RCA Engineer

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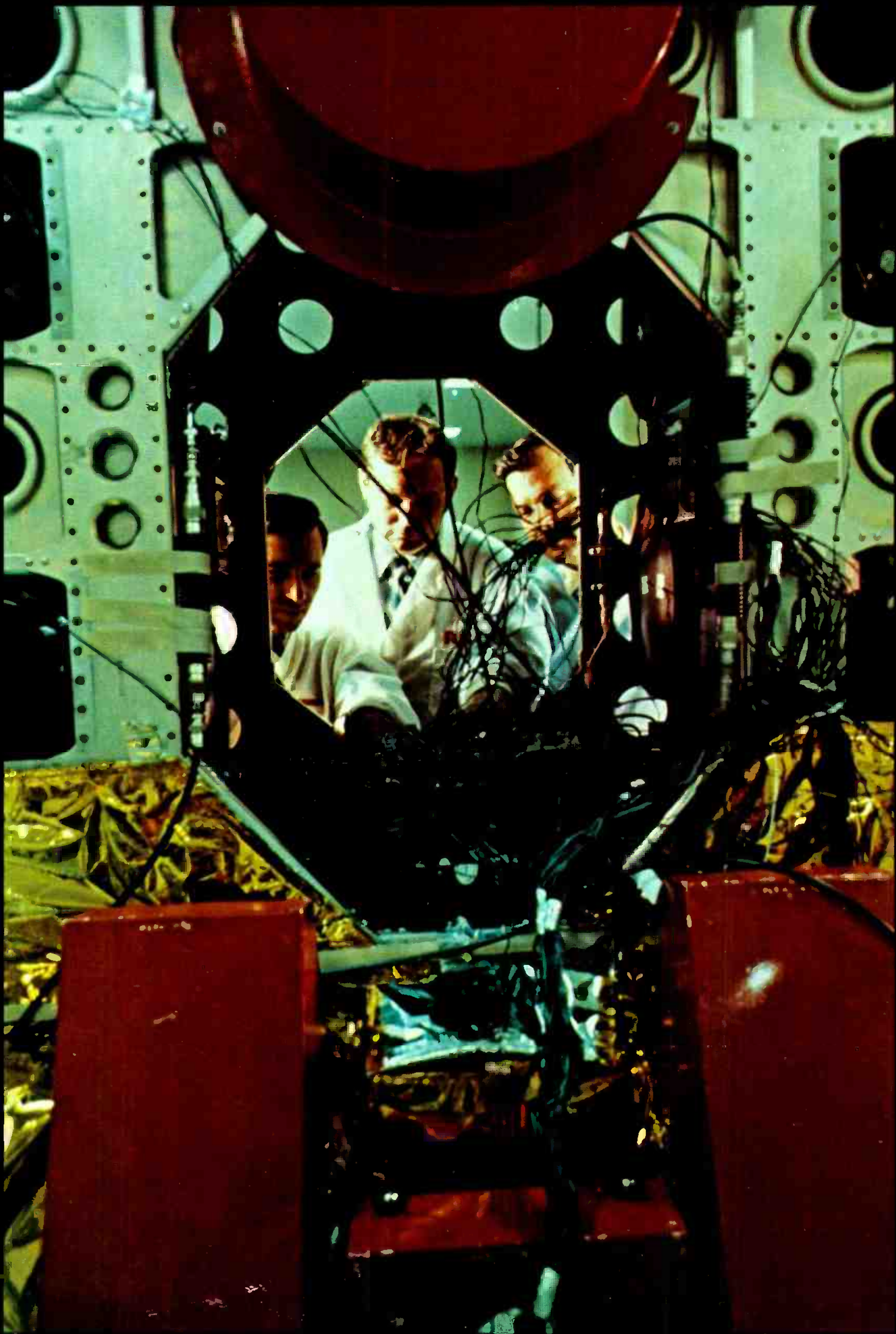
16th Anniversary Issue



16th anniversary

Relax, John Q. — Let's talk this over

In introducing this 16th Anniversary issue of the *RCA Engineer,* it is appropriate to pay tribute to you, the reader-contributor. Supported by your Editorial Representatives and the Technical Publications editorial staff, you have made this publication unique in its class. Outstanding both in the variety and the quality of its content, the *RCA Engineer* is a major forum for communication among members of the RCA professional community.

It is appropriate too, in these perplexing times, to give thought to another area of communication; one which the *RCA Engineer* as an internal publication does not address directly. I refer to the need for each of us in the technical community to help put the layman at ease with technology so he can make informed decisions about its use.

In recent months this need has been starkly and, in a way, brutally highlighted. The spectacular successes of the space program, which displayed unprecedented technical virtuosity, drew responses from the public ranging from disbelief to near adulation. Almost simultaneously, engineers and scientists were shocked to find themselves and their disciplines held responsible for the great social concerns of our time. In the mind of an alarmed lay public, technology is responsible for the threat of instant annihilation, the disruption of our ecology, the loss of our personal privacy, and in an unreasoning way even for the planet's incipient death. One direct consequence is the serious impact on engineering jobs resulting from the translation of these fears into disruption of national programs.

We in the technical community must provide the structure to bridge the communications gap. Missing from the structure now is a strong web of common personal involvement—individual engineer working with individual layman—on everyday community problems. This is one of the components needed to build confidence and receptivity, without which there can be neither understanding nor acceptance of the much needed plans and remedies generated by our profession.

It is not enough for us to go on as before, narrowly applying our skills in search of technical solutions for technical problems. We must, in addition, respectfully ease the mind of the society for whom the needed solutions are designed. There is a cogent example of this need. Anticipating the inevitable obsolescence of subsonic air transport, a development program was devised to protect a major sector of the U.S. economy that flourishes around the commercial aircraft industry. The study was terminated without reaching answers because our worried citizens and their legislators were never taught the predictability of obsolescence, the cost of being unprepared, and the amount of organized hard work that lies behind the apparent magic of technical achievement.

The kind of personal communication demanded of us taxes the whole intellect. It must become a part of our style of living. I think we owe a debt for our past neglect. We must pay the debt to earn our fellow citizens' understanding support.

A. Robert Trudel, Director
Corporate Engineering Services
Research and Engineering
Camden, N.J.

Our cover

The TIROS M (ITOS I) spacecraft shown on our front and back covers culminates more than a decade of successful meteorological satellite programs at the Astro Electronics Division. A. Schnapf, winner of this year's David Sarnoff Outstanding Achievement Award in Engineering for his "outstanding leadership of the TIROS meteorological satellite team," describes the program in some depth in this issue (p. 32). On the front cover, engineer Frank Scearce (center) and engineering specialists Paul Bizzaro (left) and Frank Fels are preparing the spacecraft for testing. The back cover shows the spacecraft and its solar cell array in the integration and test area. In the photo are Frank Fels and Frank Scearce. **Photo credit:** Dave Dallman, Astro Electronics Division.

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RCA Engineer

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• To disseminate to RCA engineers technical information of professional value • To publish in an appropriate manner important technical developments at RCA, and the role of the engineer • To serve as a medium of interchange of technical information between various groups at RCA • To create a community of engineering interest within the company by stressing the interrelated nature of all technical contributions • To help publicize engineering achievements in a manner that will promote the interests and reputation of RCA in the engineering field • To provide a convenient means by which the RCA engineer may review his professional work before associates and engineering management • To announce outstanding and unusual achievements of RCA engineers in a manner most likely to enhance their prestige and professional status.

Contents

editorial input

Protecting Privacy

From handling the rapid financial transactions of the work-a-day world to computing the complex trajectories of interplanetary spacecraft, computers operate as passive but powerful tools in the hands of skilled programmers and engineers. The versatility of modern computers is being demonstrated in literally thousands of applications, from matching prospective mates to diagnosing medical problems.

The tremendous power of the computer to store and manipulate information will continue to help us overcome what has been called the "tyranny of numbers" in modern society.[1] But as information systems mature and applications become more widespread, the strengths of the computer become serious weaknesses when handling sensitive data about individuals or organizations.

People earn wages, save money, buy insurance, apply for credit, pay bills, attend schools, pay taxes, join societies, subscribe to periodicals, and do hundreds of other everyday tasks—giving little thought to the consequence of these actions. But certain aspects of each of these actions are stored somewhere in separate data banks—and computers seldom forget. With the promise of higher capacity memories (as high as 10^{12} bits) and improved data communications facilities, both public and private interests are planning for the central storage of vast quantities of machine-readable knowledge . . . and virtually unlimited access to other large stores.

With the obvious advantages that come with such developments, several questions have been raised regarding the use of these mixtures of personal and public data.

Can we be sure that the privacy of sensitive information will be maintained? Most information being processed is likely to be private to some degree. The government, industry, and individuals are usually willing to share information about themselves only to the extent that the information is useful to a particular situation. However, it has already been demonstrated, much to the chagrin of certain individuals and organizations, that information taken from various sources can be merged into a rather complete file—constituting a serious threat to privacy.[2] Unless legal and technical restraints are imposed, information can be accessed and used without the individual's knowledge or permission.[3]

How do we know that information about us is correct? The computer has no way of tempering facts with judgment, time, or changing conditions. When data are entered incorrectly, or modified due to machine error, no mechanism exists at present to allow an individual to examine and insure the validity of his records.[4]

What guarantee does one have that stored information will be secure? Since the status and integrity of individuals and organizations in our society depends heavily on computer information, the destruction of data files could represent an unrecoverable loss. In addition to possible inadvertent operational losses, natural disasters (such as earthquakes and fires) and threats of destruction by dissident groups have increased this concern.[5]

The solutions to some of these problems lie in effective legal measures and monitoring procedures that impose reasonable checks and balances on the access and application of information. But in addition, several innovative technical and operational measures are needed to protect privacy. Computer centers must incorporate new techniques to protect information; multiple-user information systems will have to be equipped with effective "locks" that prevent access to data bases by unauthorized personnel.[6]

Several stop-gap solutions have been proposed, but the final solution may require a complete re-examination of the design of computer hardware and software systems, giving full consideration to the many ways in which data networks affect individuals, business organizations, and government agencies.

We hope to explore this fascinating subject in future issues of the *RCA Engineer*: your comments and reactions are welcome.

References

1. Hillier, J., "The tyranny of numbers" *RCA Engineer*, Vol. 14, No. 3 (Oct-Nov 1968) Inside cover message.
2. Nader, R., "The dossier invades the home," *Saturday Review* (April 17, 1971).
3. Miller, A. R. *The assault on privacy: computers, data banks, and dossiers* (University of Michigan Press; 1971).
4. Consumers now have this right in credit transactions, as a result of the Fair Credit Reporting Act, which became effective on April 25, 1971. But they still cannot control access to the information or the type of information stored.
5. Wessler, J., Meyers, E., and Gardner, W. D., "Physical security . . . fact and fancies," *Datamation* (July 1, 1971).
6. Several of the technical problems are discussed by Professors Fano and Salzer in this issue (pp 23 and 24).

Future issues

The next issue of the *RCA Engineer* discusses optics and photochromics. Some of the topics to be covered are:

Low-light-level color photography

Holographic recording in crystals

Ideographic photocomposing

Laser-beam imaging

Measuring optical properties underwater

Photochromic and cathodochromic materials

Discussions of the following themes are planned for future issues:

Solid state technology

Computer peripherals

Displays

Advanced Technology Laboratories

Systems programming

Semiconductor memories and COS/MOS circuits

Address to RCA Shareholders—1971

R. W. Sarnoff

In his address at the Annual Meeting of RCA Shareholders recently, Mr. Sarnoff emphasized RCA's "strategy of balanced expansion and diversification . . . building upon RCA's strengths in electronics and marketing" and supplementing these by "selective response to worthwhile new business activities." The full text of his remarks is reproduced below with the thought that you, as a member of RCA's Technical Staff, will want to be fully aware of the principal aspects of the new RCA to which you are making a vital contribution.

The Engineer and the Corporation

Robert W. Sarnoff
Chairman, President and
Chief Executive Officer*
RCA
New York, N.Y.
has successfully combined two careers in one—as a business executive and as a leading participant in public affairs. Mr. Sarnoff's business career spans more than 30 years in the information industry. Before assuming the Presidency of RCA in January, 1966, Mr. Sarnoff was Board Chairman and Chief Executive Officer of the National Broadcasting Company. In his 18 years with NBC, he was closely identified with major advances and innovations in the informational and educational programming of network television. Mr. Sarnoff's public service interests extend across a broad spectrum of educational, cultural and fund-raising activities. He is Chairman of the Board of Trustees of Franklin and Marshall College, a member of the Board of Overseers Visiting Committee of Harvard College, a member of the Visiting Committee of the Graduate School of Business Administration, University of California, Los Angeles, and a member of the Board of Visitors of the School of Public Relations and Communications of Boston University. He is also a member of the New York Urban Coalition, serving with its Education Task Force. The organization was formed by business, government, and civil rights leaders to help meet the crisis of urban life in such areas as employment, housing, and education. Mr. Sarnoff is a Trustee of the Whitney Museum of American Art and former President of the Friends of the Whitney Museum; a Trustee of the John Fitzgerald Kennedy Library Corporation. He was National Co-Chairman of the American Red Cross Fund Campaigns for an unprecedented third term in 1966, and in May of that year was elected a member of the Board of Governors of the Red Cross. He is a Vice President of the Greater New York Councils of the Boy Scouts of America, and he served as Chairman of the Council's 1965 and 1966 corporation campaigns. Among other recent honors, Mr. Sarnoff in 1966 received the first Frederick Douglass Gold Medal Award from the Urban League of Greater New York for "distinguished leadership toward equal opportunity and the fulfillment of the rights of man." In the same year, he was decorated with the French Order of Arts and Letters for his contributions to better understanding between France and the United States. In March, 1968, he was decorated as Commander in the Order of Merit of the Italian government for furthering cultural understanding between the United States and Italy; and in July of the same year the City of Florence honored him with its Scroll of Honor and a Gold Medal for his efforts in support of the campaign for restoration of the Florentine art treasures damaged by flood in 1966. In February, 1970, Mr. Sarnoff was awarded the La Grande Medal of Vermeil by the City of Paris, France for his outstanding achievements in the field of communications.

*Since this address, Mr. Sarnoff announced the election of A. L. Conrad as President, RCA Mr. Sarnoff continues as Chairman and Chief Executive Officer. (See "News and Highlights" this issue.)

My REPORT today is made against a background of moderate economic gains that brighten the outlook for American industry in general and for RCA in particular.

Last year, we were hit hard not only by the general business decline but also by a long and costly strike. Although our sales rose during the first quarter of this year, profit remained slightly below last year's comparable period.

We are now well into a new quarter in which earnings should substantially exceed those of a year ago. This improvement should continue at a steady pace during the second half, resulting in a much better year than 1970.

The reversal of the economic downturn has been marked by evidence of renewed consumer confidence, expressed in rising sales of such durables as color TV and automobiles. Business investment plans have also shown a moderate increase.

Continuation of these trends will set the stage for a strong economic performance in 1972, providing even further gains for RCA. A significant revival of buyer confidence will directly stimulate our consumer electronics business and our growing range of other products and services.

There have been two particularly encouraging developments in recent weeks. One is a substantial increase in television set sales. The other is a continuing increase in commitments for broadcast advertising, which should

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Address to Shareholders on May 4, 1971.

result in an improved fourth quarter for NBC. This should lead to significantly greater volume and profit in 1972.

However, we are still contending with sluggish markets in other key areas, such as government sales, commercial systems, and solid-state electronics.

While inflationary pressures have eased somewhat, we must continue vigorous action to absorb multimillion-dollar increases in the cost of materials, labor, and distribution. We are making substantial progress in our efforts to counter these effects of inflation with programs stressing increased productivity, price adjustments, and cost reductions. We have disposed of a number of marginal or unprofitable lines. Surplus plant capacity has been reduced by closing facilities and consolidating operations. Separate organizations have been combined into single administrative units. While these steps respond to an immediate need, they also have long-range significance.

Your company is being geared for progress and profit in this new environment by enlarging its scope in both traditional and new lines of business. At last year's Annual Meeting, I indicated that our aim is to develop RCA as a multinational industrial enterprise doing business primarily in diversified consumer and commercial services and in computer-based information systems.

At last February's special meeting, there were some expressions of concern at the changes this program entails. The comments reflected an apparent belief that RCA is abdicating its strong position in electronics and communications as it diversifies into other fields. I assure you such fears are groundless.

Even after our recent entry into the home furnishings business through Coronet Industries, nearly 75 per cent of our total revenue still comes from electronics, communications, and information. RCA's principal role in the home remains the broadcast or recorded program and the instrument to receive and reproduce it in picture or sound. Our lifeblood is still overwhelmingly electronics.

Selective acquisition has been a significant part of our recent growth, particularly in consumer-oriented fields. But it should not be allowed to obscure the diversification and expansion within RCA's traditional areas of business.

Actually, we are pursuing a flexible and balanced program that takes into account continuing change in technology and markets, and emphasizes profit growth.

Our strategy involves three principal elements:

- Concentration on maximum profit potential in our most successful older businesses;
- Diversification internally by expanding into new businesses with our existing technical and marketing resources; and
- Diversification externally by entry into businesses with high growth and profit potential, particularly in consumer-oriented fields.

Let me comment on progress to date and on future prospects.

Much of RCA's past growth was generated by consumer electronics and broadcasting. Recently, however, it became apparent that these activities were approaching a level of maturity that limits their growth rate, quite apart from variations in the economy.

Nevertheless, these maturing businesses should continue to contribute substantially to future sales and earnings. Only their growth rate has slowed. We intend to realize their maximum potential by efficient management, including appropriate investment in new technology and facilities. For example, we recently built a glass-making plant to supply a large share of our own requirements for color TV bulbs. And we are now creating a Center for Industrial Design at Indianapolis to generate a flow of innovative, competitive, and profitable consumer electronic products.

Still, it is clear that the older activities alone cannot restore RCA's long-term pattern of vigorous sales and profit growth. It is necessary to supplement them through diversification. Major progress has been made in reshaping the company in response to this need.

Internally, we have diversified in our traditional areas of communications, electronics, and services.

- In communications, our oldest activity, we have entered the public telephone business by purchasing and modernizing the Alaska long-distance telecommunications system. Our communications subsidiary is also seeking government authority to establish and operate a domestic communications satellite system.
- In electronics, we are making the largest investment in RCA history to establish a strong position in the computer industry. We made important progress in 1970. We continue to expect to achieve profitability in the early '70s. Far from being a diversion from our traditional pattern, the computer business involves electronics in its most sophisticated form, embracing advanced concepts of both communication and information processing. In terms of technology, RCA has been trained for this from the start—in digital communications, information theory, systems engineering, and pioneering work on the computer itself.
- In services, we have entered a number of new technical and consumer markets. Among them are maintenance of airline reservation systems and a recently established enterprise called ServiceAmerica. The latter was designed to meet an increasing nationwide need for quality service for all brands of TV sets and other electronic home instruments.

Our intensified and expanded efforts in communications, computers, and services should provide considerable profit growth over the next five years.

We anticipate further internal diversification as new business opportunities develop through the progress of technology and changes in the marketplace.

It should be evident by now that major emphasis is being placed upon building from RCA's original base in electronics and communications. It will continue so in the future. At the same time, your company must continue to explore other fields of high profit potential in order to ensure long-term growth. This is the basis for the selective external diversification that is the third principal element in our strategy.

Externally, we have sought entry into new areas of business related principally to consumer products and services. RCA has had long experience in the consumer market, in both manufacturing and service operations. Every index points to a larger, more affluent, and more sophisticated population. The prospect is for an increase in this decade of more than 50 per cent in real personal income and an approximate doubling of discretionary income.

On this basis, we have taken RCA by selective acquisition into a considerably broader segment of the consumer market. We have added profitable subsidiaries in publishing, vehicle rentals, frozen prepared foods, real estate, and home furnishings.

By the test of performance, these new subsidiaries have exceeded our expectations. They are among RCA's most profitable investments, with a higher rate of return on sales in 1970 than the rest of our consolidated businesses. And they contribute a larger share of corporate profit than the equity investment they represent. Throughout the recent economic downturn, they showed a significantly higher growth rate than some of our older businesses. Moreover, they have brought to RCA new management expertise of immeasurable value. Finally, they have increased our participation in the service sector of the national economy, which has been growing at a faster rate than manufacturing. Our marketing research studies strongly suggest that each of these new fields will grow at a rate above the Gross National Product throughout the 1970s.

We are far enough along with our new growth strategy to assess some of the results. Although the picture is partly obscured by the setback to the national economy, it is still evident that the program has been working as intended.

During the past five years, RCA's total annual revenue has increased nearly $900 million. More than three-quarters of this growth has been generated by increased diversification. The growth rate of these new activities outstripped by a wide margin our more mature businesses. In fact, without the diversification of the past five years, we probably would have had virtually no sales growth and substantially lower profit.

Today, RCA has greater growth potential than ever. It has maintained its traditional strength in color television, broadcasting, and communications while opening profitable new opportunities in electronic systems and services. It has further broadened its revenue base with entry into new consumer-oriented businesses catering to a market that promises rapid growth and profitability over the next decade and beyond. Ahead is a growing service contract business involving numerous basic home functions—food preparation, computerized banking and shopping, television, technical maintenance, and others. RCA is in a strong position to compete effectively in such a market.

We are also moving forward worldwide. The world electronics market has become increasingly competitive. The growth of the industry in Europe and Asia has generated new opportunities for a company with the skill, experience, and diversified base of RCA.

Consequently, we have established new facilities, subsidiaries, and joint ventures abroad. Recently, we opened our first plant in the European Common Market—a factory in Belgium to produce power transistors and related devices for a market in which RCA already has a strong position. Other ventures are under consideration in the Common Market, since it offers a business potential comparable to that which has prevailed in the United States.

Our activities abroad have started to generate significantly improved volume. In 1970, net sales of our foreign subsidiaries rose nearly 23 per cent over 1969. Profit remained low because of startup costs but improved earnings are ahead.

The published results of our 1971 first-quarter operations were stated in accordance with the current trend of accounting practice. After a 30-year interval, we have resumed including RCA's foreign subsidiaries in our consolidated financial statements. The result is a better reflection of the growing multinational character of your company.

In all our businesses—old and new, domestic and foreign—we are seeking out and developing the special attributes that will attract customers to RCA in preference to its competitors. We are also giving priority to the obligations that accompany the privilege of doing business.

Today, there is rising and outspoken public concern over environmental pollution, urban blight, and the quality and safety of the products of American industry. Business can and must devote a significant part of its resources and skills to the solution of these problems. RCA supports and has initiated a number of programs in these areas of social responsibility.

We have encouraged RCA employees to take part in community pollution control programs wherever we have plants and offices. Last spring, we launched the RCA Environmental Improvement Program—an annual company-wide competition. It has inspired more than 10,000 RCA men and women to participate in cooperative projects with community neighbors and civic groups.

In urban affairs, RCA is participating in a number of programs, including improvement of housing in depressed areas of Camden, N.J., and a renewal program for the city's waterfront area across from Philadelphia.

RCA's Consumer Affairs has operated at the top corporate and divisional levels for more than a year. It has proven outstandingly effective as a channel of direct communication for all our customers. Its success has brightened RCA's reputation as a company that stands behind the products and services it makes and sells. Our Purchaser Satisfaction program, for example, has set a new industry standard in the warranty terms covering our color TV sets.

In summary, I believe that RCA is in a stronger position now than at any time in its 52-year history. We have instituted a policy of change—not for its own sake, but for the attainment of profit growth in a marketplace that differs substantially from any we have known.

It should be evident from the record that we are pursuing a strategy of balanced expansion and diversification. We are building upon RCA's existing strengths in electronics and in marketing. At the same time, we are seeking to supplement these activities by selective response to worthwhile new business opportunities.

I firmly believe that this program, in a climate of rapidly accelerating change, will offer the opportunity for long-term sales and profit growth at a rate that will benefit all RCA shareholders.

RCA
Part V—the years 1966-71

Dr. James Hillier

During the years 1966 through 1971, RCA met the challenge of changing market conditions by a program of diversification in areas of high profit potential—particularly in service businesses—by the expansion of overseas activities, by the realignment of divisions, and by increased corporate marketing activities. RCA emerged, in this period, as a multinational company with industrial involvement on a worldwide scale. By the end of 1970, it had manufacturing and research activities in some 12 countries and marketing activities on all five continents.

Throughout the 1966-1971 period, RCA strengthened its position in the remote computing field with the Spectra 70/46 and 70/61. In 1969, RCA also marketed the large-scale Spectra 70/60 batch processor.

Dr. James Hillier
Executive Vice President
Research and Engineering, RCA
studied at the University of Toronto, where he received a BA in Mathematics and Physics in 1937, MA in Physics in 1938, and PhD in Physics in 1941. Between 1937 and 1940, while Dr. Hillier was a research assistant at the University of Toronto, he and a colleague, Albert Prebus, designed and built the first successful high-resolution electron microscope in the Western Hemisphere. Following this achievement, Dr. Hillier joined RCA in 1940 as a research physicist at Camden, N.J. Working with a group under the direction of Dr. V. K. Zworykin, Dr. Hillier designed the first commercial electron microscope to be made available in the United States. In 1953, he was appointed Director of the Research Department of Melpar, Inc., returning to RCA a year later to become Administrative Engineer, Research and Engineering. In 1955, he was appointed Chief Engineer, RCA Industrial Electronic Products. In 1957, he returned to RCA Laboratories as General Manager and a year later was elected Vice President. He was named Vice President, RCA Research and Engineering, in 1968, and in January 1969 he was appointed to his present position. Dr. Hillier has written more than 100 technical papers and has been issued 40 U.S. patents. He is a Fellow of the American Physical Society, the AAAS, the IEEE, an Eminent Member of Eta Kappa Nu, a past president of the Electron Microscope Society of America, and a member of Sigma Xi. He served on the Governing Board of the American Institute of Physics during 1964-65. He has served on the New Jersey Higher Education Committee and as Chairman of the Advisory Council of the Department of Electrical Engineering of Princeton University. Dr. Hillier was a member of the Commerce Technical Advisory Board of the U.S. Department of Commerce for five years. He was elected a member of the National Academy of Engineering in 1967 and is presently a member of its Council.

A PROGRAM designed to modernize the company's identity was completed in 1969 with the changing of the corporate name from Radio Corporation of America to RCA Corporation. RCA's famed circular trademark with its symbolic lightning flash was replaced by a contemporary design in which the three letters form a distinctive single unit.

In early 1970, RCA established an Office of Consumer Affairs at the top corporate level. It has responsibilities for the safety and reliability of all RCA products and services and ensures that consumer interests receive prompt attention at all levels of the company.

An era came to an end on January 7, 1970, when the Board of Directors accepted the resignation of General David Sarnoff as Chairman of the Board and a director of RCA. At the same time, the Board elected General Sarnoff the first Honorary Chairman in the Corporation's history. The Board also adopted a resolution of appreciation, which stated, in part, that "more than any other man, David Sarnoff was the architect of RCA's rise to world leadership in electronics." General Sarnoff was succeeded by his son Robert W. Sarnoff.

Computer activities

By the end of 1970, RCA had made a greater investment in its computer operations than in any previous venture. A major new peripheral-equipment plant was opened in Marlboro, Mass., in 1969. The following year, the Marlboro facility was doubled in size, and plans were announced for a $16-million office building in that location to serve as the future headquarters for RCA's computer activities.

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Throughout the late '60s and early '70s, RCA continued to develop new computers, peripheral equipment, and components to meet the accelerating need for more versatile data processing systems. The Spectra 70/46 was introduced in 1967 and the large-scale Spectra 70/61 two years later to serve the growing market for remote computing systems. These two remote computing systems were the first RCA processors equipped with virtual memory, which means that the main computer memory can appear to be expanded almost limitlessly through a series of auxiliary devices and specially developed software.

However, RCA did not concentrate entirely on remote computing. In 1969, the company marketed a large-scale Spectra 70/60 batch processor designed to handle credit and reservations systems, automate production control, and serve data banks. The following year, RCA introduced a new series of small- to medium-class computers—the RCA 2, 3, 6, and 7. Two of these new processors also have virtual memory.

In 1970, RCA introduced a new series of small- to medium-class computers—the RCA 2, 3, 6, and 7.

Progress was also made in electronic composition systems. The speed of the RCA VideoComp was increased tenfold in 1968, making it possible to set the text of a novel the size of *War and Peace* in less than an hour. Two later developments further enhanced its capabilities: the ability to set complex line drawings and then position the drawings on a page together with text and the development of a program that enables the system to produce halftone photographs composed of small ideographic characters.

Consumer electronics

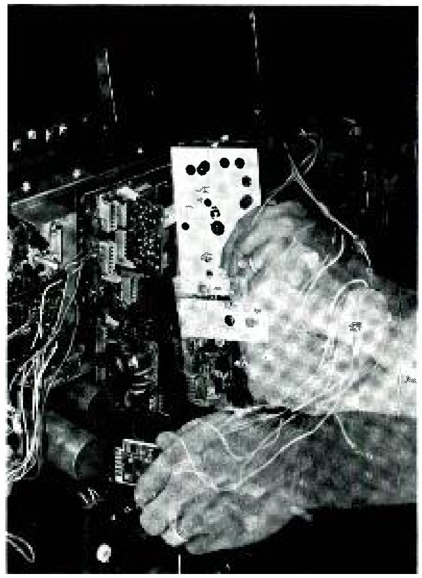
The domestic color TV boom of the early and middle 1960s began to level off in 1967 as the industry matured. Nevertheless, RCA maintained its leadership in color sales and total domestic consumer electronics retail volume. In 1969, computers began to be used to help design, produce, test, and market many RCA home entertainment products. The company recognized the potential of the youth market by highlighting colorful portable models throughout its radio, phonograph, tape recorder, and television lines.

In 1970, RCA introduced one of the most comprehensive consumer-warranty programs in the industry and instituted a multimedia advertising campaign to promote AccuColor—more accurate, brighter color with expanded automatic control.

Solid-state components were incorporated in RCA color TV sets for the first time in 1968. By the end of 1971, these components will have replaced tubes, other than the kinescope, in a large number of RCA color sets.

The RCA line of tape recorders was expanded in these years and ranges from professional-type stereo recorders to popular, handheld cassette players.

Throughout the five-year period, RCA maintained its leadership in color sales. This photo shows color television receivers on the assembly line at RCA's Bloomington, Indiana, plant.



Solid-state components have replaced tubes in a large number of RCA color sets. This photo shows RCA's solid-state modular chassis introduced in 1971.

The company also produced Stereo 8 tape decks for car owners in the United States. Four-channel sound in an eight-track cartridge configuration was introduced in 1970, providing a new dimension in musical realism.

RCA reentered the modular phonograph field in 1969 and added new models in various price ranges the following year. Late in 1970, RCA began test marketing personalized stereo consoles—an innovation that permitted the customer to choose from among 432 possible combinations of cabinet, speaker, and stereo components.

Electronic components and solid-state devices

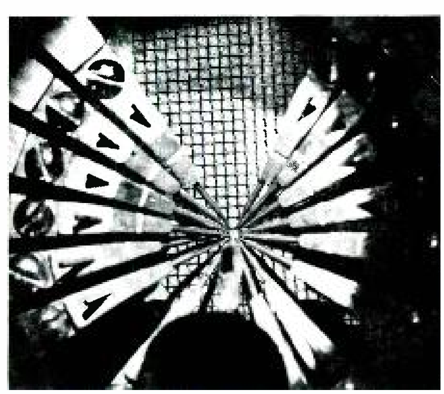
In recent years, RCA designed, produced, and marketed thousands of different types of electronic building blocks for uses that ranged from color TV to manned spacecraft. These were also years of technological change in the electronics industry. The receiving tube, one of the Corporation's oldest component lines, was slowly being replaced by products of the new solid-state technology. To coordinate activity in this field, RCA, in 1970, consolidated semiconductor activities into a Solid State Division. A new Solid State Technology Center was established at Somerville, N.J., as a focal point for semiconductor developments throughout RCA and in recognition of the need for a more intimate relationship between the RCA apparatus and systems producers and the producers of integrated circuits.

In 1967, the Corporation reinforced its position as the leading supplier of the triac, a new solid-state device that controls electrical operations with great precision and extremely low power consumption. These tiny components were used in many consumer products, including blenders, fans, and light dimmers. RCA triacs were also used in electronic scoreboards and in industrial lighting applications.

The following year, RCA made good progress in the application of microelectronics, using silicon monolithic integrated circuits. The company also pioneered the use of integrated circuits in consumer products and was the first in the industry to adopt integrated circuits for automatic fine tuning in color TV. RCA developed special COS/MOS integrated circuits for the aerospace market in 1968, which gave the company technological leadership in the field of low-power, low-speed digital integrated circuits.

In 1969, RCA developed a new, highly sensitive Silicon Target Vidicon through the combination of solid-state and electron-tube technology. The company also entered the digital display market with a NUMITRON readout device bright enough to be read in sunlight. It can be used for gas-pump indicators, desk calculators, cash registers, and automobile dashboards. In 1970, RCA expanded applications of silicon power transistors to include anti-pollution and vehicle safety systems.

Progress also was made in electron-tube technology. In 1967, new phosphors provided RCA color TV tubes with far brighter highlights than had been formerly possible. Two years later, the Corporation developed a new matrix color TV tube, twice as bright as any previous RCA tube.



An enlarged view of test-circuit probes contacting integrated circuit wafer at the Solid State Division.

In 1970, RCA developed transferred-electron amplifiers, a new family of multipurpose microwave solid-state devices. These devices, smaller and simpler than the traveling-wave tubes, have applications in electronic countermeasures; mobile, airborne, and spacecraft communications; and radar systems for weather and surveillance.

Broadcasting and recording activities

Color TV ceased to be a novelty as CBS and ABC followed NBC's lead into full-color network programming. Television became truly international in scope by 1967, when NBC arranged the first live color TV transmissions by satellite to England.

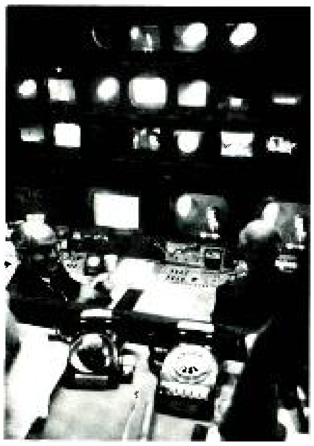
"Bonanza," the world's most popular TV series, had an estimated weekly audience of more than 400 million people in 83 countries.

RCA Records, which became part of NBC in 1969, made a number of artistic and marketing advances during this period. The Philadelphia Orchestra and its distinguished conductor, Eugene Ormandy, returned to the Red Seal label. RCA's sound-track recording of "The Sound of Music" became the best-selling album in the history of the industry, with sales of more than 13 million copies by the end of 1970. Van Cliburn's recording of Tchaikovsky's Piano Concerto #1 in B Flat Minor, was the first and only classical record to sell more than a million copies.

vations systems terminals at leading hotel and motel chains. The following year, technical maintenance services were extended for credit verification and airline reservations systems as well as data communications equipment. Also in 1970, RCA began to lease teletype equipment for both computing and communications uses.

Global communications

The rapid expansion of world business and the need for greater interaction among nations spurred the growth of global communications during the late 1960s. To serve this need, RCA Global Communications was operating more than 2,500 channels of various bandwidths by year-end 1970, nearly twice



NBC control room during live coverage of the Apollo mission in December, 1969.

The "Tonight" show hosted by Johnny Carson, was one of many successful programs presented by NBC during this five-year period.

At RCA Missile Test Project, computer specialists operate the Real Time Computer Systems, a vital part of the Range Safety function at Cape Kennedy.

Throughout this period, the NBC-TV Television Network attracted more advertisers than any other network. It was also first in attracting better educated and more affluent young adults, the category most prized by advertisers. In addition, in each of the years from 1967 through 1970, NBC-TV received more awards than any other broadcast organization: a total of more than 620, including Emmy and Peabody awards.

NBC News covered the headline-making stories of these years—the wars in Indochina and the Middle East, man's first landing on the moon, and the assassinations of Martin Luther King and Robert Kennedy. NBC Sports brought many of the top athletic events, including the New York Mets' victory in the 1969 World Series and the New York Jets' upset win in the 1970 Super Bowl, into the nation's homes.

NBC expanded its overseas operations and, by the end of 1970, was providing programs to 114 nations. That year,

Commercial services

Commercial and technical service volume of the RCA Service Company reached new peaks each year between 1967 and 1970. New branches were added to the nationwide network offering factory service to owners of RCA products, bringing the total to 180 by the end of 1970.

Commercial TV service activities also increased, largely because of the rising rate of conversions to color receivers by such institutions as hospitals, nursing homes, and hotels. In 1970, RCA reduced the cost of these conversions by designing a color installation compatible with existing black-and-white wiring.

The Service Company also handled maintenance and installation for RCA commercial communications products and provided service for other manufacturers and large users of such equipment. In 1969, it installed the hardware and provided remedial maintenance for more than 3,000 reser-

as many as were in use five years before.

The nature of the industry began to change during this period, with a pronounced trend toward increased use of telex and leased-channel services. Part of the reason for this was the development of new technological advances that permitted broad-based, tailor-made customer services at lower costs. For example, in 1967, RCA introduced AIRCON, a unique remote computing application that permitted companies that have their own private teleprinting network to plug in to a master computer for automatic relay of messages. The following year, RCA customers were able to use international voice-grade channels for simultaneous transmission of telegraph and voice, facsimile, and data communications over the same link.

In 1969, RCA inaugurated the Computer Telex Exchange, which provides international telex communications within seven seconds and reduces the possibility of error. Another new service, Interpolated Voice Data, allows two-way voice conversation on a circuit at the same time that data flow at high speeds in both directions. During pauses in conversation, the circuit instantly switches from the voice mode to data transmission. Also in 1969, the Executive Hot Line was opened between New York City and San Juan, allowing a businessman in his Manhattan office to establish immediate contact with an associate in Puerto Rico merely by lifting the handset of his special telephone.

Commercial and industrial products

The market for broadcasting equipment expanded in the late 1960s under the impetus of increasing conversions of TV stations to color, a strong replacement market, and the opening of new UHF stations. However, after three consecutive peak years, domestic bookings waned in 1970 largely because disappointing general business conditions resulted in a decline in TV advertising revenue, forcing broadcasters to defer purchases of major equipment.

Throughout this period, RCA continued to be the leading supplier to the broadcast industry. In 1968, for example, 55 UHF stations went on the air for the first time, and RCA provided transmitting equipment for more than half of them. The company strengthened its leadership that year with the introduction of the TK-44A camera, which can take acceptable color pictures at only 15 footcandles, a light level too low for reading. Within two years, it became the best-selling camera in the industry.

In 1969, the Corporation introduced a 30-kW UHF transmitter that improved the technical quality of TV transmissions by a margin of two to one. RCA also continued to be the prime supplier of multiple-antenna systems for TV broadcasting. In 1970, two tower antennas were installed on the 100-story John Hancock Center in Chicago, and an agreement was signed to construct an antenna stack atop Mt. Sutro for San Francisco TV stations.

RCA technology was also part of the new age of aviation. Most of the major airlines, including Pan Am and TWA, selected RCA weather radar for installation in their new fleet of Boeing 747 jets and other aircraft. The TWA order, placed in 1968, was the largest single purchase of weather radar equipment in airline history. In addition, RCA navigation/communications systems were standard equipment on many business and commercial jets.

In other areas, RCA expanded its mobile two-way radio line in 1970 with medium-priced systems designed to serve the growing communications needs of small businesses.

Space and defense

When astronaut Neil Armstrong stepped from the Apollo 11 Lunar Module onto the magnificent desolation of the moon, his RCA-produced man-pack radio was his electronic link to home. It carried his historic first words across 225,000 miles of space to the world and on to posterity.

The radio was only one of the important RCA contributions to the Apollo program during the five-year period. In 1968, a tiny TV camera designed and built by the company for the Apollo 7 mission sent back the first live pictures of astronauts aboard a U.S. spacecraft. Another RCA camera flew on Apollo 8, man's first voyage to the vicinity of the moon. On later Apollo missions, RCA was responsible for the rendezvous and landing radars that helped guide the astronauts in the LM to and from the lunar surface, as well as the attitude and engine control assemblies that aided them in making pinpoint landings on the moon. The RCA LM communications system enabled the astronauts to maintain continuous voice contact with earth, and the VHF communications/ranging system kept the LM in constant touch with the Command Module when the two spacecraft were separated in flight. Two RCA countdown computers at Cape Kennedy provided critical ground support for the moon missions, monitoring 3,000 functions of the Saturn 5 rockets prior to launch.

