. COM machines are often sold on the basis of how much paper they eliminate, just as computers once were sold on the basis of how many clerks they would eliminate. Truett Airhart, senior vice president of the Zytron Corp., explains further in his article, "Computer output microfilm: a powerful systems tool," appearing in *The Journal of Micrographics*, January 1974: "The severe business recession of the late '60s/early '70s proved to be the most difficult period in the history of electronic data processing hardware sales. Management's insis-

[3] Two blowback magnifications can be selected by users of this Mini-Cat I from Washington Scientific Industries (circular lens holders in foreground). The image is reflected off a mirror under the top of the hood onto an aluminized screen tilted at a convenient viewing angle.

Resolved: legibility is everything

Just how clean will be the duplications your micrographic system produces? While working copies may be several generations removed from the original films, their quality can still be estimated, based on the resolving power obtained in the first-generation camera microfilm.

The desired level of quality is established by relating three variables: the height of the lower-case letter "e" in text to be filmed, the number of generations in the system, and a resolving power pattern number derived from filming the NBS Microcopy Resolution Test Chart 1010a-1963 (a sample of this chart appears in the upper right corner of the figure). To apply the method, it is necessary to know the number of the pattern in the NBS Resolution Test Chart that is resolved at various reductions in the camera-film system. The procedure consists of four basic steps:

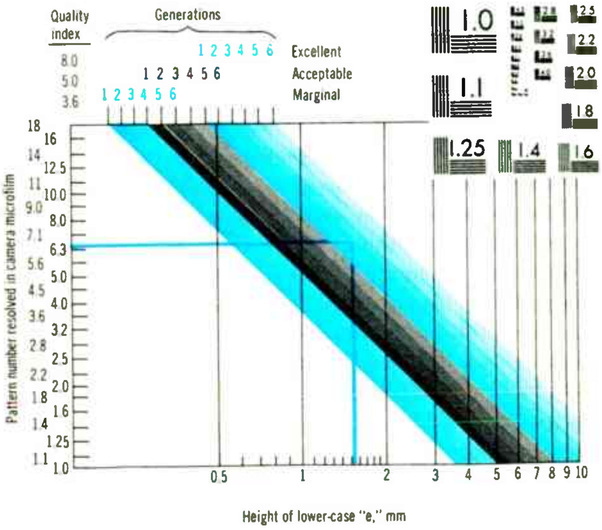
1. With a measuring magnifier, measure the height in millimeters of the lower-case letter "e" in the *smallest* printing that must be reproduced.
2. Find the corresponding letter height on the horizontal axis of the graph in the figure.
3. Move up to the group of lines within the level of quality desired and to the single line in that group that corresponds to the number of generations required.
4. Move left horizontally to the vertical scale and read the NBS resolving power pattern number that must be resolved in the camera microfilm to achieve the desired quality level in the final reproduction.

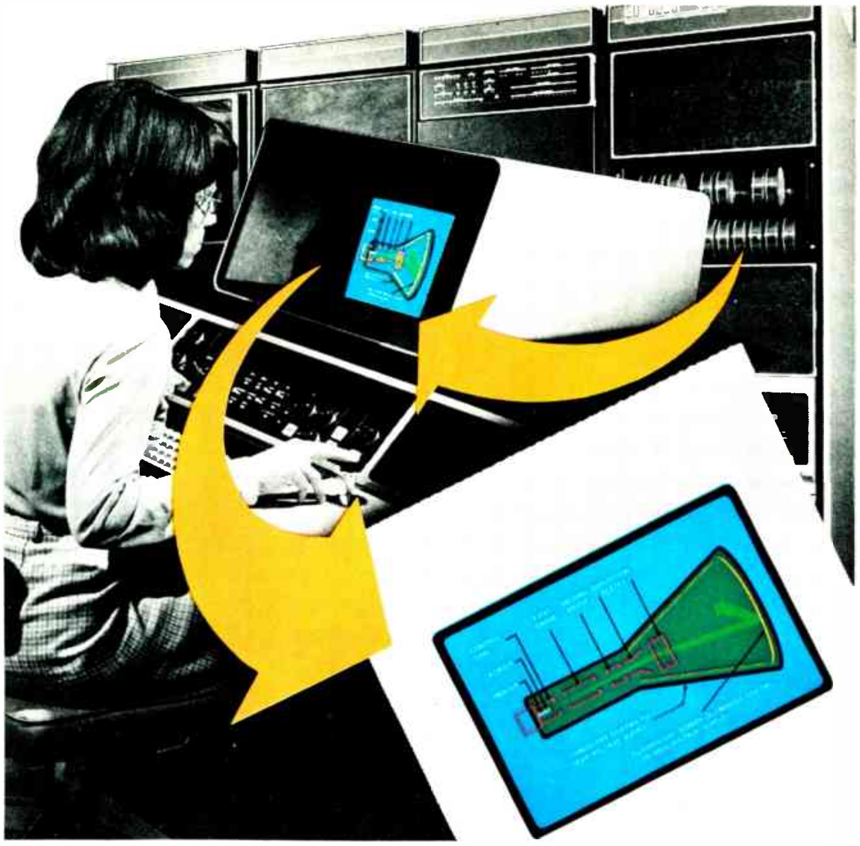
As an example, suppose we wanted to microfilm this page of *Spectrum*. The height of the lower-case letter "e" on this page measures 1.56 mm. Look for 1.56 on the horizontal axis at the bottom of the graph. Excellent quality is desired, and the system will require three generations of microimages. Following the color lines, we see that a 6.3 pattern must be resolved. It is important to note that this is required regardless of reduction used.

When the *camera microfilm* (first generation) is inspected, the number of the pattern resolved in the NBS Resolution Test Chart should be equal to (or larger than) 6.3. Testing the camera's resolution capability may be done before or after determining the smallest text to be reproduced. To determine the camera's resolution, it should first be calibrated and then a test film produced at the desired reduction. The smallest NBS pattern (largest number) resolved, over the entire field, must be found.

The procedure outlined here, known as the Quality Index Method, insures the ability to reproduce specific detail. It does not take into consideration such variables as overall sharpness, tone, contrast, quality of original documents, or distinctions between different typefaces. Further information on the subject is available from the article, "Standards: the quality index method," appearing in *The Journal of Micrographics*, Jan. 1975, and authored by Don M. Avedon, technical director of The National Micrographics Association.

Experience with the Quality Index Method indicates that legibility at a Quality Index of 3.0 is very poor and generally unacceptable. Therefore, a Quality Index of 3.6 is recommended as a minimum level of legibility. A QI level of 5.0 is considered acceptable, and a QI of 8.0 or more yields excellent results.





[4] **Consisting of an artist's console, minicomputer, and photo recorder, General Electric's Genigraphics™ is an image generation system particulary suited to creating four-color business slides. Working from a 525-line color monitor, the console operator calls up basic graphic elements (type fonts, circles, squares, etc.) from computer memory and adjusts spacing, proportion, and color for an unrestricted layout. When the monitor image is satisfactory, it can be photographed immediately or stored on tape. Actual filming is done from a 2048-line, black-and-white CRT. Color is produced by multiple exposure through monochrome filters. Genigraphics is available at $300 000 for a complete hardware package, or its services may be employed (at rates competitive with commercial art studios) through GE service centers located in New York City and Syracuse, N.Y.**

tence upon *value* as a requisite for computer expansion forced thousands of companies to make do with what they had and to forestall new purchases. And it was during this same difficult period that COM [for text material] matured."

According to Mr. Airhart, "COM does so well in adding to the value of previously all-paper systems that it is often overlooked when an on-line system must be upgraded." He provides, as an example, the experiences of a large military personnel center, where a central file is maintained (on computer) carrying a personal profile of every officer and enlistee.

Sixteen terminals provided access to the information bank, and every day between 8 a.m. and 4 p.m., when the computer was "up," operators at the 16 terminals handled inquiries from various agencies. Even though the terminals were on-line, the files themselves were updated only once every two days.

The problem was a demand for additional applications at the center—with the computer already working at full capacity. It was a question of installing additional, expensive computing power, plus more on-line terminals, or finding another option. There were no funds to purchase more computer equipment.

COM provided the acceptable answer. Instead of the original 16 on-line terminals, the facility installed 51 microfiche viewers, and, because the files were complete at every station, the operators could work around the clock, unaffected by whether the computer was "up" or "down." The mainframe was not expanded, but COM reduced the "look-up" load on the central processing unit, releasing capacity for other chores.

Consequently, the personnel center expanded look-up capability by about eight times, without spending a cent more in computer costs and with only minor changes in programming. After the expansion was complete, the center was still operating at about the same cost it had been with the old on-line system.

Even the average consumer has figured into the micrographics industry's marketing plans in recent years. Kodak, for example, has taken full-page ads in publications like *Newsweek* promoting its 2.25-kg Ektalite Reader as a way around the growing costs of printing and mailing written material. Meanwhile, Bell & Howell test-marketed its Home Information Center late in 1973, consisting of portable briefcase reader, printed indexes, and 282 98-page microfiche. The $199.95 package contained 15 standard reference works including—in their entirety—*Comptons Encyclopedia*, *Funk & Wagnalls Dictionary*, and the *Rand McNally Atlas*.

These efforts are aimed at promoting the concept of micropublishing—the direct issue of new books on fiche as a complement to, and possibly in lieu of, publishing on paper. The pitch is aimed squarely at book publishers as well as consumers.

However, one should not get the impression that micrographics will soon relegate paper and print to the museum. In the engineering field alone, there exists at least one major holdout: the construction industry. Xerox's micrographics specialist explains that a traditional avoidance of dimensionalized drawings in construction work is the snag. Builders draw to scale and pick needed dimensions off their prints by hand. Should this linear scale be distorted by imperfect reduction or magnification ratios on printback (as is often the case with any microfilm-generated hard copy) they have no way of recovering true lengths, widths, etc., of depicted structures. Of course, adding full-dimensional data to the drawings would obviate the problem. But as advocates of U.S. conversion to the metric system can testify, inertia in the guise of comfortable tradition is truly a monumental barrier. ◆

Engineer's source guide

Researching a complex problem or looking for the answer to a nagging technical question? This directory may help

Evelyn Tucker News Editor

The following is a guide to some of the sources where researchers, or the casual questioner, can find the data they need in a number of engineering and engineering-related areas. In addition to the specific categories listed, information on a variety of technical subjects is available from the Engineering Societies Library and from Engineering Index, both at 345 East 47 Street, New York, N.Y. 10017. For tabulations of reference materials, literature guides, retrieval services, and abstracting and indexing services, the reader is referred to Madhu-Sudan Gupta's *Spectrum* article, "Where to find it when you need it" (May 1974, pages 72–77). And elsewhere in this issue (pages 68–71), Oscar Firschein tells you how to keep up to date with "On-line reference searching."

Aeronautics and astronautics
National Aeronautics and Space Administration
Scientific and Technical Information
400 Maryland Avenue, S.W.
Washington, D.C. 20546

Air pollution
Air Pollution Technical Information Center
Environmental Protection Agency
Research Triangle Park,
Durham, N.C. 27711

Atomic energy
Energy Research and Development Administration
Technical Information Center
P.O. Box 62
Oak Ridge, Tenn. 37830

Broadcasting
Broadcast Pioneers Library
1771 N Street, N.W.
Washington, D.C. 20036

Chemistry, chemical propulsion
Chemical Abstracts Division
American Chemical Society
Ohio State University
Columbus, Ohio 43210

Chemical Propulsion Information Agency
Applied Physics Laboratory
The Johns Hopkins University
8621 Georgia Avenue
Silver Spring, Md. 20910

Crystal structures
Crystallographic Data Centre
University Chemical Laboratory
Lensfield Road
Cambridge CB2 1EW, England

Electric power
Federal Power Commission
625 North Capitol Street, N.W.
Washington, D.C. 20426

Edison Electric Institute
90 Park Avenue
New York, N.Y. 10016

Energy
National Energy Information Center
Federal Energy Administration
12th Street and Pennsylvania Avenue, N.W.
Washington, D.C. 20461

Geology
American Geological Institute
5205 Leesburg Pike
Falls Church, Va. 22041

Geothermal resources
U.S. Geological Survey
Geologic Division
National Center
Reston, Va. 22092

Infrared
Infrared Information Analysis Center
Environmental Research Institute of Michigan
Box 618
Ann Arbor, Mich. 48107

Mass spectrometry
Mass Spectrometry Data Centre
AWRE, Aldermaston
Reading RG7 4PR, England

Mathematics
American Mathematical Society
P.O. Box 6248
Providence, R.I. 02940

Mechanical properties of materials
Mechanical Properties Data Center
13919 West Bay Shore Drive
Traverse City, Mich. 49684

Metallurgy
American Society for Metals
Metals Park, Ohio 44073

Metrology
Electromagnetic Metrology Information Center
National Bureau of Standards
Boulder, Colo. 80302

Metals and ceramics
Metals and Ceramics Information Center
Battelle Columbus Laboratories
505 King Avenue
Columbus, Ohio 43210

Nondestructive testing
NDT Data Support Center
P.O. Drawer 28510
San Antonio, Tex. 78284

Oceanography
National Oceanographic Data Center
2001 Wisconsin Avenue
Washington, D.C. 20235

Petroleum, petrochemicals
Central Abstracting and Indexing Service
American Petroleum Institute
275 Madison Avenue
New York, N.Y. 10016

Physics
American Institute of Physics
335 East 45 Street
New York, N.Y. 10017

Radiation chemistry
Radiation Chemistry Data Center
Radiation Laboratory
University of Notre Dame
Notre Dame, Ind. 46556

Reliability of electronic components
Reliability Analysis Center
RADC/RBRAC
Griffiss AFB, N.Y. 13441

Research materials
(basic physical properties)
Research Materials Information Center
Oak Ridge National Laboratory
P.O. Box X
Oak Ridge, Tenn. 37830

Science and technology
Defense Documentation Center
Cameron Station
Arlington, Va. 22314

National Technical Information Service
5285 Port Royal Road
Springfield, Va. 22151

Library of Congress
Science and Technology Division
National Referral Center
Washington, D.C. 20540

Standards
American National Standards Institute
1430 Broadway
New York, N.Y. 10018

American Society for Testing and Materials
1916 Race Street
Philadelphia, Pa. 19103

IEEE Standards Department
345 East 47 Street
New York, N.Y. 10017

National Bureau of Standards
Standards Information Service
Room B-164, Bldg. 225
Washington, D.C. 20234

Thermophysical and electronic properties of materials
CINDAS
Purdue University
West Lafayette, Ind. 47906

Transportation
U.S. Department of Transportation
DOT/OST/TST-25, Room 9411
Washington, D.C. 20590

Transportation Research Board
2100 Pennsylvania Avenue, Room 513
Washington, D.C. 20418

On-line reference searching

'Let your computer do the walking'—it can be fast, thorough, and inexpensive

If you are surrounded by experts who can answer your every question, or if you are a researcher in a narrow field of specialization and communicate with other leaders in the field throughout the world, or if your work is "cut and dried" and no problems arise that require outside reference work, then you are in a near utopia and computerized retrieval is not for you. On the other hand, if you are finding it difficult to track your field and feel that some of your problems may be answered in unfamiliar journals, government reports, or foreign journals; or if you lack access to an adequately equipped technical reference library; or if you desire to be informed automatically and quickly of the latest references in your field; then computerized retrieval may be the very thing you need.

The on-line retrieval systems (those that respond to a search command within seconds) to be described herein do not provide the user with answers to questions but, rather, with references to documents that might have the answers. Advances in computer and communications technology now make it possible for engineers to find pertinent material among the vast outpourings of technical literature. Many reference journals that provide titles, authors, sources, and abstracts of reports, journal and magazine articles, and books are now in computer-readable form. They are accessible in an on-line mode and searches can be made on the basis of word combinations in the title or abstract of a citation (an entry in the data base that tells about a report, paper, or book, and can include title, author, source, data, pages, abstract, and search terms known as descriptors or identifiers that attempt to capture the content or meaning of a document), as well as by author, source, or contract number. Such on-line retrieval allows the user to modify his search strategy based on the response being obtained. This facility is in sharp contrast to batch systems in which searches submitted are accumulated or batched and then run through with response times of hours or even days.

One factor in the success of any search is the coverage provided by existing data bases since computer searches can only be made on computer-readable information. In the electrical/electronics engineering fields, fortunately, there are some excellent data bases. Also important, however, is the skill of the person conducting the search, how well the searcher can translate needs into appropriate search terms, and the searcher's familiarity with the data bases.

Who does the search?

It takes at least a few hours to become thoroughly familiar with the basic operation of any on-line retrieval system. Familiarizing oneself with the data bases in any given system requires additional time. Consequently, many casual users of computerized retrieval systems prefer a librarian to do the search. Engineers often like to be present when a search is being made so that they can evaluate the results of the search as it proceeds and can direct the searcher along the most fruitful lines. Other engineers prefer to have the librarian perform the search alone and merely send them the results. Librarians also have their preferences. Some are bothered by an engineer in attendance while others prefer to have the engineer guide the search.

For the most economical operation—since computerized search is billed on the basis of actual computer connect time—the librarian will work with the engineer to obtain the initial set of terms to be used. Once on line with the computer, the librarian can then obtain further terms by using vocabulary words from relevant citations obtained during the search.

Typical questions that can be answered by computerized search are:

- What recent work has been done on automated inspection and testing of electronic assemblies?
- Has a minicomputer been used to process spectrometer data?
- What are the recent patents on thermal batteries?
- What solid-state imaging techniques are used for infrared systems?
- What techniques have been used in secure operating systems?
- What is the ALOHA system?
- What problems have occurred in fabrication of electronic assemblies in Hong Kong?
- What problems have been faced by companies in the video cassette recorder field?

Note that these questions are quite specific. It would be a mistake to pose a question such as, "What information do you have on computers?" In response to such a question, the searcher would be inundated with hundreds of thousands of citations. Since the data bases concentrate on recent citations, from the 1960s on, it would also be a mistake to ask for references to papers by Thomas A. Edison, for example.

What does it cost?

Computerized search is available in-house from a number of Federal agencies including the Energy Research and Development Administration (ERDA), NASA, and the Defense Documentation Center (DDC). Commercial retrieval system vendors include the *New York Times*, the National Library of Medicine, Informatics, Lockheed Information Systems, and Systems Development Corporation. The last two vendors offer many data bases of major interest to electrical/electronics engineers.

For use of an on-line computerized system, one pays

Oscar Firschein
Lockheed Palo Alto Research Laboratory

I. Data bases of interest to the electrical/electronics engineer

Name	Number of Citations	Characteristics	Cost ($/hour) Lockheed Information Retrieval Service Dialog	Cost ($/hour) SDC Search Services Orbit III
INSPEC Science Abstracts (Institution of Electrical Engineers) (three separate data bases)	700 000	(1) Physics, (2) electrical and electronics, and (3) computers and control, taken from journal papers, conference proceedings, technical reports, books, patents, and university theses	45	. . .
National Technical Information Service (NTIS)	500 000	Government-sponsored research, development, and engineering reports plus analyses prepared by Federal agencies, their contractors, or grantees	35	60
Compendex (Computerized Engineering Index)	300 000	Coverage of the important contents of some 3500 journals, publications of engineering societies and organizations; papers from conferences, as well as selected Government reports and books published worldwide	65	95
Chemical & Electronic Market Abstracts (CMA/EMA) Predicasts	60 000	Marketing information in chemical, process, electronics, and equipment fields, taken from newspapers, business magazines, Government reports, trade journals, bank letters, and special reports throughout the world	90	. . .
Funk and Scott (F&S) Index (Predicasts, Inc.)	450 000	Domestic and international company, product, and industry information from over 1000 financial publications	90	. . .
Smithsonian Science Information Exchange (SSIE)	110 000	Research in progress from the Smithsonian Science Information Exchange	. . .	110
IDC/Libcon	850 000	Libcon includes most of the material in the comprehensive catalogs of the Library of Congress from 1965 to date, including titles from the National Program for Acquisitions and Cataloging	. . .	120
Matrix	15 000	Communications, including media, carriers, communication machines, Government	. . .	120
IFI Plenum/GEM	10 000	General electrical and mechanical patents	150	. . .

typically a monthly fee based only on the actual terminal connect time to the system plus the cost of off-line printouts of citations. Search-time rates vary from about $25 to $150 per hour, depending on the data base used, and printouts range from 10 to 20 cents per off-line print.

Computerized search requires a terminal. If one is not available from the user's company's time-shared computing service, a 30-character-per-second terminal can be leased for about $120 per month or purchased for $2500 to $3000.

Communications costs consist of a fee of about $10 per hour if Tymnet or a similar communications service is used plus telephone-line costs, if any, to the nearest Tymnet number or node.

Taking all of these costs into consideration, the average search of 10 to 15 minutes costs from about $7 to $20 (assuming a Tymnet connection and 20 off-line prints at 10 cents each).

What data bases are available?

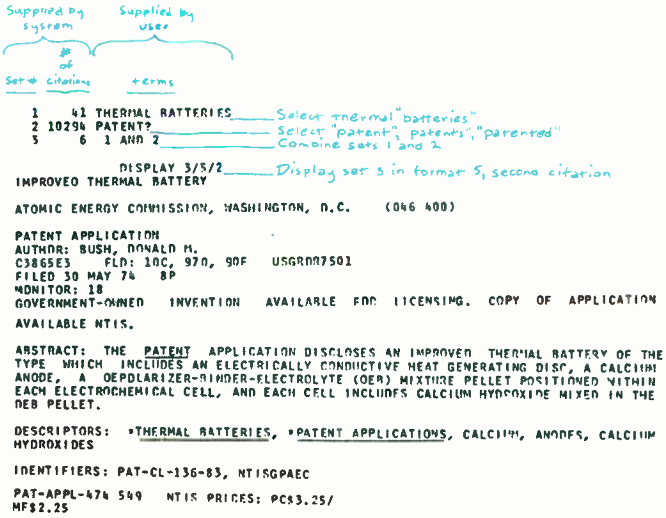
Any retrieval system is only as good as its collection of data bases. Commercial on-line services have data bases available ranging from technical ones, such as engineering data bases, to social science and business data bases. Table I summarizes those data bases of most use to the electrical/electronics engineer, the services that offer these bases, and their prices. It should be noted that, in comparing data bases in Table I, the cost of a search depends not only on the price per hour but also on the system features. Other cost factors are the skill of the searcher and the complexity of the search.

The user normally selects the data base to be searched on the basis of the likelihood that it will contain the desired references. Cost of access to the data base, availability of source documents, and other considerations also affect the decision. For example, the U.S. Government Reports data base from the National Technical Information Service (NTIS) contains valuable references, but it may take two to three weeks to receive the results of a search. If search results are needed in a hurry, it might be preferable to use the IEE INSPEC data base or the Engineering Index Compendex data base, both of which abstract the more readily obtainable periodical literature. These two data bases contain complete abstracts that sometimes eliminate the necessity for reading the actual source document.

Business data bases have been included in Table I because they provide a wealth of information on the marketing and production aspects of the electrical/electronics fields.

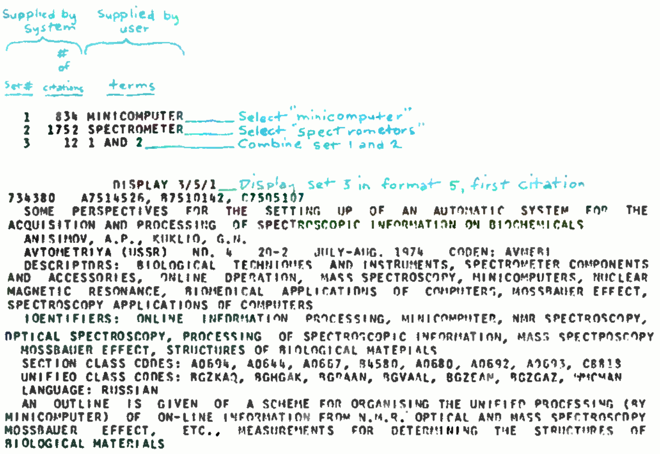
How does computerized retrieval work?