The global communications industry began to change in the late 1960s, with a trend toward increased use of telex and leased-channel services. Shown above is Globcom's Electronic Telegraph System.

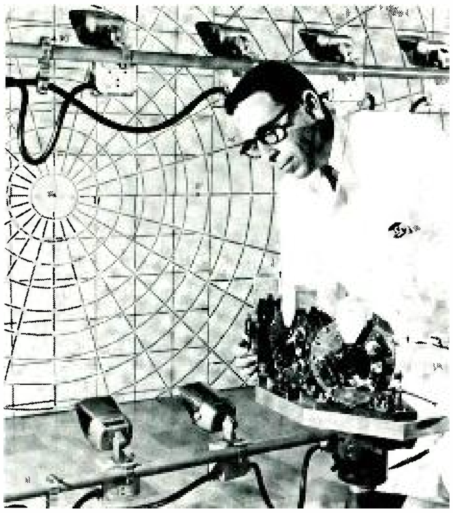
RCA continued to be the leading supplier to the broadcast industry. This RCA broadcast equipment is installed in a new UHF station in Trenton, N.J.

In 1968, an RCA-built 4½-pound TV camera was carried aloft during the first manned Apollo flight. Dick Dunphy of Astro-Electronics Division demonstrates the camera.

RCA also has played a key role in developing spacecraft and systems for the nation's unmanned space program. RCA power supply and communication equipment was aboard all three Lunar Orbiter spacecraft that, in 1967, completely mapped the lunar surface.

The company was also the nation's leading developer of meteorological satellites. By year-end 1970, more than 1.5 million television pictures had been returned from space by RCA-built satellites, most of them from TIROS/ESSA weather satellites. In 1970, the first two in a series of RCA-built ITOS satellites were placed in earth orbit. These larger, more sophisticated, second-generation spacecraft provided improved coverage of the earth's weather systems.

In another program, operational transit satellites built for the Navy provided ships at sea with the most



The advanced vidicon camera system (AVCS) developed for NASA by RCA for the Nimbus weather satellite was the predecessor of the AVCS system used on several advanced TIROS operational missions throughout the late 1960s and early 1970s. In the photo, Mort Shepetin of the Astro-Electronics Division is preparing the tri-camera unit for calibration.

accurate navigational aid in history. RCA scientists and engineers also developed the power and data storage systems for NASA's experimental meteorological Nimbus satellite, and NASA selected RCA to build the high-resolution TV and recording systems for the first Earth Resources Technology Satellites, scheduled for launch in 1972 and 1973. The cameras will take highly detailed color pictures of the earth's surface to aid in the monitoring and controlling of natural resources.

RCA, in 1969, was assigned responsibility for the development of the Navy's new Aegis advanced surface missile system, and the preliminary design for the command and launch segments was completed in 1970. The \$253-million contract was the biggest for RCA in more than a decade and might develop into the largest defense contract ever received by the company —possibly more than \$1 billion. Other military projects during the five-year period included the study and development of an advanced airborne command center, over-the-horizon radars, and a robot sailboat that can be navigated by radio command to any point on the world's seas.

Leasing and renting

In recent years, American motorists have logged several billion miles annually in automobiles they do not own. They were customers of one of the faster growing segments of the service industry—vehicle leasing and renting. In 1967, The Hertz Corporation, the largest company in this field, became a wholly owned subsidiary of RCA. By the end of December, 1970, 150,000 cars and trucks were operated by Hertz and its licensees in the United States and 107 foreign countries. Hertz service was available at nearly 3,000 locations in more than 1,900 cities. Hertz and its subsidiaries also leased and rented construction, commercial, and industrial equipment and operated parking and exposition facilities.

Late in 1968, Hertz unveiled a new service approach for the air traveler—the Sky Center at the Huntsville, Ala., jetport, where transportation, lodging, business, banking, and recreational facilities, all operated by Hertz, are housed under one roof. In 1970, arrangements were completed for Hertz to build and operate a hotel/motel complex at the Jacksonville, Fla., airport.

Overseas, Hertz reached an agreement with Soviet officials in 1969 to make auto rental available in several major Russian cities. Earlier that year, Hertz service was established in Romania and Bulgaria.

Hertz Equipment Rental Corporation entered the foreign market in 1970 with its new subsidiaries, Air Mac International Corporation and Air Mac Philippines, Inc. These concerns operate construction-equipment locations in Singapore, the Philippines, and Seattle, Wash.

Research and development

During the five-year period, thousands of scientists, engineers, technicians, and systems people at RCA laboratories in Princeton, N.J., Montreal, Tokyo, Zurich, and the product divisions provided the Corporation with viable technical alternatives on which to base future profit. These involved not only the discovery of new concepts and products but also the evaluation of technical achievements made elsewhere.

Research and development programs in laser technology and holography led to many new concepts and products. The photo shows one method used for constructing a hologram. An argon laser beam (top, left) enters an optical obstacle path where it is split into two beams by a half-silvered mirror and sent along separate paths to become the object and reference beams required to produce a hologram. The beam on the left is the object beam and can be seen to diverge into a cone just before it strikes the object (a transparency) to be holographed.

Some of this activity was devoted to the realization of the promise of the laser. In 1967, RCA combined television and laser technology for the first time for transmission and recording of images. This system used a TV camera tube that sent its pictures to a gas laser, whose beam traced them on photographic film. The same year, a new laser technique was developed that made it possible to produce holograms of large stationary objects. In 1968, RCA's research in the control of light led to the development of the world's first holographic computer memory. Such memories are capable of storing large amounts of data in a very small space and are relatively immune to the effects of dust and scratches. The following year, RCA

In 1967, The Hertz Corporation became a wholly owned subsidiary of RCA. Shown below is the Sky Center at the Huntsville, Alabama jetport, a new service approach for the air traveler.

unveiled a laboratory model of a laser-based home video player. RCA plans to market a variety of home video player systems during the next decade under the SelectaVision trade name.

RCA scientists also developed gallium arsenide lasers—the most efficient solid-state lasers ever built.

One of the most important RCA research advances during this period was using liquid crystals for electronic control of the transmission and reflection of light. Liquid crystal products of the future may range from instrument displays for automobile dashboards to flat-screen TV receivers. Other achievements included the harnessing of an electronic "avalanche" within silicon diodes to produce the most powerful solid-state microwave generators ever built and the development of the silicon storage vidicon camera—a compact TV camera with stop-action capabilities.

In 1967, RCA laboratories, Tokyo branch, moved into new research laboratories just outside that city. Research there is concentrated on magnetic materials, semiconductors and semimetals, plasma physics, and communications theory.

Publishing

From *Rosemary's Baby* in 1967 to *The Greening of America* in 1970, Random House titles were consistently represented on the best-seller lists. However, the achievements of RCA's publishing subsidiary were not limited to the trade book division.

The commercial and critical success of *The Random House Dictionary of the English Language*, published in 1966, led to the publication of a college edition in 1968 and an elementary school version in 1970. Random House maintained its position of leadership in children's books with the introduction, in 1968, of *The Right and Early Books* by Dr. Seuss.

The new RCA research laboratory in Tokyo opened in 1967.

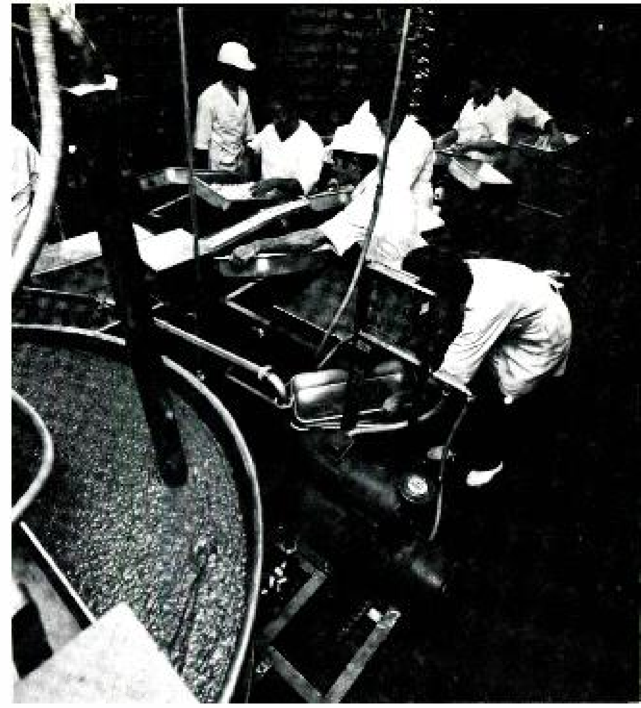
To meet the changing requirements of modern education, Random House inaugurated a series of instructional materials for classroom use. Important multimedia programs were developed in all major languages and involved textbooks, audio tapes, and film strips. And supplementary materials were designed that offered individualized instruction for students at all grade levels who had difficulty in reading and mathematics. Efforts also were directed at the junior-college and community-college levels—the fastest growing segment of the college textbook market.

Heading an outstanding list of books published by Random House during 1966 was *The Random House Dictionary of the English Language*, the first major new dictionary in many years. Advance orders required an initial printing of 350,000 copies.

New business activities

During the five-year period, RCA followed a flexible growth policy of diversification and expansion of present activities, selective new business ventures, and increased emphasis on marketing to assure a sound balance between manufacturing and service businesses. With all these changes, however, RCA remained basically an electronics and communications company—with approximately 75 per cent of its products and services concentrated in these areas.

In addition to The Hertz Corporation, two other companies became wholly owned subsidiaries during this period. Banquet Foods, Inc., formerly the F. M. Stamper Company—a leader in the frozen prepared foods industry—became an RCA subsidiary in March, 1970. The same year, RCA acquired Cushman & Wakefield, Inc., one of the nation's leading commercial real estate firms. Cushman & Wakefield's operations encompass project consultation, office leasing, building



The F. M. Stamper Company—a leader in the frozen prepared foods industry—became a wholly owned subsidiary in 1970.

management, site improvement and development, sales, and appraisal. In late 1970, an agreement for merger was reached with Coronet Industries, Inc., of Dalton, Ga. Coronet's activities range from the manufacture of floor and wall coverings and commercial, residential, and institutional furniture to the fabrication of foams, plastics, and other materials.

RCA's managerial and technical capabilities were directed increasingly toward the improvement of public education and training in the United States. During this period, the Corporation received contracts to operate the Keystone Job Corps Center for Women in Pennsylvania and the Choanoke Area Development Center for seasonal farm workers and their families in North Carolina. And in 1970, RCA received a U.S. Department of Labor contract to operate a residential Job Corps Center for the training of underprivileged youth in New York City. The same year, the company contracted to direct a federally funded program aimed at upgrading the public school system of Camden, N.J.

In 1969, a new growth opportunity for RCA opened in the northernmost state, when the U.S. government accepted RCA Globcom's bid to purchase and operate the Alaska Communication System. Plans call for a telephone rate reduction that will save the people of Alaska some $40 million during the first three years of operation. By the end of 1970, RCA Alaska Communications had already built a microwave system and a tropospheric and micro-

In 1970, RCA acquired Cushman & Wakefield, Inc., one of the nation's leading commercial real estate firms. One Astor Plaza is one of the buildings in New York City managed by Cushman & Wakefield.

RCA's capabilities were directed increasingly toward the improvement of public education and training. Shown above is a speech therapy session—part of the Keystone Job Corps Center program.

wave link and initiated direct-distance-dialing installations in Anchorage, Fairbanks, Juneau, and Ketchikan.

RCA capitalized on the increasing need for prompt, quality service by launching ServiceAmerica, a new organization to service all makes of TV sets and other home entertainment products. Ten ServiceAmerica centers were opened during 1970—five each in the Philadelphia and San Francisco areas.

In manufacturing, RCA entered the glass business in 1970 with the completion of a $19-million plant in Circleville, Ohio, for the manufacture of glass funnels and faceplates for large-screen color TV picture tubes.

International operations

RCA also embarked on a program of global expansion during these five years. In 1967, a new approach to international marketing and manufacturing was formulated, with each major division given worldwide responsibility for its products and services. At the same time, a corporate staff function was set up to coordinate international activities. In 1968, a distribution center was established in Hong Kong to serve the Far East market. The same year, RCA House was opened in London as a headquarters for administrative and marketing functions in Europe, the Middle East, and Africa.

This expansion was concurrent with the growth of color television in Europe that began in the late 1960s. Anticipating this growth, RCA and Thorn Electrical Industries, Ltd., formed a jointly owned company to construct and operate a color-tube manufacturing facility in Great Britain.

Other activities in the United Kingdom during the period have included the building of a new facility on the Isle of Jersey for commercial product activities in the European market and the construction of a solid-state applications engineering and test center at Sunbury-on-Thames. A record-pressing facility was built at Washington, in Yorkshire, and a magnetic products plant at Bryn Mawr, Wales.

In 1970, RCA constructed a $10.7-million semiconductor manufacturing plant in Liege, Belgium. This marks RCA's first electronics manufacturing facility on the European continent.

A facility was opened in 1967 on Taiwan for the manufacture of integrated circuits and memory planes. Later, the plant was enlarged for the production of certain consumer electronic products. In 1970, a 49 per cent interest was obtained in a new Taiwan company for the manufacture of black-and-white picture tubes for worldwide distribution.

An RCA Alascom tropo terminal at a frontier camp on Alaska's north slope.

In Canada, RCA opened a new color picture tube plant in Midland, Ont., in 1967 and announced plans for the construction of large new recording studios in Montreal. A year later, RCA entered the Canadian computer market with the opening of sales offices in Montreal and Toronto and the installation of a Spectra/70 data center, also in Montreal. Early in 1970, RCA Limited (Canada) moved into its new corporate headquarters at Ste. Anne-de-Bellevue, Que., on the outskirts of Montreal.

RCA was active in Mexico. The Corporation acquired Dispositives Electronicos S.A., a producer of receiving tubes for sale in Latin America. In 1969, a new Mexican corporate headquarters was established in Mexico City. A color picture tube assembly plant in Mexico City and a consumer electronics subassembly facility in Ciudad Juarez also began operations. The same year, a computer data center was opened in Mexico City for the marketing of electronic data processing equipment in that nation.

During this time, The Hertz Corporation greatly expanded its international operations. Its volume outside the United States and U.S. possessions increased an average of 30 per cent a year during the five-year period ending in 1970.

Prospects for the future

In his 1970 year-end statement to shareholders, Chairman Robert W. Sarnoff summed up the major goals of RCA. "Looking ahead through the 1970s, our program for progress aims for these major goals:

- Planned growth in areas of high profit potential, with particular emphasis upon services;
- Mounting strength and a firm position in the computer industry;
- Leadership in an expanding consumer market that is being profoundly altered by new technology and changing tastes.

As we move beyond the current period of economic adversity, the steps now being taken to achieve these objectives should position RCA for a new cycle of growth and profitability greater than any it has known in the past."

The inventor and his patent attorney

"Why didn't you ask me?"

Joseph D. Lazar

An article on the subject of inventions particularly addressed to the development of the full, clear, concise and exact terms to comply with the written description of the invention required by the patent laws and the continuing mutual duty by the inventor and his patent attorney to reveal all material relevant facts to one another and to the patent office.

As the title suggests, this article deals with people involved with inventions. As the subtitle suggests, it also is concerned with communication between the inventor, the patent attorney, and the Patent Office . . . and the lack of it.

The purpose is to help improve communication between inventors and their patent attorneys so that the remark "Why didn't you ask me?" need not be made. You might say the theme of this article is to get the inventor and his patent attorney to talk to each other. Such an exchange, it is hoped, will promote the ultimate objective of a complete understanding of the invention as the foundation for the description of it that can be made to satisfy the law.

Before discussing guidelines that may assist the inventor and his patent attorney promote mutual exchange of information, we shall discuss some challenges confronting the inventor. They are conditions that must be met by the inventor to establish in the United States Patent Office his rights to a patent.

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This discussion is based on the assumption that the reader has some rudimentary knowledge of inventions and patents. For those who have little or no such background, an appendix of "background notes on patents and invention" follows this article, together with a list of reference articles previously published in the *RCA Engineer*.

The challenges confronting the inventor (conditions of patentability)

For the most part, the patent laws and rules of the United States Patent Office are clear enough so that an inventor should be able to comply with the formalities of preparing the necessary documents to at least start the procedure of applying for a patent. Many inventors, indeed, do file for and obtain patents by themselves. Nevertheless, as one can imagine, as the preparation and prosecution of a patent application is a highly complex proceeding it generally cannot be conducted properly except by an attorney trained and experienced in this specialized practice. The United States Patent Office advises inventors to retain competent patent attorneys or agents who are registered to practice before the Patent Office. The employers of inventors often retain patent attorneys on a consulting basis, or as employees, to represent their employee-inventors.

Assuming that we are at the stage when an inventor believes he has made an invention that may be the basis for a patent, he usually will advise the patent attorney of his invention. In RCA, an inventor brings the invention to the attention of the company by completing a form known as a *Patent Disclosure* which will include his description of the invention. Other companies usually have similar procedures. It is with this description that the communication process between the inven-

Joseph D. Lazar, Patent Counsel, Patents and Licensing, Princeton, N.J., graduated from RCA Institutes in 1942, received the BEE from New York University in 1953, the LLB in 1957 from New York Law School and the JD from New York Law School in 1969. Before joining the RCA Patent Department in 1970, Mr. Lazar had experience in both the engineering and legal fields. He was employed by the Western Electric Company as an equipment engineer and by the Bell Telephone Laboratories as a Member of the Technical Staff. He was a consulting engineer in electro-magnetic devices and telephony. In the legal field, he spent several years with the patent department of the Western Electric Company. He then entered private practice including six years as a partner in law firm specializing in Patent Law in New York City. Mr. Lazar is a Registered Patent Attorney, and is a member of the Bar of New York, the District Courts of New York, the Court of Appeals of the Second Circuit, the Court of Customs and Patent Appeals and the U.S. Court of Claims. He is a member of Tau Beta Pi, Eta Kappa Nu, the American Bar Association, the American Patent Law Association, the New York Patent Law Association, the New York State Bar Association, the City Bar of the City of New York and the New Jersey Patent Law Association. He has also served as an Arbitrator for the American Arbitration Association.

tor and his patent attorney usually begins.

The challenge of the prior art

Whether the inventor knows it or not, his description of the invention must meet some pretty tough requirements. Furthermore, not only must he describe his invention properly but he is *assumed* to know everything in the field of his invention. It is of course a fiction that any one person can know everything in his own related field; nevertheless every applicant for patent is *assumed* to know all the art relating to his invention. This art is called the "prior art" since it is art *prior* to the invention. The prior art includes not only prior patents issued by the United States, but also prior patents of any of the foreign countries, and publications of whatever nature anywhere in the world. Thus, textbooks, periodical articles, Masters and Doctoral theses (if available to the public), papers submitted at professional society symposia —all these are deemed to be known by the applicant. Physical objects, even though not described in a printed publication, may also be part of the prior art. The Patent Office Examiner may rely on U.S. patents, foreign patents, and the usual textbooks and popular technical journals for the "prior art" used for his searches. There is a distinction between what the applicant is *supposed* to *know* and what is *actually known* by him.

The challenge of statutory classes of "useful" inventions

The Patent Laws define patentable invention as any new and useful *process, machine, manufacture,* or *composition of matter,* or any new and useful improvement thereof (Section 101 of the Patent Laws.) Hence, the so-called statutory classes are four-fold. For example, and without intending to be exhaustive by such examples, the *process class* may include a *process* for making rubber, or for developing pulse-code modulation signals; the *machine class* a *machine* for making textiles, or a system of apparatus (construed to be a "machine") for generating and processing pulse-code-modulation communications; the *manufacture class* may be a *manufacture* of a television receiver, integrated circuit, or semiconductor device; and the *composition class,* a *composition of matter* such as an antibiotic, a fertilizer, or a solution for electroless deposition of a conductive metal on an insulator substrate. The invention in addition to coming within the four types or classes just described, and in addition to meeting the statutory requirement of utility, just described, must also be novel.

The challenge of novelty and statutory bars

There are conditions under the statutory novelty requirements that prevent an inventor from obtaining a patent: "A person shall be entitled to a patent unless—" (Section 102 of the Patent Act), the invention was known or used by others in this country, or was previously patented, published, or the invention was physically made in this country previously by another. Any obstacle to a patent under these provisions (such as an article describing the invention or placing the invention on sale more than *one year* before filing an application for a patent) is called a "statutory bar." There are some other statutory bars which need not be described here in detail. A *statutory bar* invalidates a patent, because, in lay language, the invention claimed in the patent is not *novel.*

The challenge of obviousness

The "obviousness" condition is provided in the statute (Section 103 of the Patent Laws) as follows:

> "A patent may not be obtained . . . (even though novel) . . . , if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains . . ."

It is clear, on reflection, that the determination of what is "obvious" is an exercise of subjective reasoning. It is this requirement of the patent laws that is one of the most troublesome and controversial with respect to obtaining a patent as well as sustaining a patent in litigation after a patent issues. Although an extensive discussion of the obviousness question is beyond the scope of this article, it is important that the reader be aware that the manner in which an invention is described in a patent specification may do much to clarify for a lay [not scientifically or technically trained] judge at a later time why the invention was unobvious. Thus an invention that is not adequately described may be found to be obvious even though a more adequate explanation of the invention would have established that the invention indeed was not obvious and, therefore, was patentable.

In summary, then, an invention to be patentable must:

- be *novel*—no "statutory" bars, that is, the invention is not disclosed in the prior art;
- be *useful*—and also fall within the definition of the four statutory classes—process, machine, manufacture, or composition of matter. Of course, to be "useful" the invention should not seemingly violate the natural laws such as representing itself to be a "perpetual motion" device; and
- be *unobvious*—the test of the "skilled in the art" requirement recited above from Section 103 of the Patent Law.

The challenge of description of the invention

Let us return to the inventor who has an invention that he wants to describe in his patent application. Just how does he describe his invention? A lot depends on the inventor, his background, his expertise in the field of the invention—all these at least play a part in how the invention is at first described. But what matters in the end is what the law requires of an inventor. The background of the requirement is the patent statute which reads:

> "The specification shall contain a written description of the invention, and of the manner and process of making and using it, in such full, clear, concise, and exact terms as to enable any person skilled in the art to which it pertains, or with which it is most nearly connected, to make and use the same, and shall set forth the best mode contemplated by the inventor of carrying out his invention." *(First paragraph of Section 112 of the Patent Act)*

The words of this section of the law appear to be clear enough, one would think, to cause no difficulty. Fortunately, for the most part this is true. Unfortunately, for some patents and patent applications—particularly those covering inventions of value, as one would suspect—this section of the law becomes quite troublesome. The patent office and the courts have been forced to resolve questions of adequacy of the description of the invention against the inventor at times because he has not satisfied one or more of the conditions of this section of the law. Many times these conditions are coupled with those, just described, of *novelty, usefulness* and *obviousness.*

The inventor does his best to describe the invention, as he understands it, to his patent attorney. It is now up to the attorney to understand it. He begins by reading the original disclosure, i.e., the description of the invention. The attorney now asks himself whether the inventor has any *background* information relating to this invention which may help him, first, in understanding the true scope of the invention and, second, in having *all* the information that should be considered in preparing the patent application for submission to the patent office.

Simply describing a new oscillator circuit or a new radar system does not usually enable one to appreciate the scope of the invention. What is needed is the background of the art out of which the invention grew. Most, indeed, possibly all inventions provide a *solution* to a *problem*. The problem can be one that was previously partially or, indeed, fully unsolved. The inventive solution to such problems are usually considered patentable. Some problems in a given art have not been recognized and as such could not have been solved. Invention has been found to reside in the recognition of a problem by discovering the problem, defining it and then providing a solution. The solution, for example, in the form of a new combination of mechanical parts or a new electrical circuit, may seem simple enough as compared to the state-of-the-art structure. The newly discovered problem, however, coupled with the relatively simple solution can be sufficient to be the basis of an unobvious and therefore patentable invention.

An invention need not necessarily be limited to the form in which the inventor first makes it. The invention may take a *multitude* of forms, embodiments, or, as the statute says, "modes" (Section 112, *supra*). If the *true* scope of the invention is not appreciated by the inventor and the attorney, the one or two embodiments or modes of the invention as described in the patent can inadvertently cause a severe limitation to be imposed on the scope of the claimed invention. The inventor who does not appreciate the full scope of his invention may nevertheless have background facts about the state-of-the-art relating to the invention he contemplates that may prompt a patent attorney informed of such facts to investigate with the inventor to obtain enough additional facts to be the basis for describing and claiming the invention in its full scope. Thus, a process for making a compound X_1, Y_1 may well be only one form of a compound which can be shown to be of the class X_n, Y_n. An electrical circuit first made by the inventor to solve a problem in a limited bandwidth may well be only one form or embodiment of the invention of much broader scope. If such an invention is described properly by *teaching* other embodiments for using the invention in different and possibly wider bandwidths, a patent of broader scope may well be obtained. In both of these examples, an adequately described invention could support a claim for the broader aspect of the invention, while a more limited description may barely support a claim to the single example described.

A patent attorney who has not been told of the full background will find it difficult to appreciate the true scope of the invention and to describe it properly to meet the conditions of the patent laws that have been considered above. When the patent attorney becomes aware of some fact not told him by the inventor and asks why he was not informed of such a fact, the answer invariably is "Why didn't you ask me?"

When such a situation arises we are quite sure the answer is that the patent attorney and the inventor did not communicate. One assumed the other had knowledge which, in fact, he did not have. Either the patent attorney *"appears"* to be an expert in the inventor's field, or the inventor *assumes* that certain background facts need not be given to the attorney. One or more of such background facts later found lacking in the description of the invention can invalidate a patent or may be the basis for the rejection by the Patent Office of an application for patent. On the other hand, the patent attorney may assume the inventor described the invention in such "full, clear, concise and exact terms" so as to satisfy the laws.

What is needed is that spark of understanding that is developed at that precious moment when the inventor and the patent attorney both see that the other now understands the invention and appreciates its full scope.

Guidelines to background-fact situations

We are now ready to review the several kinds of background-fact situations which need to be studied by both the inventor and his patent attorney during the preparation of the patent application.

Test Data

Tests, experiments and related data concerning the background problems of the field of the invention and similar data relative to any embodiment of the invention actually constructed should be presented to the patent attorney. Such data should include both *adverse* as well as *favorable* results. Careful consideration of all such data should be made for the purpose of determining the *true* scope of the invention. Thus, unexpected critical relationships often support what was initially believed to be a routine state-of-the-art design as a patentable invention. On the other hand, adverse data when understood in the context of all the tests may show that more study is needed. Still worse, to everyone's dismay, such data may point to the fact that there is no operable invention at all, or that the scope of the invention is not as broad as initially asserted.

Notebook records

Notebooks and similar record books are usually the place where inventors keep records of what they do. Inventions, in concept and operative form, should be described in such record books and witnessed by competent personnel. The patent attorney should be apprised of all such notebook records so that he can get directly the full flavor of the development of the invention. Notebook records kept by the co-workers of the inventor are also important. Such records may indicate the proper or *improper* designation of inventorship. Sometimes the witness to an inventor's disclosure or a witness to a test of the invention after it has been reduced to practice may be in fact a co-inventor, that is, he made a contribution to the invention and as such is properly a co-inventor. A co-inventor cannot be a competent witness to his own invention. What is needed always is a witness who is not a co-inventor of the invention in question.

Published articles

All pertinent articles, proprietary or published, written by the inventor or his co-workers in the field of the invention should be brought to the attention of the patent attorney for his review whether written before or after the date of the invention. Possible inconsistencies or contradictions relating to the invention can be uncovered, hopefully, soon enough to correct or explain the errors, if any exist.

Public use or sale

Before the invention is embodied in an article that is to be placed on sale, the attorney should be informed, since such acts relate to conditions of patentability, either in the United States or abroad. If through some mischance, the act of selling or placing the article on sale occurs before the application is filed, the patent attorney should also be informed of all the facts relating to such acts.

Subsequent improvements

If, indeed, further work has been done on the invention after the patent attorney has prepared or filed the application, the information relating to such work should be brought to the attention of the patent attorney. Often times such information may well determine that the patent application then on file should be amended or, in some instances, replaced by a new application (technically called a continuation-in-part applicaiton if new descriptive matter has to be added to the first application). It will be clear then that the inventor has a *continuing* duty to keep the attorney informed about all aspects of the invention, particularly as long as the inventor participates in work relating to that invention. It may well be that the inventor is the only reliable source of information the attorney may have about a significant new or changed fact relating to the invention.

Revelation of the prior art

As indicated above, when the inventor describes the invention to the attorney, he should inform him of the state-of-the-art. Implicit in such state-of-the-art description are the works of others whether it be co-workers or competitors. Such works may include articles, textbooks, patents, and indeed actual devices embodying the co-worker's or competitor's invention even though no description of it is known or readily available.

Any such knowledge that comes to the attention of the inventor even after the patent application is filed should be brought to the attention of the patent attorney.

"Why didn't you ask me?"

Now, the inventor-reader may better appreciate the question posed in the subtitle; it should alert him to tell the attorney, without being asked, all *relevant* and *material facts* in the inventor's knowledge that relate to the invention. All facts whether favorable or not should be revealed. Undisclosed facts may one day come to light at a time that may jeopardize not only the validity of the patent covering the invention in question but also the reputation of the inventor, the attorney, and the company employing them.

The scientific and engineering community—the source of most inventions—should be aware of an attitude the Patent Office and the courts are taking with respect to acts, or omission of acts, which they consider to be fraud on the Patent Office. The prosecution of an application for a patent is not a proceeding whereby one party (the applicant) presents one view and a supposed hostile opponent (the Ex-

Appendix—background notes on patents and invention

A patent, more formally called a Deed of Letters Patent, is a grant by a sovereign, such as the United States, in return for a public disclosure of an invention and means for implementing it in a useful manner as described in the issued patent grant, giving the inventor the right to exclude all others for a prescribed period of years from making, using, or selling his invention within the jurisdiction of the sovereign. Thus for a United States Patent, the territorial coverage of a patent would include all 50 of the states, Puerto Rico, the territories, and its possessions, and the term of the patent is 17 years from the date of its issue. A patent gives the inventor no right to practice his own invention since another's prior patent not yet expired may dominate it.

Invention is the product of the mind of an inventor, and indeed, sometimes, the single product of the minds of two or more inventors working in concert. The invention starts in the mind of the inventor as a concept which may later be developed into one or more tangible *forms* or *embodiments.* Although the word "invention" has the attribute of being new, that is, having the attribute of novelty, all inventions are not patentable simply because of their novelty. An invention to be patentable must not only be novel, it must be useful and it must be unobvious to those of ordinary skill in the art.

Most of the countries of the world have developed patent systems whereby inventions can be reserved for the inventor's own use for a limited time in exchange for the revelation or teaching by the inventor of his invention and how to make and use it. The justification for this monopoly is that in exchange for this limited time of exclusive use of his invention the inventor agrees to dedicate his invention to the public after the patent expires. Thus, the public gets benefits of inventions which would otherwise not have been made without such an incentive.

United States patent system

Article 1, Section 8 of The Constitution of the United States grants the Congress the power "to promote the progress of science and useful arts by securing for limited times to authors and inventors the exclusive right to their respective writings and discoveries." The Patent Laws of the United States are founded on this portion of the Constitution. The Patent Laws are embodied in the *United States Code,* "Title 35—Patents" which has nearly one hundred separate divisions which together set forth the manner in which the Patent Office, an office of the United States Department of Commerce, carries out its function of receiving applications for patent and the granting of patents.

The United States Patent Office as authorized by the Patent Laws publishes a set of rules, known as the *Rules of Practice in Patent Cases,* as the mandatory guidelines which are to be followed in order to apply for the patent grant in the United States.

According to these rules, an application for patent is made upon payment of the prescribed fee (minimum fee is $65.00) together with a petition to the Commissioner of the Patent Office for a patent for the invention. Also included in the application are 1) a specification, describing the invention; 2) claims which set forth, in words, the scope of the invention the inventor believes he is entitled to over the prior art; and 3) drawings, if the invention lends itself to be shown by a drawing. The laws of the United States further require that the inventor state under oath, or by declaration, that he believes himself to be the first inventor, or inventors, of the invention described and that he has done no act which would otherwise prevent him from legally and properly being granted a patent, such as selling some form of the invention or describing it in some publication more than one year prior to filing the patent application.

When the patent application is filed, it is assigned to a Patent Examiner, an employee of the United States Patent Office, who examines the application to determine whether it meets the legal requirements for a patent.

The Examiner is knowledgeable in the field he is assigned to examine because of his technical education, his study of many patent applications in that field, and his repetitive review of state-of-the-art patents and literature. He reads the specification to understand the invention and the claims to determine what the inventor believes the metes and bounds of the invention to be. (It may be helpful to consider a deed of real property to be somewhat analogous to a patent claim, and in fact, land grants were called land patents. For an inventor to understand the words and aminer) presents an opposing view. The inventor-applicant, for the most part, has facts that are not known to the Patent Office and therefore is obligated to present all the facts *relevant* and *material* to the invention described in the patent application. *Withholding* relevant or material facts could be considered a fraud on the Patent Office. Some significant statements of the Supreme Court of the United States are worth quoting here:

> "Those who have applications pending with the Patent Office or who are parties to Patent Office proceedings have an uncompromising duty to report to it all facts concerning possible fraud or inequitableness underlying the applications in issue." (*Precision Company* v. *Automotive Company*, 324 U.S. 806, 818, 1945.)

> "By reason of the nature of any application for patent, the relationship of attorneys to the Patent Office requires the highest degree of candor and good faith. In its relation to applicants, the Office . . . must rely upon their integrity and deal with them in a spirit of trust and confidence." (*Kingsland* v. *Dorsey*, 338 U.S. 318, 319, 1949.)

We may add that these cases, although decided 25 years ago, are the basic authority upon which most present day patent cases involving the question of fraud upon the Patent Office are being guided.

Conclusion

Comments such as "Now you tell me" or "Why didn't you ask me?" can be avoided in the field of patent law, if the inventor and his patent attorney communicate fully without assuming what the other knows or *should* know. All *material* and *relevant* facts should be made available to the patent attorney who, in turn, should make them available to the Patent Office at the appropriate time whether during the preparation of the patent application or at subsequent times as such facts become relevant.

To have a worthwhile patent that will meet the rigorous tests to which patents are subjected with ever-increasing intensity, the application should be prepared to *fully* disclose the invention. The patent should also be prepared along the general guidelines provided in this article, particularly in presenting all facts with the "highest degree of candor and good faith" in all matters dealing with the Patent Office.

References to earlier articles in the RCA Engineer on patents, invention and inventors.

1. Tuska, C. D., "Increasing Creativeness in Engineers", *RCA Engineer* Vol. 1, No. 1 (June/July, 1955) pp. 50-53. *Some observations on the creative ingredients and circumstances leading to inventions.*
2. Rabkin, Morris A., "Inventive Progress", *RCA Engineer* Vol. 2, No. 1 (June/July, 1956) pp. 47-50. *Describes the evolutionary development of a three-legged stool into a chair with a backrest and armrest and the rights of each of the inventors of each step of the development.*
3. Johnson, Joel B., "Protecting Dates of Invention", *RCA Engineer* Vol. 3, No. 1 (June/July, 1957) pp. 38-41. *Explains the need for keeping records of concepts and reductions to practice of inventions with corroborating witnesses, and interference problems relating to such record keeping, an* interference *belng a legal contest between different inventors to determine priority, and thus the right to a patent covering the invention.*
4. Mitchell, O. V., "Patents and Things", *RCA Engineer* Vol. 4, No. 1 (June/July, 1958) pp. 47-49. *Explains the conditions for obtaining a patent and summarizes the various forms of property rights, including copyrights, trademarks, design and plant patents.*
5. Mitchell, O. V., "Patents, RCA and You", *RCA Engineer* Vol. 9, No. 2 (Aug./Sep., 1963) pp. 2-6. *Describes various fact situations of interference conflicts and illustrations of witnesses to the conception and reduction-to-practice of inventions.*
6. Russinoff, A., "Identification of Inventorship", *RCA Engineer* Vol. 14, No. 4 (Oct./Nov., 1968) pp. 6-7. *Describes the identification of inventors wtih illustrations of the problems of* sole *and* joint *inventorship.*
7. Russinoff, A., "Inventions and Obviousness", *RCA Engineer* Vol. 15, No. 5 (Feb./Mar., 1970) p. 101. *Outlines the requirements of novelty, utility and non-obviousness.*

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thus the scope of a patent claim, he should try to draw a picture of one form of the invention from the words of the claim. The words of the claim should be like the "metes and bounds" description of a deed of land and direct the reader from one end of the invention to the other as the land deed directs the reader over the land embraced by the description.)

The Examiner searches through prior patents and some of the other literature to find the most relevant references prior to the inventor's filing date. The Examiner should try to find a full description of the *claimed* invention in one document. If such is found, it is called an *anticipation* of the invention claimed. If the Examiner is correct in his interpretation of such a citation, the patent application should be abandoned. If the reference is not an *anticipation*, the invention as claimed may still be rejected by the Examiner as being *obvious* in view of one or more references. It is this area of the examination procedure that usually provokes the classic conflicts between the applicant-inventor and the Patent Office. By arguments and amendments (changes) of the claims, the Examiner may be persuaded to withdraw his objections and allow the application to be granted as a patent.

When the patent is granted to the inventor or his assignee, it is in the form of a document known as the deed of the Letters Patent (open letter) each one being issued with successive identification numbers. The number of patents in the United States issued since the numbering system started in 1836 is over 3,550,000. The U.S. Patent Office is now attempting to grant patents within two to three years after the application filing dates, at a rate approaching 100,000 patents per year.

Patent systems in foreign countries

Each country having a patent system has its own set of laws and rules by which patents are granted for inventions. Most of these countries, including the United States, are parties to an agreement, known as the *International Convention for the Protection of Industrial Property*. According to this agreement, patents can be obtained in each of the countries with an effective filing date the same as that of the patent application of the first-filed country provided an application is filed in such countries within one year of the first-filed date, subject, however, to the peculiar laws of each of those countries. Some foreign countries, including the Scandinavians, France, Holland and Italy, for example, require that patent applications filed in their country or in the originating "convention" country be done *prior* to any public use, sale, publication, or divulgation of the invention. Thus, inventions which are to be considered for foreign filing should be protected by a patent application filed in the United States or a suitable foreign country before any publication of the invention, otherwise certain foreign rights may be lost.

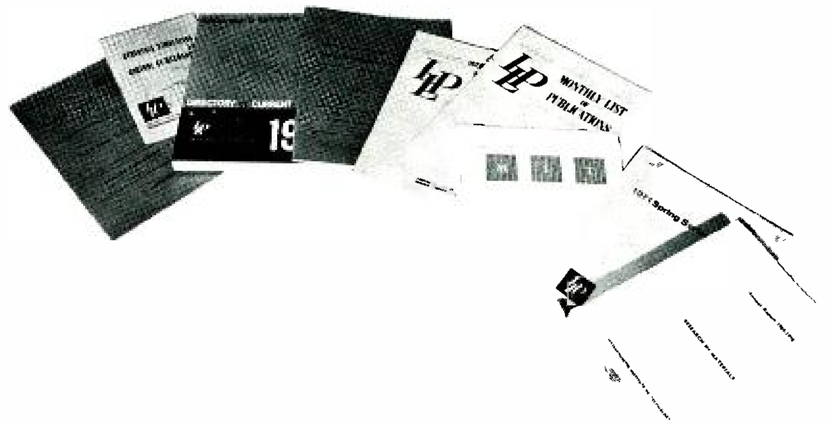
Unfortunately, most of the countries have patent laws that are unique to themselves and, for the most part, quite different from each other. Within a decade, a more uniform set of patent laws may exist which should provide the basis for a single international patent grant. The Patent Cooperation Treaty is now in the process of being ratified by the United States and other countries. This treaty may be the first step in establishing the basis for an "International Patent" by setting up procedures for using the facilities of each country for the common benefit of participating applicants.

Inventions and government contracts

Among the problems which a company such as RCA must consider when contemplating taking a Government contract is whether the patent rights obtained by the Government will seriously dilute RCA's patent position. Under U.S. Government contracts, the Government receives at least a non-exclusive license for governmental purposes throughout the world under all inventions either conceived or first actually reduced-to-practice (successfully built) under the contract. Some agencies of the Government, in addition, acquire full title to all such inventions. Thus, the Government may receive rights to inventions made under prior RCA-funded work merely because the invention is first built and tested under the contract. In some cases, these rights can be reduced to the previously mentioned license by negotiation prior to contract. Thus it is important that Patent personnel be made aware of previously conceived inventions or likely future inventions under which the Government may receive rights.