To use a typical retrieval terminal which is acoustically coupled to a telephone line, the telephone number of the retrieval service is dialed. After a high-fre-



```
   1     41 THERMAL BATTERIES
   2  10294 PATENT?
   3      6  1 AND 2

                DISPLAY 3/5/2
 IMPROVEO THERMAL BATTERY

 ATOMIC ENERGY COMMISSION, WASHINGTON, D.C.    (046 400)

 PATENT APPLICATION
 AUTHOR: BUSH, DONALD M.
 C3865E3     FLD: 10C, 970, 90F    USGRDR7501
 FILED 30 MAY 74    8P
 MONITOR: 18
 GOVERNMENT-OWNED   INVENTION   AVAILABLE  FOR  LICENSING.  COPY  OF  APPLICATION

 AVAILABLE NTIS.

 ABSTRACT:  THE  PATENT  APPLICATION DISCLOSES AN IMPROVED  THERMAL BATTERY OF THE
 TYPE  WHICH  INCLUDES AN ELECTRICALLY CONDUCTIVE HEAT GENERATING DISC, A CALCIUM
 ANODE,  A  OEPDLARIZER-BINDER-ELECTROLYTE (OEB) MIXTURE PELLET POSITIONED WITHIN
 EACH ELECTROCHEMICAL CELL, AND EACH CELL INCLUDES CALCIUM HYDROXIDE MIXED IN THE
 DEB PELLET.

 DESCRIPTORS:  *THERMAL BATTERIES, *PATENT APPLICATIONS, CALCIUM, ANODES, CALCIUM
 HYDROXIDES

 IDENTIFIERS: PAT-CL-136-83, NTISGPAEC

 PAT-APPL-474 549   NTIS PRICES: PC$3.25/
 MF$2.25
```

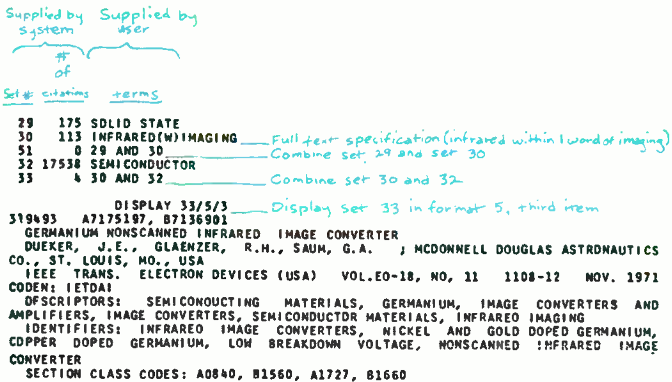
[1] **Results of a computerized on-line retrieval search, using the NTIS Government documents data base, for references that might contain answers to the question, "What are the recent patents on thermal batteries?"**



```
   1    834 MINICOMPUTER
   2   1752 SPECTROMETER
   3     12 1 AND 2

                DISPLAY 3/5/1
734380   A7514526, B7510142, C7505107
  SOME  PERSPECTIVES  FOR  THE  SETTING  UP  OF  AN  AUTOMATIC  SYSTEM  FOR  THE
ACQUISITION AND PROCESSING  OF SPECTROSCOPIC INFORMATION ON BIOCHEMICALS
  ANISIMOV, A.P., KUKLIO, G.N.
  AVTOMETRIYA (USSR)   NO. 4   20-2   JULY-AUG. 1974   CODEN: AVMERI
  DESCRIPTORS:  BIOLOGICAL  TECHNIQUES  AND INSTRUMENTS, SPECTROMETER COMPONENTS
AND  ACCESSORIES,  ONLINE  OPERATION,  MASS SPECTROSCOPY, MINICOMPUTERS, NUCLEAR
MAGNETIC  RESONANCE,  BIOMEDICAL  APPLICATIONS  OF  COMPUTERS, MOSSBAUER EFFECT,
SPECTROSCOPY APPLICATIONS OF COMPUTERS
  IOENTIFIERS:  ONLINE  INFORMATION  PROCESSING, MINICOMPUTER, NMR SPECTROSCOPY,
OPTICAL SPECTROSCOPY, PROCESSING  OF SPECTROSCOPIC INFORMATION, MASS SPECTROSCOPY
 MOSSBAUER EFFECT, STRUCTURES OF BIOLOGICAL MATERIALS
 SECTION CLASS CODES: A0694, A0644, A0667, B4580, A0680, A0692, A0693, C8815
 UNIFIEO CLASS CODES: BGZKAQ, BGHGAK, BGPAAN, BGVAAL, BGZEAM, BGZGAZ, WMCMAN
 LANGUAGE: RUSSIAN
 AN  OUTLINE  IS  GIVEN  OF  A SCHEME FOR ORGANISING THE UNIFIED PROCESSING (BY
MINICOMPUTER)  OF  ON-LINE INFORMATION FROM N.M.R. OPTICAL AND MASS SPECTROSCOPY
MOSSBAUER   EFFECT,   ETC.,  MEASUREMENTS   FOR   DETERMINING   THE   STRUCTURES   OF
BIOLOGICAL MATERIALS
```

[2] **Searching the IEE INSPEC electrical engineering data base gave these references in answer to the question, "Has a minicomputer been used to process spectrometer data?"**

[3] **The question, "What solid-state imaging techniques are used for infrared systems?," brought the below responses from the IEE INSPEC physics data base.**



```
 29    175 SOLID STATE
 30    113 INFRARED(W)IMAGING
 31      0 29 AND 30
 32  17538 SEMICONDUCTOR
 33      4 30 AND 32

              DISPLAY 33/5/3
319493   A7175197, B7136901
  GERMANIUM NONSCANNED INFRARED  IMAGE CONVERTER
  DUEKER,  J.E.,  GLAENZER,  R.H., SAUM, G.A.   ; MCDONNELL DOUGLAS ASTRONAUTICS
CO., ST. LOUIS, MO., USA
  IEEE  TRANS.  ELECTRON DEVICES (USA)   VOL.EO-18, NO, 11   1108-12   NOV. 1971
CODEN: IETDAI
  DESCRIPTORS:   SEMICONOUCTING   MATERIALS,  GERMANIUM,  IMAGE  CONVERTERS  AND
AMPLIFIERS, IMAGE CONVERTERS, SEMICONDUCTOR MATERIALS, INFRAREO IMAGING
  IDENTIFIERS:  INFRAREO  IMAGE  CONVERTERS,  NICKEL  AND  GOLD DOPED GERMANIUM,
COPPER  DOPED  GERMANIUM,  LOW  BREAKDOWN  VOLTAGE,  NONSCANNED  INFRARED  IMAGE
CONVERTER
  SECTION CLASS CODES: A0840, B1560, A1727, B1660
  INFRARED  IMAGE  CONVERTERS  USING  NICKEL  AND GOLO DOPED GERMANIUM HAVE BEEN
BUILT.  THESE  DEVICES  PROVIDE IMAGE BRIGHTNESS UP TO 1 FL AND RESOLUTION OF 25
LINE  PAIRS/CM.  THE DEVICES ARE WITHIN A FACTOR OF 100 AND 10, RESPECTIVELY, OF
:SEEING:  2-5  MUM  RADIATION FROM AN AMBIENT TEMPERATURE (=300 DEGREESK) SCENE.
COPPER  DOPED  WAS  ALSO  STUDIED, BUT WAS FOUND TO HAVE A LOW BREAKDOWN VOLTAGE
RENDERING IT UNUSABLE FOR THESE DEVICES   (11 REFS)
```

quency modulation tone is obtained, the telephone handset is placed in the recess provided in the terminal. Once a password is entered, search terms—words that are relevant to a search topic—are entered. The computer will then respond, usually within a few seconds, with the results of searching the data base for citations containing the search terms. In addition to the title, author, source, and abstract, all of which can be used as the basis for a search, descriptors and identifiers are also provided.

Before going on line, the searcher must determine whether or not the question to the retrieval system is well posed. For example, is the question too broad or too narrow and are there appropriate data bases which cover the topic area? Vocabulary lists and the engineer's and librarian's knowledge are then used to determine at least some provisional search terms. Once on line, the searcher can determine the effectiveness of the provisional strategy, modifying it as appropriate. The computer can also be used to browse indexing terminology, document citations and abstracts, and on-line thesauri of conceptually close terms to identify other potentially useful search terms.

Actual on-line search consists of locating a set of citations that satisfies a particular search term. Sets of citations are then combined using the AND, OR, NOT operators. The user can display the citations for any of the sets and use the display to determine the success (or failure) of the search.

What are some typical search examples?

The following search examples are taken from the Lockheed Dialog system. Although it differs somewhat in search format from the SDC Orbit system, both are based on a search using AND, OR, and NOT operators. In these examples, the SELECT, COMBINE, and EXPAND commands of Dialog will be used. There are equivalent commands in the Orbit system. To illustrate actual searches, some of the typical questions posed earlier will be utilized. Although there are several shortcuts that can be employed by the experienced searcher, a more extensive form is used here for clarity in illustration.

What are the recent patents on thermal batteries? To make a search on this question, the NTIS data base is a good choice because it is a source for Government

On-line retrieval in the public library

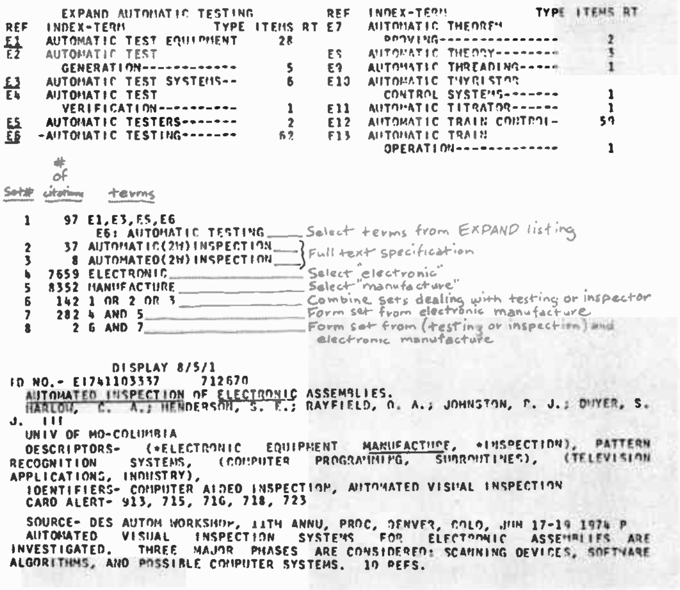
In a study sponsored by the National Science Foundation, information retrieval terminals have been installed in four public libraries in the state of California. In the first year of the two-year program, patrons were offered free retrieval service. In the second year, currently underway, the libraries are charging patrons one-half normal fees.

Public response for the first year (see Firschein, O., and Summit, R. K., "Providing the public with online access to large bibliographic data bases," 2nd U.S.A.–Japan Computer Conference, Tokyo, Japan, Aug. 1975) was enthusiastic. More than 70 percent of the patrons felt that the results of their searches were of considerable or major value. It is too early in the second year pay program to tell what the public response will be.

patents available for licensing. As shown in Fig. 1, the search term "thermal batteries" is used. The system indicates that there are 41 citations for thermal batteries forming "set" 1. Next, the term "patent?" is selected with the question mark used to take care of plural endings. The system indicates that there are 10 294 citations forming set 2. Sets 1 and 2 are combined using the AND operator and the system indicates that there are six citations satisfying both thermal batteries and patent(s). Figure 1 shows a typical citation in set 3 (set 1 and set 2), which happens to be an Atomic Energy Commission patent.

Has a minicomputer been used to process spectrometer data? For this question, the Institution of Electrical Engineers (England) INSPEC data bases on electrical engineering are used. As shown in Fig. 2, the first SELECT is minicomputer, the second SELECT is spectrometer, and then COMBINE gives 12 citations. A typical citation in the combined set is the one shown in Fig. 2. Since the source is a foreign publication in a foreign language, it is desirable to display a more accessible reference. The citation illustrated is used, however, to pick up additional descriptor terms such as "spectroscopy applications of computers," "mass spectroscopy," and "on-line operation" to continue the search.

"What solid-state imaging techniques are used for infrared systems" proved to be a question requiring a certain amount of ingenuity on the part of the searcher. To answer the question, another INSPEC base (physics) was used with the SELECT, "solid state." A set of 175 citations was obtained. A full-text search was then used, asking for citations in which the term "infrared" appears adjacent to the term "imaging." (The general form for such a request is INFRARED [*n*W] IMAGING, where *n* indicates that IMAGING should be within n words of INFRARED.) This request resulted in 113 citations. But when the solid-state and infrared imaging sets were combined, Fig. 3, no citations resulted that contained both terms. The next SELECT is then a very general term, "semiconductor," to form a set with 17 538 citations. When this set was combined with "infrared imaging," four citations were obtained, one of which is shown in Fig. 3.



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         EXPAND AUTOMATIC TESTING              REF   INDEX-TERM                TYPE ITEMS RT
REF   INDEX-TERM                TYPE ITEMS RT E7    AUTOMATIC THEOREM
E1    AUTOMATIC TEST EQUIPMENT         28             PROVING---------------        2
E2    AUTOMATIC TEST                           E8    AUTOMATIC THEORY--------        3
        GENERATION------------          5      E9    AUTOMATIC THREADING-----        1
E3    AUTOMATIC TEST SYSTEMS--          6      E10   AUTOMATIC THYRISTOR
E4    AUTOMATIC TEST                                  CONTROL SYSTEMS-------        1
        VERIFICATION----------          1      E11   AUTOMATIC TITRATOR------        1
E5    AUTOMATIC TESTERS-------          2      E12   AUTOMATIC TRAIN CONTROL-       59
E6   -AUTOMATIC TESTING-------         62      E13   AUTOMATIC TRAIN
                                                      OPERATION-------------        1

        #
        of
Set#  citations    terms

  1     97 E1,E3,E5,E6
           E6: AUTOMATIC TESTING_____Select terms from EXPAND listing
  2     37 AUTOMATIC(2W)INSPECTION___}
  3      8 AUTOMATED(2W)INSPECTION___}Full text specification
  4   7659 ELECTRONIC________________Select "electronic"
  5   8352 MANUFACTURE_______________Select "manufacture"
  6    142 1 OR 2 OR 3_______________Combine sets dealing with testing or inspector
  7    282 4 AND 5___________________Form set from electronic manufacture
  8      2 6 AND 7___________________Form set from (testing or inspection) and
                                      electronic manufacture

             DISPLAY 8/5/1
ID NO.- EI741103337      712670
  AUTOMATED INSPECTION OF ELECTRONIC ASSEMBLIES.
  HARLOW, C. A.; HENDERSON, S. E.; RAYFIELD, O. A.; JOHNSTON, P. J.; DWYER, S.
J. III
  UNIV OF MO-COLUMBIA
  DESCRIPTORS- (*ELECTRONIC EQUIPMENT MANUFACTURE, *INSPECTION), PATTERN
RECOGNITION SYSTEMS, (COMPUTER PROGRAMMING, SUBROUTINES), (TELEVISION
APPLICATIONS, INDUSTRY),
  IDENTIFIERS- COMPUTER AIDED INSPECTION, AUTOMATED VISUAL INSPECTION
  CARD ALERT- 913, 715, 716, 718, 723

  SOURCE- DES AUTOM WORKSHOP, 11TH ANNU, PROC, DENVER, COLO, JUN 17-19 1974 P
  AUTOMATED VISUAL INSPECTION SYSTEMS FOR ELECTRONIC ASSEMBLIES ARE
INVESTIGATED. THREE MAJOR PHASES ARE CONSIDERED: SCANNING DEVICES, SOFTWARE
ALGORITHMS, AND POSSIBLE COMPUTER SYSTEMS. 10 REFS.
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[4] Using the EXPAND command when interrogating the Engineering Index (Compendex) data base made it possible to obtain references in response to the question, "What recent work has been done on automated inspection and testing of electronic assemblies?"

What recent work has been done on automated inspection and testing of electronic assemblies? To obtain citations in response to this question, the Engineering Index Compendex data base was chosen. Since it was not known whether the term "automatic testing" appears in the data base, the EXPAND command was put to use to obtain the display shown in Fig. 4. From the display, it is possible to SELECT alphabetically close terms such as "automatic test equipment," "automatic test systems," and "automatic testers," as well as the original term, by using the appropriate "E" number references; E1, E3, E5, and E6. The rest of the search is straightforward, using both full text and term specification. The procedure gave two citations, one of which is shown in Fig. 4.

What about updating?

Once a search has been formulated on the Dialog system, its search command sequence can be stored in the computer. It is then possible for the user to receive updates on the search as the data base is updated with additional references. This selective dissemination of information (SDI) can keep the engineer informed of work in the field almost as soon as it is published.

Because SDI results are generated and printed in an off-line mode, and a significantly smaller file is searched (only the updates), updates are available at a more economical rate than original searches. ◆

For further reading

For a comprehensive description of on-line retrieval systems, the following two books are useful:

- Summit, R. K., and Firschein, O., chapter 8 in *Document Retrieval Systems and Techniques*. Washington, D.C.: American Society for Information Science, 1974, vol. 9, pp. 285–331.
- Lancaster, F. W., and Fayen, E. G., *Information Retrieval On-Line*. Los Angeles, Calif.: Melville Publishing Co., 1974.

For detailed descriptions of the Dialog and Orbit retrieval systems, descriptive material may be obtained from Lockheed Information Systems, 3251 Hanover St., Palo Alto, Calif. 94304; and SDC Search Service, 2500 Colorado Ave., Santa Monica, Calif. 90406.

A complete discussion of on-line search costs is given in the article:

- Lawrence, B., Weil, B. H., and Graham, M. H., "Making online search available in an industrial research environment," *Journal of the American Society for Information Science*, pp. 364–369, Nov.–Dec. 1974.

Oscar Firschein (M), a research scientist at the Lockheed Palo Alto Research Laboratory, is presently the principal investigator for a National Science Foundation study of the use of on-line retrieval terminals in a public library setting. For further details on Mr. Firschein, see *IEEE Spectrum*, July 1974, p. 48.

The EE at leisure

Scores of readers responded to *Spectrum*'s mini-study of how they invest, or while away, their spare hours

Though different in many ways, leisure and work activities may be highly interactive. While a job can pay for or prohibit leisure activities, the quality of a worker's leisure time may well determine, as much as does the job, how satisfied that worker feels with life in general. An involved, happy engineer is likely to be performing well in all of life's arenas. And, as one of *Spectrum*'s editors put it, leisure that is fruitful can be a solid measure of a man—or woman.

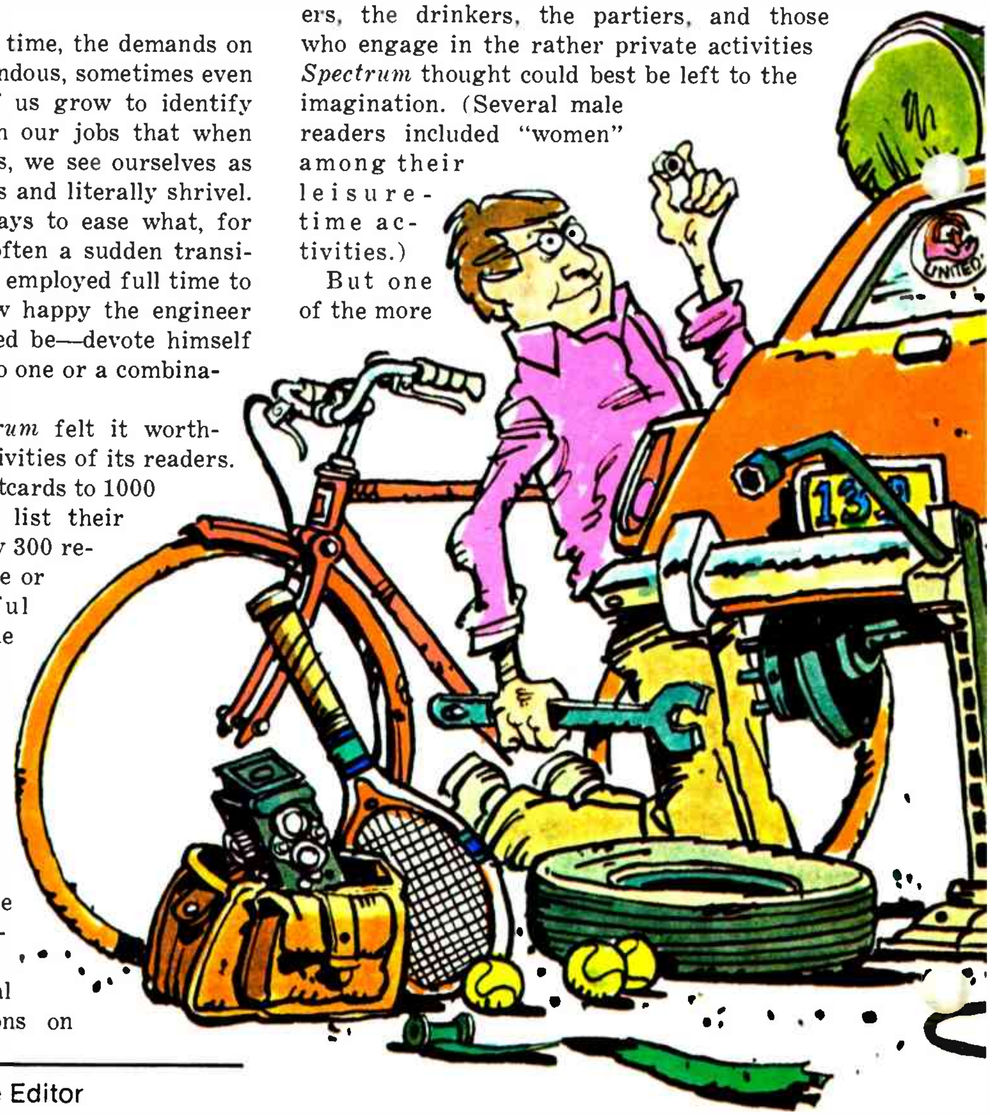
Further, and particularly applicable to the engineer, leisure pursuits today may be vital to the psychological resilience of the worker faced with retirement tomorrow. Modern medicine has increased longevity and, at the same time, heightened the trauma of retirement for many citizens. How is the retiree to stay mentally alert and emotionally fulfilled through the long days of retirement that can seem horizonless?

When there is only leisure time, the demands on personal resources are tremendous, sometimes even overwhelming. Too many of us grow to identify ourselves so thoroughly with our jobs that when those jobs are taken from us, we see ourselves as shadows of our former selves and literally shrivel. Certainly one of the best ways to ease what, for engineers especially, is too often a sudden transition, is to have learned while employed full time to develop those resources. How happy the engineer who could—tomorrow, if need be—devote himself full time, year in, year out, to one or a combination of leisure-time pursuits!

For these reasons, *Spectrum* felt it worthwhile to probe the leisure activities of its readers. To do this, *Spectrum* sent postcards to 1000 readers requesting them to list their leisure-time activities. Nearly 300 responded, many claiming three or more activities. A handful claimed to have no leisure time whatsoever and only a few respondents listed TV-viewing as one of their activities. The latter suggests one difficulty in interpreting the survey results: respondents who formed their own opinions about the intent of the survey may have overlooked activities as common as TV-watching or as serious as political or social involvement. The illustrations on page 75 group all activities mentioned at least five times. Unique activities are described on page 74.

Most of *Spectrum*'s EE respondents turn to sports when they find some hours to spare away from the office. Mentioned nearly 500 times, the general category of sports is almost as popular as all the other activities combined. Does this say that the engineer—bound to a desk and/or workbench for 40 hours a week—craves physical exercises and shuns mental exercise? Not entirely. Many of the respondents listed a variety of crafts and hobbies (250 mentions) from astronomy to electronics experimenting to photography—pursuits that clearly require a measure of intellectual application. On the other hand, a substantial number of *Spectrum*'s respondents apparently require little or no exercise of any sort—be it mental or physical. This group includes the self-professed movie-goers, the eaters, the drinkers, the partiers, and those who engage in the rather private activities *Spectrum* thought could best be left to the imagination. (Several male readers included "women" among their leisure-time activities.)