In any case, it is recommended that a patent attorney be consulted on questions involving inventions related to Government contracts.

The Engineer and the Corporation



MIT-RCA Research Conference

W. O. Hadlock, Editor

Pictured are some of the literature items available as a part of the ILP service to RCA.

Editor's Note: The information summarized in this article has been compiled from random notes, information provided by the speakers, and recordings made during the MIT-RCA Seminar. Some of the Conference speakers have indicated that more information is available.

Credit is given to Hans K. Jenny, Mgr., Microwave Solid-State Devices Operations, Electronic Components, Harrison, N.J., who provided the Editors with copious notes. Information concerning the Industrial Liaison Program as well as the photographs for this article were provided by Frank W. Widmann, Mgr., RCA Engineering Professional Development, Corporate Engineering Services. Special thanks also to the Conference speakers and J. Peter Bartl, MIT-RCA Industrial Liaison Officer.

At a recent MIT-RCA conference, faculty members of Massachusetts Institute of Technology, Cambridge, Mass., conducted a two-day seminar for the special benefit of about 80 RCA research, engineering, and technical planning personnel. Discussed during the sessions was the current progress being made in several branches of contemporary research, preselected topically by RCA for consideration (see summaries to follow). The seminar is one of numerous services being provided by MIT under the RCA-MIT Industrial Liaison Program (ILP) agreement.

The ILP program—what it is

MIT is presently conducting a $200 million research program annually that covers broad technical and business spectra. MIT operates its Industrial Liaison Program to share benefits of the total effort with industry; to achieve the objectives of maintaining a constructive role in modern education, management and scientific research; and, to promote academic programs to benefit society at large.

To achieve these established objectives, ILP serves as the principal, formal mechanism for interchanges between MIT and external research, engineering, and management activities. Contact with industry strengthens MIT's teaching and research. Companies participating in the programs provide financial support to MIT. A number of services have been developed by MIT (see Table I).

RCA is one of about 100 companies presently participating in the Industrial Liaison Program. In return for an annual fee, RCA obtains the potential of quick access to—and an active communications channel with research programs that align with RCA's current and possible future business interests.

Supplements RCA programs

RCA's own research program is aimed primarily at supporting the most critical needs of the Company in currently identified business areas. However, many important areas of research and advanced technology that also merit continued study must be bypassed because of economic priorities and limitations. Thus, the MIT research program supplements the RCA program and complements it where RCA has the need for awareness but has not invested directly.

MIT administers the program through an Industrial Liaison Office (ILO), staffed by Industrial Liaison Officers. One of the six officers, J. Peter Bartl, is assigned to interface with RCA in rendering the services available under the program. Mr. Bartl maintains direct contact with key people in each of RCA's divisions, and with Frank W. Widmann, Manager of Engineering Professional Development, Corporate Engineering Services, who administers the program for RCA.

Benefits entire technical staff

RCA engineers and scientists in all areas are eligible to benefit from the services provided under the MIT-RCA Industrial Liaison Program (see Table I). Selected periodical publications such as quarterly progress reports from various MIT departments, lab-

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oratories, and interdisciplinary centers, may be obtained. Monthly Lists of Publications (MLOP) are available through F. W. Widmann, Bldg. 2-7, Camden, N. J. (PC-3121). Except in those instances which may lead to formal consulting agreements with MIT, contact may be made directly with J. Peter Bartl, at the ILO (Room 5-207), MIT, Cambridge, Mass. 02139, Tel: (617) 864-6900, Ext. 269, 3792.

Summaries of presentations

The technical and business portions of the recent two-day RCA-MIT seminar consisted of informal, oral presentations generously interspersed with question-and-answer breaks. The topics covered during the sessions fall into the following general categories: current MIT computer research and possible applications of computers; innovations and technical entrepreneurship; various technical research projects; and marketing and business management programs.

Some presentations, such as Dr. Robert A. Alberty's after-dinner talk on "Future Trends in Science", dealt with research, engineering and the effects on the society. Following a welcome by Dean Paul Gray, Dean of MIT's School of Engineering, the workshop sessions were carried out at MIT's campus facilities in Cambridge, Mass.

The summaries reported in the following pages are intended to provide a general overview of the technical presentations; additional information and details may be available from Frank W. Widmann, Manager of RCA Engineering Professional Development or by direct contacts with MIT personnel through J. Peter Bartl, MIT's Industrial Liaison Officer.

Impact of the seminar

The presentations and discussions with faculty members represent not so much a panacea for solving our present problems but a strong stimulus to become more involved with new research and engineering tools and their relationship to present and future applications.

There is much effort being expended on developing meaningful models, by use of computer methods, to tailor new ideas and concepts not only to our business but to the people who influence it. We have not yet scratched the surface in utilizing the computer as an information-system tool. Hopefully, the informative presentations will stimulate greater involvement.

More attention seems indicated in defining problems and in the formulation of ideas; small innovations, even including "fringe ideas", can be significant in a company's success. The complete recognition of the customer's demands on technology (rather than just the technical potential) can improve our effectiveness.

The technical entrepreneur can be one of the key ingredients to this success—particularly in advancing a promising young product line that needs to grow. Proper encouragement and recognition are motivating factors.

Finally, consideration of whether the customer gets value and service must be given by every single member of the line organization—and especially by each management member who can do something much more than simply ship a replacement device. Most importantly, a determination of the "right problem" by engineers can reduce the number of "right solutions to wrong problems."

Table I—Services provided by the ILP.

1) *Research conferences* to discuss MIT's research in progress.
   a) Fall and Spring Symposia series covers all areas of potential industrial interest.
   b) Bi-annual, two-day management briefing developed especially for RCA. This is a special arrangement made for RCA; and, MIT faculty focuses on research areas of mutual interest to MIT and RCA.
   c) Notices and invitations of one-day seminars and special lectures, held primarily for the MIT staff, are distributed by the Industrial Liaison Office (ILO) to RCA people in the MIT locale.

2) *Advance announcements* of summer courses (individual attendees pay for courses), regular seminars, and special courses enable RCA people to register early and avoid over-subscribed courses.

3) *Publications*—periodic and automatic distribution of certain MIT laboratory reports and other publications by ILO. The annual "Directory of Current Research" and the "Monthly List of Publications" (MLOP) are of special importance. The "Directory of Current Research" initiates the exchange of information between individuals at MIT and in Industry. The MLOP lists abstracts on research in progress, generally before outside publication (reports and bibliographies may be ordered).
   Regular distribution of announcements and publications covered in 1) through 3) is made to RCA libraries and Chief Engineers or other key representatives in each RCA division/location.

4) *Inquiries* concerning specific technical problems can be handled in writing through the ILO, or by telephone. This is one of the most important services, since aid, in problem solving and in locating technical information, is available without the expense incurred in a personal visit.

5) *Visits by RCA* representatives to MIT for consideration of unusual company problems. Such visits provide RCA an opportunity to talk with faculty concerning their experience in specific fields, and to interest faculty members in problems of interest to RCA.

6) *Visits by MIT* representatives to RCA.

7) *Opportunity to influence the direction* of MIT's research program (requires close rapport, right project, and timing).

8) *Opportunities to sponsor* special research work from MIT using ILO fee to offset up to 50% of the overhead charges for purchased research work.

9) *Opportunity for direct participation* in research activities, as a resident guest at the Institute or as a fellow in the Center for Advanced Engineering Study.

10) *Assistance* in finding consultants.

11) *Assistance* in recruiting personnel with special capabilities.

12) *Inter-library loan privilege* enables RCA libraries to borrow books from MIT which has one of the best technical libraries in the country.

13) Library privilege cards have been made available to RCA facilities in the vicinity of MIT, and may be used by RCA engineers.

Photos below, (L. to R.): Dr. Paul E. Gray, Dean, School of Engineering, welcomed the RCA participants and reviewed the objectives of the conference; J. Peter Bartl, MIT's Industrial Liaison Officer, served as chairman of the meeting; Dr. James Hillier, Executive Vice President, RCA Research and Engineering, and Professor Louis Smullin, Head, Dept. of Electrical Engineering, exchange views at the dinner meeting; Banquet host, Mr. Vincent A. Fulmer, Vice President and Secretary of the Institute, conversing with A. R. Trudel, Director, Corporate Engineering Services; and Howard W. Johnson, President of MIT, who presided as host and luncheon speaker.

Trends in research

Dean R. A. Alberty reviewed some of the outstanding scientific breakthroughs occurring since 1920. Such achievements in biology, chemistry and physics (even though substantial at the time of innovation) have pointed to existing gaps and inadequacies in many areas of science. It is the combination of future developments that are sure to come . . . and the numerous opportunities that already exist for scientific progress which constitute a substantial challenge for engineers and scientists engaged in contemporary research.

Future trends in science

Dr. Robert A. Alberty
Dean of the School of Science

One thing that seems sure is that the future in science will be full of surprises, just as it has been, as I review my own span of interests in science, since the 1920's.

In reviewing the gold mine of scientific gems recorded between 1920 and 1971 in the *Times Almanac,* I find the following of significance in broad fields of engineering, generally: TV Scanner, conditioned reflex, neutrons, nylon, jet engine, fission, electron microscope, controlled nuclear fission, electronic computers, the transistor, and the laser. The next 50 years should produce many more. A review of a few scientific fields in this same period 1920-1970 may provide a clue to the direction or trends.

Biology: insulin, electro-cardiograph, vitamins A and B, function of chromosomes in heredity, sulfa, penicillin, DDT, streptomycin, polio virus, synthesis of RNA and DNA molecules, replication of DNA.

About 2 years ago, the first enzyme and the first protein molecule were synthesized in the test tube by two groups using entirely different methods. The enzyme has a molecular weight of 16,000 and in time larger enzyme molecules will be produced. Another recent discovery is the isolation of the gene from a living cell; more recently, a gene has actually been synthesized.

Certainly, biology is in an active and interesting phase; however, there is no scientific theory on how to go about the job of developing drugs to attack a specific disease. Many of the advances in biology also relate to chemistry as shown below.

Chemistry: mass spectrometer, heavy hydrogen, first crystalline enzymes, determination of 3-d structures of hemoglobin, and the pill for birth control, and advances in radio-chemistry.

Physics: photo-electric laws, structure of atoms, wave nature of electrons, quantum mechanics, neutron, nuclear resonance, transistor, and maser/laser.

In the field of physics, the particles that were few in number in 1920 (protons, neutrons, electrons) have grown to over 120 fundamental particles. The higher the experiments go, in terms of energy, the more particles show up. However, the basic theory of these particles is not in good shape in spite of some advances. The situation in particle physics now compares with the situation in atomic physics prior to the time when quantum mechanics clarified what was going on.

Our illusions of simplicity are shattered by the internal structures of the proton and neutron that have been discovered. It is almost like getting into the atom again, having a nucleus of about 10^{-13} cm surrounded by electrons. The proton (10^{-13} cm) turns out to have things inside it smaller than 10^{-15} cm.

By going to higher-energy accelerators, as in the 400-billion-electron-volt facility in Chicago, physicists will, no doubt, discover more basic particles. To put everything in perspective, 400-billion electron volts is not a terribly high energy compared with cosmic ray energies of 10^{20} electron volts. There is a big gap between what exists in the universe and what we are able to create or duplicate in the laboratory.

Astronomy has made possible spectacular discoveries in recent times of very distant quasars and of pulsars which have radio-wave emissions; some correlation has been observed of the emission of X-rays and light waves.

There are many X-ray sources in space that have been identified with visible objects and many that remain very mysterious. Although we have seen considerable progress in astro-physics, there remain many phenomena to be explained.

Earth sciences: Earthquakes remind us of tremendous forces we don't have very much knowledge about or any control over. The recent West Coast quake was only 1/80th as strong as the disastrous San Francisco earthquake. We should do two things: find out where the earth is shifting; and, look for possible help in reducing shocks to take place in more gentle fashion. Ten years ago, no respectable geologist believed in continental drift; now, methods are being perfected for the study of a continental drift. Remarkable progress in radio astronomy offers the possibility of using long-base-line interferometry to measure continental drift. Measurement of velocities of one centimeter per year appears possible.

Oceanographic studies are exciting and holes have been bored into bedrock in the deepest part of the Atlantic Ocean to get a history of the sediments of the Atlantic ocean and the earth's history itself.

It is now known that material is coming up at the mid-Atlantic ridge so that the European continent and the American continent are drifting away from one another.

Meteorology and electronics can be combined to establish temperature and pressure profiles from satellites instead of ground-based observation systems. Computers can help to put it all together for a better understanding.

I hope I live to see these developments in science which are sure to come. One thing is certain: there will be many surprises and there is a lot of raw material to provide challenges for the scientific minds.

Research projects

The next four papers by Zimmermann, Kennedy, Stern and Baddour give you an idea of the broad scope of research and engineering effort at MIT and relate the direct application of an academic research effort to the solution of significant problems in industry and in our total society.

The extensive scope of such research is described in MIT's 1971 directory of research projects (contact F. W. Widmann). However, the talks for the current seminar emphasized the new research areas in general physics, quantum electronics, plasma dynamics, communications sciences, surface acoustic waves, environmental sciences and in quality control.

Current activities of research laboratory of electronics (RLE)

Professor H. Zimmermann,
Director, Research Laboratory of Electronics

The Research Laboratory of Electronics evolved from the MIT Radiation Laboratory which had a strong background in physics and electrical engineering. The present complement (with academic research emphasis) is as follows: 100 faculty, 300 graduate students, 100 undergraduates, and 150 general support personnel. Over the years the activities expanded to the present size of ten participating departments. There are three general areas of research: general physics (quantum electronics), plasma dynamics, and communications sciences.

General physics—quantum electronics

In the general physics area, the emphasis is on quantum electronics. The molecular-beams group has conducted research on nuclear magnetic moments that led to the cesium clock, making very precise time measurements possible. This in turn has led to work in low-temperature phenomena particularly with helium and hydrogen . . . and some work has been started on the reflection and evaporation of atoms from surfaces at temperatures near absolute zero. Atoms are emitted from the surface non-uniformly in a spatial variation determined by the weak forces that bind molecules together.

This research has led to studies of large aggregates of molecules as encountered in ceramic and magnetic domains . . . and in the biological domain, the macromolecules. The hope is to determine why the structures go together the way they do, from a physics standpoint, by means of a so-called molecular microscope. One model under consideration seeks an understanding of the reason blood components (thrombin) attach to artificial (plastic) arteries, no matter how smooth the surface, and eventually clog the plastic artery.

Another interesting project is the high-contrast, high-resolution electron microscope; the basis for this will be a very thin spherical-foil lens which has excellent characteristics. This is going forward as a computer simulation prior to construction.

Another area involving quantum electronics is an active program in radio astronomy and related radiometric techniques to make measurements of the earth's atmosphere and measurements of galactic sources. There is an interest in studying the oxygen-molecule concentration in the earth's atmosphere. The hope is that precise temperature measurements can be made (with the help of satellites) to determine communication characteristics and indicate what variations exist in oxygen content in the atmosphere layer around the earth. The results may indicate significant information about pollution.

Radiation studies are being made from infrared stars. Out of 500 stars studied, 24 were found to radiate substantial amounts of power at 18 cm wavelengths. The radiation is so intense that it would seem to be caused by maser action.

Another area of interest is in radio astronomy using very long baselines (many thousand miles) to obtain extremely high angular resolution. Coherent measurements are made possible by an atomic clock at each observatory station. Measurements have been extended to about 1.35 cm wavelengths to study newly discovered intense water-emission sources. Precise measurements can also detect changes in earth dimensions and influences of the planets.

Laser technology is another area of interest. Studies of quantum phenomena which cause noise have led to investigations of stable CO_2 lasers for numerous applications.

Plasma dynamics

The plasma dynamics group has a general interest in plasma instabilities, plasma containment in magnetic bottles, various plasma diagnostic techniques, and laser generation of plasmas.

Most of these efforts are aimed at the study and use of power generated by controlled thermonuclear fusion. We are constructing a toroidal device called "alcator" which generates extremely high-density plasmas in order to study some of the problems arising in controlled thermonuclear fusion. Ionized particle densities are expected to reach the order of $5 \times 10^{15}/cm^3$, temperatures up to 5000 electron volts, and containment-times of one second. Very-high-density magnetic fields are being produced successfully around the 140-kilogauss level.

Communication sciences

The studies in communication areas are very broad and involve generation, transmission, and processing of signals in both living and man-made systems. Research areas include linguistics, speech communication, the auditory system, visual perception, communication theory and computer applications.

Picture processing, image enhancement, and bandwidth reduction are studied by making use of combined digital and holographic processes. Picture processing has led to biomedical applications and automation of clinical processes used in the analysis of variations in immature and pathological white and red cell behavior. Manual slide methods are inadequate.

Computer-based display systems provide detailed catalogs of neural anatomies for biomedical application studies. For example, computer processing can potentially be used to build up three-dimensional displays of neural anatomy from thin slices of tissue. Similarly, 3-D (X-ray) displays could be constructed from two or more plates taken in different directions.

Studies are being conducted on reading machines for the blind; the experimental machine scans a printed page or newspaper and speaks the contents in English. The input is a scanner, and the output is a speech synthesizer; in the machine, is a graphic-to-phonic transducer which stores rootwords, prefixes, and suffixes . . . and then interconnects them.

Linguistic studies include detailed speech-communications surveys of many languages to determine structural similarities and differences.

Communications studies in the research laboratory of electronics

Professor Robert Kennedy
Department of Electrical Engineering
Research Laboratory of Electronics

The speaker described activities of a group of researchers working in the area of optical communication. Problems being considered include the familiar noise problems, propagation and path loss problems, fading and dispersion, and the noise associated with fundamental quantum effects. There are many instructive analogies between these problem areas and similar problems in conventional microwave communication. Particular emphasis has been placed on 1) communication through a clear turbulent atmosphere, 2) communication through scattering channels (haze and clouds over-the-horizon), and 3) quantum physics aspects of optical communication. A good general reference on the field is the October, 1970 issue of the *IEEE Proceedings*.

In optical communication, the atmosphere is a complicating factor in that it introduces fading and dispersion in time, space and frequency. Except for the spatial effects, this is similar to some of the problems encountered with tropospheric channels at microwave frequencies. To date, most researchers have concentrated on clear turbulent atmospheric channels. Few people outside of MIT's Research Laboratory of Electronics have seriously studied communication through scattering channels. The problems posed by such channels are similar to those found in clear turbulent channels except that many problems are more pronounced and therefore different solutions must be found.

Another area of interest is the quantum aspect of optical communication. Thus far, it has not been possible to create a model of the receiver that accounts for fundamental limitations imposed upon the system by the laws of quantum physics and a model which is sufficiently general to incorporate receivers that may be developed in the future.

Surface acoustic waves and their application

Mr. Ernest Stern
Lincoln Laboratory

The author and five associates are concentrating on a study for the Advanced Ballistic Missile Defense Agency (ABMDA)—involving lithium-niobate devices for signal processing.

Many analogies can be made between acoustic wave phenomena and the patterns of water waves. Disturbances caused by acoustic waves (as with water) decay exponentially into the surface and particle motion beneath its wave is elliptical and retrograded; but, here the similarities end. Where a water wave occurs every 10 or 20 seconds, the acoustic wave crests occur every 5-billionth of a second.

Other differences are that amplitudes of acoustic waves are measured in angstrom units. Water waves are measured in feet and they are dispersive, since the velocity of waves on the surface of water is a function of the distance between wave crests. In uniform solids the velocity of the acoustic wave is independent of the frequency. The velocity of the water wave is independent of direction on the surface; for lithium niobate and other crystals, velocities of surface waves vary with direction. The author described other characteristics of acoustic waves that prove desirable such as:

1) Acoustic media that propagate energy waves five orders of magnitude more slowly than electromagnetic waves. Signals can be crammed into a 1-inch lithium-niobate crystal that would ordinarily fill a mile-long cable.
2) Acoustic waves are less lossy, presenting one-tenth to one-hundredth the loss of commercial cables.
3) A surface wave is accessible everywhere—and the wave can be easily manipulated.

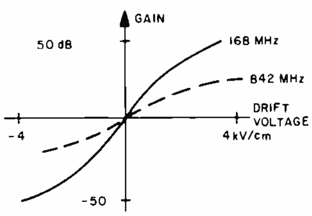
Surface acoustic waves can be generated in response to electrical signals (impulses) and electrical signals can be transduced into acoustic waves.

Waveguides consisting of a relatively slow acoustic medium can be placed on top of a stiff high-velocity medium (such as zinc oxide on sapphire). Wave patterns for various combinations and applications are studied by the use of jello molds.

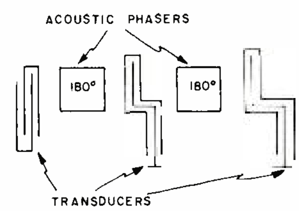
A surface wave on lithium niobate having piezoelectric properties produces an associated electrostatic field that extends out from the surface. Acoustic amplifier action is obtained when a semiconductor, with carriers drifting at a velocity in excess of the acoustic wave velocity, is brought within the ambient range of the electrostatic field.

Many acoustic surface-wave, low-loss devices can be built for various applications including tapped delay lines, memory storage, filters, and correlators. The waveforms and diagrams included in this summary show some of the phase-shift, power switching and delay-line characteristics of acoustic-wave devices. The amplifiers are acoustic devices only—and are not intended as a substitute for electronic amplifiers.

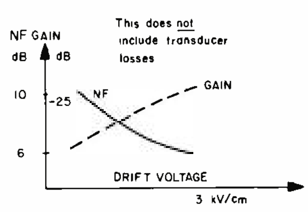
Examples:



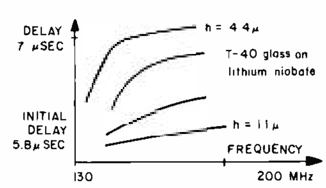
a) Silicon accumulation layer amplifier



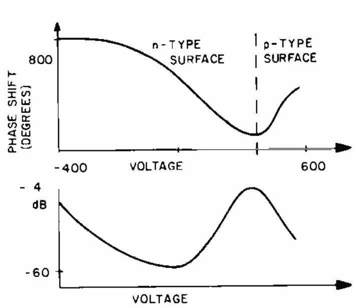
d) Power switching



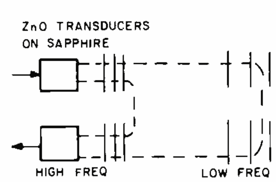
b) NF gain of silicon accumulation layer amplifier



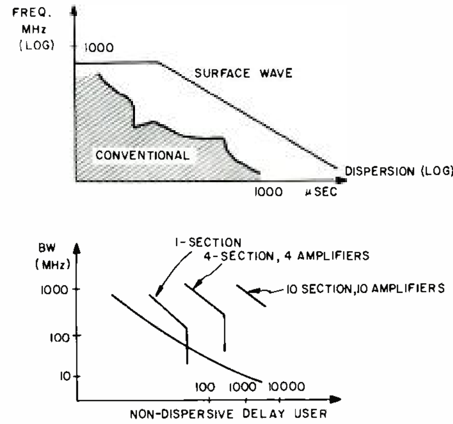
e) Delay lines



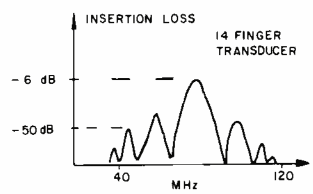
c) Phase shifter



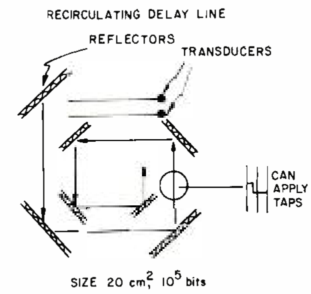
f) Dispersive delay as function of frequency



g) Performance potential



h) Filters



i) Memory device

The acoustic-wave devices are quite flexible in that frequency, velocity, bandwidth, and delay characteristics can be easily controlled and manipulated; losses are low and lines can be tapped at any convenient point. Fabrication is compatible with the photo-lithographic processes used with integrated circuit techniques. Surfaces (in contrast to bulk wave devices) can be fabricated by planar techniques. Quality control is less stringent than it is for semiconductors. Production yields are good and acoustic devices are forgiving to certain kinds of mishandling.

Environmental sciences

Professor R. Baddour
Head, Dept. of Chemical Engineering

MIT has now set up the Environmental Laboratory for interdisciplinary mission-oriented programs. The author is Director and has a Policy Advisory Committee and a Council to assist in coordination with educational programs, the Interdisciplinary Environmental Council. Contacts include people both in government and in industry to determine what major problems need pursuit. The primary objective of these contacts is to define the most pressing environmental problems. Support for work on these tasks comes from government agencies, industries (oil, gas, utilities), foundations and private groups. Some important environmental problem areas to be pursued are described herein.

Energy production and consumption

Energy consumption has shown a frightening monotonic linear growth in terms of fossil fuel consumption when plotted on log paper; this represents a tremendous problem for the future, since the "die is cast" for the present decade in types of fuel used for power sources. Substantial use of nuclear power cannot come before the 1980's.

Thus, study is required on a national and international scale to formulate policies on the fuels and methods we choose to produce energy, and the pollution specification levels.

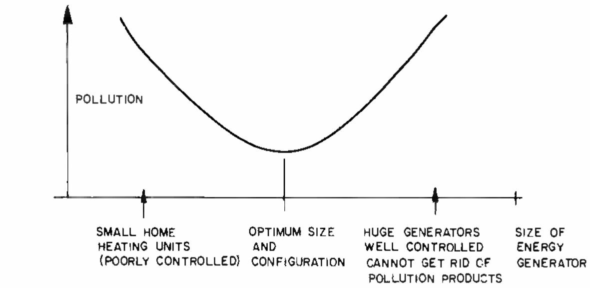
- The U.S. needs a national energy policy.
- The world is competing for energy-producing raw materials.
- Any decisions made now on a major change in energy sources will not become effective until after 1980.

In developing a national policy those recommending its form must be credible and reliable. Coordination is usually challenging since industrial firms are restricted in divulging information to one another. Industry, society and government all are forces to be considered and various fuels, electric heating and nuclear methods are involved. Those groups involved and knowledgeable all have their own special interests: oil companies, public services, utilities, AEC, etc., etc.

MIT is fortunate to be in a position to communicate with most all groups, and to be able to make a study taking all variables into account. MIT should be able to provide the government with the kind of background studies required to develop a rational national energy policy.

Environmental problems

During July 1970, a study sponsored by MIT and Chaired by Professor Carroll L. Wilson was made at Williams College. The summary and recommendations were published in October in a "Study of Critical Environmental Problems," MIT Press. Portions of the study have been read into the congressional record, and considerable actions by government agencies have resulted from the work. An international version of the portion of the study dealing with man's impact on climate will be held in Stockholm this summer, sponsored by MIT Environmental Lab.



Planning for minimum pollution dispersion problem.

It is felt that individual home heating plants will eventually go to electric power. Substantial effort on automotive problems leads to the same conclusion but breakthroughs in battery designs are needed.

Pollution control studies were initiated in preparation for a UN Conference on *Man and the Environment* to be held in 1972 in Stockholm.

Motion of air currents and effect on pollution

If power companies could burn cheap, high-sulphur fuels on days when the flue gas would be washed harmlessly into the sea and use expensive low-sulphur fuels at other times, the savings would be enormous. This is only one practical example of why we need to know more about air currents and air sheds. Thus, much must be learned about the air current phenomena .

Currents and motions of coastal waters

Similarly, knowledge of currents and motions of coastal waters is imperative. An objective of this study is to keep sewage and other pollution away from the fish breeding grounds which are close to shore.

Computer research and application topics

The first three presentations by Saltzer, Fano and Forgie review current MIT computer research and point to technical areas that require the serious attention of engineers and scientists so that the best interests of society will be served and so that specific services provided to society will be enhanced. The increased use of computers in research and the need for more direct interaction between actual users and the computer without expensive and unnecessary intermediate disciplines, are considered. The contrasting problems of maintaining individual privacy and still effecting a controlled sharing of nation-wide computer networks are explored (hypothetical examples are cited in which up to 750-thousand government employees might require access to the histories of 25-million people recorded in security-surveillance files). In the continuing use of computers, the ability to store knowledge (not data) in directly usable form must be further developed; a key to such solution lies in the "coupling" to people.

A fourth and specialized presentation relating to the application of computers concerns an imaginative, inexpensive and seemingly most powerful approach to upgrade grade-school learning methods. Maybe you have sufficient interest and initiative to discuss this with your school board. Significantly, Dr. Papert reports that fifth graders learn to control the "turtle" computer more quickly than seventh graders; the next step extends the program to the third grade.

Impact of computer presentations: **the four technical presentations relating to the use of computers cause the manager and the engineer to think: "What can the computer do for me? Have I made a serious attempt to utilize it? The cooperation between the user and the creators of program models seems to be the real answer.**

Computer Systems: future research directions

Professor Jerome H. Saltzer
Department of Electrical Engineering

Clearly, one can hypothesize a computer system and construct on paper a design. One can even model the design, build simulations, and explore results of the simulation. But the one problem you run into, especially if proposed systems have unique features different from those of any other systems, is that you have no way to model how users are going to load the system.

Methods of information system research

If you know what the load looks like, you can simulate, and get results limited only by your ingenuity. Otherwise you have no way to predict the load and you are stuck. The conclusion, if you accept this premise, is that to do research on computer systems, you've got to have real users. You are going to have to do something to find out how real users react to your proposals; you can't have real users unless you build the system. This leads to the general technique that the computer system research group of Project MAC has followed in developing two major systems at MIT, the Compatible Time Sharing System and the Multics system.

Of course, there are some limitations in this approach; you can't be guaranteed that everything is going to work out perfectly. You can't propose to make changes so radical that no user is willing to try the result.

Another obvious limitation to this approach is that it forces you to work only with strategies which are economically viable. This is a limitation because there are ideas you would like to try which may not be economically viable today, but will be in five years. On the other hand, it does tend to assure some contact with reality.

Another limitation is a need to control the rate of change. Unfortunately, while you may be providing the user with a better interface he has adapted to the old one already, and his patience and willingness to readapt are probably limited. Finally, there is the problem of insuring that the user load which you attract is representative of a broad class of information system user.

The objective of information system research

Recognizing these limitations, the research objective of the computer systems research group at Project MAC is to turn the fabrication of large-scale information processing systems into routine engineering development projects. Of course, this objective requires learning much more about the conceptual understructure of such systems. That is a much broader objective than merely inventing ingeneous techniques of fabrication. The problem is that today, systems of the size of Multics, whether they're implemented at a university, in the Department of Defense, or at a computer company, invariably are a back breaking effort of high powered specialists. You could ask, "Well, what's wrong with doing it with high powered specialists?" and the answer of course, is that there simply aren't enough of them to do all the things we'd like to do. There are dozens of projects waiting to be done if it were possible to do them routinely.

Professor Saltzer then gave several examples of such projects including the ABM support system, the FAA air-traffic-control system, the National Data Bank, and the "on-line company."

Some topics of information system research

With this overview, Professor Saltzer reviewed a few areas in which he has hopes that progress will be made. The first of these was large files. Today Multics—and other on-line systems as well—have mechanisms that handle 10^{10} bits of on-line storage very smoothly. By way of comparison, that is enough storage to maintain the programs and data of 1000 scientific programmers; or the inventory of a Jordan Marsh size department store. Unfortunately, there are a lot of interesting problems which need 10^{12} bits—that's 100 times as much. One of the reasons you can't build a national data bank is that no one knows how to keep 10^{12} bits organized.

What's the problem here? Why doesn't memory usage just scale up? Multics certainly doesn't scale up, and it is fruitful to see why not. One of the things found necessary to provide absolute storage reliability in Multics is to copy, once a week, all of the on-line information storage onto tape (a few hours each Sunday night). The trouble is that 100 times as much would require two weeks to make the copy.

A second research topic is memory modeling. For analysis as well as synthesis we need good models of the way users load the system. The difficulty here is simply that there are many different kinds of devices with a variety of properties and users to do various kinds of different things, but there is no good way to predict what kind of performance is going to result. We have a lot of results on apparently independent topics. You can look in the research journals and pick out papers telling you what happens if you have interleaved memory, and what happens if you use a cache memory on certain kinds of loads, and you find another result that tells you what is the effect of disk arms moving in certain ways for certain assumptions. Other papers report on demand paged virtual memories. No-one as yet has seen the understructure that allows a common view of the situation such that most problems can be solved by inspection.

The speaker mentioned briefly a variety of other research topics such as that of network information being shared at a distance. Probably, the one topic which has the biggest immediate academic payoff is called "simplification of mechanism." In looking at a piece of a system one frequently discovers a way (with half the code) to do all the same things, some of them better, and add a couple of other features. That can only happen when one has acquired additional insight into what it was he was doing. There are several examples in Multics experience in which modules have been rewritten two or three or four times and each time gained a factor of two or four or sometimes ten in operating effectiveness.

Another good research topic is one named "implementation of protection between mutually suspicious programs." Multics contains a protection mechanism based on concentric rings of greater and greater authority. This seems to be an adequate technique for a class of problems in which program A is suspicious of program B, but B is willing to trust A. For example, the instructor doesn't trust the student, but the student trusts the instructor. That kind of arrangement implements very smoothly with rings of protection, since they are purely hierarchical.

The mutually suspicious user is harder to handle. For example; user A has constructed a proprietary income-tax-calculating program which he doesn't want user B to copy. User B is willing to pay for the use of A's program, but he doesn't want A's program to make a copy of B's tax records. No system available today provides facility with this protection for arbitrary, user-provided programs.

Computers in society

Professor Robert Fano
Ford Professor of Engineering

There is an important lesson that computer people have learned during the last decade, at considerable cost in dollars, time, and frustration. The lesson is that it is inappropriate and dangerous to design or evaluate computer equipment out of the context of the operating system software that provides the interface to its users. An extension of the same lesson has to be learned. Namely, that it is inappropriate and dangerous to design or evaluate a computer system out of the context of the community of people that will use it or that, in one way or another, will be affected by its use.

There are important reasons why computers are used in the operation of society. If computers were not available, the level of activity attainable in many segments of society would be strictly limited by the fraction of the population that society could devote to the necessary bookkeeping tasks. Computers have made it possible to circumvent this fundamental limitation on the attainable level of activity. It is now generally realized, however, that a similar limitation is beginning to appear with respect to tasks of a substantially higher intellectual character, and that unless we succeed in circumventing it through the proper exploitation of computers, the operation of society may well begin to crack under its own weight of complexity.

The root of such problems as the inadequacy of medical care, education, and judicial processes is that the society does not possess the human resources necessary to perform all of these tasks well, particularly in view of their growing complexity and of the rising expectations on the part of the population.

Storing knowledge

Part of the problem is that the knowledge and experience required to provide these services cannot be readily transferred from one person to another. Could a good part of this knowledge and experience be stored in a computer program and made available on demand?

In at least one case, truly significant knowledge has been stored in a program allowing a computer to perform symbolic integration tasks requiring real intellectual skills.[2]

Mass production of services

The techniques of mass production make available to the entire population goods of a quality limited only by the total knowledge and capabilities of the society. In contrast, the quality of the goods produced by an artisan is strictly limited by his own knowledge and skill. With respect to services, we are still at the artisan stage. The quality of the services that we can obtain is still limited primarily by the knowledge, experience, and skill of the person that provides them. What we need, by analogy, is the mass production of services. For this purpose, information instead of matter must be transported and brought to bear on a specific situation. A widespread and effective information network will be essential to the mass production of services, just as a widespread and effective transportation network has proved to be essential to mass production of goods. The goal is not to replace people, but rather to make it possible for them to provide more, higher quality services based on the total knowledge and experience of society.

Intermixing human processing with computer processing

The ability to intermix human processing with computer processing becomes of crucial importance when computers are employed in any facet of the operation of society involving problem solving and decision making. In actual practice, problem formulation and problem solution proceed concurrently most of the time, and this takes place not by choice but by necessity. The reason for this is that one is never sure whether a problem has been properly and completely formulated. It is only in the process of working out a solution that one becomes aware of defects of formulations.

Since computers are very powerful aids in problem solving, while problem formulation lies inherently in the human domain, the ability to establish close collaboration between man and computer becomes of crucial importance. The late Professor Norbert Wiener used to warn us on this point way back in the late forties.[4] Computers, he used to say, are literal minded; they solve the problem that has been presented to them, not the one that ought to have been presented.

Knowledge is power

Computers provide access to knowledge, and knowledge restricted to a segment of society gives power over the rest of society. Thus, unless computers are made truly accessible to the population at large, there will develop a dangerous power gap between those who have access to computers and those who do not, and particularly between organizations, whether public or private, and the private citizen. To avoid this danger, it is essential that the power of computers be redirected toward assisting the individual in his daily life by enabling him to cope more successfully with the complex environment in which he must live, and, above all, toward bringing about much better communication within society.

Protecting privacy

The protection of individual privacy has received the greatest public attention among those issues raised by the growing use of computers. Society, to function effectively, needs information about its members. Disclosure of information about one's affairs is usually inherent to collaborative activities and often essential to receiving effective assistance from others. Furthermore, the desire to share information about oneself with others appears to be a common human characteristic. Thus, the ability to disclose information selectively under secure control is essential to the protection of privacy. Moreover, control is important not only over the use of personal information, but also over the accuracy of the information itself. In other words, the right to privacy includes the right to check and correct information about oneself.

Very few computer systems currently in operation make it possible to control access to individual data files, and only one, to my knowledge, (the Multics system at M.I.T.[3]) includes means for enforcing restrictions on their use. Even these systems, however, are not adequately secure against determined attempts to circumvent their control mechanisms. Solutions to the individual technical problems are not lacking. The challenge lies in solving all such problems simultaneously without unduly interfering with other design objectives. Unfortunately, this challenge is not receiving adequate attention, and even proven control techniques are not being incorporated in commercial computer systems.

The future

There is a tendency in some quarters to dismiss the computer as just another machine which in due time will find its proper place in society without causing any major change in its structure and operation. I do not agree with this view because computers deal with information, the glue that holds society together. I am reminded in this respect of the point made several years ago by Dr. Asimov, the well-known science fiction writer. In his luncheon speech at the 1966 Spring Joint Computer Conference, he chose to exploit his talent for science fiction in time reversal. He spoke about an imaginary report prepared by a special committee of the Imperial Academy of Science on the future social impact of the printing press. The report fabricated by Dr. Asimov was very entertaining and also very much to the point. Its major conclusion included a comment to the effect that, "In any case, the social impact of the printing press is likely to be minor because, after all, there are so few people that can read".

This summary contains portions of a paper written by Professor Robert M. Fano which was presented at the symposium, *L' Informatica, La Cultura e La Societa Italiana*, held at the Fondazione Giovanni Agnelli, Torino, Italy, Dec. 9-11, 1970. The full paper will appear in the Conference Proceedings.

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Terminal support processor for graphics facilities in a computer network

Mr. James Forgie
Lincoln Laboratory

The speaker described the efforts of a group at Lincoln Laboratory concerned with computer graphics work supported by the information-processing techniques office of the Advanced Research Project Agency (ARPA) of the Department of Defense. Lincoln Laboratory has been primarily concerned with a small hardware/software system called terminal support processor system (TSP) aimed at supporting interactive graphics users.

ARPA's *primary goal* is to demonstrate an inexpensive reliable message-switched digital communications network (something the common carriers haven't been providing and something DoD needs). Current cost estimates to provide network communications anywhere in the country are about $.25/megabit; since network cost is fixed, the cost/megabit depends on traffic in the network; a reasonable level of activity could bring costs as low as $.10/megabit. The communication capability was first demonstrated when parts of the network became operational in 1969.

The *second major goal* is to explore the cooperative use of computers in a network which can provide services that individual computers cannot; one obvious feature is the advantage of network load sharing. For example, through time differences, and by shifting programs back and forth, certain time periods can be shared between East and West Coast computers. Another advantage makes special facilities available to a much broader class of users. The ARPA computer network has special facilities such as the ILLIAC IV computer which is a very large, very fast, specialized machine; also, there will be a large 10^{12} bit storage facility; interesting research applications are possible.

Another advantage of the network is the greater access to special programs such as the ARPA suported Rand Corporation Climate Modeling program on the West coast. The RAND objective is to compute the effects of various parameters on the climate over long periods of time, involving such parameters as atmospheric pollution and the melting of polar ice.