But one of the more

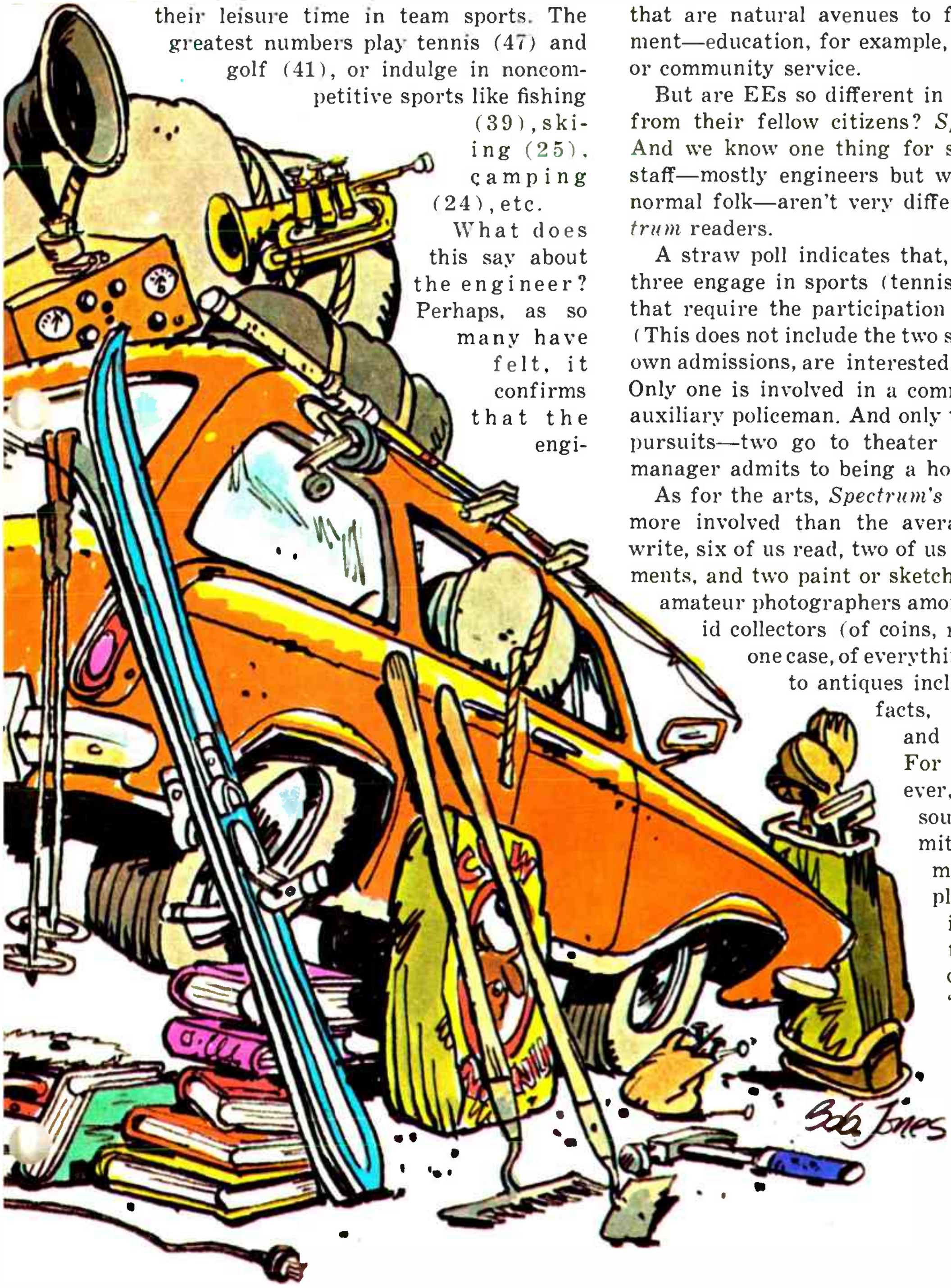


Ellis Rubinstein Associate Editor

remarkable aspects of *Spectrum*'s survey results is the apparent lack of social interaction in the bulk of leisure-time activities mentioned. There were only 60 mentions (out of 1000) of anything that could be construed as a community activity, for example. Twenty of these were church-related activities. Another eight involved fraternal, or service, organization membership. Two scattered references indicated political interests. Three respondents were volunteer firemen. Two others belonged to the U.S. Power Squadron. And only one *Spectrum* reader who responded to the survey was a member of his local school board.

By far the vast majority of EEs appear to spend their free time in pursuits that can be accomplished in isolation: 54 in the survey are amateur photographers, 52 enjoy gardening, 48 are readers. Even in the category of sports, there were no more than a handful of respondents who spend their leisure time in team sports. The greatest numbers play tennis (47) and golf (41), or indulge in noncompetitive sports like fishing (39), skiing (25), camping (24), etc.

What does this say about the engineer? Perhaps, as so many have felt, it confirms that the engineer is socially uninterested or, worse, inept. At the very least, it suggests that the EE tends to be a loner. Further, it relates directly to the observations made earlier about the importance of fruitful leisure-time activities as a hedge against the trauma of retirement. While many of the activities listed by our sample readers are without doubt providing the kind of immediate gratification that makes it easier to set out for work each morning, few seem likely to replace the job as sources of fulfillment *apart from* that job. How many engineers will feel that playing tennis everyday—or gardening or shooting pictures—satisfies their inner need to feel productive?



Some perhaps, but others, used to a "life's work," can only feel a great sense of loss at retirement. When the illustrations showing the *Spectrum* readers' choices in leisure activities are analyzed, one finds a significant dearth of the kinds of pursuits that are natural avenues to fulfillment in retirement—education, for example, or productive skills, or community service.

But are EEs so different in their leisure choices from their fellow citizens? *Spectrum* thinks not. And we know one thing for sure: The *Spectrum* staff—mostly engineers but with a smattering of normal folk—aren't very different from the *Spectrum* readers.

A straw poll indicates that, of 20 staffers, only three engage in sports (tennis, judo, and frisbee) that require the participation of a second person. (This does not include the two staffers who, by their own admissions, are interested in sexual athletics.) Only one is involved in a community activity—an auxiliary policeman. And only three admit to social pursuits—two go to theater and our production manager admits to being a hooker (of rugs).

As for the arts, *Spectrum's* staff is only slightly more involved than the average EE—five of us write, six of us read, two of us play musical instruments, and two paint or sketch. There are also five amateur photographers among us, and three rabid collectors (of coins, rock records, and, in one case, of everything from first editions to antiques including printers' artifacts, woodworking tools, and electronic gear).

For the most part, however, we are sedentary souls. We abashedly admit to watching too much television, to playing games and doing puzzles, and, in two cases, to "navel contemplation" and "regretting." Perhaps after contemplating his own paltry list of leisure activities, this writer too will add "regretting" to his leisure-time routines.

Map-maker extraordinaire

Spectrum reader S. Paul Otsuka is a project engineer for the Hughes Aircraft Company's Electron Dynamic Division where he designs and supervises the construction of traveling-wave tubes for military and commercial satellite communication. But in addition, reader Otsuka has two unusual hobbies that absorb much of his free time. On the one hand, he is a veteran amateur astrophotographer; on the other, he is a neophyte, but already accomplished, amateur cartographer.

About a year ago, Mr. Otsuka began creating three-dimensional maps like that of the western portion of California's Palos Verdes Peninsula (shown in the illustration) where he presently makes his home. This project represented reader Otsuka's first attempt to follow through on a childhood interest in 3-D cartography. Finding his local library without either books or magazines on the subject, he determined that he would develop his own techniques using "the cut and try method." Says EE hobbyist Otsuka, "I started with U.S. Geological Survey topographic maps and made Xerox copies. My other principal raw material is 0.025-inch-thick cardboard. This thickness gives about a 4 to 1 height exaggeration if one uses one sheet per 20 feet of elevation. The cutting of the map starts from the highest elevation and progresses toward sea level. The highest elevation on the Palos Verdes map is about 1200 feet. With 0.025-inch-thick cardboard for each 20 feet of elevation, it required some 60 layers. It takes one to two hours to cut the contour on one layer and paste it onto the next layer. So, during a time span of about one-half year, it took 100 hours to finish this western portion of the peninsula; I hope to complete the entire peninsula some day."

Icarus, EE

Marvin Ortbals, an Oklahoman, an EE, and a *Spectrum* reader, is director of transmission system planning for the Western Farmers Electric Cooperative in Anadarka, Okla. Mr. Ortbals writes: "I have always been interested in construction projects, beginning with model airplanes. I have been interested in flying for as long as I can remember." Put the two together and you have a modern-day Icarus who is building his own airplane in his own home workshop.

Reader Ortbals is not working from scratch; he's using a kit. But even so, this little hobby is estimated to require 1000 hours of his time, if not a prohibitive amount of money. If you're interested in this kind of hobby, EE Ortbals recommends Bede Aircraft, Inc., Municipal Airport, Newton, Kans. 67114.

At least, he hopes he can safely recommend this kit-maker—so far, he's still working on the wings. *Spectrum* wishes him more luck than the original Icarus had.

The man from MARS

Prevented for years from practicing his favorite hobby because, as an alien in the U.S., he couldn't get a ham radio license, former chief engineer Jack Ball, now in retirement, has become an amateur radio expert and a *bona fide* member of Air Force MARS. No, *Spectrum*-reader Ball is not a Martian; his one-time alien status stems from an English birth (so he claims), and MARS is an acronym for "military affiliate radio system."

Joking aside, Mr. Ball regards his participation in MARS as rewarding. "We handle morale communication for armed forces and U.S. Government civilian personnel throughout the world. The messages are transmitted abroad and across the U.S. on HF, and state-wide on VHF. We also provide emergency communications and are in the process of setting up a local 2-meter repeater on allotted MARS frequencies."

Mr. Ball also holds the positions of ASMD (Assistant State MARS Director) Ohio, and Geauga County (Ohio) Disaster Services Technical Systems Coordinator, Radio and Media. And as if all this weren't enough, hobbyist Ball notes: "In my spare time, I got interested in slow-scan TV in the HF spectrum of amateur radio. This allows contacts to be made the world over."

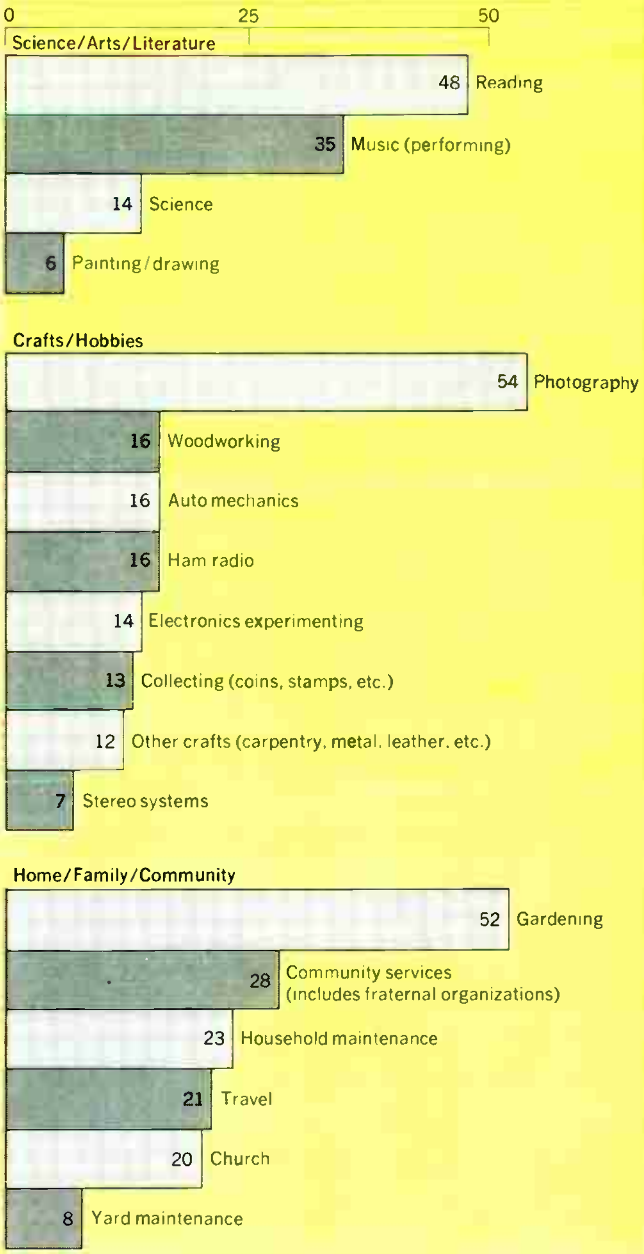
No wonder Mr. Ball can credibly say, "I find myself as busy as ever since my retirement."