The *third major goal* is to reduce the cost of research on computers; typically, such research involves much computing and ARPA wants to begin new research programs at U.S. educational institutions. New installations can be funded by providing network terminals to allow computing wherever excess time exists.

In 1966, Lincoln Laboratory set up a wideband connection to the System Development Corp. as a time-sharing system. The results convinced Lincoln that the communications and protocol problems were manageable. So, ARPA decided to put together a computer network; activity started in 1969; a network became operational with a four-node segment in the Fall, 1969.

There was an attempt to provide multiple connectivity from any network node to any other nodes in the event of a telephone line failure. Thus, the IMP's (interface message processors) which are small computers were introduced to serve the network and perform store-and-forward and routing jobs; should an IMP go down, communication would still be possible. There are actually 14 IMP's now installed and working.

The so-called host computers are the ones interfaced to the network; some systems have two hosts interfaced with one IMP of the network; the IMP was designed by Bolt, Beranek and Newman (BBN), consulting firm in the Cambridge area. There are 17 host computers now connected physically and there will be a total of 21 within the next few months. The network continues to grow (ARPA estimates 30 nodes in another year), and traffic flow simulations indicate that as many as 100 nodes could be served with present facilities. Interconnecting links are presently 50-kilobit digital communication lines.

The main problem of implementing the computer network is agreeing upon protocols. Protocols are conventions for interpreting messages that come over the link; these occur at several levels. The first IMP level was specified by BBN.

The next level of protocol is between the hosts themselves. A network control program (NCP) exists in each host in the operating system. The NCP is a multiplex communication control that allows multiple users at one end to talk to multiple users at the other end to keep all messages straight.

The third level of protocol now being discussed has to do with user-to-user protocol. The Lincoln Laboratory involvement is to explore graphics in this environment and to interface two of Lincoln's computers as general network hosts. One computer is an IBM 360/67; the other an experimental machine (TX 2).

Interactive graphics

Consoles of the TX-2 support interactive graphics applications by means of both refreshed displays and Tektronix 611 storage scopes coupled with Sylvania "Tablets." It is an aim of the TSP to support (in a network environment) interactive graphics applications similar to those that the TX-2 has supported.

In a network situation, there are two sources of response problems. One results from scheduling of the remote computer, and the other is the transit time of transmitting information through the IMP's to the remote processors.

Because of such delays, the use of interactive graphics from a really remote facility is not attractive. The solution is obviously to partition the problem in some way to do locally the operations to be done fast; and, do others more slowly when handling large computations. The user then is prepared to accept more delay (10 or 20 second wait for some computations).

What has been done is to put together a small, fast, time-sharing terminal processor system aimed at serving 20 consoles with displays, keyboards and tablets. The system includes a small fast disc; three small 16-bit micro-processors which are tailored to specific functions; and 65,000 words (16-bit words) of memory.

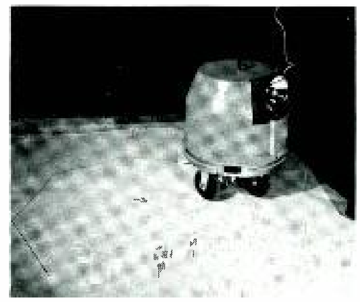
The processor specifically handles input/output functions associated with the tablet. The terminal support device must be capable of being programmed by the user so it can do what the user wants. It has a full alphabet plus some phonetic symbols provided for work on speech.

The terminal support processor provides a graphics terminal for the computer network; it was originally conceived as an approach to achieve interactive graphics at modest costs. Experience with the TX-2 system demonstrated that the system would perform the operations desired. However, it was too expensive to provide such a design aid for any great number of designers. With this terminal processor support, a hardware cost of about $25,000 per console can be reached which includes the console and the pro-rated cost of the processing that supports it (the latter is a factor defeating most systems). It was concluded that such a cost figure should do a good bit to broaden the market for interactive graphics.

Artificial intelligence: recent application in education

Professor Seymour Papert
Director, MIT Artificial Intelligence Laboratory

All school subjects demand that a child think, yet nowhere in our present educational system is thinking taught. Popular educational theory suggests that if a child thinks about thinking, he will not be able to do it. Professor Papert disagrees with this concept and actually proves that the "core skills" of thinking must be taught and he uses a computer ("turtle") successfully to do it.



Professor Papert's "turtle" which can be programmed by 5th graders to draw patterns.

The computer offers real advantages in teaching thinking to children. The student at the terminal can work through a project in which he sets his own goals and conquers whatever "bugs" come up on the way. In the course of proving out his own notions, the student tastes the joys and frustrations of research and discovery. A child senses personal triumph when he makes his own program work in his own way.

In this context it is possible to introduce the child to concepts, which will allow him to think constructively about the process of thinking. Examples of such concepts are: subgoals, debugging, first order theory. Thus the child can be taught *about* thinking. The need for this is confirmed by experiments on how children think about thinking. Many gave prescriptions such as: "make your mind a blank and wait for an idea to come!" Those who have been through Professor Papert's course are able to give more constructive and articulated descriptions.

The most visible new idea in this work is providing the child with a powerful technology by giving him the ability to control real-world physical devices by programming computers. These devices include the previously mentioned computer controlled buggies called "turtles," music generators, puppets, geometric displays and a range of modular components for a "control theory" or "cybernetics" laboratory.

Two full scale courses for children have been taught, one at the seventh grade level and one at the fifth grade level. In both cases the majority of selected children were "below average"—some very much below average. These children who could not learn how to multiply and divide in normal school classes, acquired mastery of a programming language and of cybernetic concepts! They also showed improvement in traditional subjects.

Professor Papert complains bitterly about the tendency for technology in education to mean using new fangled devices to teach the same old stuff in a thinly disguised version of the same old way. He also complains about current prices, and asserts that 90 minutes a week at the terminal should cost less than $50/yr.

Innovations and entrepreneurship

The following presentations by Marquis and Roberts involve the elusive role of innovation and entrepreneurship in industry. Studies show certain correlation of research and development with that of company growth and with price/earnings ratios.

Another factor is the rare and unpredictable nature of major innovations which often occur outside the walls of large companies.

A study is described in which upwards of 300 companies were identified and studied as being formed by "technical entrepreneurs" who preferred to form their own small businesses instead of continuing government research. Following the identification of 105 companies "spun-off" from four of MIT's labs, other studies continued, centering on an electronics corporation where loss of technical entrepreneurs was prevalent. The study revealed that 44 engineer-entrepreneurs (from the one company) successfully founded 39 separate companies. The presentation also discussed methods of retaining entrepreneurs within the company.

The sources of successful technical innovation

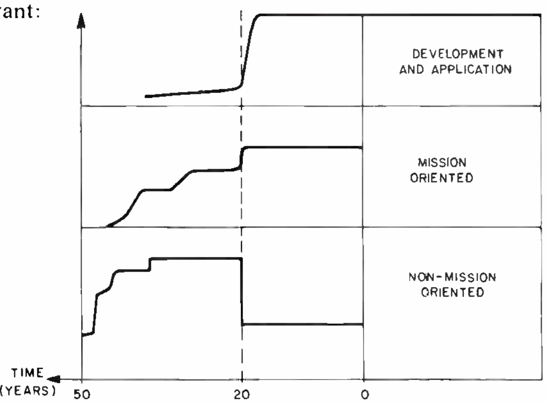
Professor D. Marquis
A. Sloan School of Management

One of the critical problems every company faces is the reaction resulting from a squeeze on earnings. The results take the following forms: 1) layoffs, 2) moves from basic to applied research and development, 3) long-range work to short-range and 4) a tighter coupling to marketing and production.

Although we attempt to achieve the best results from research and development, there is no really good way to measure and evaluate the outputs of R&D. Thus, these areas are always hard hit when one must relate results in terms of sales, profit and growth.

Is there any evidence that cutbacks in R&D will seriously help or hurt company progress? Historical evidence from studies at MIT and results of studies published in financial journals tend to indicate some correlation between increased R&D investments, increased growth factors, and better price-earnings ratios.

This study, initiated by DoD, traced back twenty years looking for significant advances utilized in defense systems. DoD found a large number of technical advances that contributed to present technology. The total study, when completed, uncovered 710 significant advances that were defined as being important and actually used. Only 8% of the total was non-mission oriented. Battelle then traced one project back 150 years and found many more significant scientific events. Illinois Institute of Technology selected five breakthroughs and then traced the fact that the scientific basis for all five occurred much earlier in the sequence. So, science is essential but often the time lag between discovery and practical usage is hard to justify. Investment in science has a longer-range payoff. The following breakdown is relevant:



Breakdown of significant advances by category versus time.

1) 10% were engineering. 2) 20% were mission oriented and 3) 70% were in science areas.

In times of a profit squeeze, basic research may be hard to defend since modern technical developments use old science.

Types of innovations

The studies continued to attempt to define or understand the various types of innovation. Of 90 major breakthroughs (that could create or transform a whole new industry) only 19 originated in the laboratories of large companies; however, most of these were subsequently developed in large laboratories where development and startup could take place. Most writing emphasizes science, since this is more dramatic. Innovations are divided among accidents, happenstances and those definitely planned. One thing in common stands out—major breakthroughs are rare. The following innovation by industry was described:

1) Aluminum industry (1946-1957)—Of 149 significant innovations, only seven were major and only one originated with a large primary producer.
2) Steel Industry—Of 13 major innovations, none were originated by U.S. steel producers and seven were originated by independent inventors.
3) Petroleum Industry—Seven major innovations (representing past and present refining processes) were by independent inventors, and then later developed by large oil companies.
4) Dupont (as a leading innovator)—Of 25 of their major innovations (1920-1950), 10 were originated by Dupont, and 15 by outsiders.

Finally, a data base of 567 commercially successful innovations was evaluated and identified as follows:
45% resulted from perceived market opportunities;
35% resulted from perceived production processes;
15% resulted from technical advances that might find use.

There are several conclusions from the studies as follows:

1) Don't count on major innovations; they are rare, unpredictable, and usually originate outside large companies.
2) In the period between innovation—concept and invention, 70% of the information used was widely available.
3) If you can formulate a reasonable problem—somebody can solve it.
4) A recipe for success would appear to be not to isolate technical people, but encourage their close cooperation with marketing and production.
5) Average cost of 567 innovations is $45,000 each but 68 cost over $1 million (most in computer development).
6) A definition of the problem is a potential solution.
7) Innovation is usually the fusion of technical possibility and economic need.

Technical entrepreneurship

Professor Edward Roberts
A. Sloan School of Management

The author describes a study that delved into the reasons for the spin-off of "technical entrepreneurs" who preferred to form their own small businesses instead of continuing government research. Over 250 companies were studied and identified as being so formed. Following the identification of 105 companies "spun-off" from four of MIT's laboratories, the investigation led to a study of a selected division of an electronics corporation where the loss of "technical entrepreneurship" also proved to be prevalent. Although the company Personnel Dept. was initially aware of only three cases in which their technical employees left their employ and pioneered new businesses; the study revealed that 44 engineer-entrepreneurs had left and successfully founded 39 *separate companies.*

An industrial electronic systems contractor in the greater Boston area was chosen that satisfied the following requirements: an activity in electronic systems technology to make it similar to the MIT labs. previously studied; at least a 1,000-man organization for compatibility of size; and, it was to be a post-war company. A list of all the organizations that would fit these criteria was completed, and it was a fairly long list. We could have included RCA Burlington; we could have included a couple of divisions of Sylvania; we could have included a couple divisions of Raytheon; we could have included Laboratories for Electronics, a piece of IBM, or pieces of some other organizations in the Boston area. But none of these was used; the company chosen was not named.

NEARLY 300 "SPINOFF" COMPANIES WERE FOUND DURING THE STUDY.

SOURCE OF FOUNDERS		*Number of companies formed*
MIT		
	Electronic Systems Lab	11
	Instrumentation Lab	30
	Lincoln Lab	50
	Research Lab for Electronics	14
	Aeronautics Dept.	18
	Chemistry Dept.	18
	Electric Engrg.	15
	Mechanical Engrg.	10
	Metallurgy	8
OTHERS		
	Govt. Labs (AFCRL)	16
	Non-profit (MITRE)	5
	Industrial Electronics Firm	39
	Computer Firms	16
	Consumer Oriented Mfg.	46

The study covered the span of 1950 to 1966. In the year 1966, the 39 separate "spin-off" companies out of the single firm were grossing $72 million compared with a total of only $30 million by the parent division from which they emerged. As the study continued further, intensive interviews revealed that most technical entrepreneurs would have preferred to have stayed with the large company under the right circumstances.

Professor Roberts discussed many alternatives a large company could exercise to encourage their technical entrepreneurs to remain in the corporation.

MAKING ENTREPRENEURS A CORPORATE ASSET
ALTERNATIVE STRATEGIES
(Listed in increasing order of effectiveness)

A. Apply legal restraints.
B. Pursue idea exploitation approaches:
   (i) joint ventures; (ii) licensing; (iii) entrepreneurial sponsors; (iv) "loose strings."
C. Create product teams or profit centers.
D. Develop incentives tied to profit center performance.
E. Distribute pseudo-stock in profit centers.
F. Form venture organizations.
G. Sponsor spinoffs by providing:
   (i) "pieces of the action"; (ii) corporate funding; (iii) corporate managerial assistance; (iv) sheltered markets.

Some (such as legal restraints) were proposed as being ineffective solutions. Other alternatives such as profit centers, miniature business entities, compensation incentives, profit sharing and stock participation were proposed as being more appropriate. Incentive formulas can include penalties such as cuts in base salary for non-performance. The true "Technical Entrepreneur" is presented as a responsible "risk taker" who wishes to pursue a good idea through to a successful conclusion that results in profit—and will be willing to stake his reputation to do it.

Remember that the entrepreneur is the champion of an idea; he uses every formal and informal way to push his idea toward success. He pursues the promotion of his idea far beyond the requirements of the job. Perhaps he gets on a lot of people's nerves and makes them uncomfortable, but he's vital to the organization because it is his perseverance that pushes new products to fruition.

Quality

In this relevant overview of the quality problems in American industry, Professor Leo B. Moore places management at the heart of the quality effort. According to Professor Moore, it is management's responsibility to firmly establish throughout an organization the basic economic principle "that the customer decides how long you stay in business".

Q C—Quality Crusade

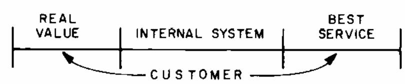
Professor Leo B. Moore
A. Sloan School of Management

Problems, like bananas, always come in bunches. At a time when American management is being charged with the outgrowths of the current forms of American socialism, it is also being beset by one of its own problems which, like an incipient rash, emerges from time to time and demands attention, but seemingly defies treatment. Quality is that problem, or rather the lack of it! Wherever he turns—be it the post office, the car dealer, or the local laundry—the American customer has for a long time been doing a slow burn and today he is getting mad enough to demand his just due. Have you been watching the ever-growing import situation? Economists talk of comparative labor rates, but the real reason is comparative quality!

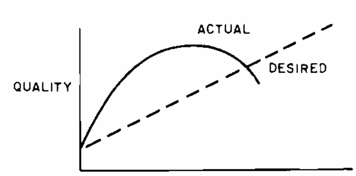
Why is Ralph Nader riding high as the champion of the American purchaser and gathering around him others to carry on the crusade? It is simply that he now serves as the focal point for the years of complaints of individuals who, on their own, were helpless to receive prompt attention to their just demands. **Q C** under this condition was and still is seen as **Quality Complaints** and the objective of the enterprise as finding some hardheaded method of dealing with these annoyances.

Why does this condition arise? Complaints are predictable when the simplistic view is taken that quality is a sales gimmick, with the onus on the customer to decide on his own how much value he receives for his money. Promotional activities persuade the customer that he is getting a good deal when he buys a particular brand of TV, washer, or whatever. To back these assurances, quality has long been an engineering responsibility and has been (in typical engineering fashion) ubiquitously labeled **Q C Quality Control**—supported by an array of engineered procedures for testing and inspection with statistical techniques in a variety of elaborations. Marketing sells the engineered specifications and standards that manufacturing makes the products to, or at least that is the basic premise. In reality, the internal system copes with what is basically the quality/price compromise from which emerges a kind of product variety that forces the customer supposedly to select how much quality he wants for what price. In this difficult decision, the salesman is always most helpful. But before the deal is closed, he also asks the customer to protect himself from the failures of the internal system through service policies and extended warranties. Even he knows that considerable question must be raised as to whether quality is in "control", in spite of obvious devotion to cause.

The internal system is highly engineering-oriented with strong logic for solving the many interface problems that quality must face as an engineering responsibility, but with an uncertain concern for the ultimate customer whose normal impact on engineering provides a feeling that **Q C** stands for **Quiet Customer.** In between the ultimate customer and company engineering, marketing provides representation for and handles that customer, but always with its own prime interests in mind. After all, engineering knows more about the product than any customer. However, the individual customer is alone and far away with problems of his own. He is reassessing the answers to his original value question as he now lives with the product or service in actual use. He could care less what the internal system is busy doing or not doing.



The customer's initial concerns were with the kind of performance he thought he purchased with his money, but these are quickly over-shadowed by how much time and money it actually cost to install, operate, maintain, and repair as measures of quality over time. He is not only engrossed with the immediate but also with the lasting values. Such a customer becomes most knowledgeable about the total costs and more pointedly vocal about his complaints, particularly when maintenance and repair costs are beyond belief, and, worse still, beyond his own skills and patience because of engineering and production techniques. Every design engineer should serve some time in the sales department and every production engineer should serve some time in the service department. He would find what everyone else knows—that over time, quality reaches the peak that the system provides and then it goes down. The important struggle is to find ways to reach for ever higher quality standards because every customer will tell any engineer who will listen that he is primarily interested in better quality at a lower cost, not cost reduction through quality reduction:

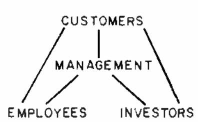


But every company is aware of this inevitable curve. For that reason every two years or so, there is a quality revival designed to make **Q C=Quality Consciousness.** These renewal efforts, supposedly to influence the course and speed the process, are variously named concentrations on the *aims* of *engineering.* New jargon is devised such as quality assurance, reliability, maintainability, zero defects, and one wonders what the next fad will be. But whatever it is, it will absolutely do nothing to influence the performance curve unless it shows some fundamental understanding of the *aims* of the *customer.* For many years, the concept of the annual model was an engineer's dream and a marketeer's inspiration that suggested to the customer that his complaints, suggestions, and ideas were being considered, while, in fact, it maintained the mass production and consumption base for American industry through the genius of built-in obsolescence. The inevitable curve is still with us, therefore, as best exemplified by the valiant efforts of DoD to buy quality through insistence on value engineering in its massive purchases of military goods. How much *more* does it cost this Nation to send up a satellite or put a man on the moon because of quality problems? How much more does it cost every one of us every day because the over-riding *aim* is the mediocrity of obsolescence?

The American customer is changing because he is beginning to know this self-defeating policy. Under the pressures of rising prices and increasing taxes, he is gathering facts and facing them on his terms. With more active consumer groups, he is finding that there are many others who feel as he does. With clearer facts and feelings in hand, he reacts to slogans such as 'Buy American', as he would to the travelling medicine show of days gone by. As a general proposition, American quality has never faced its real challenge, that of the customer whose final decisions are inexorable.

What are the prospects for American business? I would suggest two stages will be required to make some headway with the quality situation—now, total managerial responsibility, and ultimately, total corporate responsibility. These are not two separable and sequential recommendations, but rather aimed at two different problems, and both will require **Q C—Quality Creativity,** together with **Conviction** and **Concern.**

The task to be faced at the level of managerial responsibility is to turn the enterprise around by starting with a new concept of **Q C** as **Quality Challenge,** not some drum-beating, song-singing program but a solid statement of quality philosophy and objective support for realistic, attainable quality goals that will require every bit of creativity and determination that the organization can muster. The key to these and related managerial efforts lies in the continued enunciation of a simple but basic economic principle that the customer decides how long you stay in business. Three groups are required for every business enterprise—customers, employees, and investors—with the management group in the middle:



It is the customer that has the rope around the neck of management!

The task at the level of corporate responsibility will require development since it must reflect long range considerations of current trends, under the aegis of **Q C** as **Quality Care.** These considerations will more likely be on the agenda of the Board of Directors or certainly that of the Executive Committee, for they will extend to the very existence of the enterprise and will include the interests of the employees, the investors, and the community itself. For example, the issue of pollution in its broadest dimension must be expected to have serious impact on our quality posture. The question must be—Why should there be any pollution at all?—not just minimum fouling of the air, neater piles of debris, and cleaner effluents. In this vein, it might be noted that not once was the word 'consumer' used in this text, for the reason that the typical customer does not consume his purchase, especially the package that it comes in.

As a different type of example, note the recent willingness of the Courts to hold strict product liability on the part of the manufacturer. A woman and her daughter were awarded heavy damages when the Mother used a cleaning fluid to light an outdoor barbecue fire and the material flared up, seriously burning them both. This case would seriously suggest that the company lawyer as well as treasurer might have more than a passing interest in what the internal system is busy doing. Not the least concern at the corporate level would be that wholly unexplored area of the quality of life in the community of which the company is a part.

That elusive quality bird has finally come home to roost and has brought several wild birds along with it. The job of capturing and taming all of them will require a crusade involving the special dedication of the engineering discipline and the full support of the whole organization from the top, all the way down. The message, like the arrival of the vultures of the desert, is very clear—quality or else!

Management information systems

The next three presentations by Amstutz, Zannetos, and Urban concern management information systems and the modeling of programs for managers. Strong emphasis throughout is placed on developing models that result in better, more timely decisions in all areas of management, sales and marketing. Emphasis must also be placed on the individual manager's way of operating, and the manager's experience and personality. It is entirely up to the manager to show the interest and initiative to develop and use such models. If you just expect some "other" MIS organization to present you with a perfect system or model all ready to work—forget it—because it will not suit your needs and you will never use it. The MIT people have hit the nail right on the head—this is the weak point, in general.

Computer simulation for market research

Professor Arnold E. Amstutz
Alfred A. Sloan School
of Management

It is seldom possible to prepackage a management information system. Each company's management has unique information needs based on its perspective of the market environment, its priorities, objectives and goals, and its management style. To develop an information system that will provide management with the information it needs, means that management must participate in the system development process.

Management is first called upon to determine the decision environment upon which the system will focus and to describe the functions it is to perform. After establishing a focus for system development, the management group is asked to make explicit the assumptions, beliefs, perceptions and perspectives that underlie decision-making in that environment. The process of explication often uncovers the not altogether surprising fact that various members of management have different implicit ideas about the decision environment. Making these ideas explicit and unambiguous is critical to the system development.

Project organization: task force and project group

One successful approach to management system development is to organize the management team into two groups: 1) a policy management Task Force, and 2) an operating management Project Group. The Task Force is normally composed of six to eight members of the company's top management team who speak for the company in matters of policy. Their initial objective is to define their decision environment—to identify:

- Major elements and interactions within the decision environment.

- Important elements and interactions within the action environment—the sphere influenced by management.
- Planning and decision making processes to be supported by the system.
- Behavior or responses to be monitored by the system.

The task force also establishes system objectives, priorities, and performance criteria. It is particularly active during the initial stages of system development, but continues to review project status and resolve priorities and means of achieving objectives.

The Project Group consists of company operating personnel who are responsible for designing and implementing the system to meet Task Force objectives. The group is involved with data organization and analysis, model design and validation as well as detailed hardware, operating system and programming specifications. Project Group members are particularly active during the later stages of system development. At periodic intervals, joint Task Force—Project Group meetings are held to evaluate progress and to verify conformance with Task Force objectives.

An example: management involvement in system development

Management's role in system development may best be illustrated through a description of the Task Force meetings of a corporation producing a diversified line of food products. The Task Force consisted of the president and other executives responsible for marketing policy and strategy.

The first Task Force meeting opened with a series of questions. "How can we establish boundaries for this system? How much detail should it encompass? What factors should it include?" The Vice President for Production suggested that "it should certainly include our operation." After some discussion, the project coordinator drew a rectangle on a large pad of paper and wrote:

PRODUCER

"How about distributors?" The project coordinator drew a second box connected to the first:

PRODUCER———DISTRIBUTOR

Four hours later, the group had produced a flow chart like that illustrated in Fig. 1.

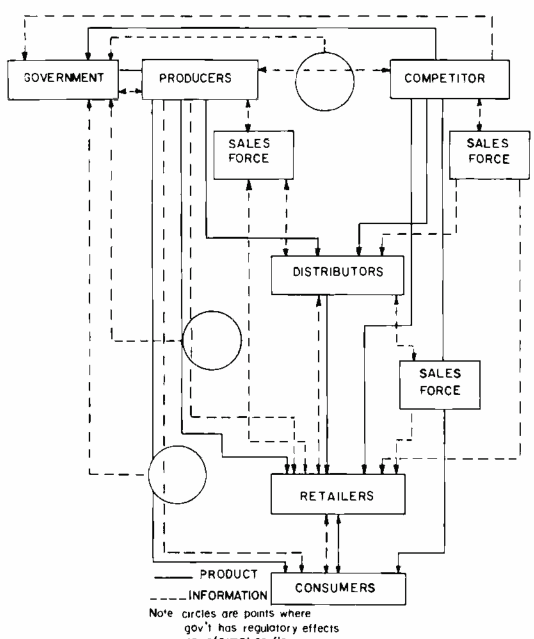


Fig. 1—An environmental structure.

Once an overall structure of the environment had been established, the Task Force focused on processes associated with each interaction point. Backlogs, delays and transfer points where rates of product, or dollar flow could be measured were identified.

The first objective of the system development process was simply to identify a limited number of elements and interactions within the decision environment. Having completed the first objective, the Task Force was eager to "make things more realistic" and through a series of Task Force meetings examined more closely the distribution system, consumer exposure and response to advertising, as well as consumer needs and attitudes. Management's intuitive understanding of market processes was converted to explicit and testable behavioral models. Relationships between management actions and consumer response were formulated in terms which permitted model validation against available market data. As an example, let's consider one consumer decision point—the decision to shop. The Task Force asked, "Which management actions and characteristics of the market influence a consumer to shop for a product?"

The Task Force's assumptions regarding this question led to a qualitative concept of "perceived need," which, they proposed, increases with:

- Positive attitude toward the brand.
- Opportunity to use it.
- Time since last purchase.

The Project Group then began to work within the structures provided by the Task Force to refine and test their key behavioral assumptions.

Consumer attitude toward a brand was measured by asking respondents to rate the brand on an eleven point Osgood scale ranging from +5 (strongly favor) through 0 to −5 (strongly dislike). An exponential relationship was observed between positive attitude and perceived need.

Opportunity to use was measured by the number of times during the preceding quarter a consumer had an opportunity to use a brand within the product class being studied. This information was obtained by direct interview as well as diary maintenance. A linear association was established between use opportunity and perceived need.

Time since purchase was measured in periods of average product life (1 week). An exponential relationship was obtained between time since purchase and perceived need.

Initial attempts to validate the perceived need concept showed that actual shopping behavior was also dependent on income.

Management's role in system development

In a similar manner, other decision and response concepts developed by the Task Force were tested and evaluated by Project Group members. Some were validated without difficulty. For others, empirical evidence suggested alternative structures and Task Force members met to develop and evaluate them.

The manager's role as a Task Force member did not involve new or strange activities. It did, however, place new emphasis on familiar concerns. Little or no time was spent in routine analysis, evaluation or allocation. The Task Force members were concerned with broader policy problems which they approached with increased effectiveness due to the availability of more meaningful data and a better understanding of their environment. They were concerned with problem definition and devoted substantial time to the broader planning functions that are too often relegated to low priority positions to make way for crisis curtailment. Much of their time was spent in refining insights and making them explicit, testing, validating, or rejecting hypotheses regarding the environment and impact on it.

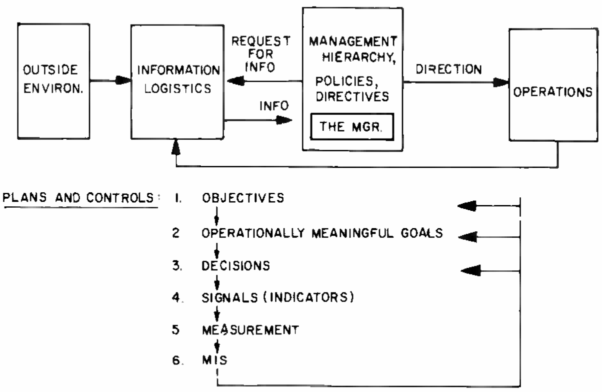
Management information and decision systems

Professor Z. Zannetos
A. Sloan School of Management

The common misconception is that management information systems are data systems; data are necessary but not sufficient for the generation of information; data must be put in a decision-making context (a model: formal or informal) to generate meaning. The managerial model determines the type of manipulations which must be imposed on the data. Only in this sense we have information (not data) systems for decision making.

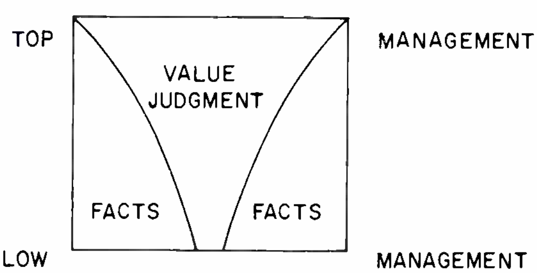
The priority must always be on the planning by the manager so that the content of the MIS will be appropriate—and you (the manager) must determine the filters which will evaluate and condense data so that you will not be inundated with useless data. For example, you cannot simply state that the objective is to make a profit; you must define how to do it. Your assumptions on what is happening and what would happen in certain instances are very important to know. If your plan is geared to certain assumptions regarding the environmental externals such as competition, tastes of people, state of the economy, etc., or internals such as technical capabilities, availability of critical facilities, and technological breakthroughs, you will do very well if you design an information system which will, among other things, monitor the validity of the critical assumptions. In this way you will get signals ahead of time to prevent undesirable consequences. The meaningful goal is to determine what kind of management information system to design in order to provide the necessary signals for management by exception (probabilistic). These signals must be preferably diagnostic and prognostic rather than post mortem.

Thus, planning must always precede the system model and is far more critical to establish than is control. In effect, management is teaching people *how to plan better.* Thus, the plan comes first and is more important than ceremonial apprenticeship. Without a formalized plan, the computer cannot help the manager who learns from experiences and performs on the basis of facts and subjective planning. The MIS system must be based on a good subjective model of the manager and not of the computer specialists or the accountants.



A good model (above) teaches "how to plan better" rather than simply how to carry out operations in a conventional manner.

Perhaps the best illustration is what *not to do.* For example, a manager wants to utilize computers to help run the business and hires a computer specialist. The specialist asks the manager what he wants him to do. Manager says: "Well, I hired you to develop this MIS, don't you know how?" The specialist decides he should, but doesn't and goes to the accounting department where he is clued into the secrets of the double-entry accounting system invented for the Medicis in 1450 to cut down on fraud. So now the manager has a computerized accountant but no MIS —a time waster instead of a time saver because it produces reams of paper nobody uses except for filing purposes. Result—staff meetings with more time spent on post mortems rather than on planning to avoid problems. The manager must take the time and initiative to see that an MIS system is developed for him, not the accounting department.



Planning and constraints.

Thus, the model or system created must be according to the Manager's plan so that all the elements of controlling the system will include these factors:

1. A control characteristic
2. Sensory device
3. Controller or comparator (Management by exception)
4. Goal or standard (need plan)
5. Effector (close gap)

In conclusion, MIS systems must be based on the manager's model. Blend intelligence with system capability: a) develop cause and effect relationships; b) develop consequences; c) suggest avoidance. Use your decision rules, not somebody else's. Only 1 to 2% of information available in reports is needed to make optimum decisions.

Advertising, budgeting, and geographic allocation

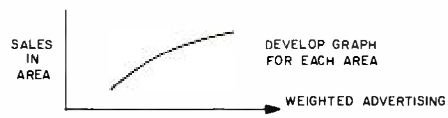
Professor G. Urban
A. Sloan School of Management

Over 500 computer program models have been constructed and published to assist managers in controlling advertising programs, advertising and marketing budgets, and determining how advertising affects sales in various geographical areas. However, unfortunately, the total application and use of such programs are minute, with almost no implementation.

What's wrong? Why is this so? Don't the models work? The basic reason is that the computer program models do not truly represent the marketing or advertising manager's thinking and are not adequately data based.

Thus, the primary objective must always be to build the models carefully so that the managers will understand their customers' buying habits and patterns better. Thus, the practical application of behavioral and management sciences is paramount.

An example of a typical sales and marketing problem is to determine how much to spend in advertising and where the money should be spent, geographically, to return the greatest sales; the approach would be to build the model based on the sales forecasts as a reference and construct into a usable model.



Other factors are how to share or allocate advertising costs in national and local media such as radio, TV and the press. The model must estimate the effects of carryover from one period of advertising to the next. If advertising is up in one period, how will its effects extend into the next period of reduced effort?

Profit, sales graphs, carry-over advertising effects, price-cost relationships are all factors to be included and monitored by an effective model. Thus, the manager must find the best solution for his total budget, split funds nationally and locally and allocate appropriately to geographical areas. In essence, he must put the money where the advertising provides highest sales . . . and be able to rely on the computer to find the optimum condition. The example described above was applied to a practical case of on-line use by a manager with the following results:

Re-allocation of advertising funds increased profit 5%;
Total budget +75% more advertising increased profit 10%;
Salesmen have re-allocated their efforts and increased sales 15%.

In conclusion, once a model has been properly developed and is in use, other variables such as competition and product interaction effects can be added to fit individual needs. However, for any useful model, the following conditions are significant:

Design model to fit the user;
Accept a long process 1-3 years (will start being helpful in 3-6 months) experiment;
Use above criteria of what a model should be.

Design and orbital performance of ITOS-1 (TIROS-M)

A. Schnapf

The TIROS, ESSA, and ITOS programs have demonstrated how satellites can be effectively employed for peaceful use by all mankind on this ever-shrinking planet. Their objectives have been met and exceeded, assuring scientists and weather forecasters of many nations continuous daily global satellite observation without interruption. During the ten years of TIROS, ESSA, and ITOS space operations (1960—1970), a total of 21 consecutive mission successes have been achieved by 10 TIROS, 9 ESSA, and 2 ITOS satellites. The second decade of the US meteorological satellite program was inaugurated with the successful launching on January 23, 1970, of ITOS-1, the second-generation operational satellite.

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received the BSME from the City College of New York in 1948 and the MSME from Drexel Institute of Technology in 1953. Until his recent promotion in April 1970 Mr. Schnapf had been Manager of the TIROS and TOS programs at Astro-Electronics Division since the first TIROS program was started by NASA in 1960. He was responsible for management of design and fabrication of ten TIROS and nine ESSA weather satellites; all were successful. In 1967, his responsibilities were increased to include the TIROS M/ITOS program; two satellites of this series are already successes. He is a professional engineer in New Jersey and an Associate Fellow of the AIAA. He is listed in American Men of Science and he is a member of the New York Academy of Science. This year, Mr. Schnapf received the 1971 David Sarnoff Outstanding Achievement Individual Award in Engineering "for outstanding engineering leadership of the TIROS meteorological satellite team." He holds a number of patents and has presented and published numerous papers.

During the first decade (1960—1970) of weather satellite operations, TIROS progressed steadily from a research and development program in 1960, to a semi-operational meteorological satellite system between 1961 and 1965, and the world's first global operational system with the launching of the TIROS Operational System (TOS) spacecraft (named ESSA 1 and ESSA 2) in February 1966. From 1966 to 1969, the TOS program continued to provide additional ESSA satellites for the operational system and, in January 1970, the second generation system, the Improved TIROS Operational System (ITOS), was introduced with the launching of the ITOS-1 satellite by a Delta N launch vehicle from the Western Test Range. A second ITOS spacecraft was successfully orbited on December 11, 1970. This satellite was designated NOAA-1. (Fig. 1 summarizes the orbital operations of these satellites.)

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These spacecraft were designed, built, and tested at the RCA Astro-Electronics Division, under the technical management of NASA's Goddard Space Flight Center. The operational meteorological satellites are funded and operated by the U. S. Department of Commerce's National Oceanic and Atmospheric Administration (NOAA) formerly called the Environmental Science and Services Administration (ESSA).

System evolution

The system evolution of TIROS, ESSA, and ITOS spacecraft is shown in Fig. 2. During the evolvement from a research and development program to a global operational system, a number of system designs were carried forward into each new spacecraft series to assure orderly growth, to improve performance over the predecessor sat-

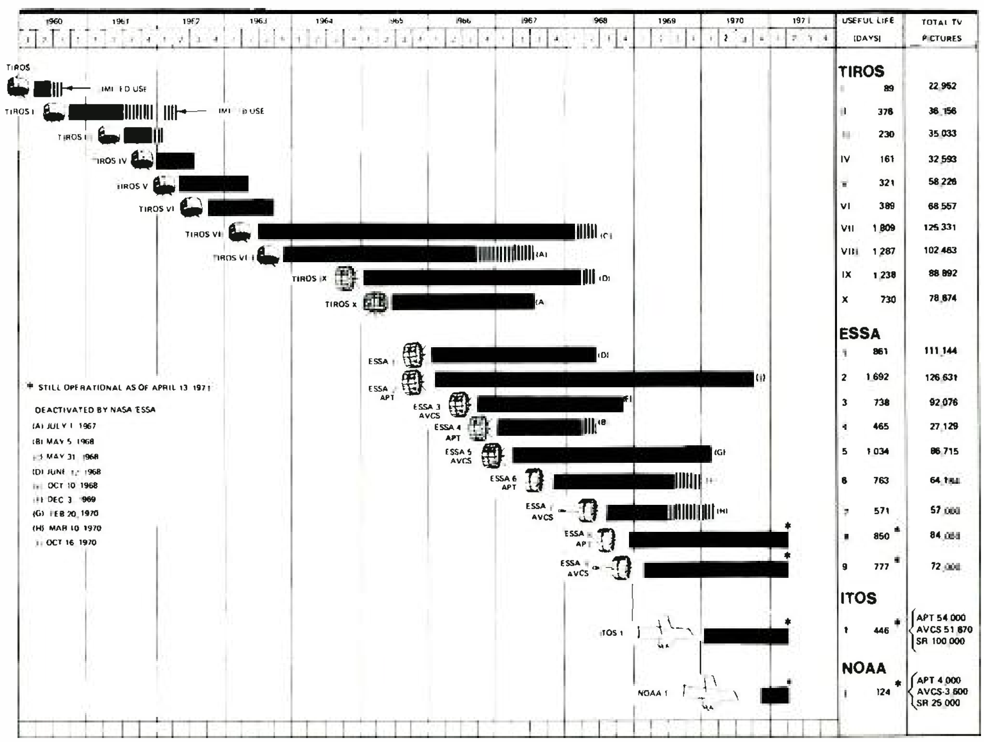


Fig. 1—TIROS/ESSA/ITOS/NOAA program summary.

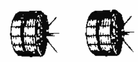
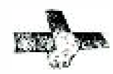
1960-63	1965-66	1966-69	1970-73
			
TIROS R&D mission	*TIROS wheel*	*APT AVCS* *TIROS operational system*	*Improved TIROS operational system*
TIROS I Television feasibility Infrared experiments Narrow and wide-angle TV TIROS II Magnetic torquing Narrow and wide-angle TV TIROS III Limited operational use U. of Wisconsin radiometer NASA radiometer Wide-angle TV TIROS IV through VI Limited operational use Wide-angle TV TIROS VII Limited operational use Ion temperature probe NASA radiometer Wide-angle TV TIROS VIII First use of APT for real-time TV Wide-angle TV	TIROS IX First wheel-mode spacecraft Near-polar sun-synchronous orbit for daily global observation Forerunner of TIROS Operational System Wide-angle television TIROS X Interim operational satellite Wide-angle television ESSA 1 Operational satellite Wide-angle television	ESSA 2, 4, 6 and 8 APT spacecraft for real-time global readout ESSA 3, 5, 7, and 9 AVCS spacecraft for daytime global TV observation; remote sensing and storage for U.S. readout S-band transmission from ESSA 7 and 9	TIROS M and ITOS A, B, and C Daytime global APT readout Daytime global AVCS readout Day and night real-time and remote IR and visible scanning radiometer Solar-proton monitor Flat-plate radiometer Earth-stabilized platform with growth capability for future sensors ITOS D, E, F, and G Scanning radiometers and very-high resolution radiometers for day and night real-time and remote IR and visible data—global coverage Vertical temperature profile of atmosphere Solar-proton monitor

Fig. 2—System evolution.

ellites, to increase the operating life in space, to provide increased quality of more timely data to the user, and to keep the evolving system compatible with the ground network of global receiving stations throughout the world.

A single new-generation ITOS satellite is capable of performing the global operation mission that previously required two of the predecessor ESSA satellites, one APT (automatic picture transmission) and one AVCS (advanced vidicon camera system) configuration; it also provides, for the first time, operational day and night infrared and visible radiometric data. Global observation of the earth's cloud cover is now provided every 12 hours with a single ITOS satellite instead of every 24 hours with two of the first-generation ESSA satellites. Here again, the predominant objective was to upgrade the operational data in quantity and in quality and still permit cost-effective operation while continuing a baseline system that can accommodate further growth and enhancement.

An example of how the space-proven technology of the earlier satellites has been carried forward and extended is in the area of attitude stabilization. Spin stabilization has been present throughout the TIROS and ESSA series.[1,2] On ITOS-1 the spin stabilization concept evolved into a dual-spin system: the main structure of the spacecraft is despun to one revolution per orbit to effectively provide an earth-oriented stable platform weighing 650 pounds, while a 36-inch momentum wheel (20 pounds or 1/30th the mass of the spacecraft) is rotated at 150 r/min to provide precise pitch-axis stabilization. Fig. 3 depicts this mode of operation for the despun ITOS spacecraft with spinning flywheel.

Another technique that has been extended continually throughout the program is the magnetic torquing that was developed on TIROS II in November 1960 and utilized in all subsequent TIROS satellites. This system was refined for the ESSA satellites for roll and yaw control and again extended into the ITOS design for roll and yaw control as well as adjustment of the satellite momentum by magnetic spin-coil commutation (an adaptation of the magnetic spin-control technique used on the ESSA satellites). The roll-yaw magnetic coils are controlled by a special unipolar programming technique to remove the solar torque disturbances on the large asymmetrical solar array. Fig. 4 shows these devices.

ITOS-1 (TIROS-M) design

The ITOS-1 spacecraft was conceived to be a second-generation operational system with cost effectiveness an underlying requirement. In keeping with this basic concept, the spacecraft has been designed to have the following key characteristics:

1) The spacecraft provides an earth-stabilized platform for a multiple family of primary and secondary meteorological sensors.
2) To support the operational sensor requirements, the spacecraft bus provides flexible commands and controls for the selection of the redundant primary sensors, data processing, storage, and communication channels.
3) The spacecraft is capable of performing the combined mission of ESSA APT and ESSA AVCS satellites. It provides direct real-time readout of APT pictures to stations anywhere in the world, as well as the recording of AVCS TV data for playback to the main TOS Control and Data Acquisition (CDA) stations in the US. The ITOS system also provides, operationally, day and night two-channel scanning radiometer data in the infrared and visible range for both real-time and stored data. In this configuration, daily 12-hour global observations of weather data have been made feasible.
4) The spacecraft configuration is compatible with the Delta N launch vehicle and is designed to operate in a sun-synchronous near-polar circular orbit at an altitude of 790 nautical miles, with the orbit inclined to the equator at 101.7° and having a period of 115.2 minutes. The spacecraft is capable of performing the full mission over a 30° to 60° sun-angle range, and of being utilized in a morning or afternoon orbit.

The major operating parameters of the ITOS-1 spacecraft are presented in Table I. All of the primary sensors are supplied in redundant sets to provide backup in the event of failure.

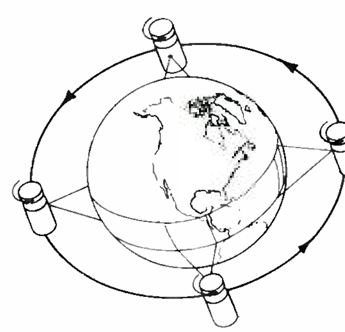


Fig. 3—Dual-spin (Stabilite) system.

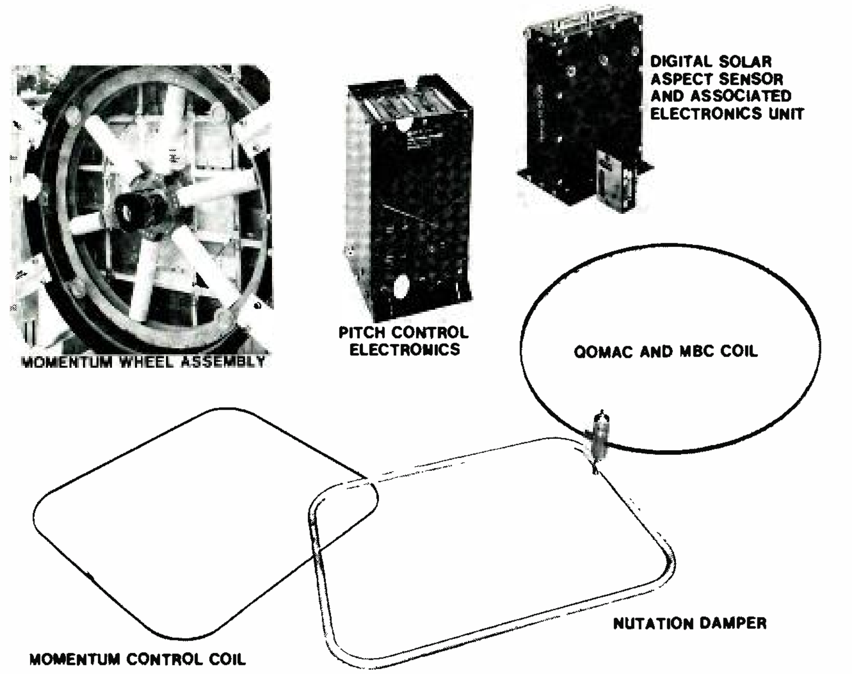


Fig. 4—ITOS dynamic control components.

Table I—ITOS-1 major operating parameters

Spacecraft orbit	
Orbit type	Sun-synchronous, circular, near-polar
Altitude	790 nautical miles
Inclination	101.7° (78.3° retograde)
Period	115.2 minutes
Spacecraft stabilization	
Dual spin	Main body, 1 revolution per orbit: Momentum wheel, 150 rpm nominal
Magnetic torquing	QOMAC—hi-torque—11°/orbit lo-torque 1.2°/orbit Unipolar torque—0.337°/orbit (max.) Magnetic bias—±1.80°/day MASC—23 (r/min)/day (max.)
APT camera	
Picture coverage	1800 by 1200 nautical miles
Picture overlap	20% in orbit track
Time per picture	158 seconds
TV lines per frame	600 lines
Picture interval	260 seconds
No. of pictures	11
Ground resolution	2 nautical miles at local vertical
Scanning radiometer	
Picture coverage	Continuous swath in direction of satellite travel. (Swath from horizon to horizon).
Channels	One infrared channel—10.5 to 12.5μm One visible channel—0.5 to 0.73μm
Resolution	Visible—2 nautical miles Infrared—4 nautical miles
SR recorder	
Storage capacity	2 recorders, each can record for 145 minutes
Record speed	1.85 in. tape/second.
Playback speed	30 in. tape/second.
FPR	
Field of view	2 steradians
Detectors	Black—0.3 to 30μm White—7 to 30μm
SPM	
Detectors	Detect proton energy: 1) >60 MeV 2) >30MeV 3) >10 MeV 4) 270 KeV to 60 MeV Detect electron energy from 100 to 750 keV. Detect alpha particle energy from 12.5 to 32 MeV.
AVCS TV camera	
Picture coverage per frame	1800 x 1800 nautical miles
Pictures per orbit and time	11 pictures—44.2 minutes
Picture interval	260 seconds
Picture overlap	50% in orbit track 20% minimum in adjacent orbit
Lens	f-1.8, 5.7-mm focal length
Field of view	108° across diagonal
Line resolution	Approximately 800 TV lines
Ground resolution	2 nautical miles at local vertical
Vidicon read time	6.25 seconds
AVCS recorder	
Storage capacity	38 pictures (3 orbits)
Record and playback tape speed	30 in./second
Playback time	2 min./orbit
ITR	
Record—incremental (stepper)	350 minutes (90 ft tape)
Record mode	15 bits per second per track 3 tracks—tape advance 0.0033 inch/increment 15 times per second
Playback	162 seconds
Command link	
Frequency	148.56 MHz
Data	128 digital command signals to spacecraft
Beacon and telemetry link	
Frequency	136.77 MHz
Transmitter power	250 milliwatts
Data	Beacon signals, housekeeping telemetry, command verification, spacecraft attitude, vibration data (launch phase only)
Real time link	
Frequency	137.5 or 137.62 MHz (on alternate spacecraft)
Transmitter power	5 watts (minimum)
Data	APT video, real-time SR video
Playback link (S-band)	
Frequency	1697.5 MHz
Transmitter power	2 watts (minimum)
Data	Recorded AVCS video, AVCS flutter and wow, SR video, SR flutter and wow, FPR and SPM sensor data

The scanning radiometer system is an additional backup to the AVCS or APT sensors.[5] The full complement of primary and secondary sensors can be used on these spacecraft because of the unique stabilization scheme chosen. The main body of the spacecraft rotates at only one revolution per orbit with the pitch axis maintained normal to the orbit plane. Hence, the sensor-side of the satellite continuously faces toward earth. This is in contrast to the basic ESSA satellites in which the entire spacecraft spins and the sensors are triggered as their optical axes pass through the local vertical.

Structure

The general physical configuration of the ITOS satellite is shown in Fig. 5. The satellite is a rectangular, box-shaped structure, approximately 48 inches long and 40 inches wide. On the bottom of the structure, a cylindrical transition section attaches to the 37-inch diameter adapter section of the second stage of the launch vehicle. The testing, calibration, and handling of the spacecraft are important operations in the ITOS programs. Prior to buildup of a spacecraft, a phase of integration, debugging, test, and calibration takes place. With this important phase of the program in mind, the ITOS spacecraft was designed to be a simple box-like structure that can be readily disassembled or "buttoned up" for the various phases of the above-mentioned tasks. Fig. 6 shows the spacecraft with the primary equipment panels in an open horizontal configuration. As required, the side walls are easily raised to "button up" the spacecraft for final tests. The large flat equipment panels permit flexibility in configuring and mounting new mission equipment. The two side panels carry the primary television sensors and their associated electronics and data storage recorders. The baseplate houses the equipment for the bus functions, such as power, telemetry, communications, command, and control. The large front and rear panel opening permits accessibility to spacecraft hardware for test and replacement in the buttoned-up configuration, hence, avoiding the need for spacecraft disassembly. The three solar panels are mounted along the main

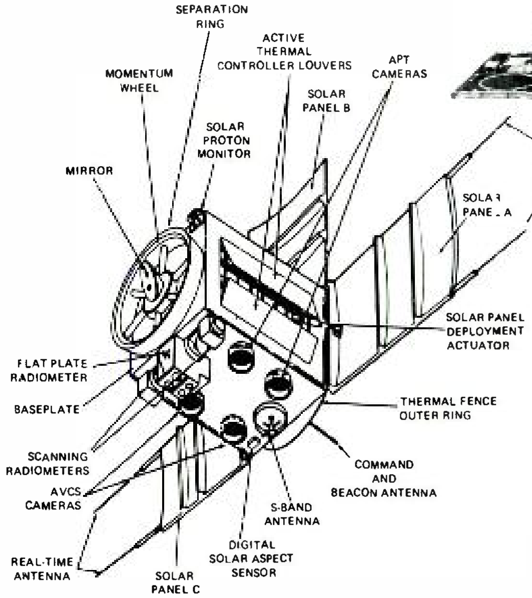


Fig. 5—ITOS-1 spacecraft.

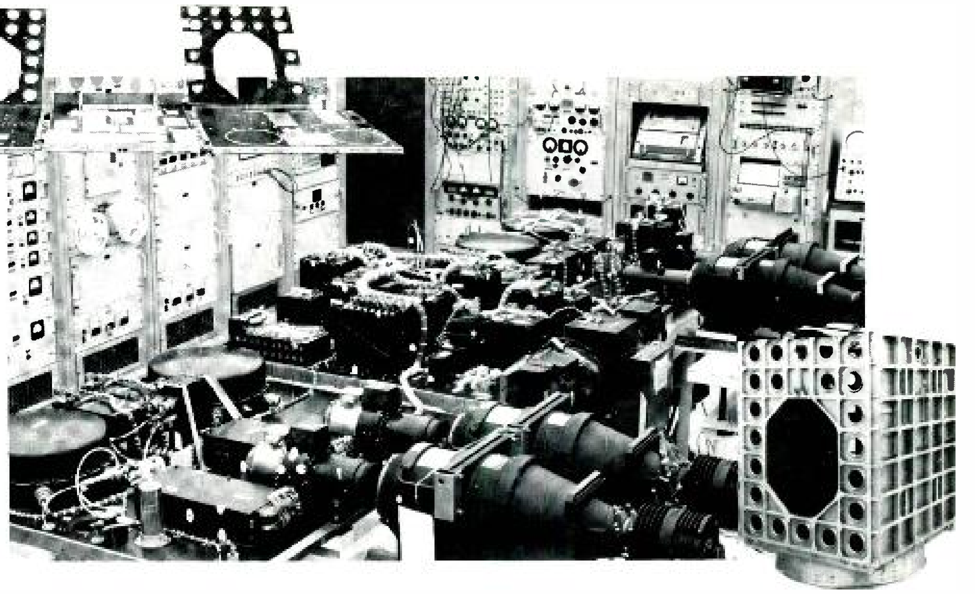


Fig. 6—Upper left photo shows spacecraft panels "unbuttoned" for equipment mounting; the lower right photo shows the equipment panels "buttoned up". In the center is a completely assembled spacecraft being tested with the side panels down.

body of the satellite with their hinge lines at the top of the structure; during launch these panels are held flat against the sides of the spacecraft in a stowed position as shown in Fig. 7. Once the satellite achieves mission mode, the panels are deployed by actuators. In the deployed position, they are normal to the spacecraft sides and parallel to the top of the structure and are approximately aligned in the orbit plane.

Thermal control

Thermal control is achieved by the application of passive and active thermal-control techniques. Most of the satellite is covered by multilayer insulation blankets, except for the primary sensor openings and the areas used for the active control devices. Passive thermal control is provided by a variable absorptivity device, designated the "thermal fence": a pair of concentric black-body, thin-wall surfaces mounted on the top of the satellite. As the sun angle varies with respect to the two vertical walls of the fence, the amount of solar absorption will also vary. The heights of the fence walls were selected to provide maximum heat input at a sun angle of approximately 60 degrees. This passive-control device will, by itself, maintain the satellite temperatures within design limits. However, an active-thermal-control system is also utilized to augment the passive design, providing a narrower range of temperature variations throughout the satellite's mission life. This active device consists of thermal louvers that can be opened or closed to vary the effective emissivity of the spacecraft, hence limiting the thermal excursion of the spacecraft's electronic equipment.

Attitude control

The design of the ITOS attitude control system was largely dictated by the pointing and stability requirements of the multiple primary sensor system and by the rates of satellite and orbital plane motion. The optimum orientation for a multiple sensor platform is continuous earth orientation. The coupling of a despun platform, through a bearing, to a spinning flywheel is the simplest method of meeting the primary sensor requirements while maintaining all the desirable dynamics of a spin-stabilized spacecraft.

The dynamic subsystem enables the satellite to align and maintain the roll, yaw, and pitch axes so that the sensors are looking directly downward at the earth, as shown in Fig. 8. The subsystem will:

- Gyroscopically stabilize the despun platform (equipment module);
- Damp the nutation of the satellite to a half-cone angle of less than 0.3°;
- Precess the spacecraft until the momentum vector is nominally aligned with the orbit normal;
- Adjust the total momentum to within ±1.3% of the nominal design value of 212 inch-pound-seconds;
- Align and maintain the attitude about the pitch, roll, and yaw axes to ±1°; and
- Align and maintain the momentum vector to within ±1° about the orbit normal.

The subsystem is designed to operate continuously in the space environment for at least 1 year. The subsystem consists of a redundant pitch control loop, functionally redundant magnetic roll and yaw axes control including attitude sensors, redundant momentum control coils, redundant nutation dampers, and a digital solar aspect sensor.

In orbit, motion about the pitch axis is controlled by a flywheel and torque motor, utilizing error signals from one of two pitch horizon sensors, and the shaft encoder. The system is redundant, except for the flywheel. The horizon sensors derive their scanning from a mirror mounted on the flywheel. The pitch look can be commanded to operate in the open-loop or closed-loop mode. The open-loop mode causes the flywheel to rotate at one of two fixed speeds for dynamic stability. The closed-loop mode causes the wheel to rotate at a speed that will despin the equipment module to 1 revolution per orbit and establish its proper pitch orientation. The pitch-control loop is capable of performing this orientation maneuver within a maximum time of 11 minutes after the closed-loop command is received. At nominal condi-

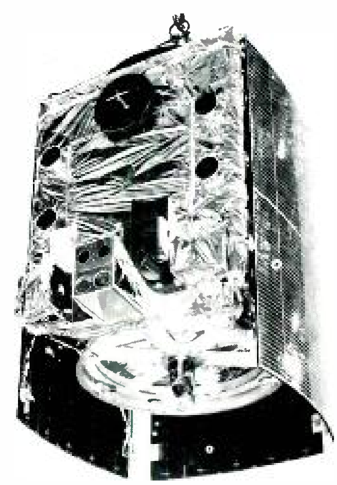


Fig. 7—ITOS-1 spacecraft with solar panels folded back in the launch configuration.

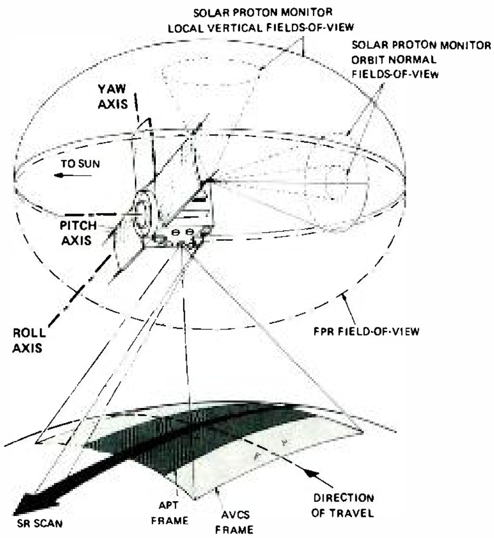


Fig. 8—ITOS-1 sensors—fields of view.

tions, the maximum capture time is about 6 minutes.

If the momentum is not near nominal, redundant magnetic coils can be activated to correct the total spin-axis momentum. In addition to pitch-exis control, the subsystem provides roll and yaw axes control by ground command. This is accomplished by utilizing the torques developed by the interaction of the earth's magnetic field with controlled dipole moments generated within the spacecraft. The controlled dipole moments are generated by the same type of magnetic coils flown successfully on the ESSA spacecraft.

The MBC (magnetic bias control) coil, which is controlled by the magnetic bias switch, provides continuous torquing to offset part of the residual magnetic dipole along the pitch axis (flywheel spin axis) of the spacecraft. The level of current, and thus the dipole magnitude, is adjusted by ground command until the total dipole creates a torque that corrects for attitude changes due to orbital regression. The QOMAC (quarter-orbit magnetic attitude control) coil provides torquing to precess the spacecraft pitch axis about any desired vector lying in the orbit plane. Perpendicularity of the pitch axis with respect to the orbit plane can therefore be maintained. A constant level of current is applied to the QOMAC coil for a period determined by a ground-commanded program, with the direction of current being reversed on a quarter-orbit basis. Three QOMAC modes of operation are provided: The high-torque mode uses the combined maximum dipoles of MBC and QOMAC to provide a precession rate of about 10° per orbit at nominal momentum. A lower precession rate (1.2° per orbit) and, therefore, better granularity is obtained with the QOMAC coil operating alone. Finally, in the unipolar mode, the continuous current-on time is reduced and programmed to generate only unidirectional dipoles at half-orbit intervals to achieve precession about the line of nodes. This mode of operation is used to offset solar torque disturbances.

Spin-axis nutation is dissipated by liquid dampers similar to those flown on the TOS spacecraft. Nutation may result from the following disturbances: 1) second-stage-booster nutation, 2) operation of the separation equipment, 3) operation of the magnetic control components, 4) bombardment by micrometeorites, and 5) operation of payload components with uncompensated momentum.

The spacecraft is equipped with infrared sensors to provide attitude information during each flywheel revolution. Additional attitude information is obtained from the digital solar aspect sensor (DSAS) during spacecraft orientation maneuvers. The DSAS is similar to those flown on TOS and is mounted on the equipment module.

Primary sensor subsystems

The primary sensors on the ITOS spacecraft consist of:

1) Two redundant advanced vidicon camera subsystems (AVCS), each having a camera sensor, an electronics unit, and a three-channel magnetic tape recorder.
2) Two redundant automatic picture transmission (APT) subsystems, each having a camera sensor and an electronics unit.
3) Two redundant scanning radiometer (SR) subsystems, each composed of a scanning radiometer and control electronics, a dual processor, and redundant three-channel tape recorders.

The fields of view of these sensors are shown in Fig. 8.

Power- and signal-switching circuits, which are controlled by ground command, enable the selection of either AVCS camera in conjunction with either of the two tape recorders for operation. The same flexibility is provided for the selection of the radiometer and tape-recorder combination for SR operation.

To fulfill primary mission requirements, one AVCS camera and one AVCS tape recorder are used to obtain and record cloud-cover pictures from the daylight portion of the orbit. The stored AVCS data is played back to the CDA station over one of the redundant S-band transmitters. Concurrently, one of the two APT subsystems provides daytime cloud-cover pictures for real-time transmission to local users. In general, during the nighttime portion of the orbit, one scanning radiometer and one SR recorder are selected to measure and record data in both the visible and infrared regions; in addition, the infrared data is transmitted in real time to provide cloud-cover pictures to APT stations. A daytime option for the operation of SR may also be used.

The redundant scanning radiometer subsystem provides global, day and nighttime, infrared radiance data every 24 hours. The subsystem has both a visible and an infrared channel, and is capable of transmitting real-time data throughout the orbit. However, the subsystem normally transmits real-time infrared data while the subsatellite point is in the nighttime portion of each orbit. The real-time scanning radiometer data can be interleaved with the APT data during transmission to the APT stations. The radiometer consists of a scanning unit and an electronics package. It has two data channels, one which responds to energy in the infrared region of the spectrum (10.5 to 12.5 μm) and the other to energy in the visible region of the spectrum (0.52 to 0.72 μm). One of the two outputs is selected in the dual-SR processor by ground command; the selected signal amplitude-modulates a 2.4-kHz subcarrier in the SR processor. This signal is one of the inputs to the real-time transmitter for transmission to local APT stations. The normal mode of operation calls for scanning radiometer operation at night in the infrared region of the spectrum. The visible channel can be used in the daytime with SR data interleaved between APT picture readouts.

The scanning radiometer subsystem is also capable of collecting and storing (on magnetic tape) radiance data throughout the orbit. All coverage is provided by a line-scan radiometer, with scan essentially normal to the orbit plane. The total storage capacity is approximately 290 minutes of data, when both scanning radiometer recorders are used in a single remote sequence. During one orbit, the subsystem is capable of storing all the data obtained during the orbit. The SR recorder for this system is of unique design, having no drive belts or gears but using instead a direct-drive, servo-controlled motor with a 16-to-1 playback speed.

Secondary sensor subsystem

The secondary sensor subsystem consists of the flat plate radiometer (FPR), solar proton monitor (SPM), data format converter (DFC), and incremental tape recorder (ITR).

The FPR, developed by the University of Wisconsin, is designed to gather earth heat-balance data. From the output of its four detectors, which, after on-board processing by the FPR electronics, consists of 8-bit digital words, the amount of heat being radiated from the earth into space may be determined. By comparing this with the solar influx, the amount of heat absorbed by the earth may be ascertained.

The SPM, developed by the Applied Physics Laboratory of Johns Hopkins University, is used to determine the proton and electron fluxes encountered at the altitude of the orbit. The SPM data is expected to provide a better means of measuring and predicting solar-flare activities, which exert detrimental effects on radio communication and can impose a hostile environment for manned space exploration.

The SPM monitors the environment with six solid-state detectors. Five of these are proton detectors, whose design permits commutation to provide sequential readout of six energy levels. The sixth detector, which is designed to detect and measure electron activity, is used to ascertain the degree to which proton flux measurements have been contaminated by high-speed electrons.

Power supply

The power supply subsystem comprises a solar array, power supply electronics, batteries, and external shunt dissipators. The solar array consists of three panels (each 36.5 x 63.5 inches) providing 48 square feet of array surface. Each panel has five circuits with nine parallel strings of seventy-six 2-x-2-cm. solar cells. A total of 10,260 cells comprise the complete solar array. The cells are wired in series-parallel combinations to provide component redundancy. The array has an initial power output of over 400 watts.

Operating goals

The ITOS satellite has been designed to satisfy the requirements of the meteorological operational system. When in mission mode, it can provide complete data from the primary and secondary sensors every orbit. The minimum design mission lifetime of the satellite is six months with a one-year goal. (ITOS-1 exceeded this goal on January 23, 1971.) To meet this requirement, design factors have been incorporated to allow for degradation of both solar array output and transistor characteristics due to aging and radiation bombardment. Premature termination of the mission because of subsystem failures has been minimized by the use of cross-strapped redundant units. Generally, redundant units have been included for those subsystems which are primary to the mission. Where it has not been feasible to provide a redundant unit in a primary subsystem, as in the command distribution unit, the unit has self-contained redundant circuits or functions.

As a further aid to improved reliability, the redundant units are generally cross-strapped by resistive coupling. Thus, it is not necessary to provide signal switching; the selection and powering of the desired redundant units automatically produce the desired subsystem combinations.

Mission operations

The ITOS orbit-injection sequence is initiated immediately after separation from the upper stage of the launch vehicle. The events from injection to the achievement of the mission-mode attitude, under nominal conditions, are expected to take up to 24 hours. Upon separation from the upper stage, the satellite is spinning at approximately 3.5 r/min, with the spin axis approximately normal to the orbit plane. This spin rate provides the required momentum value for controlling satellite attitude.

The momentum wheel in the pitch-control system (Stabilite) is then spun up to 115 r/min. At this point, the satellite is stabilized about the spin axis of the flywheel. Then, the magnetic torquing coils are employed to adjust the momentum vector (spin axis) from the initial injection attitude to mission mode, in which the spin axis is normal to the orbit plane.

When the satellite reaches mission-mode attitude and desired spin rate, the solar panels are deployed. In the deployed position, the panels are in the orbit plane and fully illuminated by the sun. Under nominal orbital conditions, the sun vector would be at 45° to the spin axis; however, complete mission operations can be realized with a sun angle within the range of 30 to 60° with respect to the spin axis.

The pitch-axis control system is commanded to achieve local orientation of the sensor platform by transferring most of the total momentum of the satellite main body to the flywheel. The spin rate of the flywheel increases to 150 r/min, while the main body of the satellite decreases to one revolution per orbit to keep the sensor side of the satellite facing earth throughout the orbit.

ESSA-ITOS operations

The important product of the TOS and ITOS systems is the observation of weather data in all parts of the world and the processing of this weather data rapidly into a useful form. Major weather systems (such as fronts, storm centers, tropical and extratropical flows, hurricanes, typhoons, and distinctive cloud patterns) are viewed by the TV cameras and scanning radiometers in the ESSA and ITOS satellites.

Several of the more than 1,500,000 television pictures returned by the TIROS, ESSA, and ITOS satellites are shown in Figs. 9, 10, and 11. Although reproduction by printing results in the loss of detail, the high quality of the ESSA and ITOS photographs is evident in these illustrations.

Since the TOS system is still operational (ESSA 8 APT and ESSA 9 AVCS are in operational use), the changes planned for ITOS were chosen to reflect an orderly transition with the second-generation operational system. The phase-in process from TOS to ITOS reflects the requirements of common usage of existing ground station and data processing facilities to accommodate the simultaneous use of TOS and ITOS during the initial, developmental flights of the new series of satellites.

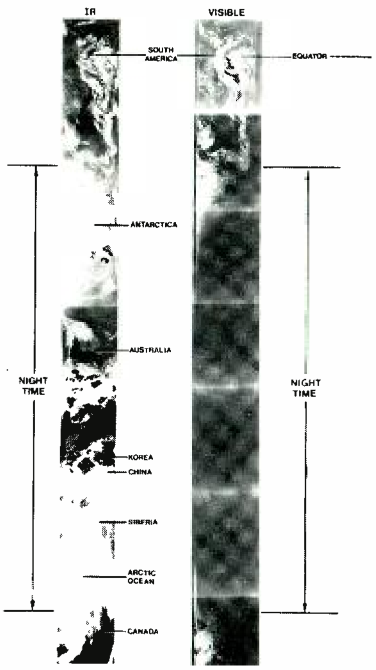


Fig. 9—Day-night scanning-radiometer photos taken by ITOS-1 on February 2, 1970.

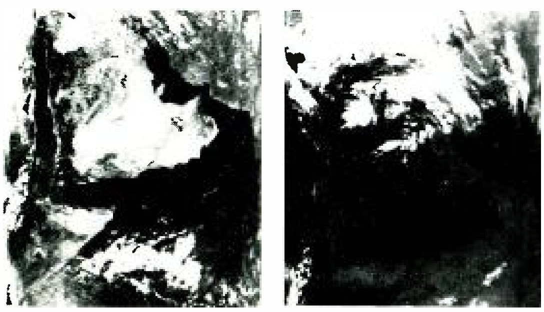


Fig. 10—ITOS-1 scanning-radiometer photos of Saudi Arabia, Persian Gulf, and Red Sea.

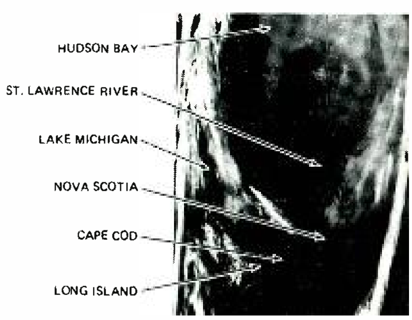


Fig. 11—ITOS-1 infrared scanning-radiometer photo of East Coast of U.S.A. and Canada.

Table II—Orbital parameters.

Parameter	*Predicted Value*	*Actual value*	
		ITOS-1	*NOAA-1*
Altitude	763 to 818 nmi.	773.6 to 798.3 nmi.	768.1 to 795.0 nmi
Inclination	101.44° to 102.04°	101.993°	101.948°
Orbit period	115.14 min	115.005 min	114.825 min
2nd stage/spacecraft spin-up	3.2 to 5.0 r/min	4.3 r/min	3.19 r/min
Attitude at separation	10° off orbit normal	10° off orbit normal	12° off orbit normal
Orbital precession rate	0.9857°/day	1.0126°/day	1.0082°/day
Orbits per day	12.5	12.5	12.54
Nodal regression	28.8° in longitude/orbit	28.75° in longitude/orbit	28.7° in longitude/orbit
Time of ascending node	1500 LMT	1500:39 YMT	1502:50 LMT

ITOS-1 orbital performance summary

The TIROS-M spacecraft was successfully launched from the Western Test Range at Vandenberg AFB, California, by the Improved Delta N Vehicle (designated Delta 76) on January 23, 1970, at 1131:02 GMT. After final cut-off of the 2nd-stage engine, the rocket and the attached spacecraft were yawed approximately 80° (or 10° off orbit normal). The combination was spun up by a cold gas system to 4.3 r/min, thus providing to the TIROS-M spacecraft the required initial momentum of 309 in-lb-sec. The TIROS-M spacecraft was separated from the launch vehicle and injected into the desired sun-synchronous orbit, becoming thereupon the ITOS-1 satellite. The excellent orbital parameters achieved by Delta 76 are shown in Table II.

Attitude control

The ITOS-1 satellite, upon separation from the second stage, was spinning at 4.30 r/min, providing the spacecraft with a total system momentum of 309.3 in-lb-sec. Immediately upon separation, the pitch-control system (PCS) automatically energized the enabled motor 1, which accelerated to 115 r/min. The spin rate of the satellite main body (its solar panels still folded) reduced from 4.30 to 2.05 r/min. During the initial orbit, the satellite attitude was determined. The quarter orbit magnetic attitude control (QOMAC) was programmed to remove the initial 10° offset of the pitch axis from the orbit normal. By the fourth orbit, the QOMAC cycle had successfully reduced the attitude error to less than 1°. On the fifth orbit the pitch control system gain was switched to normal, increasing the wheel rate from 115 to 150 r/min. This resulted in a transfer of momentum from the main body to the flywheel, hence, reducing the body spin rate from 2.05 to 1.31 r/min. On orbit 0005, the solar panels were deployed by a ground command that initiated the firing of squibs in the solar panel caging mechanism. The three panels deployed on schedule and locked in position, normal to the spacecraft's long axis. In this attitude with the spin axis normal to the orbit plane, the solar panels were oriented in the plane of the orbit. In the deployment of the solar panels and the resultant increase of the satellite inertia, the main body spin rate was reduced from 1.31 to 0.776 r/min, the momentum wheel rotation was still 150 r/min, and the spacecraft momentum was at 305.3 in-lb-sec. During the subsequent orbits the satellite's momentum was reduced by executing a series of magnetic-attitude spin control system cycles which adjusted the momentum from 305.3 to 235.8 in-lb-sec. This resulted in a reduction of body rate from 0.776 to 0.199 r/min.

On orbit 0042, the satellite was programmed for a pitch-loop automatic acquisition phase earth-lock. Within a 30-second period the PCS loop acquired the earth-lock and the satellite's sensors were oriented towards the local vertical while the main body rotated at 1 revolution/orbit.

In over 16 months of orbital operation, the ITOS-1 attitude control system has stabilized the satellite within ±1° in all three axes. All planned events were executed efficiently and on the desired schedule. The satellite's dynamic characteristics and values were very close to the prelaunch calculations.

The MWA lifetime, in spite of the failure of one of the two redundant MWA motors, is expected to exceed two years in orbit, thus surpassing the design objective by one year.

Thermal performance

The ITOS-1 thermal system design has performed very satisfactorily. The passive control system, consisting of a multilayer thermal insulating blanket and the variable solar absorption fence, in conjunction with the four active thermal control louvers on the two equipment walls have been maintaining the satellite internal temperatures in the range of the predicted values. The electronic systems are operating at a nominal 20°C with variations of ±10°C throughout all phases of orbital operations over the past year.

Power

The ITOS-1 power system derives its power from the three solar panels. During the phase from orbit insertion to solar-panel deployment (revolution 0005), the folded panels on the rotating main body provided adequate power (approximately 200 watts) to support the satellite's requirements for command and control, attitude sensing and control, and communications. The satellite was capable of operating in this phase indefinitely. Once the panels were deployed and satellite earthlock was achieved, the array output was approximately 11 amperes, well above the required full operational mission power load of 6.25 amperes. The solar array operating in a relatively active man-made and natural radiation environment at 790 nmi, has been decaying gradually. After 13 months in orbit the array output is above 8 amperes.

Primary sensors

The three primary sensors consisting of redundant APT real-time television, the redundant AVSC television for stored global data, and the redundant dual-channel scanning radiometer have all performed satisfactorily. Typical sensor data is shown in Figs. 9, 10, and 11.

With the successful deployment of the ITOS-1 satellite, global operational data from the television cameras and the visible and IR channels of the scanning radiometers is provided both in the direct and stored data modes of operation.

ITOS-D, E, F, and G configuration

A second configuration of ITOS spacecraft is now under development by the Astro-Electronics Division for NASA and ESSA to expand the operational capability of the ITOS system. This forthcoming system will utilize the ITOS basic space bus with a new complement of operational meteorological sensors. The system will be reconfigurated with a new redundant very high resolution radiometer (VHRR), redundant vertical-temperature-profile radiometer (VTPR), improved redundant scanning radiometer (SR), and the solar proton monitor (SPM). The APT, AVCS, and FPR systems will be deleted in this new configuration. Four spacecraft (ITOS-D, E, F, and G) are contemplated for this group, which is to provide operational meteorological data for the period 1972 to 1975. Although the basic mission is an extension of ITOS-1, utilizing the same launch vehicle (Delta N) in a 790 nmi sun-synchronous orbit, the complement will again provide both real-time direct data to receiving stations throughout the world and stored radiometric data to the two primary TOS CDA stations. Fig. 12 shows the ITOS-D, E, F, and G configuration.

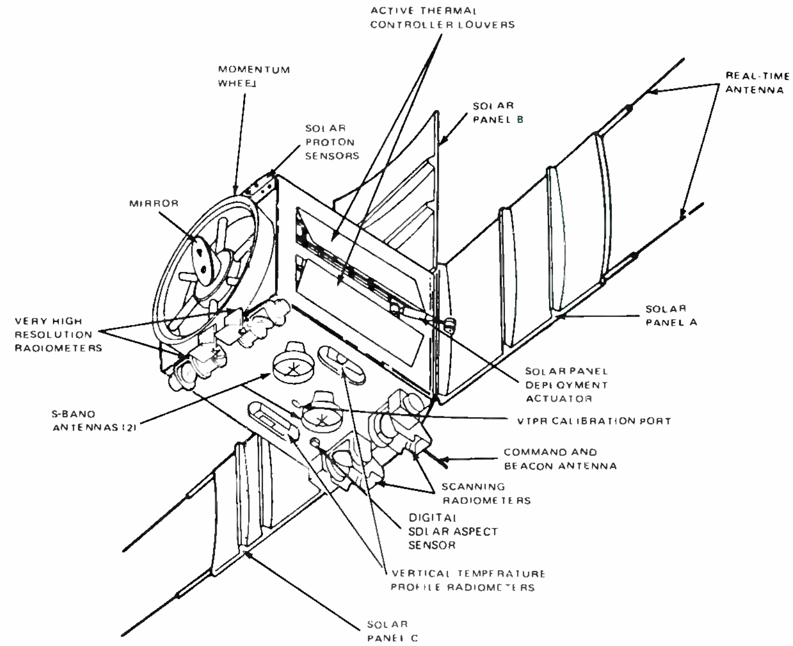


Fig. 12—ITOS-D, E, F, and G configuration.

The real-time data will be available in two forms to the local users. The SR data, which is similar to that of ITOS-1, and the VHRR two-channel scanning radiometer, which will provide data in two spectral regions to the local users: 0.6 to 0.7 μm (visible) and 10.5 to 12.5-μm (infrared). The local VHRR ground station users will be able to obtain VHRR data when the spacecraft is at least 5° above the horizon. The resolution at local vertical is 0.5 nmi. Stored data from the SR, VHRR, and the VTPR will be played back to the ITOS CDA stations by the same techniques used in the existing ITOS spacecraft.

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5. The AVCS is explained, in some depth, in Callais, R. T., et. al., "Nimbus—an advanced meteorological satellite," *RCA Engineer*, Vol. 9, No. 1 (June-July 1963) pp. 29, 30. Also, see Ref. 1 for more information on the APT and AVCS configurations.

Acronyms and abbreviations

Program and satellite designations

CDA	Control and Data Acquisition (station)
ESSA	Environmental Science and Services Administration
ITOS	Improved TIROS operational system
NOAA	National Oceanic and Atmospheric Administration
TIROS	Television and infrared observation satellite
TOS	TIROS operational system

Primary sensors

APT	Automatic picture transmission
AVCS	Advanced vidicon camera subsystem
SR	Scanning radiometer
VHRR	Very high resolution radiometer
VTPR	Vertical temperature profile radiometer

Secondary sensors

DFC	Data format converter
FPR	Flat plate radiometer
ITR	Incremental tape recorder
SPM	Solar proton monitor

Attitude control subsystem

DSAS	Digital solar aspect sensor
MBC	Magnetic bias control
MWA	Momentum wheel assembly
PCS	Pitch control system
QOMAC	Quarter orbit magnetic attitude control

New low-voltage COS/MOS IC's offer 25-ns speed and direct interfacing with saturated logic

R. E. Funk

The COS/MOS CD4000A Series is a new line of 3V-to-15V Complementary-Symmetry/Metal-Oxide-Semiconductor (COS/MOS) integrated circuits recently announced by the RCA Solid State Division. These devices feature 25-nanosecond gate-propagation delay, 10-MHz clock frequency, and can be directly interfaced with saturated-logic IC's.