Give me a home where my reptiles can roam . . .

Jimmy L. Clements, a young Corpus Christi EE, and his girl friend recently became interested in snakes. Today, Mr. Clements has four sizable serpents slithering about his domicile. These include:

- One 4-ft-long African ball python, "so called because of its habit of curling into a tight ball whenever it feels threatened."
- One 2-ft-long Indian rock python—a three-month-old baby that will eventually measure a mere 22 ft in length and 1 ft in diameter.
- And two red-tailed South African boa constrictors—one, an 18-inch infant; the other, a four-footer.

Mr. Clements, who is chief administrator of an electrical contracting firm bearing his name, insists that snakes are easy to care for. His are nonvenomous, purportedly tame, and require only: "A cage with a water bowl, a branch to wind around, a weekly cleaning, and a few mice to swallow . . . whole." As for Clements himself, his girl friend tells *Spectrum* that he is similarly easy to care for. He's also nonvenomous, relatively tame, and requires only a roof over his head, a desk to work at, an occasional shower, and a few snakes and mice for diversion.



Bees, snakes, rabbits, and other creatures great and small

What secret hobbies
lurk in the minds of EEs?
Spectrum knows . . .

Scattered across the rather arid landscape of EE leisure-time activities are sudden surprises—here a blooming flower, there a dark thicket—surprises too rare to be mapped in the illustrations above. Somewhere in your firm—perhaps the fellow you lunch with, your colleague at the workbench, your employer or employee—there may be an EE who quietly goes about his work by day. But at night or on the weekends, safe from the intrusive eyes and gossiping tongues of his fellow IEEE members, this apparently mild-mannered technologist may be engaged in the most bizarre activities.

In the course of its survey, *Spectrum* has uncovered several such "closet hobbyists" among its readers and, as a public service, we reveal, for the first time in print, examples of the kinds of activities that could be going on in your community!

Somewhere in the vast United States (only *Spectrum* knows where and we have brought this to the attention of the local authorities), there is a no-doubt bespectacled EE who is raising rabbits for meat! Further, there is an engineer who secretly controls a growing apiary—a veritable honeycomb of hives—wherein an armada of bees buzz at his command. And there are: a snake-raiser, no less than three fellows who indulge a mad obsession for caves, and one reader who proclaims a "mild interest in boomerangs."

But what of the engineer who wrote *Spectrum* that he is deeply involved in "multilevel symbolic communication techniques," and in "noncorporeal Christology"? Could this be the first EE to effect the teleportation of his soul?

Inside amateur radio

Devoted to public service transcending geographical and political boundaries, today's ham is not a mere tinkerer

An off-duty taxicab driver points his antenna in a predetermined direction, carefully tunes his receiver around an expected frequency, and picks up satellite tracking beacons. A student—a grade-schooler—flicks a switch and she and her classmates are greeted from outer space. A mother paces back and forth in the corridor of a Colombian hospital while her daughter lies unconscious in an intensive-care unit. Thousands of miles away in Cincinnati, Ohio, an amateur radio operator picks up a medical emergency: a Colombian child will die without drugs only two hospitals—one in Chicago, the other in California—can provide. A few phone calls and the drugs are on their way to Bogota.

Amateur, or "ham," radio has come a long way from the early days of often idle chatter between radio pen pals. Its purposes can be profound and its technology can be sophisticated. Solid-state transistors have replaced audions. Synchronous spark gaps are no longer rotated by the motor of mom's Maytag washer. But hams—the last of the great tinkerers in an age when industrial team research has made of the individual experimentor an endangered species—keep fiddling and transmitting. And with the advent of satellites exclusively for hams, amateur radio has entered the space age. At the fingertips of every amateur radio operator are the satisfactions that can be had from international camaraderie, public service, and education—both cultural and scientific.

Although this picturesque setting is in Scotland, hams throughout the world do it—make field calibrations, that is!

Ragchewers, International

One of the great joys of the amateur radio operator has always been "chewing the rag" with hams far removed from home base. "Ragchewing" is radio jargon for the kind of chatter that can result in friendships that know no boundary—be it geographical, cultural, economic, or even political.

Through a language of international recognized *Q* signals, routine exchanges can be made in code without extensive knowledge of another language. And with the current widespread use of English, relaxed chats on single-sideband (SSB) voice communications with hams in locations as diverse as the Ukraine, Japan, or Sikkim are not unusual. Dialogue usually includes all manner of shop talk—from modes and equipment to propagation conditions. In the end, these interactions often provide a catalyst for synergistic accomplishment, resulting in such positive results as a new antenna design, a keyer, or even a personal friendship.

Judith C. Gorski *QST*

December 12, 1961, was a monumental day in the history of amateur radio—one that saw the addition of a new dimension to the hobby. On that Tuesday, a Thor-Agena rocket surged from its launch pad carrying the world's first nongovernmental, noncommercial satellite—called Oscar, for "orbiting satellite carrying amateur radio." Designed and built by radio amateurs themselves, the ten-pound "homemade" satellite transmitted the greating "hi" in Morse code to radio hams on all continents during its trips around the world.

A succession of ham satellites have followed. Oscar-6 was launched by the National Aeronautics and Space Administration in October 1972 and, at last report, it was still being used by some 2400 radio amateurs in 87 countries and all 50 states of the U.S. Late last year, NASA launched Oscar-7, the most complicated in the series and the culmination of a four-year Radio Amateur Satellite Corporation (AMSAT) project, which will not only be able to talk to children in classrooms, but to transmit hurricane warnings, relay important medical information to isolated areas, and provide other emergency communications functions.

Ham and education

Some of the most vital of today's novel applications of amateur radio are in the educational sphere. This is true at far more sophisticated levels than the elementary school project mentioned at the outset. In one recent instance, a university research scientist beamed radio signals to bounce off an Oscar satellite orbiting 1000 miles above the earth. The purpose was to gather fundamental data about the propagation of radio waves through the upper atmosphere.

In the classroom, students, at all levels, are gaining hands-on experience in space science through an Oscar

What('s) a ham?

A "ham" or amateur radio operator is, according to the Federal Communications Commission (FCC), a person interested in radio technique solely with a personal aim and without pecuniary interest, holding a valid FCC license to operate amateur radio stations.

In the United States, the total number of licensed radio amateurs as of May 1974 was 255 111, a figure that can be misleading since not all hams are "on the air." As a matter of conjecture, it is the general belief that only 50 percent of licensed hams are active, since during a five-year license period some go inactive or are deceased. There are some 280 000 hams in Japan, 28 000 in Germany, 18 000 in the United Kingdom, 15 000 in the U.S.S.R., and 14 000 in Canada.

There are five grades of amateur licenses—Novice, Technician, General, Advanced, and Extra—of which the General class comprises 43.5 percent. Novices, who have an unrenewable license term of two years, make up 8.5 percent, while those amateurs proficient enough to qualify for the Extra class make up only 5 percent. The Technician class, for which a code speed of only 5 words per minute is required (like the Novice), is 19.1 percent of the total; and the Advanced class, with a code speed of 13 words/min, comprises 23.9 percent.

In general, a ham's station license is combined with his operator license, which is indicative of the type of activity he wishes to engage in. It is also possible for a ham to get a secondary station license (for added locations), as well as FCC permission to operate from a "portable" location. Repeater operation, whereby a licensed station automatically retransmits the signals of other ham stations, makes it possible to extend the range of relatively short-range frequencies, such as those of the two-meter band. It is significant that in every major metropolitan area there is an FM repeater of one sort or another. These are constantly monitored by control stations to make sure that users do not talk excessively long or use flagrant language. This is especially important since many repeaters can be heard for as far as 100 miles or even further.

As the largest ham society, ARRL has about 100 000 members in the U.S. alone, of which 87 000 are licensed amateurs and the balance nontransmitting associates; worldwide membership is about 112 000. Also headquartered in the U.S., the International Amateur Radio Union is a global federation of national noncommercial amateur radio societies designed to promote two-way radio communication.

Amateur frequencies available in the U.S. include 80 meters (3.5 to 4 MHz), down through 40, 20, 15, 10, 6, and 2 meters; other assignments include bands ranging from 220 MHz to 21 GHz, and all frequencies above 40 GHz. Although there are restrictions on the type of emission from band to band, the 160-meter band (1.8–2.0 GHz) is now severely limited in power, frequency, and geography because it is shared with Loran.

With the creation of citizen-band (CB) frequencies, there has been a diversion of many potential ham operators. Devoid of any code requirements, the CB user employs easily licensed equipment available from many sources; hence, the FCC has essentially lost control of this service. The self-policing aspects of ham operation—especially under the leadership of organizations like ARRL—are totally lacking in the CB service, whose vast numbers of unlicensed operators are beginning to regard it as a hobby service, which it was not originally meant to be.

The attitude of hams toward CB operators was reflected recently when a national electronics publication was deluged with irate mail for erroneously referring to CB operators as "hams."

Alexander A. McKenzie (LS), WA1RGF/W2SOU
Contributing Editor

Coming a long way

Amateur radio has come far since the days of "200 meters and down," when that portion of the spectrum was considered generally worthless and ceded to the amateurs. Today we find radio hams conversant with such sophisticated areas as VHF antenna gain and pattern measurements, RF power determination, and complex encoding, accessing, and switching systems; and they even have their own communication satellite. The potential of amateur radio for educational purposes is so vast (see article) that one wonders at the reluctance of many countries in the world to actively foster and support it. It is not surprising that those countries that hold a leading position in electronics today are the same who have encouraged amateur radio.

Technical development in ham radio over the years has been largely contributed to by those who engage in the art for its own sake. The pace and sophistication of modern research, however, have in general taken much of the development away from the amateur's basement and placed it in the professional laboratory. When we scratch beneath the thick skin of today's scientist or engineer, though, we frequently find that some of his early experience has been in ham radio.

The purpose of amateur radio is expressed differently in various parts of the world, ranging from true appreciation of its worth and value to a nation, to bare tolerance or contempt. The usual excuse for the latter is the great need for government or commercial spectrum space in the national interest, which precludes any greater consideration for the amateur service. But the largest nations are generally the most appreciative of amateur radio. Regardless of the country, however, amateurs consider their function to be in the national interest. Their record for providing communication in time of disaster and emergency is second to none, government and commercial facilities included. In fact, whenever the latter fail, it is the amateur who is counted on to fill the gap. Without a doubt, the ham has saved the world from much untold misery!

A conservative estimate of the world's amateur population by the year 2000 is almost 2 million. Throughout the history of international spectrum negotiation, portions allocated to the amateur have decreased, while their numbers have increased. No other service today utilizes its spectrum allocation as efficiently as the amateur service. Consideration of noise power and means of improving signal-to-noise ratios are almost second nature to amateurs. Speech compression results in practical bandwidth reductions of up to 800 Hz and an improvement in SNR of 6–12 dB. Furthermore, recent developments in speech bandwidth reduction have indicated significant future results in occupied bandwidth from 2:1 to at least 5:1, compared with presently utilized values.

The 1979 World Administrative Radio Conference of the ITU will consider reallocation of the entire usable radio spectrum. Since the last comparable conference in 1959, major portions of the international fixed public traffic have been transferred from HF circuits to submarine cables and satellites. The WARC in 1959 allocated approximately 50 percent of the spectrum from 3–30 MHz to the fixed service. Despite the multitude of possible uses of the HF spectrum, countries of the world should recognize the potentials of the amateur service in preparing their positions to be submitted to the ITU for the 1979 conference. Vast improvement in the amateurs' potential for communication in the HF and VHF/UHF should be urgently considered in light of their great increase in numbers, and their potential for operation in the national interests.

A. Prose Walker
Chief, Amateur and Citizens Division
Federal Communications Commission

educational program developed jointly by NASA and the American Radio Relay League (ARRL), the predominant amateur organization in the U.S. and Canada. Using inexpensive terminals to receive Oscar data, students find themselves immersed in a total sensory learning experience—listening for radio signals, manipulating equipment, and applying data collected firsthand to standard textbook formulas. They participate physically and emotionally, as well as intellectually, in what would otherwise seem abstract, even esoteric, topics.