THE NEW CD4000A low-voltage series heralds a major broadening of COS/MOS applications to include use in equipment where minimum system cost is the primary virtue and minimum power consumption is secondary. Since COS/MOS devices can accommodate designs of greater complexity in MSI configurations and can provide additional performance versatility, the designer now has a large number of cost-effectiveness options. Further, these more cost-effective COS/MOS devices can be intermixed with high-speed TTL logic using the same 5-V power supply for both types. Of course, for strictly low-power applications, COS/MOS will make possible exceptional cuts in power consumption.

Prior to introduction of this 3V-to-15V low-voltage series, COS/MOS devices were offered in the 6V-to-15V CD4000 Series which is still available. This series is pin-for-pin compatible with corresponding low-voltage types in the new series. Currently available are 32 low-voltage CD4000A types and 21 CD4000 types. Both series encompass a broad range of packages and types of construction, such as the premium ceramic structure and plastic. They are also available as chips. There are high-reliability types available as standard items, and specially selected units may be obtained as well.

It is natural that the superior performance of low-voltage COS/MOS in logic applications will immediately open the question: "How does COS/MOS look vs. TTL?" So, this comparison is summarized initially, before launching into a survey of CD4000A.

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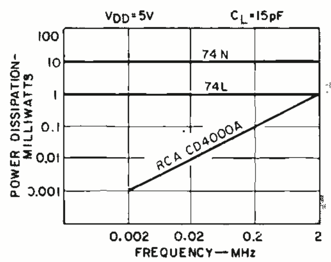


Fig. 1—Speed-power products of low-voltage COS/MOS gate and TTL gates.

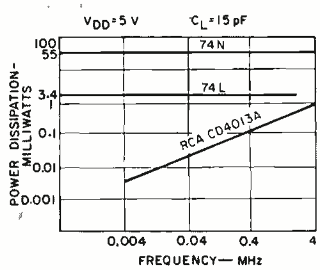
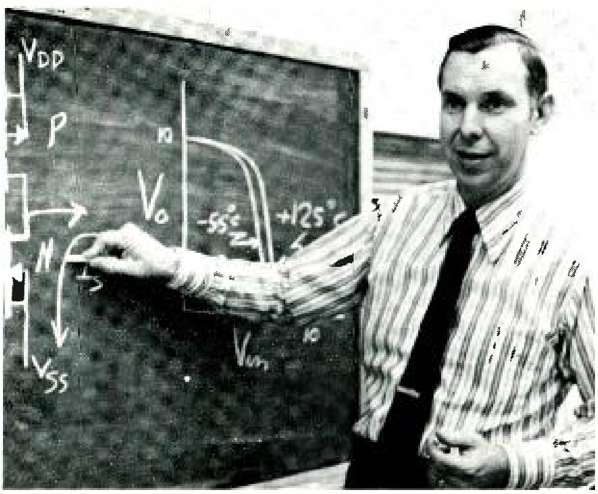


Fig. 2—Speed-power products of low-voltage COS/MOS flip-flop and TTL flip-flops.



Richard E. Funk, Ldr., MS Applications, Solid State Division, Somerville, N.J. received the BSEE and MSEE from Drexel Institute of Technology in 1956 and 1961 respectively. Mr. Funk initially joined RCA as a co-op student in 1953 and designed circuits for Airborne Radar Systems in Camden. He specialized in analog-computer circuit design from 1956 to 1959. In 1959 he began his digital-logic design career with responsibility for Data Link system logic in the era of RCA 2N404 discrete logic. In the early 1960's Mr. Funk was responsible for high speed code-generator logic design for real time digital communication systems. In the mid 1960's, he employed saturated logic digital IC's in Minuteman modular test systems. Between 1966 and 1970, he was responsible for logic and circuit design for digital frequency-synthesizer and control functions in the Defense Communications Systems Advanced Technology section in Camden. In 1968, Mr. Funk began working closely with Electronic Components, Somerville, in pioneering use of the new ultra-low-power RCA COS/MOS logic for the next generation of man-pack and hand held radios. In early 1970, Mr. Funk joined the Solid State Division as a group leader in application of MOS IC's. His responsibilities include logic-device specifications and usage, the high reliability program, constant-selection, and application materials for the burgeoning COS/MOS IC product lines.

Low-voltage COS/MOS vs. TTL

Since TTL is currently the most widely used logic form, it is important to establish how the new COS/MOS stacks up against TTL at 5-V operation. Fig. 1 demonstrates that, below 2 MHz, the low-voltage COS/MOS NOR gate has a decided edge in the all-important speed/power tradeoff. The crossover point with respect to the low-power TTL gate is 1 mW at 2 MHz, below which COS/MOS power decreases linearly with frequency.

At 2 MHz, the normal-power TTL gate dissipates ten times the power of COS/MOS. The typical COS/MOS gate will operate up to 7 MHz where its dissipation is but 5 mW.

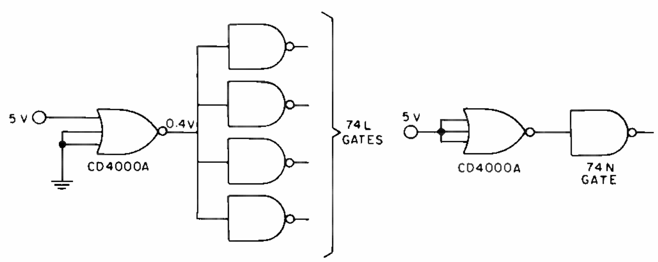
Fig. 2 shows the comparative toggle-frequency rate vs. power-dissipation curves for the COS/MOS CD4013A flip-flop and the TTL low- and normal-power flip-flops. At 4 MHz, where the COS/MOS flip-flop limits out, its power dissipation is one third that of the low-power TTL flip-flop and one fiftieth that of the normal-power TTL flip-flop.

Low-voltage COS/MOS has the advantage of being able to operate at frequencies considerably above those shown in Figs. 1 and 2; the increase in operating frequency is proportional to the inverse of the voltage up to a maximum of 15V. For example, the RCA CD4013A flip-flop has a typical toggle rate of 12 MHz at 15V.

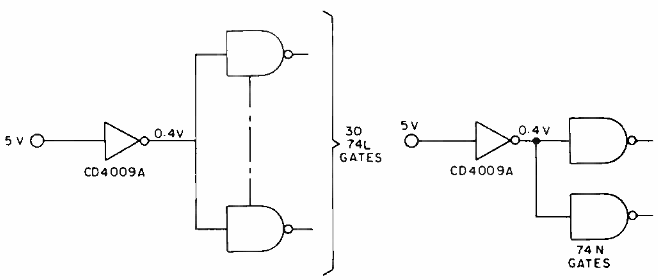
The ability of some COS/MOS logic to directly drive TTL logic using the single +5-V supply common to both logic families is extremely important in light of the present widespread use of TTL. Low-voltage COS/MOS can do just that, and Fig. 3 illustrates two COS/MOS devices that have this direct-drive capability.

Also of vital interest is the relative noise-immunity of COS/MOS and TTL devices. The fact that COS/MOS logic uses complementary circuitry means that COS/MOS should switch at 50% of V_{DD}, the supply voltage. Typical noise margins are, in fact, 45% of V_{DD}, and guaranteed noise margins are 30% of V_{DD}. On the other hand, TTL devices are only able to achieve a maximum noise immunity of 18% of the power supply voltage. Furthermore, TTL devices exhibit as much as ±20% shift in DC-transfer characteristics over a temperature range of −55°C to +125°C, while COS/MOS devices, due again to their complementary structure, have a total DC shift of ±1.5% of V_{DD}.

Not to be omitted, of course, is the fact that COS/MOS integrated circuits are necessarily more cost-effective than TTL. The operation of two basic "laws of nature" illustrates why. One is that COS/MOS chip packing-densities are from four to ten times greater than TTL densities; for example, COS/MOS gates take but one fourth the chip area of the equivalent TTL circuit. Second, the COS/MOS manufacturing process is simpler, requiring many fewer steps than the TTL process. Differences of those types are manifest in such cost-effective COS/MOS MSI devices as the 64-bit static shift register and a 23-stage binary counter, to name but two examples.



a) CD4000A NOR gate directly drives four low-power TTL gates and one normal-power TTL gate.



b) CD4009A hex inverter drives 30 low-power TTL gates and two normal-power TTL gates.

Fig. 3—Direct interface with TTL using common power supply and retaining inherent COS/MOS and TTL noise immunity.

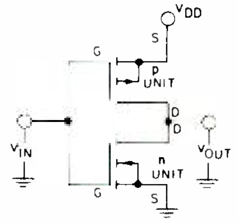


Fig. 4—Basic COS/MOS inverter.

COS/MOS basics in review

The remainder of this article will highlight low-voltage COS/MOS performance characteristics. A short review of the basic COS/MOS inverter and transmission gate is included here to familiarize the reader with COS/MOS circuit operation. All low-voltage COS/MOS integrated circuits are constructed from those two basic building blocks.

The simplest COS/MOS circuit is the digital inverter shown in Fig. 4. When a zero-volt signal (logic 0) is applied to the input terminal of the inverter, the gate-to-source (V_{GS}) of the P-channel device is equal to the supply voltage and is of the correct polarity to turn the P-channel unit ON. Under these conditions, a low-impedance path is formed from the power supply to the output terminal and a very high impedance path is formed from the output terminal to ground. As a result, the unloaded output voltage becomes equal to $+V_{DD}$ with respect to ground (logic 1). When the applied input voltage is $+V_{DD}$ (logic 1), the situation is reversed. As a result, the unloaded output voltage becomes zero with respect to ground (logic 0).

The new low-voltage COS/MOS devices can be used to form nearly perfect transmission gates that approach the ideal conditions of extremely low ON impedance and infinitely high OFF impedance. This can be accomplished by

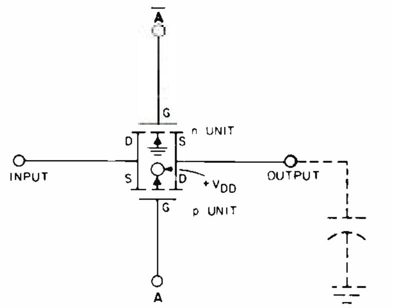


Fig. 5—Low-voltage COS/MOS transmission gate. Gate conducts when $\bar{A}$ is high and A is low.

connecting two complementary MOS transistors in parallel as shown in Fig. 5. By applying the control signals as shown, the device functions as a bilateral switch and provides either a low ON or high OFF impedance to any signal level between ground and $+V_{DD}$. [It must be noted here that this gate also constitutes an analog-signal switch of exceptional linearity, making possible the elimination of a number of circuits otherwise needed in such applications as audio and video switching systems.]

Using the basic inverter and transmission gate as building blocks, a wide variety of low-voltage gates, flip-flops, MSI structures, and LSI structures can be built, as listed below:[1,2]

- *Gates*—NOR, NAND, transmission, AND-OR select, exclusive-OR, complementary pairs
- *Shift Registers*—8 stage, dual 4-stage, 18-stage, 64-stage static; 200-bit dynamic
- *Counters/Dividers*—
  - Binary: ripple-carry, 7- & 14-stage
  - Presettable: up-down, divide-by-*N*
  - Decade: 10 decoded outputs, 7 segment display outputs
- *Flip-flops*—"D", J-k
- *Arithmetic devices*—adders, parallel processors
- *Decoders*—BCD-to-decimal, 3-bit binary-to-octal
- *Multiplexers*—Quad bilateral switch
- *Hex Buffer/LogicLevel Converters*—Inverting, non-inverting
- *Memories*—16- and 64-bit NDRO static RAM, 32-bit word-organized 256-bit fully decoded RAM

But versatility is only part of the COS/MOS story. The "magic" of MOS is that a complete logic system can be put onto a single chip. In such a case, a large logic array (more than 400 gates) can be customized to the user's specifications. The Solid State Division has developed a substantial custom design and production capability that can offer worthwhile advantages to the maker of low-cost equipment.

Circuit structure interactions

Because complementary MOS circuits require only active devices (and not large-value resistors or capacitors), low-cost low-voltage integrated COS/MOS structures can be manufactured that contain many hundreds of interconnected logic networks.

It is not the intent of this article to describe in detail the process of integrating N- and P-type devices on a single silicon substrate. The following paragraphs, however, do provide insight into some of the circuit and device-structure interactions that affect the performance of COS/MOS circuits.

For example, an edge view of a COS/MOS digital inverter is shown in Fig. 6a. In the process of diffusing the P- and the N-device sources and drains, and also when diffusing the P well, a number of parasitic diode elements are formed which become connected to certain signal nodes of the inverter circuit. Fig. 6b shows a protection circuit in which these parasitic diode elements are back-biased across the output signal line and across the power supply. So connected, these diodes contribute to the quiescent leakage current of the integrated structure, and also add parasitic capacitance to the signal and power supply nodes of the inverter circuit.

Low-voltage COS/MOS devices vary in complexity from simple gates and flip-flops to more complex MSI counter, register, and memory functions. Because of that structural variety, the specific contribution of the parasitic elements to the electrical performance of any given device will vary widely from device to device, even though all are manufactured with the same process.

Quiescent dissipation

In either logic state of the COS/MOS inverter or gate, at least one MOS transistor is ON, while at least one is OFF. The resultant quiescent power dissipation is therefore extremely low; it is the product of V_{DD} times the sum of the OFF-unit leakage current and the associated parasitic-diode back-biased leakage currents. The actual dissipation for any particular COS/MOS integrated circuit will depend upon the number of digital inverters or other such basic circuits employed, and will also depend upon device-sizes which have a direct bearing upon the total area of the parasitic elements. For example, the RCA CD4001A gate typically dissipates 0.01 μW at 10V quiescent, whereas the more complex CD4020A 14-stage ripple counter typically dissipates 10 μW at the same voltage, even though both devices are produced by the same process.

DC characteristics

The DC transfer characteristic of a typical low-voltage COS/MOS digital inverter is shown in Fig. 7. The input and output voltage excursions vary between the zero-volt level (logic 0) and $+V_{DD}$ (logic 1). The typical switching point is shown to be 45 to 50% of the magnitude of V_{DD} over a wide range of supply voltages. Fig. 7 also shows that there is only a negligible change in switching point as a function of ambient temperature. The precise location of the switching point on the x axis of the transfer character-

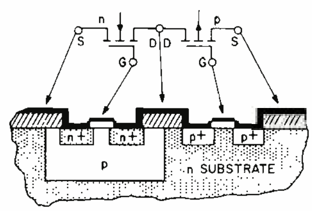


Fig. 6a—COS/MOS inverter cross-section.

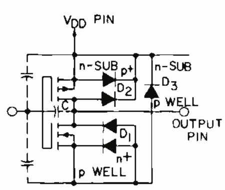


Fig. 6b—COS/MOS inverter parasitic diodes.

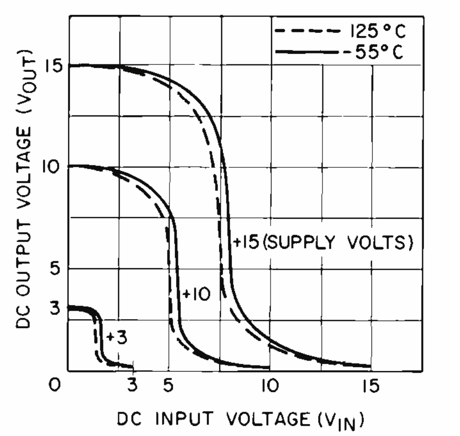


Fig. 7—CD4000A Devices. Typical voltage transfer characteristics.

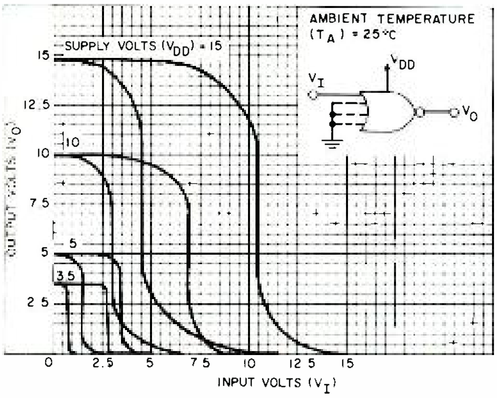


Fig. 8—CD4000A devices. Min. to max. voltage transfer characteristics.

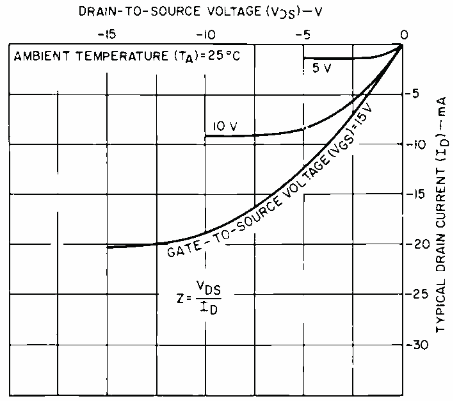


Fig. 9—Impedance as a function of the drain-to-source voltage for N and P devices.

istic, however, is a function of the impedance balance between the N and the P devices, which in turn is a function of the individual device-geometries and threshold voltages. In other words, depending on which device (P or N) exhibits the lower ON impedance, the position of the switching curve departs either to the right or left of ideal.

Because of normal manufacturing process variations, the individual N- and P-device thresholds within a given integrated structure will be similar but rarely identical. Also, relative device-geometries will differ, often by design, especially in multiple-input gate structures composed of series-and-parallel-combination devices. As a result, COS/MOS devices will exhibit a range of minimum-to-maximum switching-point characteristics, as shown in Fig. 8. This range is sufficiently tight to provide superior noise margins and yet sufficiently loose to ensure high production yields.

AC dissipation

Each COS/MOS inverter within an integrated circuit draws a transient switching current from the power supply during each 0-to-1 transition. This transient current is drawn because both the N and P devices are momentarily ON during the transition and, also, because the various device-node capacitances charge or discharge during the transition. The magnitude of the transient switching current depends upon the relative magnitude of the P- and N-device threshold voltages as compared with the magnitude of the power supply voltage. In addition, the magnitude of the transient current depends upon the number of devices switching within the circuit and upon the impedances of each of the devices.

Because of the many interrelating factors cited above, the dissipation of low-voltage COS/MOS devices, which in the quiescent state is in the ultra-low microwatt range, increases approximately linearly with increasing switching frequency and increases with increasing load capacitance on the external circuit nodes.

AC performance

During switching, the node capacitances located within a given device, or connected to the output terminals of a given device, are charged or discharged through the impedance of either an N or P device, whichever is turned ON. The impedance of either device is a non-linear function of V_{DS}, as a close scrutiny of Fig. 9 indicates. The larger the value of V_{DS}, the faster the device can switch. Also, the lower the individual device's threshold, the faster the switching speed. Those two characteristics of low-voltage COS/MOS integrated circuits set them apart from other forms of logic and are two marks of the superiority of RCA's new, low-voltage CD4000A Series. The designer has the freedom to choose a power supply voltage to suit his requirements; this choice is available from 3V to 15V with a constant 45% typical noise immunity.

Performance characteristics, low-voltage COS/MOS

Essential performance characteristics of the low-voltage COS/MOS IC's are highlighted here. Refs. 3 and 4 provide more detailed listing of characteristics.

Quiescent dissipation

Table I lists the range of quiescent power dissipation for gates, flip-flips, and families of MSI devices. Note that even the most complex functions dissipate less than 2.5 μW at standby with a 5-V supply.

Table I—Low-voltage COS/MOS. Typical quiescent power dissipation for COS/MOS devices; V_{DD}=5V (all values are in microwatts).

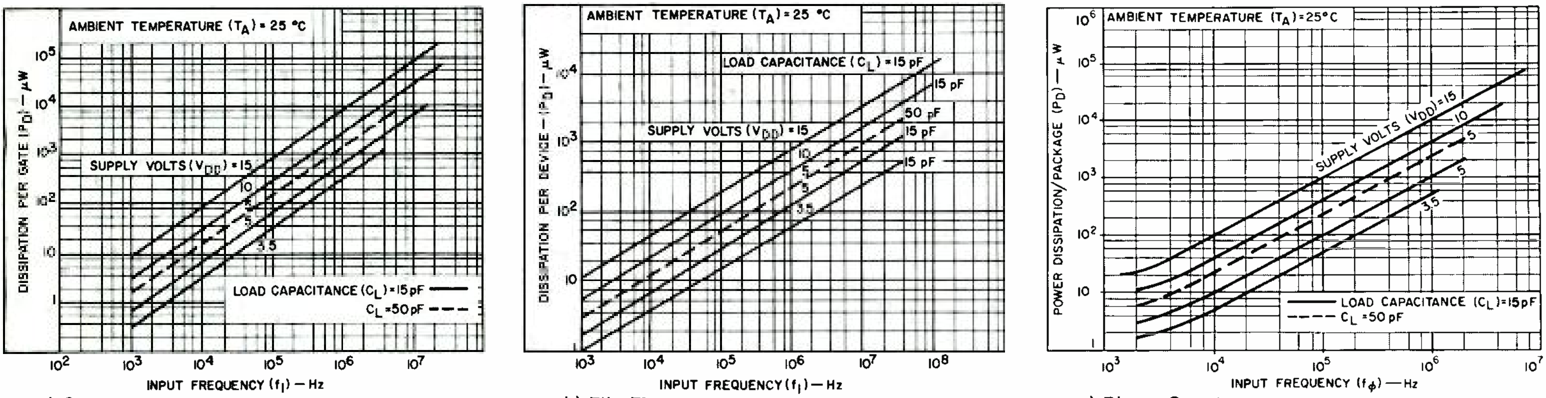
Logic function	Quiescent device dissipation
Counter/dividers	0.025 to 2.5
Arithmetic devices	1.5
Memories	0.1
Gates	0.001 to 0.15
Shift registers	0.025 to 2.5
Flip flops	0.025
Hex-buffer/logic-level converters	0.15

Output source and sink current

For COS/MOS-only systems, COS/MOS devices drive purely capacitive loads. Fan-outs of greater than 50 are practical. For interfacing with the "outside world," however, or with saturated logic, output source and sink-current capability is important. Table II shows the range of low-voltage COS/MOS output currents at 5V. For greater voltages, output currents are greater.

Table II—Low-Voltage COS/MOS. Typical output source and sink currents; V_{DD}=5V (all values in milliamperes).

Logic function	Output current (P) source	Output current (N) sink
Counter dividers	−0.25 to −0.5	0.3 to 0.5
Arithmetic devices	−0.5	0.5 to 1
Gates	—0.5 to −2	0.5 to 1.5
Shift registers	−0.15 to −0.5	0.1 to 0.3
Flip flops	−0.5	1
Hex-buffer/logic-level converters	−0.4	4



a) Gate b) Flip-Flop c) Binary Counter

Fig. 10—CD4000A devices. Typical power consumptions as a function of frequency.

Switching

The minimum and maximum switching points for RCA's two series of COS/MOS devices have been spaced symmetrically about the center of their transfer characteristics. The CD4000 series of COS/MOS devices has a typical switching point at 45% of V_{DD} over the range of 6V to 15V. CD4000A low-voltage COS/MOS devices switch at the same percentage over the wider range of 3V to 15V.

Propagation delay

The ranges of propagation delay for families of low-voltage COS/MOS devices are shown in Table III. Gate delays are shown at both 5V and 10V (V_{DD}).

Table III—Low-voltage COS/MOS. Typical propagation delays (tpHL–tpLH). Output load capacitance C_L=15pF (all values in nanoseconds).

Logic function	Sequential devices	Gate-level devices	
	V_{DD}=5V	5V	10V
Counters/dividers	150 to 350	—	—
Arithmetic devices	90 to 100	—	—
Memories	5 to 25*	—	—
Gates:			
Simple	—	35 to 50	25
Complex	—	100 to 150	50
Shift registers	200 to 500	—	—
Flip flops	150 to 200	—	—
Hex buffers/logic-level converters		50	25

*Access Time

Toggle rate

Maximum toggle rates for all sequential devices are given in Table IV at V_{DD} of 5V and 10V.

Dynamic dissipation of COS/MOS devices

Fig. 10 shows plots of typical power dissipations as a function of frequency for several types of low-voltage COS/MOS devices.

Logic-system design

Low-voltage COS/MOS devices offer unique system-design opportunities. Their low power consumption, wide operating-voltage range, simple device structure, and high noise immunity suggest many interesting logic applications. A few guidelines will be presented here; many more applications are cited in Refs. 3 and 4.

Parallel gates

Multiple-gate packages, such as CD-4000A, CD4001A, and CD4002A, can provide greater current-sinking, greater sourcing capability, and higher switching speed if all inputs and all corresponding outputs of adjacent gates are paralleled. The amount of additional sinking current is equal to the sum of sinking currents listed in Table II.

Positive or negative logic nomenclature

All COS/MOS-device data sheets refer to positive logic functionality. It is simple, however, to redefine these devices for negative logic functionality. For example, the CD4001A positive-logic NOR gate can be made a negative-logic NAND gate by redefining the logic levels. Similarly, the CD4011A positive-logic NAND gate can be made a negative-logic NOR gate.

Table IV—Low-voltage COS/MOS. Typical toggle rates, sequential devices. Load capacitance C_L=15pF (all values in megahertz).

Logic function	Toggle rate	
	V_{DD}=5V	10V
Counter/dividers	2.5 to 6	5 to 10
Shift registers	2.5 to 3.5	5 to 10
Flip flops	3.5 to 4	5 to 7

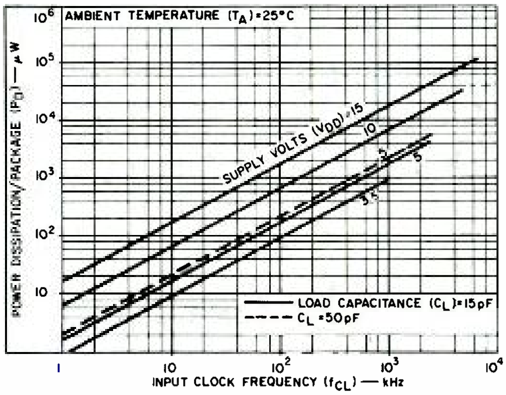
System power calculation

To calculate the total power dissipation of a system incorporating COS/MOS devices, it is necessary 1) to estimate the various switching rates and duty cycle of each device, 2) to estimate the output node capacitances, 3) to choose the desired operating voltage, and 4) to estimate both the quiescent and operating power for each device. Typical rather than maximum device dissipations may be used in this calculation, especially if many devices are used; it is extremely rare for all devices simultaneously to exhibit maximum dissipation.

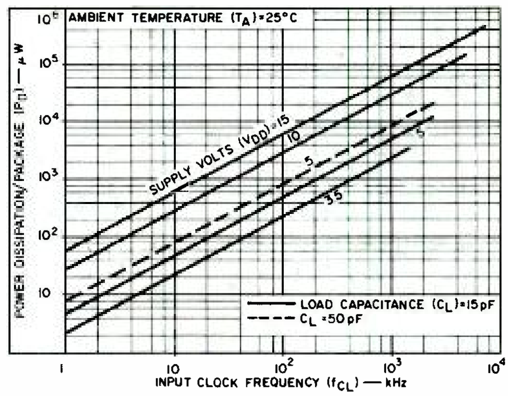
Regulation and filtering

An examination of the DC-switching characteristics of COS/MOS devices indicates that they switch reliably over a wide range of power-supply voltages. Specifically, RCA CD4000A COS/MOS integrated circuits operate reliably over a range of 3V to 15V. The width of this range now enables the designer to use an unregulated or minimally-filtered supply to power COS/MOS systems provided that, on the one hand, the maximum device-voltage limit of 15V is not exceeded and, on the other hand, that the required system speed is no greater than that speed which can be supported by the COS/MOS devices operating at the lowest instantaneous value of V_{DD}. Fig. 11 relates voltage regulation and maximum peak-to-peak ripple for a COS/MOS system as a function of desired system speed.

To establish the extent of supply regulation required, the designer must first



d) Synchronous Counter



e) Shift Register

determine the maximum operating frequency required of his system. Usually, one device in the system is the limiting element in the chain. Referring to the operating-frequency-as-a-function-of-voltage characteristic for this device, the designer can determine a minimum value of supply voltage as a function of both required device-speed and the number of unit-loads driven. A nominal power supply voltage, midway between the minimum and the 15-V maximum, is selected. The percentage of permissible power supply regulation and ripple is then easily calculated.

System interfacing

Proper interfacing between a COS/MOS device and a device from another logic family requires, ideally, that both devices operate at a common supply voltage and that logic levels between the two are compatible. In addition, both devices must maintain safe power dissipation levels and noise immunity consistent with the requirements of the system.

Low-voltage COS/MOS devices are unique in that they can interface directly with more logic technologies than any other device. The logic families that need no special interface circuit nor any added power supply are: 1) RTL, 2) DTL, 3) TTL, 4) P-MOS (low and high threshold), 5) mHTL, and 6) N-MOS. Only for interfacing with ECL is a special interface circuit required.

Conclusion

As more-complex MSI devices are made available in the low-voltage COS/MOS family, and as costs decrease with volume usage, these new COS/MOS integrated circuits will find increasing application in systems that are now totally fabricated with bipolar-logic families. In addition, the low voltage requirements and low power dissipation of the new COS/MOS give the designer of portable battery-operated systems the basic digital building blocks never before available to him. For example, one important new equipment application is the electronic watch and clock field. Also, the wide operating-voltage range makes COS/MOS devices attractive for automotive applications and in others where regulation is poor or where filtering is almost nonexistent.

But such applications as the two just mentioned are only the next, logical steps by equipment designers and only hint at distances that low-voltage COS/MOS will enable designers to go. And, indeed it is even now true that lower-threshold devices capable of operation at 1.3 volts V_{DD} are available for single-cell applications. Further reductions in device sizes and chip capacitances will yield devices that will increase digital system speeds to more than 20 MHz. MOS device-complexity is already four times that allowed by the most sophisticated bipolar MSI devices, and the limits have not yet been reached.

At the current rate of development, COS/MOS devices will soon find application in almost every type of digital system, whether it be industrial, commercial, or aerospace. And, it is safe to predict that by 1975 most digital equipment will be profitably employing both standard and custom COS/MOS devices.

References

1. A complete list of the COS/MOS product line is given in COS-278, "The low-voltage COS/MOS product guide" RCA Commercial Engineering, Harrison, N.J. 07029.
2. At this writing, 32 standard low-voltage COS/MOS products have been announced, and at least another 15 are due this year.
3. *RCA COS/MOS Integrated Circuits Manual*, CMS-270. RCA Commercial Engineering, Harrison, N.J. 07029.
4. CD4000A-series, *Data Bulletin* (File No. 479); also see numerous *Application Notes* available. RCA Commercial Engineering, Harrison, N.J. 07029.

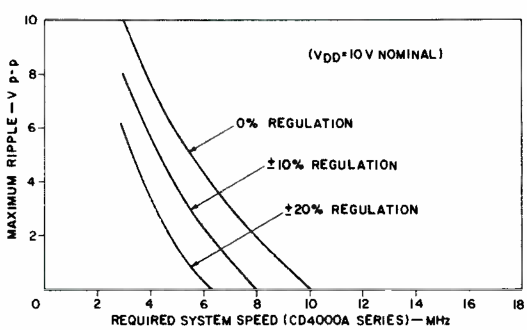


Fig. 11—Low-voltage COS/MOS power supply considerations.

The human role in command and control systems of the 70's

B. Patrusky

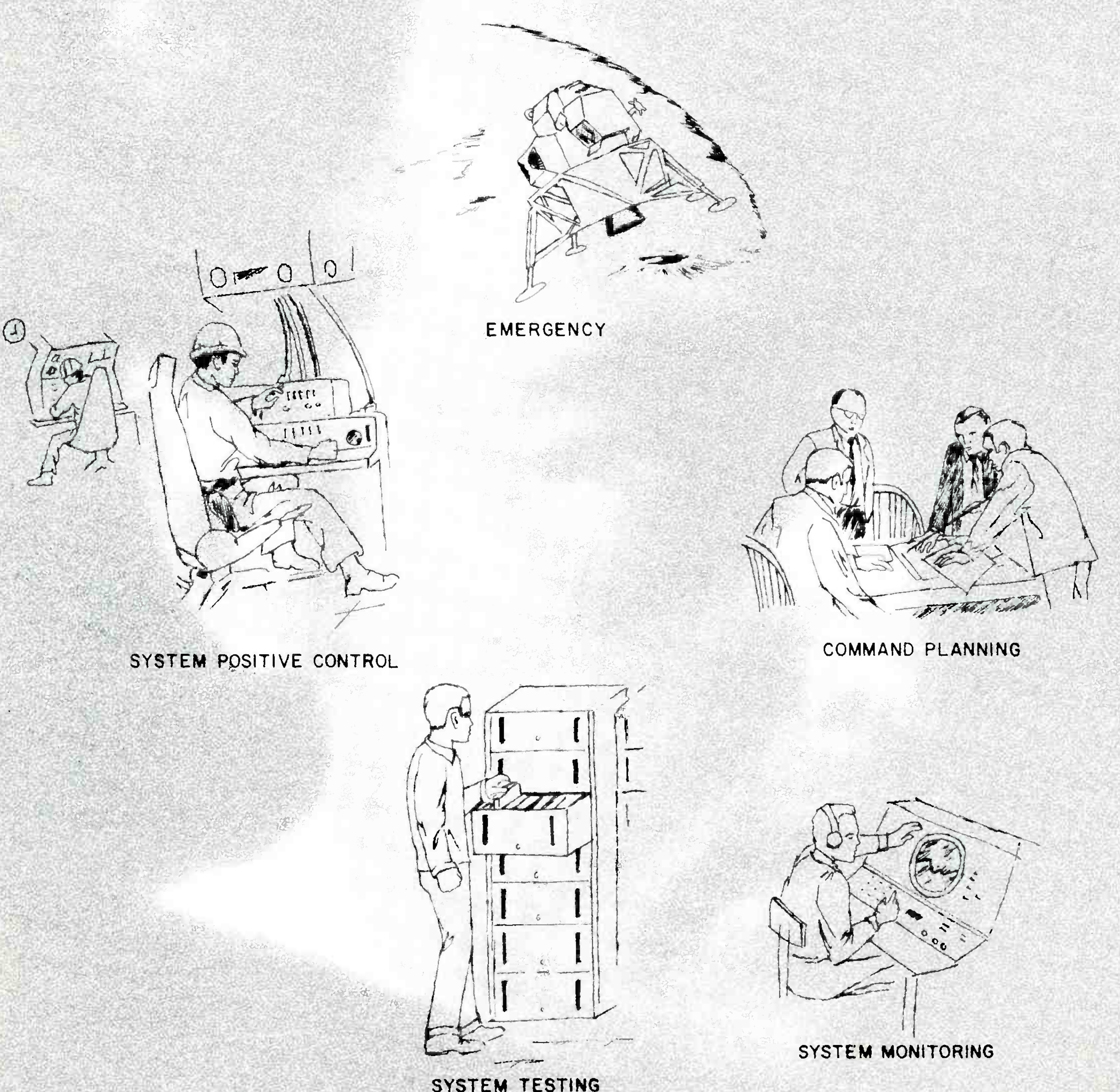


Fig. 1—Man will maintain a major role in the command and control systems of the 70's.

Although the trend of command and control systems is for complete automation of the operational system, man will still have a major interface with the command/control systems of the 70's. The role of man will diminish in the command and control operations, but there will remain a residual number of peripheral functions which he will still have to perform. This paper discusses these functions as they relate to present and future defense systems.

In the past, a ship command/control system used man's senses to detect an enemy assault. From this sensory information, he made decisions assigning targets of priority to manned gun turrets. Voice communications served to provide target direction parameters to the gun crew.

Eventually man was assisted in this weapon-control function by automated fire-control systems. This has developed to an extent that new systems are automatically sensing, selecting targets, and making the optimal selection for the most effective response to a threat. The trend in the 70's is illustrated by the Aegis system which integrates detection, warning, decision, and weapon-control functions as a completely automated system. This operational system, as others in the 70's, has a minimal manned interface. But, man's role in the command and control system of the 70's is still important because of key functions which still must depend on human decisions.

There are five major areas, as shown in Fig. 1, where man will continue to play an important role in the 70's:

1) System positive control
2) Major command decisions and/or decisions involving multiple systems or multiple options.
3) Emergency actions/system backup
4) Monitoring system status
5) System testing and maintenance

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System positive control

System positive control is defined as the capability of man to start or stop the automated system—a role that can never be relinquished. The function of positive control for a weapon system goes further in that it places the capability of exercising this type of control in the hands of specifically authorized persons.

Major command decisions

The second role of man is major military attack command decisions. These are the decisions which involve choice and judgment normally performed by the highest echelons of authority. These command decisions are preplanned based on postulated attack scenarios, and incorporated as an integral part of the operational software programs which are stored in the central system computers and govern system response.

These plans can integrate the actions of more than one command/control system. Apriori information is not normally available however to permit automatic selection of the execution program to be followed in response to a specific attack. It therefore still remains the role of man to select which attack option to follow and to inform the automated system of the option chosen.

The Minuteman system is an excellent example of the significance of preplanning. Operational programs for Minuteman system involve a great deal of high level decision as to system strategy. The burden on the planners is to predict all possible environments and attacks the system will face and then program the system to handle each situation. It is important to integrate the system response with the programmed response of other systems. This preplanning and programming effort is by far the most important function for man.

Man's role in the preplanning stage was to create and program the system with planned responses. During the actual operation, man must choose which plan to follow (depending on the specific attack circumstances) and indicate his choice by manually selecting the operational program to be executed by the system computer.

The following hypothetical example further illustrates this situation. Suppose a single incoming missile was to be detected by our perimeter defenses. It is likely that in the seventies this missile would be destroyed by a Spartan defensive missile without any human intervention other than

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the decision to employ the defense system. However, what then? The response to such an attack cannot be automated. Was the attack intentional or accidental? What were the underlying factors? These unanswered questions must be resolved prior to taking counter action. Time is not a pressing factor. Thus, we see a type of decision which cannot be automated due to lack of sufficient data. Suppose we did decide to counter with a like attack on an enemy target; which command and control system should be used? Again a real-time choice exists. A land-based missile or a submarine-launched Poseidon missile could be employed. Political factors would direct the ultimate decision. The conclusion to be drawn is that man must direct the command/control system as to the attack plan. The actual attack execution can then be fully automated.

Emergency actions/system backup

A third major area concerns emergency backup responsibility. The easiest and least costly emergency backup system is usually a manually operated system particularly if it is a relatively complex operational sequence. Although one would like to be able to handle emergency backup on an automatic basis, the simplicity and low cost of a manual system usually makes the manual system a clear choice. The most well known and outstanding example of this is the manual backup maneuvering system provided the Apollo spacecraft command control system. Indeed, the manual system was often called upon to aid reentry, docking and landing operations.

Manual backup system functions must be chosen carefully. Manual backup features are not always cost effective or technically feasible. While it is not practical to manually aim a weapon to counter an incoming missile, it may be practical to manually patch in standby equipment to replace failed operational equipment to restore the system to a state of readiness. Early system trade studies normally determine what manual backup functions are desirable or necessary.

Monitoring

System monitoring serves many purposes. A major purpose is to insure the readiness of the system prior to actual usage; however, monitoring is also necessary to detect attack and assess success or failure of system operations, and to determine if and when emergency procedures are required during operations. In effect, system monitoring during operations serves as the required observer.

The AEGIS system will have a comprehensive self-verification monitoring system which will locate failed replaceable units on line while the system is operating. In addition, the radar scans will be monitored for the purpose of corroborating the evaluation of the computers that an attack is underway. This is required before the system is unleased. Battle results are also monitored.

Similar to AEGIS, SAFEGUARD system monitoring is used extensively to assure that the system components are in a state of operational readiness.

The trend in monitoring appears to be in the direction of easing the man's burden by use of more sophisticated computer controlled displays rather than printers or a conglomeration of lights. The displays of the Kinescope type, including color and projection displays, will be used more often because of increased availability of relatively low cost "off-the-shelf" MIL spec units.

System testing and maintenance

By continued testing one can determine the operational readiness or availability of a system. If the testing reveals operational deficiencies, maintenance will have to be performed to return the system to its maximum availability. With any automated system, the key problem is to keep the system at maximum availability. This is an especially difficult problem in military systems where high-skill-level technicians are not available. The trend is toward sophisticated automatic checkout equipment not requiring high-skill-level operators. Periodic thorough system checkout is the means for insuring system availability.

The trend in system testing is use of online automatic test equipment. It is most likely that in the systems of the 1970's failures will be isolated with very high confidence to at least a removable, replaceable unit and even be analyzed for fault to the replaceable module. Command and control systems strive for high availability or up time. This is best achieved by redundancy and on-line plug-in replacement of failed components.

The on-line computers of most new systems will perform verification testing on a routine basis. Special tests and fault isolation testing may be automatically commanded once a fault is detected. Maintenance personnel will not require special skills. Module repair at the depot may require skilled personnel, and a tradeoff is usually required to determine if automated module testing is cost effective. It is quite possible that central repair depots will handle all types of module repairs for many unrelated systems. Centralization of module repair depots would greatly decrease the number of highly skilled test personnel required.

In contrast to simplified operational test and maintenance, off-line system testing and system computer simulation is likely to keep pace in sophistication with the increasing sophistication of the command system. As discussed previously, many command control systems have very complicated computer programs, are designed to face severe environmental threats, and are required to operate even in a highly damaged or degraded mode. This poses the problem that it is not possible to completely test the actual system in all possible combinations of degraded modes and environments that the system might encounter. In these instances employment of sophisticated simulation testing will be needed.

Conclusion

The human role in Command/Control systems will continue to be important in the 70's; although "push-button" systems are now in operational use, there remains relatively large areas where automation will not be the answer.

Assessment of queue formation in computer systems

A. S. Merriam

Queuing for use of a service facility is necessary to the well-utilized computer system, yet queue sizes are difficult to predict analytically even in simple situations. With emphasis upon the interarrival-of-events pattern, some queue parameters have been illustrated, calculated, and discussed. Systems simulators will recognize the situations in which the results of computer simulations are superior to the approximations of analytical techniques.

Queues must be regarded with cautious enthusiasm. The novice in system design instinctively feels that they cannot be good because they represent items waiting while valuable microseconds tick by. Alternatively there exists the manager of a batch-processing establishment whose happiness is a well-filled set of input disks, and who knows that it is better to be able to promise two-hour turn-around than to be able to run a solo job in two minutes. The novice soon learns that no-waiting-ever comes at an impossible price, and the computer center manager can guess, if he has not experienced it, how quickly he can be buried under input decks and tapes if his service time is not included to his disk capacity and customer load.

Because queues are necessary, if not desirable, and because they exhibit "dangerous" tendencies to "blow up," it is mandatory that system architects explore ideas which cultivate a reasonableness of attitude towards queues. Understanding of the queue formation situation is vital to queue control. An analytical rather than a simulation approach leads to most direct and thorough understanding. With the easy availability of good numerical approximations, the analytical route appears the way to go, and it is, up to a point. Application of mathematical formulas to real-life situations involves simplification. Sometimes, however, the concomitant analysis of how much the initial simplifications "hurt" the final results becomes a study as great as the original. By reducing the simplification necessary to model a queuing situation analytically, system simulation via computer offers a promising extension to queuing studies.

When it is best to move from analytical computation to simulation of a queuing situation is an individual problem. The solution will depend upon factors giving rise to the queue, simplifications that can be tolerated, quality of results desired, and amount of effort budgeted for those results. Judgement of the system architect will be depended upon here, and it will be the better for his experience in both queuing theory and queuing system simulation. Both techniques of study are juxtaposed in three experimental situations, which can only suggest a range of examples—from textbook elementary to currently practical.

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Queuing theory background

Some descriptive definitions

At the heart of the queuing problem is time—time at which events happen or are permitted to happen. Though not all events can be denoted as *random* or *regular* in time, these classifications are general enough to be useful and credible. From these classifications, approximations can extend to cover wider application later, although ultimately the rules for the one or the other become inadequate.

Random and regular processes are characterized by the probability functions shown in Figs. 1 and 2, respectively.

The probability of a *random function* occurring is low, uniform, and independent of time as shown in Fig. 1a. The

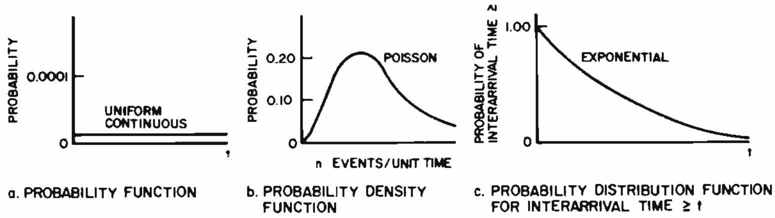

Fig. 1—Typical probabilities involved in random events.

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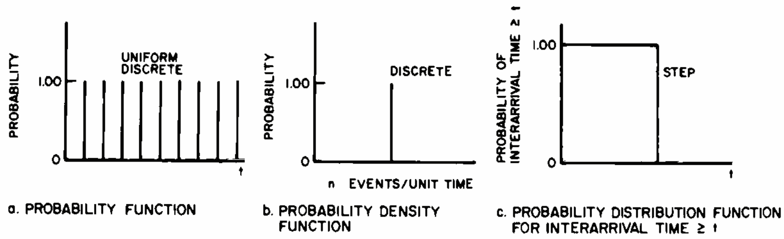

Fig. 2—Typical probabilities involved in regular events.

chance of a *particular number of random events* occurring in a specific unit of time is characterized by a Poisson distribution, as shown in Fig. 1b. The probability that the *interarrival time* (the time between successive events) is a particular period of time greater than t is an exponential function, as illustrated in Fig. 1c. The *mean interarrival time,* T_a, is a parameter of interest in queuing.

The corresponding functions for a regular process are the *uniformly-repeated discrete, discrete,* and *step,* as illustrated in Fig. 2a, b, and c, respectively. *Service time* (time from the acceptance of a request for service from the queue, as it arrives, to the completion of that service) is analogous to interarrival time. The *mean service time,* T_s, is another parameter of interest in queuing.

For convenience in discussing formulas, the following conventional quantities with their symbols are defined:

λ = *mean arrival rate* = $1/T_a$ (1)

μ = *mean service rate* = $1/T_s$ (2)

ρ = *utilization factor* = λ/μ (3)

The last is a most important parameter in the description of queuing systems. Values greater than unity need not be considered, and those edging towards unity will be assessed with caution rapidly increasing to the point of alarm. In the analysis of queuing situations, the following functions are of interest:

A_a = *probability distribution of interarrival times.*

S_a = *probability distribution of service times.*

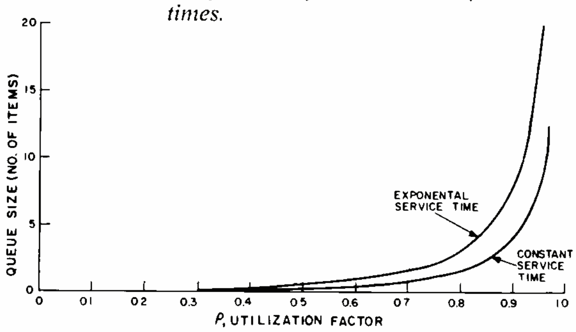

Fig. 4—Queue size as a function of utilization factor for random input to random and regular service.

Both are cumulative functions of probability densities. Erlang and hyperexponential functions vary from the exponential function by less and greater variance from the mean, respectively, as illustrated in Fig. 3. The constant-rate distribution (Fig. 2c) for regular events is the ultimate in Erlang (or hypoexponential) distributions. Mean interarrival time or mean service time is analytically linked to these functions of which the exponential situation yields most easily to manipulation.

Parameters of interest to the system designer are:

n = *number of items in queue and service facility*

m = *number of items in queue alone*

v = *waiting time in queue and service system*

w = *waiting time in queue alone.*

These parameters can be formulated in terms of ρ as the independent variable.

Convenient formulations

Within the field of operations research, much has been done to make the analysis of queuing situations routine. A queuing system is regarded as being in a state which is characterized by the numbers (including zero) of items in the queue or in the service facility. For example, change of state is effected by having an item join the queue, leave it by entering the service facility, or leave the service facility after completion of service. If the probabilities for a change of state are known, steady-state solutions are frequently possible from the state change equations: Convenient results are given below as a "cookbook" for the simulation experiments.[1,2]

As has been indicated, the simplest system analytically is the random arrival for random service times with a first-come-first-served dispatching discipline. The mean values of system parameters are calculated as follows:

$$\bar{m}=\frac{\rho^2}{1-\rho} \quad (4)$$

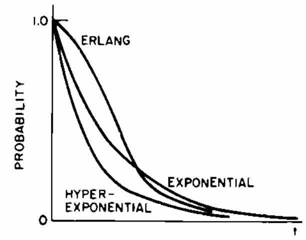

Fig. 3—Erlang hyperexponential functions compared to the exponential function for random interarrival time greater than or equal to t.

$$\bar{n}=\frac{\rho}{1-\rho} \quad (5)$$

$$\bar{w}=\frac{\rho}{1-\rho}\,T_s \quad (6)$$

$$\bar{v}=\frac{1}{1-\rho}\,T_s \quad (7)$$

For constant service times, the mean values are slightly altered to:

$$\bar{m}=\frac{\rho^2}{2(1-\rho)} \quad (8)$$

$$\bar{n}=\frac{\rho^2}{2(1-\rho)}+\rho \quad (9)$$

$$\bar{w}=\frac{\rho}{2(1-\rho)}T_s \quad (10)$$

$$\bar{v}=\frac{2-\rho}{2(1-\rho)}T_s \quad (11)$$

Between the constant- and exponential-rate situations, a factor may be applied to constant-rate formulas to interpolate between the two. This factor $(1+\zeta)$ is based on a comparison of variance, V, for the partially random case and for the entirely random case where

$$\zeta=\frac{V}{\lambda^2}$$

These formulas plus a short FORTRAN program and approximately one minute of machine time result in some convenient tables for the queue estimator. The increasing sensitivity of queue size to utilization factor increase for random and for uniform service times is illustrated in Fig. 4.

Formulations have been made covering queues for multiple-service facilities and for dispatching disciplines other than first-come-first-served. Although it may be interesting and applicable to the design of computers, discussion of these formulations must be postponed.

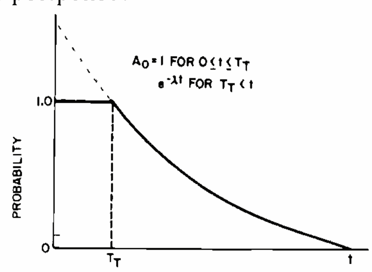

Fig. 5—Truncated exponential probability distribution function.

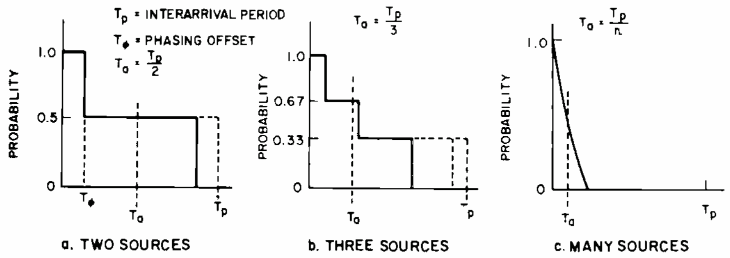

Fig. 6—Probability distribution functions for constant and equal-rate inputs.

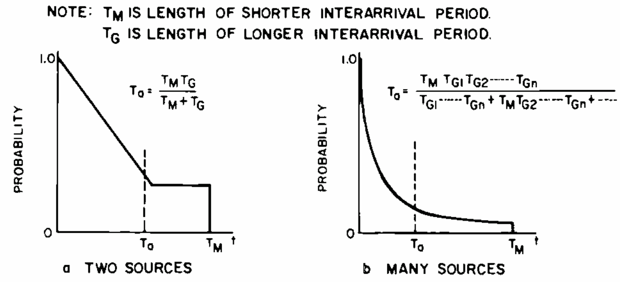

Fig. 7—Probability distribution functions for constant and unequal-rate inputs.

Further considerations

Structures of rapidly increasing complexity can be easily conceived using the simple queue-and-service facility. The multiserver mentioned above is one of the simpler. Complex inputs to a single-service facility are more analytically elusive. Two types of interarrival patterns—truncated exponential distribution and multiple complex input distribution—have a particular bearing on the experiments that follow. Distribution functions are not only of interest for comparison with real-life measurements but for making estimates of mean interarrival times necessary for the calculation of utilization factor.

The truncated exponential is a distribution in which interarrivals up to a certain frequency have been suppressed. The familiar exponential curve is altered as shown in Fig. 5, and the probability distribution function, A_o, becomes

$$A_o = \frac{1}{\exp(-\lambda T_T)} \exp[-\lambda(t'+T_T)] \quad (12)$$

where T_T is time of truncation and

$$t = t' + T_T$$

T_a can be calculated from this distribution:

$$T_a = 1/\lambda + T_T \quad (13)$$

Such a distribution has been used in modeling random interarrival times of items which take a fixed minimum time to produce.

The probability distribution for more than one constant-rate input is somewhat harder to analyze. If two sources of the same constant-rate input feed a service facility, the resultant probability distribution curve, shown in Fig. 6a, is dependent upon their phasing. (The case in which both inputs arrive simultaneously is excluded for convenience.) A probability distribution for three inputs of constant and equal rate, shown in Fig. 6b, illustrates the development of these trivial situations. Increasing the constant and equal rate sources to a large number leads to the distribution shown in Fig. 6c where the steps smooth out and the maximum interarrival time becomes very small.

When two sources of constant but unequal rates are combined, the resultant function may appear like the function shown in Fig. 7a. Exact slope and height of step depend upon relative sizes of the two interarrival periods. The addition of further sources adds to a greater proportion of small values of interarrival times and, to a lesser extent, larger values, with a curve similar to Fig. 7c resulting.

If an exponential (random) rate source is added to several constant-rate sources, a distribution such as shown in Fig. 8 can be expected. The likelihood of short and long interarrival times is markedly increased with the short ones having a greater increase. If the mean interarrival time of the exponential is less, by roughly a factor of 1.5 or more, than the mean interarrival time of the constant-rate sources, the function will approach the hyperexponential, although it will always differ from hyperexponential because of truncation.

Experiment 1

The basic queue-and-server system can be observed in the following arrangement:

1) Randomly arriving requests for service are queued without regard for numbers on a first-come-first-served basis. The facility completes service at random times.
2) Randomly arriving requests, as above, are queued for a facility of constant service time.

In both situations, the utilization factor (ρ) has been varied and the length of queue, (m) studied. Results, shown in Fig. 4, are easily calculated from Eqs. 4 and 8.

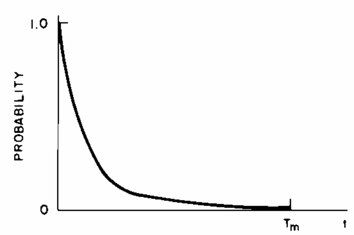

Fig. 8—Multibus arrangement with four main memories and two central processors, each with two I/O channels.

In estimating queue formation, it may be sufficient for the systems architect to know that the facility service time is hypoexponential and that the true situation will lie between the two curves plotted.

Experiment 2

The intent in this experiment is to check some of the speculations and approximations presented above concerning complex interarrival rates. A computer-simulated facility of constant service time is entered from a single channel fed by several sources. For the first series of runs, constant rate inputs are combined. The second series of runs is similar to the first except that one exponential source is added. The parameters varied in both series are interarrival rates of the sources as well as numbers of sources. The quantities measured are:

1) Interarrival times,
2) System utilization factors, and
3) Numbers of items in queue at steady state.

From the first measurement, the probability distribution function is plotted and a system utilization factor calculated for a check against measured values. Fitting a hyperexponential curve to the measured curve will also lead to a calculated utilization which in turn can be verified against the simulated case. Finally, the resulting utilization factors are used to calculate the quantity of items in the queue at steady state for further comparison.

Experiment 3

The final model was constructed in response to a real problem where it was foreseen that several active components and several passive components would be sharing a two-channel bus. The situation arises in the design of a multi-processor—a computer in which two or more independently controlled processors, each with its own I/O channels, share more than one in-

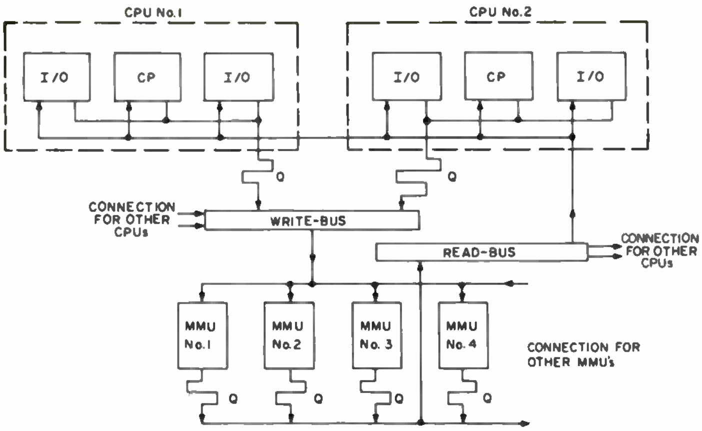

Fig. 9—Multibus arrangement with four main memories and two central processors, each with two I/O channels.

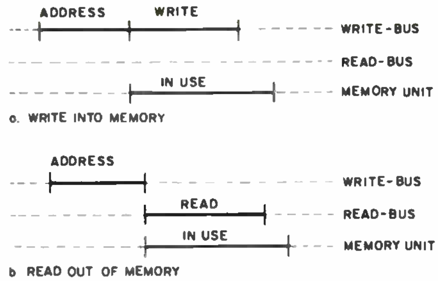

Fig. 10—Gross timing scheme for buses and memory units.

Table III—Typical interarrival time parameters.

Request source	T_a, *mean interarrival time* (μ *s*)
Central processor	2.7
I/O channel	1.5

dependently accessed memories, either for their own use or for the exchange of data. The interconnection, locally called a "Multibus" and shown in block form in Fig. 9, is a powerful arrangement but has obvious limitations in the write and read buses.

The gross timing of occupancy of bus and memory facilities is shown in Fig. 10. At this level of detail, overlappings of addressing time with memory function will be negligible. The significant characteristics of active and passive components are listed in Tables I and II, respectively. Organization of activity is shown in the flowchart of Fig. 11. Modularity is provided in the model so that different versions containing more or less of the basic components can be studied. The flowchart, therefore, shows where additional channels may be plugged in and where additional central processing units (CPU's) can be entered.

Table I—Characteristics of active components.

Unit	*Associated with*	*Shares access to*	*Access type*	*Rate of access*
CP	Several I/O channels	All MMU's	R/W single	Exponential[a]
I/O channel	One CPU	All MMU's	R/W burst	Constant[b]

[a] but not less than T_o
[b] within the burst

Table II—Characteristics of passive components.

Unit	*Occupancy*	*Access from*
Write-bus	Single	CPU queue
Read-bus	Single	MMU queue
MMU	Single	Write-bus

Bus request generation

Requests for memory come from two quite different sources, the central processor and the I/O channels. When processing a set of instructions, a central processor must access storage for fetching and storing instructions, data, and perhaps intermediate results. This has been modeled as a random process with a modified exponential distribution of interarrival times for memory requests. The distribution has been truncated at a minimum interarrival time because the computer modeled must exclusively perform certain elementary operations between the end of one access and the start of the next.

The I/O channels, by contrast, have been assigned constant-rate distributions in bursts of tens to hundreds of items interspersed by quiescent periods. The on-off cycle can be made of randomly variable period to simulate transfers of varying amounts of records from tapes or disks. The mean rate of arrival from I/O channels is much lower than that from the processor, as indicated in Table III.

Bus queuing

Independently flowing requests generated by the complex sources of a central processing unit (CPU) must be checked by the rules of single occupancy of the bus and single access of any main memory unit (MMU). For this model, the rules are:

1) Requests are queued at a CPU if the write-bus is busy or if less than 775 ns have elapsed since the last request from this CPU.
2) The central processor within the CPU is inhibited from generating requests if a queue has formed for use of the bus or if it has an outstanding request to a MMU.
3) The I/O channels are not inhibited. The CPU's compete on first-come-first-served basis for the use of the bus.

Bus-memory action

Once the bus has been engaged for an addressing operation it can be held for a write operation, otherwise it is relinquished with engagement of the read-bus. The write-bus is then free for another addressing operation while the read-bus works on the first request. A memory unit once accessed, however, must go through a regenerative period before it can be accessed again.

Results of experiment 3

What design factors can be readily estimated in this model? Obviously its queuing systems are so complex that, at best, calculations can be made which will establish plausibility of estimates which will come from simulations. Nevertheless, some calculations will be explored to exemplify the approximations, simplifications, lookups, extent of effort, and ranges of results that are possible.

The primary queuing situation in this last model is competition for the write-bus. If a CPU finds the bus busy, it may have to curtail processing until it can engage the bus; if the write-bus is busy, it can remain so far beyond the nomi-

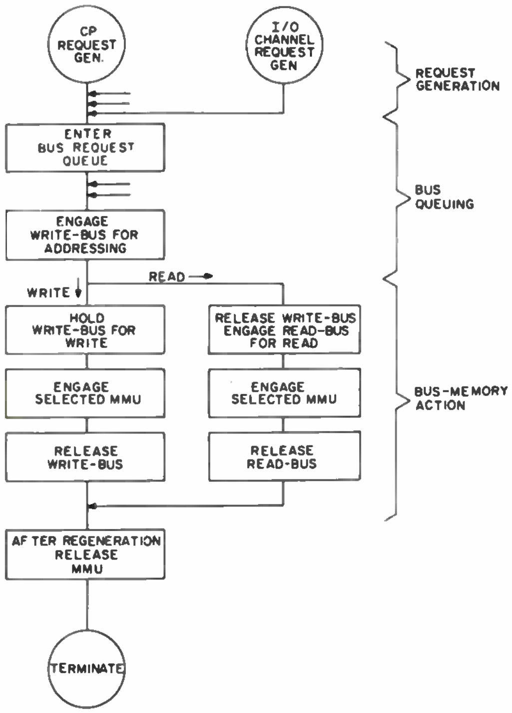

Fig. 11—Multibus flowchart.

nal time when an address is on the bus for a busy memory unit. Nor is the nominal service time on the write-bus simple. Using the values for the basic service time parameters, presented in Table IV, the nominal service time for a write is calculated to be 600 ns (address-write). Also, the nominal service time for a read is calculated to be 250 ns (address only). If the write-to-read ratio is postulated at 0.2, average service time will be approximately 310 ns with a variance of 2.0×10^4 ns^2. On the occasions when busy memory units are addressed, service time will be increased up to 750 ns. Should this happen 1% of the time for all references (possibly high but this will depend upon programmed memory allocation), average service time, T_s will lengthen to only slightly beyond 310 ns, but will have a variance of 2.3×10^4 ns^2.

Table IV—Basic service time parameters.

Operation	T_s, *service time (ns)*
MMU addressing	250
MMU write	350
MMU read	350
MMU cycle	750

The model and its problems can be artificially partitioned to yield some information. First, the peripheral I/O channel alone will be considered, then the CPU alone, with the idea that characteristic activities of each will lead to estimates of their activities in concert.

From one I/O channel device, a transfer rate of 6.7×10^4 items/s might represent the byte rate of a high-speed tape stand, with triple this rate from a disk and five times for a drum. As a first approximation, these rates can be considered constant; i.e., basic interarrival time of 15 μs with no variance.

Postulating a simultaneous load of four tape stands, two disks, and one drum (15 units) from each of two CPU's, and assuming that each CPU does nothing but dispatch all the I/O requests, what is the utilization of the bus? Here

$T_a = 15/30 = 0.5\ \mu s$
$T_s = 0.30\ \mu s$
$\mu = 3.3\ \mu s^{-1}$
$\lambda = 2\ \mu s^{-1}$

and the *utilization factor*, $\rho = 0.60$.

With 60% utilization, the bus cannot be under stress, but the mean interarrival time for I/O requests from each CPU is close to the minimum time between dispatching bus requests for one CPU. The conclusion is that to increase I/O channels, another CPU would have to be added. Even without an increase in I/O channels, the arrangement would be impractical because all processing would be shut off because of heavy I/O channel throughput.

Starting again with the model and considering each CPU to have no I/O channels operating, is there an interference problem?

The probability distribution of interarrival times is a truncated exponential function because all requests, though otherwise considered random, must be separated by at least 775 ns. The modified mean interarrival time can be calculated as indicated in Fig. 5. For four CPU's without I/O:

$\lambda = 4\times0.383 = 1.53\ \mu s^{-1}$
$\mu = 3.33\ \mu s^{-1}$

$\rho = 0.46.$

Again it appears that four CPU's would not strain the write-bus system and cause it to inhibit CP activity.

Before thinking of simultaneous I/O and processing activity, it would be well to consider which of the two threatens the stability of the system. The less predictable is processor performance in this model, though a mode of operation idle-and-burst of I/O channels might be described which would contradict this.

It has been suggested previously that systems with high utilization factors are so unstable as to be impractical. Queue instability may be estimated by studying the rate of change of queue size with respect to utilization. Differentiating Eq. 4:

$$\frac{d\overline{m}}{d\rho} = 1 + \frac{\rho(2-\rho)}{2(1-\rho)^2}(1+\zeta) \qquad (14)$$

Values for $dm/d\rho$ have been plotted against ρ in Fig. 12 for this example with a value of 12 for the factor $(1+\zeta)$. Where the constant-rate peripherals work alone, a range in utilization factor of 90 to 95% would leave leeway for slight variations in mechanical operation; however a change of 90 to 95% in the utilization factor in the random situation for these paremeters, would result in a change on the order of 5000 items. Thus, the results of this analysis indicate that CP use should be kept down to 40% or below, depending upon combination with peripherals.

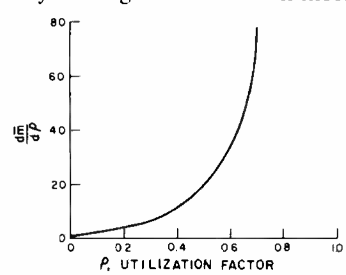

Fig. 12—Queue instability as a function of utilization factor.

This analysis has only covered the grossest aspects of the primary queuing situation for this model, and certain violations of the model have been made to attain them. The most flagrant violation is the assumption of infinite queuing capacity. In real life, either data is lost or a source unit is shut off before the buffers can overload. In this model, the CP must cease processing. To the queue watcher, this postponement of processing is an ameliorating feature, but to the machine architect, this postponement represents deterioration of processing capacity.

Conclusion

Practical limitations have made for a treatment of queue assessment which have poached here and there in the well-ordered preserves of operations research. Unbalanced and partial views of an emergent discipline may be undesirable; however liability for this defect is risked in the hope that systems architects and simulators will hereby be encouraged to expand their cultivation of a rationally cautious attitude towards queues.

Emphasis has been placed on the inputs to queuing systems rather than on varieties of servicing because the demands of a specific design problem led in this direction and very soon went beyond the range of theoretical analysis. For the computer system modeler and simulator the conclusion is favorable. It does not take a very complicated situation to defy theoretical analysis. The adroit simulator will first assess not the queue, but the queuing system, and can advise the computer system architect of the most cost-effective method of queue prediction.

References

1. Short-order cooks are referred to Martin, J., *Design of Real-Time Computer Systems* (Prentice-Hall, 1967) See Ch. 26 for a rapid orientation and the tables and graphs following it for a wealth of instant confections.
2. The more mathematically inclined are referred to Ruiz-Pala, E., *et al.*, *Waiting-Line Models*, (Reinhold Publishing, 1967) and Morse, P.M., *Queues, Inventories and Maintenance* (John Wiley & Sons, 1967). The two should be read concurrently.

New high impedance interphone amplifier

J. L. Hathaway

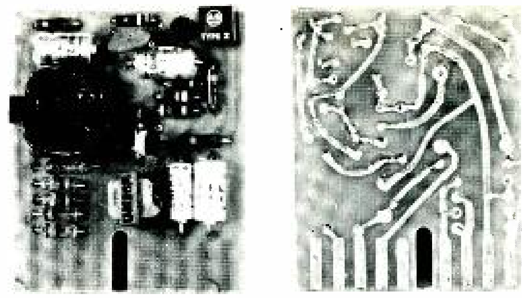

Fig. 1—The new PLAMP.

Intercommunications has often been referred to as a weak sister in an otherwise strong broadcasting system. This has become more evident with the increased frequency of large scale broadcasts involving twenty or more remote locations. This paper describes private-line amplifier (PLAMP) with several significant improvements, including increased terminal impedance, higher undistorted output power, and better stability.

An improved studio intercommunications system was described by Pierce Evans in the *Journal of the SMPTE*, October 1959, and the basic principles have been extensively employed by broadcasters over the intervening years. A two wire line connected the various private line (PL) units and supplied dc operating power. Bridge rectifiers were used in each unit so that either polarity supply voltage on the buss could be accommodated while maintaining correct polarity at the earphone amplifier. There was a means of driving the line from a carbon microphone. Also, a resistance bridge was provided for cancellation of the microphone signal at the input of the companion earphone amplifier. Results were greatly improved over previous PL systems not endowed with an amplifier or suitable side-tone cancellation facilities.

It seemed desirable, a few years later, to also amplify the microphone output and so increase the "PL buss" level. This offered further improvement and has been widely used. However, with the passage of time, television intercommunication systems have expanded to the point where results still leave much to be desired. For example, large field pick-ups such as the World Series or important football games frequently entail more than twenty PL amplifiers (PLAMP's) loading down a communication buss. Each PLAMP exhibits 40 to 60 ohms at its terminals, depending on design, voltage, whether the microphone switch is *on* or *off*, etc. The resulting buss load may thus be 2 ohms or less if we neglect the interconnection wiring. Specific buss wiring can also be a problem, where some lengths are very short and others may be more than 1000 feet of twisted 24 gauge! Further complicating the problem may be a very high acoustical noise which must be over-ridden by the PL equipment. This combination of adverse factors has sometimes led cameramen into rather primitive communication just short of wig-wag, in order to rush information to or from central control.

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Recently, the severity of the low impedance loading has been somewhat reduced by connecting each PLAMP unit to the buss through a 1-to-10 ratio impedance step-up transformer. This helps materially with the high resistance long-line problems, but part of the benefit is lost in the voltage step-down action of the transformer feeding the earphone amplifier. Nevertheless, it does give an overall improvement and our new units, for interchangeability reasons, work with such transformers. However, this alone is far from a solution to the main problems.

Last year, in a desperation move born of unbelievable troubles, NBC undertook development of an improved PLAMP. This new design has been found to possess several advantages over the known predecessors, including:

1) Terminal impedance increased by roughly six-to-one.
2) Undistorted output power from the microphone amplifier into a given impedance load increased many fold.
3) The new unit is highly stable and unaffected by reasonable changes of temperature or operating voltage.
4) Ordinary manufacture has produced units of almost duplicate characteristics.

Terminal impedance problems

To raise the terminal impedance to appreciably above the 40- to 60-ohm range, consideration was given to the causes of such low impedance. First, numerous low value resistors were in the circuit effectively shunting the two wire line. For example, the side-tone-cancellation bridge circuit has been a serious offender, especially when an adjustment of around 60 ohms was needed in one leg for proper cancellation. These bridge resistors and a number of others of relatively low impedance have placed an upper limit on the maximum attainable impedance without including the several other causes of low impedance. One of the latter is a negative-feedback component from the earphone amplifier which further reduces impedance, especially when gain is raised. Then there is a negative feedback impedance reduction from the microphone ampli-

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received the BSEE from the University of Colorado in 1929 and joined NBC. Actively engaged in NBC development ever since, with the exception of the years 1941-44, when on leave of absence he served on faculty appointment at Harvard University. On return to NBC he participated in a government sponsored project on high altitude night photography. This included a year of development, flight testing, and subsequent consultation. Since 1946 he has engaged in all phases of NBC's television and radio engineering. He has delivered numerous papers at NAB Engineering Conferences as well as to Audio Engineering, SMPTE, and IEEE Conventions. He has spent a large amount of time during the past 14 years in developments relating to the ultra portable camera systems and the radio microphones used at NBC. During several years in the 1950's he spent considerable time in patent litigation consultation. He has also been granted 37 US Patents, mainly in the field of broadcasting. He was winner of the Scott Helt Award of the Professional Broadcast Group of the IEEE in 1962. Also in 1956 he won an Emmy Nomination for contributions to the first live broadcast from Cuba, and again in 1962 another Emmy Nomination for development of Interleaved Sound. In 1969, he was awarded the National Association of Broadcasters Engineering Achievement Award and in 1970, he was a winner of the David Sarnoff Individual Achievement Award in Engineering.

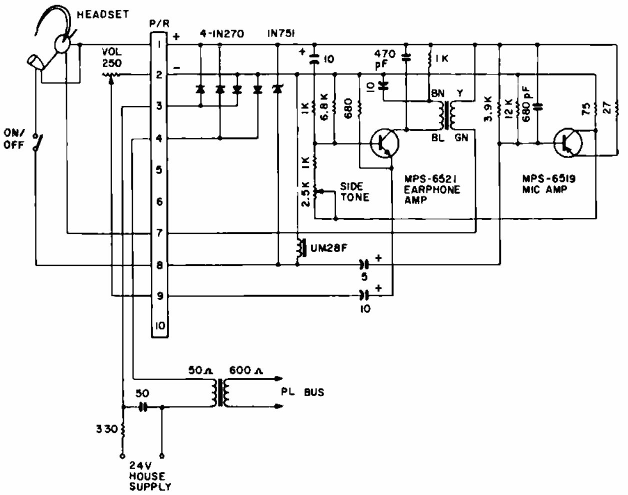

Fig. 2—Schematic diagram of the PLAMP.

fier. When the microphone is *on*, it shunts this amplifier's input and so prevents most of the feedback. However, when it is switched *off*, the input biasing resistors create a feedback condition appreciably reducing terminal impedance.

New private-line amplifier

The newly developed, high-impedance PLAMP is pictured in Fig. 1. This printed circuit card measures $1\frac{11}{16}''$ by 2" including the connector fingers. It is plug-in interchangeable with one of the earlier models used exclusively.

Fig. 2 is a schematic of the new PLAMP, including the remotely located headset, volume control, impedance step-up transformer, and a "house supply" DC voltage source. Circuit wise, the new unit is somewhat similar to the old, with a few main exceptions.

1) Instead of a low resistance bridge for side-tone cancellation, an adjustable high value resistor feeds an out-of-phase signal from the microphone amplifier to the input of the companion earphone amplifier.
2) A low voltage zener diode is connected at the microphone circuit so that whenever the switch is thrown "off" the zener conducts and so places an effective short circuit on the amplifier's input. This prevents negative feedback and its consequent reduction of impedance.
3) The polarity of the earphone transformer secondary produces a negative feed back component on the buss. However, the transformer primary is bypassed so as to give a compensating positive feedback. Thus, the overall feedback from this amplifier is negligible, regardless of volume control setting.
4) The transistors are silicon, each stabilized with emitter resistors and relatively low-value base resistors. The microphone amplifier is biased for optimum output rather than backed-off on collector current to avoid a runaway condition from heating, as was the case in the old unit.

Development problem

An interesting but revolting situation arose during the development of the new PLAMP. The preliminary model was tested extensively in the laboratory and found to outperform its predecessors. Then it was tried in the field, on short and long cable lengths. Reports, without exception, were glowing: less distortion, more level, less loading, etc. Next, eight were constructed for a semi-operational test. These, in a studio, gave good results at certain locations but at others the earphone amplifier refused to work. After more lab tests the trouble was found in the studio. Some of the earphones contained a little green bead connected across the terminals. We had assumed this to be a small capacitor, but it turned out to be a duo-diode limiter. Its purpose seems to be to greatly reduce loud clicks. For simplicity, we had avoided the use of transformer coupling to the earphone, so the small DC collector current had caused the duo-diode to short out the earphone. None of the first dozen or so headsets used in testing contained the limiter, but subsequent search in the studios turned up a great many that did. So, to avoid future confusion, we changed over to transformer coupling. Incidentally, if an earphone has a one-volt peak-to-peak sinewave signal across it, and a limiter bead is then connected, the signal changes to 0.5V, almost perfect square wave. In our service the distortion so created is of little consequence, however, because the signal is quite loud at the verge of limiting.

Operating characteristics

Operating characteristics for the new PLAMP and those of the latest known predecessor are listed in Table I. For the new unit, only a single set of values is shown, since our measurements of 19 units gave insignificant differences. Two of the predecessors were selected to show the wide divergence between units, but it should be pointed out that these two do not represent the entire range encountered.

The first improvement in the new units is in the loading impedance, which has been raised about six to one. Then, the output power, as shown has been raised 11 to 1 over the better of the old units, and 72 to 1 over the other. It should also be noted that gain of the new microphone amplifier is appreciably less than that of the old (average about 11 dB). In the new circuit, the microphone feeds a higher impedance and also it has a higher DC current, by way of the choke, resulting in about 6 dB higher output voltage. This means 5 dB lower effective gain in the new unit, which is a definite advantage. The old ones have excessive gain and as a result, low-level talk produces maximum output level. With them, when the user needs greater output he talks louder, and about the only increase is in distortion. His voice becomes non-understandable. With the new unit, low level speech does not approach full amplifier output, so if more signal is needed to cut through for some reason, such as high ambient acoustical noise, the user can speak much louder without loss of intelligibility.

Thirty of the new PLAMP's have now been in daily service with gratifying results. We have heard the comment that intercommunication is no longer the weak sister of television broadcasting.

Table I—Comparison of new and old PLAMP

	New	Old #5	Old #34
Input impedance	3800	530	760
Gain to earphone (voltage)	2.1	2.1	2.3
Max undistorted p/p V, earphone with limiter	0.4	0.4	0.4
Max mic amp p/p, V, output (10% dist)	1.7	0.5	0.2
Mic amp voltage gain	0.5	2.0	1.6
Total current drain (mA)	41	29	21

Notes: 1. Measured at 1kHz
2. 8.5VDC into unit
3. Measurements at high-z side of 1 to 10 trans.
4. 100-ohm load across high-z side, tests D & E.

Engineers: what can you do for society?

Dr. G. H. Brown

Editor's note: Prompted by several requests from our readers, we are inaugurating a new series of articles in the *RCA Engineer* devoted to the engineer and society. Papers written by engineers dealing with pollution, privacy in a computer-oriented society, urban problems, transportation, or any topic affecting the human domain will be included in this series. The success of this series will depend entirely on papers written by RCA engineers and scientists. To discuss a possible paper for this series, contact the editors directly or your Division Editorial Representative (inside back cover).

This first paper of the series is based on an address by Dr. George H. Brown at the Engineers' Club of Philadelphia on the occasion of Young Engineers' Night, February 2, 1971. Dr. Brown's presentation, although originally aimed at younger engineers, contains thoughts of broad interest to the engineering profession. Portions of Dr. Brown's speech, along with the spontaneous question-and-answer dialog that followed his formal remarks, are reproduced below.

A PROFESSOR ONCE TOLD ME, "The opposite of a correct statement is not always a false statement. The opposite of a profound truth may well be another profound truth". If my statement this evening does not, in your opinion, constitute a profound truth, at least be charitable in allowing that I may be stating another profound truth even though it may not be apparent to you.

Truth is often lost in the random noise

However, we should guard against the truth being lost in the random noise. If one responds to every demand of every vocal group, one would be twitching all the time. Last December, the sensational press played up the noise made at the meeting of the American Association for the Advancement of Science in Chicago—the assertions that scientists are "uncritically creating knowledge" and the demands that scientists stop creating knowledge which could be used to further evil events.

This led me to speculate on the past. Suppose that Pasteur had come to his laboratory one morning and had said to his associates, "I am really deeply concerned. Do you realize that if we continue down this path and pass on our knowledge concerning bacteria, some evil men 100 years hence may be able to wage germ warfare? Burn our notebooks and destroy our test tubes"!

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The hard cruel fact is that somebody has to supply the money.

This is of course the direct preventative approach to evil uses, for these evil men would not be alive today because their ancestors would have died before the age of puberty from cholera, smallpox, dysentery, or some other of a large selection of diseases.

Or, consider Newton. There is an apocryphal story that he was conked on the head by an apple while he was sitting under an apple tree in his uncle's orchard. While in this dazed state he solved the mysteries of gravity, invented calculus, and worked out the equations for objects traveling in outer space. If, however, he had waited for his head to clear, he would have realized that his work could add to the efficiency of weapons of all kinds and that the British Colony across the Atlantic could, in a few hundred years, waste a lot of money in going to the moon. If Newton had anticipated the results of his cogitations, he would no doubt have acquired a cider press and gone into the apple-juice business. Then he would have been faced with a dilemma. Should he use a preservative to keep the cider sweet, or should he let it turn to hard cider and thus add further to the alcoholism in Britain?

The engineer's responsibility

The responsibility of an engineer to his society and to his environment is certainly as great as that of every other citizen. But, the responsibility as a whole rests with the body politic. The hard cruel fact is that somebody has to supply the money.