Such pioneering pilot programs have been undertaken with good results at the Talcott Mountain Science Center in Avon, Conn., as well as in schools throughout the U.S. With educators at the Talcott center, the ARRL has prepared a comprehensive curriculum-supplement guide available to teachers. As headquarters, the Newington center acts as liaison between teachers and nearby area radio ham operators who are able to provide both the equipment and the expertise for demonstrations. Testifying to the success of the program, a Boston teacher reported: "Most of my students had never seen a communications receiver and had no conception of radio communications outside of what they had seen on television. The idea of actually being able to hear a satellite transmit, to plot its course, and to interpret the telemetry was sufficient to motivate the students to learn more."

Public service

- Driving on a slick road late one rainy evening, a mobile operator in Michigan spotted a car down an embankment with the driver slumped over the wheel. He alerted the police, who promptly arrived at the scene with emergency first-aid.
- A tornado raked an Arkansas town, resulting in fatalities, injuries, and extensive property damage. Although commercial communication lines went down, amateur nets relayed emergency traffic for the Red Cross.

As these stories indicate, service for the public good is another facet of ham radio's many dimensions. The log of communications handled in emergency situations by ham operators each year is impressively long. From routine aid to stranded motorists to the dramatic rescue of life during natural disasters, the amateur operator can, and often does, function in the role of a liaison for transferring essential information from one source to another.

To meet the heavy pressures generated by crisis situations, amateur radio clubs schedule mock emergency and training sessions to enable hams to operate under rigorous conditions, thus ensuring the smooth operation of existing traffic nets in time of crisis. In addition, field-day contests sponsored by the ARRL encourage operators to maintain portable, battery-powered equipment in peak running condition.

One extremely helpful public service performed by hams is that of *phone patching*, in which the operator by means of special equipment transmits the voice message of someone isolated in a remote area back to his home country, where the recipient hears it over normal telephone lines. This technique is used only in cases where no access to commercial telephone lines exists between two areas. Ham stations often accompany medical, missionary, or scientific expeditions to such remote areas as the Antarctic or the Andes Mountains of South America to put through just such morale traffic and emergency communications for the expedition members.

Yet, with the tremendous volume of emergency and morale-building traffic relayed by the amateur ham, one of his most significant contributions to public welfare spins off as still another dimension of the art. To be physically confined to a wheelchair in the silence of deafness and the darkness of blindness can be a lonely existence; yet such is the fate of many throughout the world. What better means for breaking these limitations than to have at one's fingertips equipment that knows few geographical boundaries? Through the *handi-ham* program, another ARRL-affiliated service, many physically handicapped individuals find companionship and vast geographic horizons at the flip of a switch. Placing the fingers inside the cone of a loudspeaker allows the deaf to copy the dots and dashes of Morse code by feel. Utilizing an instrument called Tellatouch—a sort of typewriter keyboard with Braille characters—allows the sightless to transmit. Club-sponsored programs are designed to aid the handicapped in obtaining licenses and thus discover a medium in which no physical limitations prevent their meeting people everywhere.

What's in the future?

To encourage the continued growth of amateur radio, the Federal Communications Commission recently issued Docket 20282, a proposal that aims at providing a broader licensing structure with a dual-ladder approach. After an extensive opinion survey of its 100 000 membership, ARRL filed a counterproposal that it feels represents the best interests of amateur radio.

In 1979, the General World Administrative Radio Conference of the International Telecommunication Union (ITU) will examine all existing international radio regulations affecting all services, including amateur radio. The all-important table of frequency allocations, which establishes ham bandwidths, will especially be subject to revision.

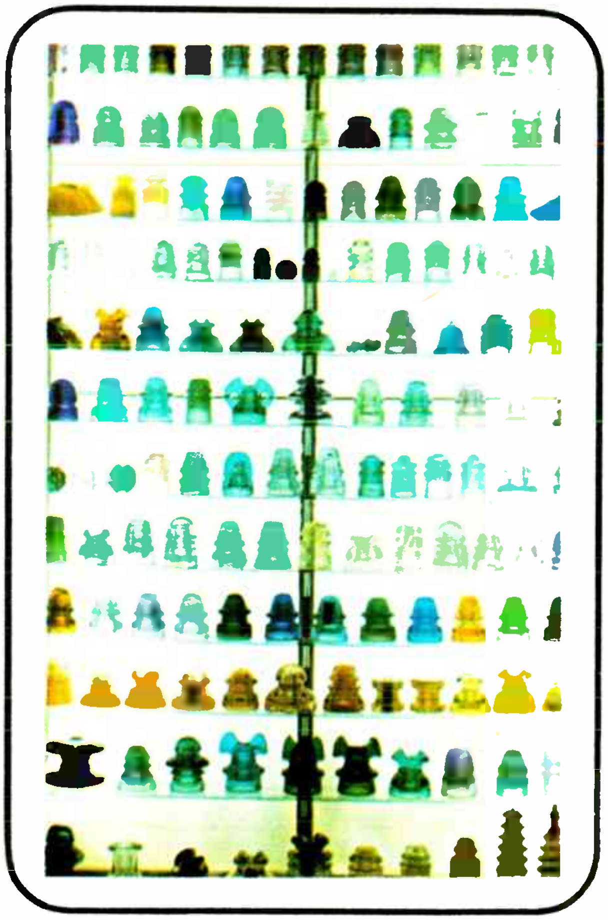
The health and fortune of ham radio, then, revolve around these major events. Whether amateur radio can continue to be both a fun pastime fulfilling the creative needs of its participants, and a viable national communications and educational resource, is a question that only time can answer. ◆

Judith C. Gorski is a staff member of *QST*, the official monthly journal of the American Radio Relay League (ARRL), which, as mentioned in the text, is the principal ham organization in the U.S. and Canada. Although perhaps unfamiliar to many *Spectrum* readers, *QST* has been around since December 1915, when it was first published and distributed at 10 cents a copy. The magazine serves as a rostrum for technical expertise, as a forum for ARRL member opinions and news, and as a synthesizer for the ham fraternity. Companion publications of the ARRL include a flock of how-to manuals and handbooks for beginners as well as experts. And ARRL headquarters at Newington, Conn., serves hams by answering difficult questions, testing products in its own laboratory, and providing summer apprenticeship training, local area courses to assist prospective hams to obtain their licenses, and instructional films and related materials.

A collector's guide to romance and nostalgia

Where to find antique vacuum tubes, TRF receivers, glass insulators, dc generators, and old trolley cars

Documenting the history of their profession seems to be a popular leisure-time pursuit among electrical and electronics engineers. Collectors and collections abound. Exhibitions range from one at the prestigious Smithsonian, where there are warehouses full of donations still to be unpacked, to small private collections of glass insulators or telegraph keys. The following list serves not only the dedicated historian but the casual sightseer who might be interested in anything from old-time trolleys to antique telephones to memorabilia of some of the profession's best-known pioneers. Exhibit locations are called out in blue so that readers can identify items of interest in their areas, and it should be noted that the list presents only a sampling of the many collectors and groups actively devoted to preserving the romance of engineering's past—and its artifacts.


Part of Esta Brown's collection of glass insulators.

American Radio Relay League, 225 Main Street, Newington, Conn. (near Hartford). Collection of antique amateur equipment.

Antique Wireless Association, Holcomb, N.Y. (near Rochester); Bruce Kelley, Secretary. Membership includes anyone in the profession interested in antique wireless. Collection is now housed in the Electronic Communication Museum (see below).

Automatic Electric Company, Northlake, Ill. Exhibition of early switching equipment in lobby.

Broadcast Pioneers Library, 1771 N Street, N.W., Washington, D.C. Features prints, books, etc., relating to the history of radio, as well as an ongoing oral-history project with some 200 interviews to date.

Brown Insulator Collection, Two Buttes, Colo. Gerald and Esta Brown's private collection of antique glass and porcelain insulators. May be seen by appointment.

Burndy Library, Norwalk, Conn. Although roughly half of Bern Dibner's collection, including the rarest items, has been donated to the Smithsonian (see below), the Library founded by Mr. Dibner still has many rare items (books, manuscripts, letters, etc.) relating to the history of science on display, as well as valuable reference material.

Canadian Bell Museum, Montreal, Que., Canada. Although emphasis is on development of the telephone, there is an exceptional display of early tubes and some radio equipment.

Columbia University Oral History Project, New York, N.Y. Taped interviews with radio personalities, including engineers such as Ernst Alexanderson.

Corpus Christi City Museum, Corpus Christi, Tex. Exhibition of rare commercial and broadcast equipment under supervision of Frank Smith, owner of local television station.

De Forest Pioneers, Inc.—Society of the Pioneer Associates of Dr. Lee De Forest. Secretary and Treasurer: Kenneth Richardson, 254 Vincent Avenue, Lynbrook, N.Y. Most of the De Forest memorabilia is now housed in the Foothill Museum (see below). Mr. Richardson has a small exhibit in his home of his own early inventions leading to present-day receivers and transmitters, which may be seen by appointment.

DeLaplaine Collection, 125 Georges Road, New Brunswick, N.J. Private collection of George DeLaplaine includes antique lamps, tubes, radio and wireless sets, wiring, Tiffany fixtures, electric automobiles. Shown to groups by appointment.

Edison Collection, in Henry Ford complex, Dearborn, Mich. Includes a museum of Thomas Edison

Evelyn Tucker News Editor

memorabilia and, in Dearborn Village, Edison's laboratory transported from Menlo Park.

Edison National Historic Site, Main Street, West Orange, N.J. Features a museum of Edison's inventions.

Electronic Communication Museum, East Bloomfield, N.Y.; in cooperation with the Town of East Bloomfield Historical Society. Antique Wireless Association's collection of more than 30 000 items ranging from Fleming valves and early Marconi equipment to World War I spark transmitters.

England Collection, 6651 Pollard Street, Los Angeles, Calif. Classic broadcast and early commercial receivers.

Foothill Electronic Museum, Foothill College, Space Science Center, 12345 El Monte Drive, Los Altos Hills, Calif. Includes the Douglas Perham collection of antique electronics, a complete exhibit of De Forest equipment (with Mrs. De Forest as adviser), the story of Federal Telegraph through the company's books for the period prior to 1916, and the recreation with the original equipment of Charles Herrold's San Jose radio station established in 1909 (the predecessor of Station KCBS).

Freeman Collection, Yankton, S.Dak. Early radio equipment and telegraph instruments.

Gray's Museum of Wireless, Cincinnati, Ohio. Collection of engineer Jack Gray (now deceased) has been transferred to the lobby of Cincinnati's Public Television Station.

IEEE Headquarters, 345 East 47 Street, New York, N.Y. Rather dusty showcase in the tenth floor foyer displays some items from IEEE's past, including early IRE and AIEE *Transactions* volumes, a page from a handwritten De Forest manuscript from 1906, and AIEE Board minutes dated June 3, 1884.

Illinois Bell, 225 West Randolph, Chicago, Ill. The museum on the 20th floor features the only working antique telephone equipment in North America.

Illinois Railroad Museum, Union, Ill. Antique railroad equipment, including some electric equipment.

Indiana Historical Radio Society, Elkhart, Ind. Maintains a permanent exhibit of antique radio equipment at the State Museum, Indianapolis, Ind.

Lapp Insulator Company, LeRoy, N.Y. Collection of antique insulators.

Milholland Collection, 145 East 168th Avenue, Spanaway, Wash. M. and E. Milholland's private collection of antique insulators. May be seen by appointment.

Mount Vernon Museum of Incandescent Lighting; contact E. Francis Hicks, 717 Washington Place, Baltimore, Md.

Mucho Collection, Elgin, Ill. Ralph Mucho is said to have the largest collection of broadcast sets in the world.

National Archives, Washington, D.C. Publishes a bibliography of recordings (both acoustic and electronic) dating back to 1920; will supply tapes upon request.

National Museum of Science and Electricity, 1867 St. Laurents Boulevard, Ottawa, Ont., Canada. Includes antique communication equipment.

Nelson Collection, Concord, N.C. Collection in the home of Wayne Nelson, owner of local broadcasting station, includes broadcast, amateur, and commercial equipment.

New England Museum of Wireless and Steam, Tillinghast Road, East Greenwich, R.I. Features individual exhibits devoted to various pioneers (amateur, commercial, and broadcast).

Ontario Hydro Museum, Ontario Falls, Ont., Canada. Only sizable collection of antique power equipment in North America.

Paramus Catholic High School, Paramus, N.J. The school's Science Department has a large collection of antique tubes.

Pavek Museum, 55 South 12th Street, Minneapolis, Minn. Early broadcast and amateur equipment.

Peckham Collection, Ormiston Road, Breesport, N.Y. (north of Elmira). Lauren Peckham's collection of early tubes as well as early radio equipment.

Phillips Collection, 1010 Monte Drive, Santa Barbara, Calif. Rare amateur and commercial equipment as well as old-time wireless stock certificates.

Pittsburgh Railway Museum Association, Pittsburgh, Pa. Railroad equipment, including electric items.

Plains-Panhandle Museum, Canyon, Tex. Collection includes 200 antique insulators.

Power Museum, Rocky Reach Dam, Wash. Some early powerhouse equipment.

Princeton Tube Collection, Princeton Junction, N.J. Large tube collection (more than 18 000).

Quarter Century Wireless Association, 2012 Rockingham Street, McLean, Va. 22101. Collection of antique wireless equipment and memorabilia, maintained primarily for, and by, the members of the association. (Can be seen by others by appointment through the curator: Clarence Seid, Radio Hill, RFD 1, Middletown, N.Y. 10940.)

Signal Corps Museum, Fort Monmouth, N.J. Both military and nonmilitary communications equipment.

Smithsonian Institution, Washington, D.C. Comprehensive collection in all areas of electronics. Will soon include the Bern Dibner collection of rare instruments, manuscripts, and books documenting the history of science and technology (see *Spectrum,* April, page 108).

Society of Wireless Pioneers, P.O. Box 530, Santa Rosa, Calif. 95402.

Sutton Museum, Sutton, Que., Canada. Large radio collection.

Telephone Museum, Abilene, Kans. (adjunct of the Dickinson County Historical Society and Museum). Large exhibition includes a collection of insulators and such items as an antique paystation telephone.

Telegraph Museum, Seattle, Wash. Exhibition of early telegraph equipment, sponsored by the Smithsonian.

Trolley Museums: Branford, Conn. (near New Haven); Kennebunkport, Maine; Rio Vista, Calif. (San Francisco Bay area); San Francisco, Calif. (Cable Car Museum); Wheaton, Md.

W6AX Pioneer Museum, 21120 Sullivan Way, Saratoga, Calif. Collection of Thorne Mayes (director of the Foothill Museum) includes very early amateur and commercial wireless equipment and an assortment of high-voltage apparatus.

W2ZI Wireless Museum, 19 Blackwood Drive, Trenton, N.J. Commercial equipment, telegraph keys, and other historical material, including 500 items from the 1899 period and a 1903 tuner.

The leisure bookshelf

Wherein a selection of topical books and useful magazines is offered for the hobbyist reader

In case you weren't aware of it, there are magazines on everything! *Spectrum* found this out when it set about putting together a reference bookshelf on EE leisure-time activities. What follows is a selection of some key magazines on the most popular of those activities, as well as a listing of current books recommended, for the most part, by the editors of those magazines. The bookshelf is organized by popularity of the activity (see this issue, pp. 72–75), beginning with photography.

Photography

Profiting from the rising interest in photography are two magazines recommended for the amateur who has gone beyond the Brownie and the Polaroid. One is *Popular Photography* (1 Park Ave., New York, N.Y. 10016); the other, *Modern Photography* (130 East 59 St., New York, N.Y. 10022).

The editors of *Popular Photography* were reluctant to recommend particular books on the subject, feeling there were too many to choose from. Consequently, *Spectrum* has come up with its own shopping list. Only tutorial books are included; for those expensive, spectacular collections of the photographs of the greats and near-greats, we suggest the reader visit a local library or fine-books store.

- Brummitt, W. B., *et al., Photography: the Amateur's Guide to Better Pictures.* New York: Golden Press, 1964, 160 pp., soft cover, illus., $1.95 .
- Sussman, A., *The Amateur Photographer's Handbook.* New York: Thomas Y. Crowell, 1973, 562 pp., illus., $8.95.
- Swedulund, C., *Photography: A Handbook of History, Materials, and Processes.* New York: Holt, Rinehart and Winston, 1974, 368 pp., soft cover, illus., $14.50.
- *The Here's How Book of Photography.* Rochester, N.Y.: Eastman Kodak, 1971, 394 pp., illus., $10.95.

Gardening

A giant in this field is, of course, *House & Garden Magazine* (350 Madison Ave., New York, N.Y. 10017). Rather than choose among the avalanche of gardening books available, the magazine's gardening expert recommended *Spectrum* get in touch with the New York Horticultural Society Library, 128 West 58th St., N. Y., N. Y. 10019—an excellent recommendation for the EE–gardener as well. Some of the books cited by the library are:

Outdoor gardening

- Bush-Brown, J., and Bush-Brown, L., *America's Garden Book.* New York: Scribners, 1966, 752 pp., illus., $10.00.
- Seymour, E. L. D., *The Wise Garden Encyclopedia.* New York: Grosset and Dunlap, 1970, 1380 pp., illus, $9.95.
- Taylor, N., *Taylor's Encyclopedia of Gardening.* Boston: Houghton-Mifflin, 1961, 1329 pp., illus., $15.00

Indoor gardening

- Crockett, J. U., and the Editors of Time-Life, *Flowering House Plants.* New York: Time-Life Encyclopedia of Gardening, 1971, 160 pp., illus., $7.95.
- Crockett, J. U., and the Editors of Time-Life, *Foliage House Plants.* New York: Time-Life Encyclopedia of Gardening, 1971, 160 pp., illus., $7.95.
- Elbert, G. A., *The Indoor Light Gardening Book.* New York: Crown, 1973, 250 pp., illus., $10.95.

An excellent series of four soft-cover books ($1.95 each) on various aspects of gardening is available from Grosset & Dunlap (51 Madison Ave., New York, N.Y. 10010). Titles include: *Clear & Simple Gardening, Gardening in Containers, Vegetable Gardening and Cooking,* and *House Plants.*

Other gardening magazines include the following large-circulation generalist types: *Better Homes & Gardens* (1716 Locust St., Des Moines, Iowa 50336) and *House Beautiful* (717 Fifth Ave., New York, N.Y. 10022). Two magazines appealing to more specialized interest are *Flower and Garden Magazine* (4251 Pennsylvania Ave., Kansas City, Mo. 64111) and *Organic Gardening and Farming* (33 East Minor St., Emmaus, Pa. 18049).

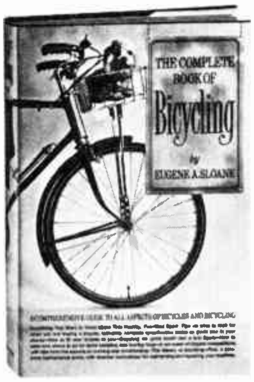
Tennis

The magazine to subscribe to is *Tennis Magazine* (297 Westport Ave., Norwalk, Conn. 06856). One

Ellis Rubinstein Associate Editor
Barbara Gail Music Editorial Assistant

of the *Tennis* editors suggested the following books:

- Gallwey, W. T., *The Inner Game of Tennis.* New York: Random House, 1974, 141 pp., illus., $7.95.
- Gonzales, P., and Hyams, J., *Winning Tactics for Weekend Singles.* New York: Holt, Rinehart and Winston, 1974, soft cover, 136 pp., illus., $6.95.
- Harman, B., and Monroe, K., *Use Your Head in Tennis.* New York: T. Y. Crowell, 1975, 256 pp., $6.95.
- Newcomb, J., and Newcomb, A., *The Family Tennis Book.* Norwalk, Conn.: *Tennis Magazine,* 1975, 157 pp., illus., $9.95.



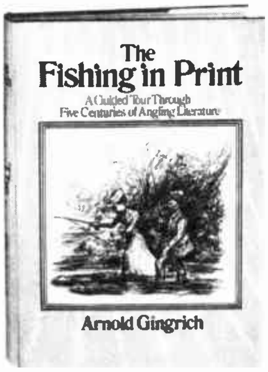
Golf

Top magazines include *Golf Digest* (297 Westport Ave., Norwalk, Conn. 06856) and *Golf* magazine (380 Madison Ave., New York, N.Y. 10017). The editors of *Golf Digest* supplied *Spectrum* with the following list of recommended books:

- Armour, T., *Tommy Armour's ABC's of Golf.* New York: Simon and Schuster, 1967, 187 pp., illus., $5.95.
- Aultman, D., and the Editors of *Golf Digest, The Square-to-Square Golf Swing.* Norwalk, Conn.: Golf Digest, Inc., 1970, 127 pp., illus., $5.95.
- Nicklaus, J., *Golf My Way.* New York: Simon and Schuster, 1974, 264 pp., illus., $9.95.
- Toski, B., *et al., The Touch System for Better Golf.* Norwalk, Conn.: Golf Digest, Inc., 1971, 128 pp., illus., $6.95.

Fishing

Field & Stream (383 Madison Ave., New York, N.Y. 10017) and *Outdoor Life* (380 Madison Ave., New York, N.Y. 10017) are classics. *Field & Stream's* editors deluged *Spectrum* with suggested books, including these:



- Brooks, C. E., *The Trout and the Stream.* New York: Crown, 1974, 216 pp., illus., $7.95.
- Gingrich, A., *The Fishing in Print: A Guided Tour Through Five Centuries of Angling Literature.* New York: Winchester Press, 1974, 344 pp., illus., $12.95.
- McClare, A. J., *Fishing with McClare.* Englewood Cliffs, N.J.: Prentice-Hall, 1975, 332 pp., illus., $12.95.
- Sosin, M., and Dance, B., *Practical Black Bass Fishing.* New York: Crown, 1974, 216 pp., illus., $7.95.

Skiing

Skiing (1 Park Ave., New York, N.Y. 10016) vies with *Ski* (280 Madison Ave., New York, N.Y. 10017). The former is for the purist who plots the force of vectors on his bindings. The editors of *Ski* suggest two of their own books:

- Scharff, R., *et al., Encyclopedia of Skiing.* New York: Harper & Rowe, 1975, 256 pp., illus., $15.95.
- *Ski* Magazine, *America's Ski Book.* New York: Scribners, 1973, 16 pp., illus., $12.50.

Household maintenance

Magazines galore serve the "do-it-yourselfer." One of the best is *Popular Science* and its editors recommend these books:

- The editors of Sunset Books and *Sunset* Magazine, *Basic Home Repairs.* Menlo Park, Calif.: Lane Brooks, 1971, 96 pp., soft cover, illus., $2.45.
- *Family Handyman* Magazine, *America's Handyman Book.* New York: Scribners, 1970, 529 pp., illus., $12.50.
- Gladstone, B., *The New York Times Complete Manual of Home Repairs.* New York: Macmillan, 1966, 438 pp,. illus., $8.95.
- Hand, J., *Complete Book of Home Repairs and Maintenance.* New York: *Popular Science,* 1971, 358 pp., illus., $8.95.

Camping

For the campers, *Spectrum* suggests *Camping Journal* (229 Park Ave. South, New York, N.Y. 10003). *Camping Magazine,* the official publication of the American Camping Association, Bradford Woods, Martinsville, Ind. 46151, supplied *Spectrum* with the Association's *1975 Catalogue of Selected Camping Publications,* a 36-page listing of publications on every aspect of camping. This catalogue provides not only descriptions and prices of each publication but order blanks that will be processed by the association itself no matter who the publishers. (And, incidentally, American Camping Association members are eligible for 10-percent discounts on most of the items listed.)

Bicycling

Consider a subscription to *Bicycling!* (55 Mitchel Blvd., San Rafael, Calif. 94903). *American Bicyclist and Motorcyclist,* a trade publication whose office is located at 461 Eighth Ave., New York, N.Y. 10011, suggested two bicycle reference books:

- DeLong, F., *DeLong's Guide to Bicycles & Bicycling.* Radnor, Penn.: Chilton, 1974, 278 pp., illus., $12.95.
- Sloan, E. A., *Sloan's Complete Book of Bicycling.* New York: Simon and Schuster, 1970, 342 pp., illus., $9.95.