In our industrial society, most engineers are working for a company. If the engineers are to make the final decisions as to the nature of the product to be produced, one of two conditions will prevail:

1) The engineers must have all the information available to management, take the responsibility of management,

Dr. George H. Brown, Executive Vice President, Patents and Licensing of RCA received the BSEE in 1930, the MSEE in 1931, the PhD in 1933 and the Professional EE degree in 1942, all from the University of Wisconsin. In May, 1962, Dr. Brown was honored by the University of Wisconsin with a Distinguished Service Citation for leadership in industry and engineering. In 1933, Dr. Brown joined RCA Manufacturing Company in Camden. In 1942, he transferred to the newly formed RCA Laboratories at Princeton. It was during his career at Camden that he developed the Turnstile antenna, which has become the standard broadcast antenna for television. During World War II, Dr. Brown was responsible for important advances in antenna development for military systems, and for the development of RF heating techniques. He and his associates also developed a method for speeding the production of penicillin. From 1948 to 1957, Dr. Brown played a leading part in the direction of RCA's research and development of color and UHF TV systems. In 1952, he was appointed Director of the Systems Research Laboratory. In 1957, he was appointed Chief Engineer of the Commercial Electronic Products Division at Camden, and six months later was named Chief Engineer, Industrial Electronic Products. In 1959, he was appointed Vice President, Engineering, of RCA. He became Vice President, Research and Engineerings, in November 1961, and was named Executive Vice President, Research and Engineering in June, 1965. Dr. Brown was appointed to his present position in August, 1968. Dr. Brown has received numerous awards and citations for his pioneering work in research, design, and development and for his work in the community. Dr. Brown is a member of the RCA Board of Directors. He is also a Director of the Trane Company, the First National Bank of Hamilton Square (N.J.), RCA Global Communications, Inc., RCA International, Ltd., and RCA Engineering Laboratories, Ltd. He is a Fellow of the IEEE and the AAAS; a member of Sigma Xi, The Franklin Institute, and the National Academy of Engineering. A prolific inventor, Dr. Brown holds 79 U.S. patents. He is a Registered Professional Engineer of the State of New Jersey and the author of numerous articles appearing in scientific journals since 1932.

and thus become management. If this path is followed, management must have engineering talents of their own so they can step in and do the work formerly done by the engineers. Or,

2) Management will need other engineers to work a profit, and the first team will be given the privilege of working without salary.

Now, I don't mean to say that any engineers that I know of will work on projects that are definitely designed to rob banks, or to do anything else that, in general, is illegal or immoral. But, the plain hard fact is that somebody has to pay for the engineer's work, and if you decide that you don't want to work on televisions because you hear that they might X-ray some people, you might be concerned, and you might be vociferous. But if you decide you don't want to work on television sets and you happen to be working for a small company that has no other product, I don't see what the heck you do but quit. It's your great American privilege. But I think that we are talking about things that have to be put into much better perspective before we do much more talking about them, and I think that we all have to do a lot more thinking.

Humanists, scientists, and engineers

Now, let me turn to an area to which I have given much thought for a long time: the distinction made by science writers, the general public, and puzzled young men who are trying to decide on a particular college or university discipline. I refer to the distinction between scientists and engineers, as well as the distinction between so-called humanists and scientists and engineers.

Living as I have for many years in a community which encompasses a small liberal-arts college[1], I have frequently been asked "Are you an engineer or a scientist?"

At first, I was puzzled . . . for I had studied as much physics as most physics majors, as much mathematics as most math majors, and machine design as well . . . so I did not realize that I had to choose sides since science meant to me a knowledge of the physical world as well as a procedure for doing something about it—and engineering meant the same thing. Then I became aware of "pure" science, "pure" research, "pure" mathematics. These terms, to many seemingly well-educated people, mean the observation and classification of facts, with a determination to not allow this knowledge to become useful.

These neat distinctions between scientists and engineers bring to mind an analogy: the difference between a thermometer and a thermostat. A thermometer may observe and register with great precision the condition of the environment in which it finds itself, with no ability to influence this environment. A thermostat, on the other hand, may measure its environmental conditions with equal precision, but has the ability to make use of this knowledge and exercise control of its environment—in other words, to do something useful with its knowledge.

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Gap in our educational system

These experiences soon brought me to an awareness of a great gap in our educational system, not a gap between engineers and scientists, for I had often observed engineers working in our laboratories with scientists—that is, physics graduates, chemistry graduates, math graduates—and at times it was difficult to distinguish the engineer from the scientist, at times their roles were completely interchanged. They simply became intelligent, experienced workers who shared technical educations of slightly different disciplines, equally well-grounded in the fundamentals of physical science. The gap of which I speak exists in the educational process of "liberally educated" people. Most college students are not headed toward science or engineering. Typically, they are enrolled in a so-called liberal-arts curriculum—either at a separate college, or in a college of arts and sciences of a university. Unfortunately, to most of them, "liberal arts" means all fields *except* science—a gross misrepresentation of the term which once was intended to include mathematics and science.

Courses are needed which help such students think their way through and appreciate such great concepts as the origin and evolution of the universe and of life; the nature and behavior of energy and matter and radiation; the structure of atoms and molecules; and the ways in which these and other scientific concepts and laws are discovered, evolved, and tested.

Engineering—art and science

Webster[2] says that engineering is "the art and science by which the properties of matter and the sources of power in nature are made useful to man in structures, machines, and manufactured products." These engineering acts—making useful to man the properties of matter and the sources of power—may take place in many ways: through research and invention, development, design and testing, or through management, finance, and sales. Without his penchant for brevity, Webster might have continued by saying that engineering is a creative and constructive force which brings forth new ideas, new products, new services, and continually renews the vitality of business and industry. It stimulates business growth and economic strength and is the foundation upon which our industrial society is built.

The applications of electricity and electronics continue to grow in the fields of control of energy, in the fields of communications, and in furthering the technology of all branches of science and engineering. Electronic computers, in conjunction with automatic scheduling and memory devices, are having profound effects on scientific investigations, selection and control processes in the factory, data handling in the marketplace, and in every facet of life. Chemical and metallurgical engineering continues to give us materials of construction, the raw materials of industry, and an understanding of physical phenomena. Controlled nuclear-fusion reactions—perhaps combined with thermoelectric devices—will, after two parts of basic science are carefully mixed with approximately ninety-eight parts of engineering and a few pinches of common sense, afford the buffer against depletion of oil and coal as a source of energy.

In a further quest to aid in focusing my picture of an engineer, I sought guidance from the *Encyclopedia Britannica*, where I found the following delightful description of a professional engineer:[3]

> "So diversified are the services required of professional engineers throughout the wide range of industries, public utilities and governmental work, and in the discovery, development and conservation of resources, that men of extremely various personality and physique may achieve success. Qualifications include intellectual and moral honesty, courage, independence of thought, fairness, good sense, sound judgment, perseverance, resourcefulness, ingenuity, orderliness, application, accuracy and endurance. An engineer should have the ability to observe, deduce, apply, to correlate cause and effect, to co-operate, to organize, to analyze situations and conditions, to state problems, to direct the efforts of others. He should know how to inform, convince and win confidence by skillful and right use of facts. He should be alert, ready to learn, open-minded, but not credulous. He must be able to assemble facts, to investigate thoroughly, to discrimate clearly between assumption and proven knowledge. He should be a man of faith, . . ."

It concludes by saying,

> "The engineer's principal work is to discover and conserve natural resources of materials and forces, including the human, and to create means for utilizing these resources with minimal cost and waste and with maximal useful results."

Well, that just about wraps it up, doesn't it? If we could produce this model, we would need only four—one for the military, one for industry, one spare, and one for engineering evaluation and product improvement.

Foundations of a professional career

As a limited goal, our engineering schools might first strive to produce men who can adapt to a wide variety of circumstances through the breadth of their understanding of natural forces. It is but a step from this conception to the recognition that the engineer, if he is to meet the responsibilities of his professional status, must understand not only the management of physical forces by man, but a good deal about his interaction with other men and with the institutions of society.

There is dignity and importance in the mastery of useful knowledge. The foundations of a professional life may profitably be laid in the undergraduate years, combining with and contributing to a liberal education, to the enrichment of both. Much of the strength of our educational plans in the better engineering schools has been derived from the rigor and thoroughness of the method. From the day he enters as a freshman, the undergraduate learns to work in depth and to be held accountable for the results. He learns also to work under pressure and to marshal and employ his knowledge under test. From this discipline and mastery of fundamentals comes an intellectual self-reliance that will stand him in good stead.

But the formal instruction of lectures and classroom is properly only part of the educational process. The intellectual discipline of tests and problems must be supplemented and enlivened by other forces that will arouse and stimulate the impulses of originality latent in every student. One must seek to stir the students' imaginations, to encourage them to break free from the channels of conventional thought, and to teach them to bring to bear upon their problems the facts and methods acquired in the classroom.

The engineer is concerned with making and producing, with converting the yields of fundamental science to useful products and services. His function is to adapt knowledge to beneficial ends, to find ways and means of solving the practical problems of human existence. There is therefore, in the education of the engineer, the most compelling reason to develop by all possible means, the creative and constructive power of each student. We have an obligation to impart to engineering students an understanding of both the privileges and responsibilities inherent in the professional estate. Above and beyond all technical competence, the truly professional man must be imbued with a sense of responsibility to his employer, or his client, must have a high code of personal ethics, and a feeling of obligation to contribute to the public good.

As a limited goal, our engineering schools might first strive to produce men who can adapt to a wide variety of circumstances through the breadth of their understanding of natural forces.

Clothing the bare bones of science

In a talk before such an audience as this, I am impelled to read my favorite quotation from the writings of Herbert Hoover.

> "The great liability of the engineer compared to men of other professions is that his works are out in the open where all can see them. His acts, step by step, are in hard substance. He cannot bury his mistakes in the grave like the doctors. He cannot argue them into thin air or blame the judges like the lawyers. He cannot, like the politicians, screen his shortcomings by blaming his opponents and hope that the people will forget. On the other hand, unlike the doctor, his is not a life among the weak. Unlike the soldier, destruction is not his purpose. Unlike the lawyer, quarrels are not his daily bread. To the engineer falls the job of clothing THE BARE BONES OF SCIENCE with life, comfort and hope. No doubt as years go by, people forget which engineer did it, even if they ever knew. But the engineer himself looks back at the unending stream of goodness which flows from his success with satisfactions that few professions may know".

Rules of conduct

To be somewhat more definite, the rules of conduct laid down by Shakespeare[4] with the words he put in the mouth of Polonius, as the latter's son, Laertes, was departing, might well be aimed at young and old engineers but are equally applicable to non-engineers. Paraphrasing Shakespeare:

> Be familiar, but not vulgar
> Do not act without thinking
> Listen a lot but do not talk too much
> Hang on to your trusted friends, but test your new friends
> Neither a borrower nor a lender be

An old and respected professor of mine advised us to "so live that we could look anyone in the eye and tell him to go to hell. But," he added, "Don't use such crude language." So, Polonius paraphrased my professor more elgantly when he further told Laertes:

> "This above all: to thine own self be true,
> And it must follow, as the night the day,
> Thou canst not then be false to any man."

Questions and answers

QUESTION: *Lately, we have seen many demonstrations for all sorts of causes, and a lot of people are participating in them. To what extent do you feel that engineers, as such, should participate in these activities?*

ANSWER: I don't know why you're discriminating against engineers; I think this is a great confusion. Why must there always be some special purpose group or some specially privileged group? We have seen the doctors with the American Medical Association and they have causes, but I don't think they represent all the doctors by any means. I don't want *my* professional society to represent *me* in politics, and this is one of the dangers I see in a couple of them; they are beginning to get that way. As a citizen, if you don't like what the Government is doing, you ought to be more careful whom you vote for; and after all, if you voted someone into office, you should give him a chance.

To me, demonstrations mean nothing, because they never tell me whether the twenty people running down the street represent the majority of the people in the country, or whether they are representing themselves. So, if an engineer wants to do that, at least he ought to do it on his own time.

To me, demonstrations mean nothing, because they never tell me whether the twenty people running down the street represent the majority of the people in the country, or whether they are representing themselves.

QUESTION: *We are going into de-escalation of the massive defense effort and many engineers, particularly on the West Coast, are being channeled out of defense industries. Do you think the country should put these engineers into more productive areas such as urban problems?*

ANSWER: Certainly, all you need is money to do it.

QUESTION: *Do you think that enough has been done in these areas?*

ANSWER: No, I don't think enough has been done. If we look around at some of the cities on the East Coast, there has never been enough done. But the question is this: can these engineers change over? Many can, but an awful lot of them can't. In this great military effort (and it doesn't matter what your feelings are about the military effort) you have many people who should have never been engineers in the first place; some of the jobs they have are those of high-grade draftsmen; then suddenly they are unemployed engineers. If a man is really first rate and well grounded, he isn't an unemployed engineer, he is just plain unemployed, and he probably can do a lot of things. But, no matter what their technical training has been, they ought to be good for something more than we are using them for. We have thousands and thousands of engineers who should be employed profitably, and a lot of them have mortgages, so they need to be employed.

I would rather have all the problems we have now than to have the problems we had thirty-five years ago. Even though we have a lot of unemployed engineers, most of them have hope that something is going to happen to help them turn the corner. Those of you who lived through the depression know that there were years when people were absolutely discouraged and not even confident that we would ever turn around. Everything isn't so bad. I look at it, and people who are my age look at it, and say "'What are people complaining about now? Now, at least, somebody is listening."

QUESTION: *Aren't some of the larger cities like Philadelphia facing some very real problems that could be helped by an engineering approach?*

ANSWER: Yes, but that isn't the whole answer either. For every dollar you spend on engineering, you are going to spend another $100.00 paying the contractors, buying the land, and so on. There are so many things that engineers could do, if there could be an endless supply of money; city planning is just one of them.

QUESTION: *What do you see as the contribution of the technical society for the engineer?*

ANSWER: There is much that a technical society can do in the realm of promoting the well-being of society and its members without getting into politics. I see the technical society as a common meeting ground for people starting their careers in engineering and science. But, the societies should have good presentations first. We haven't even licked that one. I'm sure you have sat through some of these sordid presentations with thousands of equations on a little slide.

A technical society can have many fine goals; for example, look into educational problems. But when I say politics, I mean just that. I don't see why any technical society should have a lobby, especially one as big as the IEEE with about 180,000 members.

QUESTION: *Do you think that the various engineering societies should be combined into one National Society like the American Medical Association or the American Bar Association?*

ANSWER: Oh no! Because look what happens when they get big enough. For example, the IRE got so big it was unwieldy, so it divided into professional groups. And then it combined with the American Institute of Electrical Engineers to form the IEEE and again they are splinter groups that never even see each other.

For a while, the combination reduces overhead because it eliminates the professional executive secretaries, but they fight you tooth and nail when you try combining. Once the societies have combined, able people get in and build up a "staff," and it is just as much of an overhead as when you had separate societies.

The technical society problems deserve a great deal of study. I don't get much out of the IEEE any more as such, because it is so big. I would like to belong to something where, when I see the people, I would remember seeing them from last year. Now you go there, and there is a horde of people. Of course I'm past the stage now where half of the horde is trying to hire me. Half of them are recruiters and the other half are willing to be recruited. Frankly, I haven't thought too deeply about what should be combined, but I happened to be in some of the go-arounds to combine the IRE and the AIEE, and I was saying tonight to someone that the people in the AIEE would say, "Those radio people, they aren't quite professional are they? Didn't they just start up in 1912?" and the IRE people would say, "Oh, those power engineers, there aren't going to be any more power plants you know, we're going to do it with a couple of electrons and a molecule"... I find them both kind of grubby when they get like that.

Look at the publications we get out now: The things that engineers are writing (and physicists are worse). Instead of being able to explain what they are going to do and what they did and then putting the equations in the back (or say send a postal card if you want the equations), they are sprinkling it all throughout, and who wants to read PhD theses three or four times a week? And now I find they are republishing. The new authors don't know it, but they are re-inventing and republishing, and boy, what a waste of paper.

But the technical society problem is very great and really deserves a great deal of study. Right now, I am not interested in studying it, but I think people in the engineering profession ought to be very much more vociferous about their societies; they should not let the professional staff run them. This happens in so many of the technical societies.

QUESTION: *Do you feel that the engineer should help educate the public? For example, right now there is a legislation out to take lead out of gasoline because of lead and lead oxide poisoning. But this could cause other problems, possibly because an aromatic would have to be used in place of the lead. But the unleaded gas may cost more and actually be more dangerous due to the additives. To what extent should the engineer speak out on matters in which he can help to educate the public ?*

ANSWER: We cannot all be experts on everything, so we have to get our knowledge from someplace. I think the real problem first of all (and this is one where we may need some help in solving it) is which statement is the true one. Once that has been settled, *of course* engineers should be explaining these things and the consequences to other people.

QUESTION: *What advice would you give to a young engineer who is coming into the job market—as bad as it is today—with so many experienced engineers out of work?*

ANSWER: I started into the job market at a bad time, too. I received my Ph.D. in 1933, when there weren't any employed engineers, they were all unemployed and nobody was worrying about when *I* was going to eat. You went out and looked for a job. I wrote hundreds of letters and made many trips. It was a little discouraging. In one instance, I went to a company in Milwaukee, and they were offering $65.00. I thought it was a week . . . it was a month. So, I kept looking for a long time.

I didn't get a job with RCA because I filled out an application. I got it because I saw an opportunity and I followed up. I had read several papers about Beverage Antennas and I got myself to Chicago where the Institute of Radio Engineers was having its National Convention; 250 people in attendance, mind you. Also (I looked it up a while ago) the banquet was $2.25. I didn't go to the banquet because I wasn't throwing around money like that, but I looked up Beverage. He had a room at the hotel, and I called him about seven in the morning to be sure I would get him, and told him I wanted to talk to him. (I am not recommending that this is the way to let it happen to you.) I talked to him and I pestered him all summer about going to work for him on Rocky Point, where RCA had a Laboratory. And I desperately wanted to work on antennas there. It just happened that everything was working for me. RCA stripped off Westinghouse and G.E., or vice versa. That meant RCA had to do its own antenna engineering in Camden. Somebody in Camden wrote to Beverage and said send down one of your men. His people didn't want to leave Long Island, but he thought of me out in Wisconsin. RCA got me for $35 a week. And I know Personnel had nothing to do with it, because after I had been working for about a month, I received a letter forwarded to me from Wisconsin, asking for my photograph to complete my application and in big letters: THIS DOES NOT MEAN WE ARE OFFERING YOU A POSITION. The way they were laying them off in Camden those days, *I sent the photograph too,* so they would have my application on file in case disaster should strike.

But what is the best way? Write letters, but for goodness sake, get yourself on a bicycle and get out there and knock on the door. I can say this really works. *Get there* and *push,* that is the only way. You've got to get out and make yourself known. This is important to get into college, to get into graduate school, or to get a job. Show up on the spot, and unless you come with hair down to your shoulders, why you're liable to be in.

I read something amusing in the *Wall Street Journal* recently—somebody giving advice to young men. I like all this advice . . . "Don't wear a beard to an interview. Did you ever hear of anybody on the Board of Directors of a major company wearing a beard?"

References

1. *Editor's note:* Dr. Brown resides in Princeton, N.J.
2. *Webster's New International Dictionary of the English Language* (Second Ed.; Unabridged; G&C Merriam Co., Springfield, Mass., U.S.A.; 1955).
3. *Encyclopedia Britannica,* (Encyclopedia Britannica, Inc.; Chicago, London, Toronto; 1949) Volume 8, p. 443.
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Did you ever hear of anybody on the Board of Directors of a major company wearing a beard?

Product analysis using a time-sharing computer

R. E. Kleppinger

Product-analysis programs have been written for developmental microwave integrated circuits using a time-sharing computer. Use of these programs have reduced to one-tenth the time required for new product cost estimates. In addition, the computer provides overall efficiences and yields, parts ordering information, and production personnel placement. At the same time, the product analyzer is given more time to concentrate on the completeness and accuracy of the initial data.

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received the BSEE from the University of Nebraska in 1951 and a MS in mathematics from Stevens Institute of Technology in 1955. He joined RCA in 1951 as an engineer. In this capacity, he developed germanium alloy transistors for different frequencies and power, and low power germanium drift transistors. In 1960 he became an Engineering Leader. As such he has been responsible for the design and processing of small signal germanium and silicon transistors, rectifiers, and MOS transistors. From 1968 to 1971 he was responsible for the module processing of microwave microelectronics. Mr. Kleppinger has one patent issued and has authored or co-authored several technical papers. He is a Senior Member of the IEEE.

PRODUCT ANALYSIS is the examination of the various product constituents and their relationship to each other and the final product. Such analysis leads to higher-quality lower-cost products, whether the product is just being developed or has been manufactured for some time. Product analysis can be divided first into data collection and then the translation of the collected data into a summary report highlighting those areas requiring technical and administrative action. The data translation is most effectively accomplished by use of time-sharing computers. In this way, more attention can be paid to the accuracy and completeness of data collection.

In general, product-analysis computer programs are best written to handle the peculiarities of a particular class of devices or products. For instance, it is best to write separate programs for transistors, tubes, integrated circuits, or microwave integrated circuits. These programs are normally initiated to satisfy a particular need. However, with a little forethought they can be broadened to provide additional valuable information. This paper discusses two computer programs written to provide summary cost data for developmental microwave integrated circuits. For very little extra programing effort, information on parts ordering, production personnel placement, and overall efficiencies was obtained.

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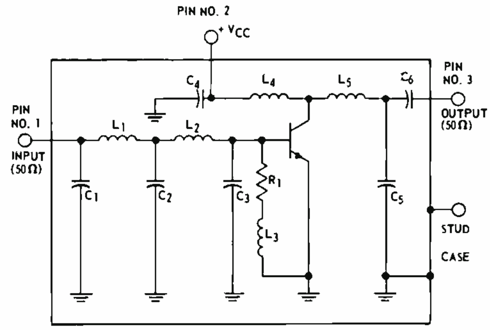

Fig. 1—Circuit diagram of a representative MIC.

MIC products

Microwave integrated circuits (MIC's) made by lumped-element techniques can be divided into two categories: hybrid circuits utilizing wire bonding and passive integrated hybrid circuits. The circuit diagram of a representative MIC is shown in Fig. 1. In hybrid form, the various resistors, capacitors, and inductors are batch fabricated, separated, assembled with transistor chips, and wire bonded to provide the desired electrical results. A photograph of such a circuit is shown in Fig. 2. The passive integrated hybrid circuit is obtained by batch fabrication of different passive components with deposited inner connections on a single substrate. These circuits are then separated and assembled with transistor chips. A photograph for this type circuit is shown in Fig. 3.

Because the basic process concepts for these two circuit types are different, each requires a separate computer analysis program.

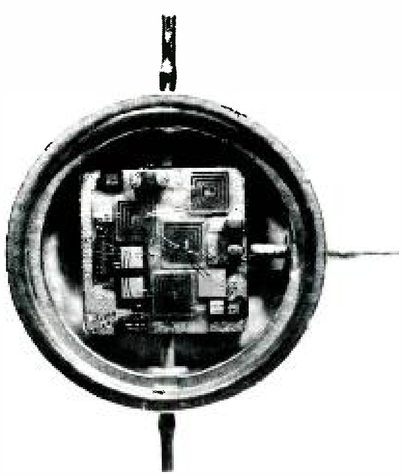

Fig. 2—Hybrid circuit utilizing wire bonding.

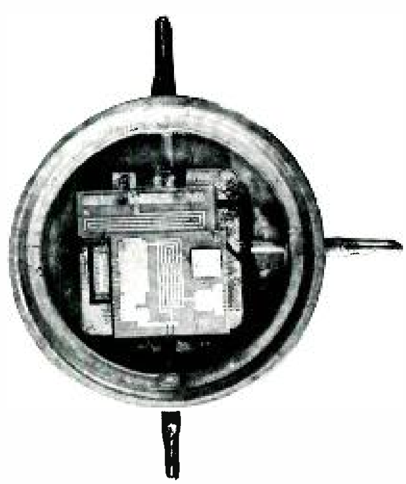

Fig. 3—Passive integrated hybrid circuit.

Table I—Hybrid data.

I) Operator, technician, engineer rates
II) Thin-film component data
1) MOS Capacitor Data
a) Number of different electrical values
b) Process hours required per wafer, evaporator basket costs per wafer, evaporated material cost per wafer, wafer cost, assembly parts loss
c) Electrical value, number per wafer, process yield for each different value
2. MOM capacitor data
a)—c) same as II-1 except wafer cost set at 0 because it is common to parts in II-3.
3) High dissipation coils
a)—c) same as II-1 except wafer cost set at 0 because it is common to parts in II-2.
4) Purchased wafer costs for II-2 and II-3
a) Amount of volume-cost data
b) wafer size
c) volume-cost data
5) Low-dissipation coils
a)—c) same as II-1
6) Bar inductors
a)—c) same as II-1
7) Thin-film resistors
a)—c) same as II-1
III) Thick-film component data
1) Capacitors
a) Number of different electrical values, assembly parts loss
b) Electrical value, amount of volume-cost data
c) Volume-cost data
Note: b) and c) are repeated for each different value
2) Resistors
a)—c) same as III-1
IV) Transistor chips
a)—c) same as III-1 except the electrical value is replaced with a four-digit transistor number
V) Substrate
a) Amount of volume-cost data
b) Process yield per part, process hours per part, material cost
c) Volume, material cost, labor cost data
VI) Package
a) Amount of volume-cost data
b) Package volume-material cost per package-labor-expense cost per package

Table II—Hybrid terminal input data.

1. Number of different: MOS capacitors, MOM capacitors, high dissipation coils, low dissipation coils, bar inductors, thin-film resistors, thick-film capacitors, thick-film resistors and transistors.
2. Number of MOS capacitors for each different electrical value—skip if 0
3. Number of MOM capacitors for each different electrical value—skip if 0
4. Number of high dissipation coils for each different electrical value—skip if 0
5. Number of low dissipation coils for each different electrical value—skip if 0
6. Number of bar inductors for each different electrical value—skip if 0
7. Number of thin-film resistors for each different electrical value—skip if 0
8. Number of thick-film capacitors for each different electrical value—skip if 0
9. Number of thick-film resistors for each different electrical value—skip if 0
10. Number of transistors of each different type number—skip if 0
11. Number of substrates, number of circuits, assembly-test yield, package yield
12. Assembly hours per circuit, technician hours per circuit, engineering hours per circuit

Table III—Example of hybrid input data.

```
5,0,1,0,0,1,1,0,1
1,3.1,2,6.9,1,12,1,25,2,70
4,25
1,10
2,2000
1,xxxx
1,100,100,100
X,Y,Z
```

MIC hybrid analysis

There are two classes of data required in product analysis. One class consists of general data concerning labor rates, material costs, and process yields which change slowly with time. This information can be stored in the computer memory and accessed as needed for different MIC products. Periodic updating of this information can be readily achieved. The other class of data consists of details concerning the actual MIC product being analyzed. This information is inserted during operation of the computer program.

For a hybrid circuit, the following data are best stored in memory:

I) Hourly rates,
II) Thin-film component data,
III) Thick-film component data,
IV) Transistor chip data,
V) Substrate data, and
VI) Package data.

Each section provides information on the amount of data stored, process time required, material costs, process yield, and volume purchase-price data on major items. For example, all information on an MOS capacitor of a particular value would be found in section II-1 of the stored data as shown in Table I.

The data inserted during program operation (see Table II) consist of the number of different components used in each class, the number and value of each different component, quantities and yields, and time required to complete one circuit. For example, the number of different MOS capacitors would be found in section 1 while the number and value of each would be found in section 2. A typical example of the form of this data is seen in Table III.

The program uses these data to sort out the pertinent information stored in memory and then combines all data to print a product summary sheet as shown in Table IV. The first section of Table IV gives the data inserted during program operation to obtain the summary data that follow. The first column of the second section of the summary sheet lists the number and identity of each part required to make the circuit. The second column notes either the number of parts obtained per wafer or the purchase price per part. The third column indicates either the number of wafers that must be started for each part, or the number of parts that must be purchased to make the specified number of devices (in this example 100). The fourth column relates the number of each part required to assemble one good device or amplifier and, hence, is a measure of the yield of each part. The fifth and sixth columns give the material and labor-expense cost of each component in a

Table IV—Product summary sheet.

```
NMOST=2,1,1,1,1,1,1,1,1
NMOS(I)=1,3,1,2,6,9
NMOM(I)=1,2
NCUC(I)=4,25
NALI(I)=1,15
NAUI(I)=1,1
NR(I)=1,10
NTFC(I)=2,2000
NTFR(I)=1,100
NT(I)=1,0000
BE=1,100,100,100
ASH=0,0,0

ASSEMBLY YIELD= 100.00% PACKAGE YIELD= 100.00%
  PARTS/AMP              NO/WAFER  TOTAL PARTS  PARTS        COST/AMP
                         COST/PART  OR WAFERS   /AMP       M $      L-E $
1-   3.1PF MOS                1        100       1.0      0.000     0.000
2-   6.9PF MOS                1        200       2.0      0.000     0.000
     TOTAL SILICON WAFERS=             300
1-   2.0PF MOM                1        100       1.0      0.000     0.000
4-  25.0NH CU L               1        400       4.0      0.000     0.000
    TOTAL SAPPHIRE WAFERS=             500
1-  15.0NH AL L               1        100       1.0      0.000     0.000
1-   1.0NH AU L               1        100       1.0      0.000     0.000
1-  10.0 OHM R                1        100       1.0      0.000     0.000
       TOTAL GLASS SLIDES=             300
2-2000PF TFC          $    0.00        200       2.0      0.000
1- 100 OHM TFR        $    0.00        100       1.0      0.000
1-TA   0              $    0.00        100       1.0      0.000
1-BEO                 $    0.00        100                0.000     0.000
 PACKAGE              $    0.00        100                0.000     0.000
                                 TOTAL PARTS COST=$       0.000     0.000
                                    ASSEMBLY COST=$                 0.000

                             PER DEVICE          100DEVICES
          TOTAL MATERIAL=$      0.00       $        0.00
     TOTAL LABOR-EXPENSE=$      0.00       $        0.00
       TECHNICAL SUPPORT=$      0.00       $        0.00
              TOTAL COST=$      0.00       $        0.00
    0.00 BREAKEVEN COST=$       0.00       $        0.00
  SALES PRICE AT  0.0% NET=$    0.00       $        0.00

                       PER DEVICE      100DEVICES      PER MONTH
WAFER PROCESS TIME     0.0000HRS       0.0000HRS     0.00PEOPLE
     ASSEMBLY TIME     0.0000HRS       0.0000HRS     0.00PEOPLE
TECHNICAL SUPPORT TIME 0.0000HRS       0.0000HRS     0.00EMM
BE=
```

good circuit. The last two columns, of course, relate the importance of one part to another and to the finished circuit.

The third section of the summary sheet gives cost summary for each device and the total cost for making the required number of devices. Also included is the technical support cost to make the devices, the break-even cost, and the selling price. The fourth section of the summary sheet relates the number of hours needed for all circuits required, and the number of people needed if all circuits are made in one month.

Integrated hybrid analysis

The following data can be stored in memory for a passive integrated hybrid circuit:

I) Transistor chip data,
II) IC wafer data,
III) Substrate data,
IV) Thick-film component data,
V) Package data, and
VI) Assembly-test hours per circuit.

As in the hybrid case, each section provides information on the amount of data stored, transistor-chip identity or wafer or substrate size, material costs, parts losses, and process hours. For example, transistor chip data would be found in section I, and IC wafer data in section II as shown in Table V.

Table V—IC stored data.

I) Transistor chip
1) Amount of cost data, type number, parts loss
2) Chip volume-cost data
II) IC wafer
1) Amount of cost data, wafer length, wafer width, evaporated material costs, process hours per wafer
2) Wafer volume-cost data
III) Substrate
1) Amount of cost data, substrate length, substrate width, process hours per part
2) Substrate volume-cost data
IV) Thick-film components
1) Electrical value, purchase volume, purchase cost, parts loss
Note: Repeated for each different value used.
V) Package
1) Amount of cost data
2) Volume-material cost-labor expense cost data
VI) Assembly-test hours

Table VI—IC terminal input data.

1. Number of different: transistor types, IC circuit sizes, substrate sizes, thick film components
2. Number of transistors for each different type number—skip if 0
3. Number of IC circuits, length, width, and process yield for each different size—skip if 0
4. Number of substrates, length, width, and process yield for each different size—skip if 0
5. Number of thick film components for each different value—skip if 0
6. Assembly-test yield, package yield

Table VII—Product summary sheet.

```
/CODE
NTT=2,2,1,1,100
NT(I)=1,2000,2,1111
NC(I)=1,.100,.100,100,3,.200,.200,100
NB(I)=1,.350,.350,100
NHC(I)=2,50
AY=100,100

PARTS/AMP                     TOTAL   PER PART           COST/AMP
                              PARTS                      M          L-E
1 -3A    0                     100   $  0.00      $    0.00
2 -TAIIII                      200   $  0.00      $    0.00
0.0-SAPPHIRE  1.00X 0.73                          $    0.00   $    0.00
0.2-SAPPHIRE  1.00X 0.75        21   $  0.00      $    0.00   $    0.00
1 -BEO  0.350X 0.350           100   $  0.00      $    0.00   $    0.00
    50-HYBRID PART             200   $  0.00      $    0.00
   PACKAGE                     100   $  0.00      $    0.00   $    0.00
                                 TOTAL PARTS COST=$    0.00   $    0.00
                              ASSEMBLY-TEST COST=             $    0.00

                              PER DEVICE       100DEVICES
              TOTAL MATERIAL=$      0.00    $       0.00
          TOTAL LABOR-EXPENSE=$     0.00    $       0.00
    TECHNICAL SUPPORT AT   0.00%=$  0.00    $       0.00
                  TOTAL COST=$      0.00    $       0.00
         0.00 BREAKEVEN COST=$      0.00    $       0.00
     SALES PRICE AT  0.0% NET=$     0.00    $       0.00

               YIELD      CIRCUIT SIZE   PROCESS      NO/WAFER   WAFERS
     OVERALL 100.00%     .100X .100     100.00%         63          1
     OVERALL 100.00%     .200X .200     100.00%         15         19
    ASSEMBLY 100.00%
 BEO PROCESS 100.00%     .350X .350
     PACKAGE 100.00%

                         PER DEVICE      100DEVICES      PER MONTH
   WAFER PROCESS TIME    0.0000HRS       0.0000HRS     0.00PEOPLE
        ASSEMBLY TIME    0.0000HRS       0.0000HRS     0.00PEOPLE
TECHNICAL SUPPORT TIME   0.0000HRS       0.0000HRS     0.00EMM
 1460
```

The data inserted during program operation (Table VI) consist of the number of different parts of each class; the number and type identity of each transistor chip; number, size and process yield of each integrated passive circuit and substrate; the number and value of each different thick-film component; and the assembly-test and package yields.

The program then uses this data along with the stored information to print a product summary sheet as shown in Table VII. The data in the first section of Table VII is inserted during program operation to obtain the summary data that follows. The first column of the second section of the summary sheet lists the different materials and the amount required to make one good circuit. The second column lists the total amount of each part used to make the required number of amplifiers (in this example 100). The third column lists the per part cost. The last two columns give the material and labor-expense cost of each item to make one good circuit.

The third section of this summary sheet again gives cost summary including technical support costs to make the devices, break-even cost, and selling price.

The fourth section relates yield, process yield, number of circuits per wafer and the total number of wafers required for each circuit size. Assembly yield, substrate (*BeO*) yields for different sizes, and package yields are also included.

The last section again relates the number of hours needed to make a circuit and converts this to the number of people needed if all circuits are made in one month.

Conclusions

Product analysis programs can be written for time sharing computers and prove to be of great value. Rather than have one program to encompass all devices, it is best to write separate smaller programs that are tailored to to fit the specific needs of a particular class of devices. This was done successfully with two different programs for lumped-element microwave integrated circuits. One program handles hybrid circuits and the other passive integrated hybrid circuits. Although the prime objective of these programs was cost analysis, additional valuable information was readily obtained. Use of these programs has reduced the time required for new product cost estimates by a factor of ten and allows the analyzer to concentrate on the completeness and accuracy of the initial data.

Holographic information storage and retrieval

Dr. R. S. Mezrich

The current information explosion will soon cause present-day information storage and retrieval systems (e. g., microfilm and aperture cards) to become obsolete. Holography—by virtue of its large storage potential, its inherent redundancy, and its relaxed mechanical tolerances—offers an exciting and promising solution.

Acknowledgment: Many of the ideas and much of the effort on the applications of holography to information storage and retrieval was contributed by Dr. D. H. R. Vilkomerson of the Laboratories.

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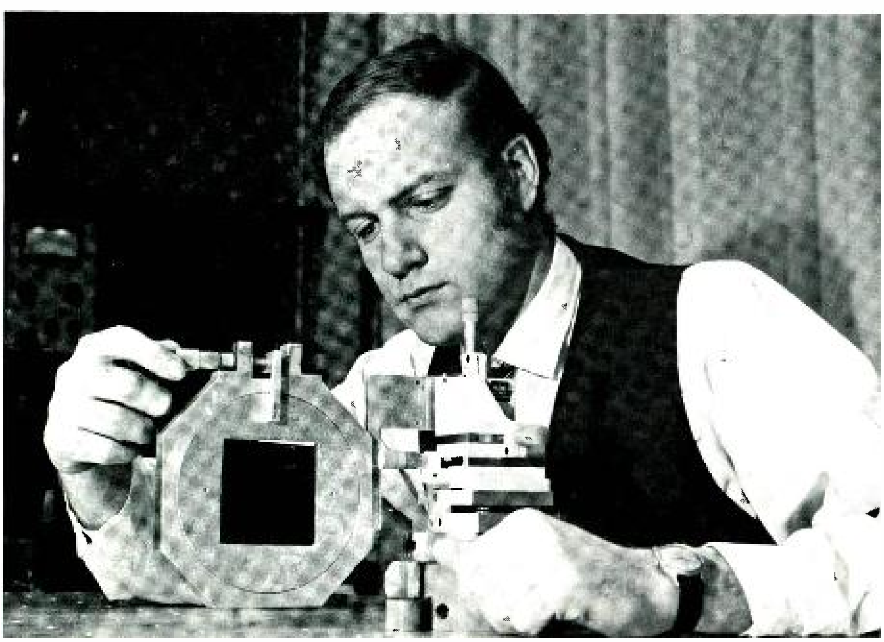
received the BSEE from the Polytechnic Institute of Brooklyn in 1963. He joined the RCA Laboratories in that year as a member of the research training program, and initially was engaged in research on cryogenic computer systems. He received the MS in 1968 and, with the aid of an RCA Laboratories Graduate Study award, the PhD in 1970 from the Polytechnic Institute. Since 1965 he has been studying holographic storage and retrieval systems with applications to mass storage and to computer memories. His recent work is concerned with holography on thin magnetic films. Dr. Mezrich was the recipient of an RCA Laboratories outstanding achievement award in 1969 and the co-recipient in 1968 and recipient in 1969 of IR-100 awards (for the 100 most significant new technical products of the year).



IT HAS BEEN SAID that "of all the scientists who have ever lived, 90% are alive and active today." The corollary to this is that "of all the paper that has ever been, 90% is with us today"—much of it in our files, both circular and vertical.

The solution to at least part of the problem, the problem of too much paper, is obvious. The data—graphs, bits, documents—must be compressed. We must store more documents per filing cabinet, more images per cubic meter, more bits per cubic centimeter if we are not to drown in a flood of paper.

Unfortunately, cramming more in the cabinet is not the complete solution to the problem; if it were, the information explosion would have been resolved long ago. Early in this century, Emmanuel Goldberg already succeeded in reducing full book pages to 1/10-mm images, the proverbial "bible on the head of a pin."

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There are two parts to the problem: storage and retrieval. To be of value, data must not only be stored densely, but in a form that is readily retrievable and then read easily. There is no advantage in storing documents in 1/10-mm images if it is likely that, due to defects in the material or because of scratches from the retrieval mechanism, much of the image will be obliterated. The need for rapid access to one out of many documents is not satisfied if the image must be positioned carefully and focused by a high-power microscope.

Existing storage techniques solve the problem to some extent. Aperture cards, which store images as 35-mm frames mounted on computer punch cards, combine reasonably high density storage with easy mechanical access. Microfiche cards, which store a multiplicity of images on a file card, allow even greater total storage capacity, although with less detail per image. Roll films have a potentially large capacity, but with a correspondingly large access time.

Photographic systems such as these have the potential of simple high-capacity storage but offer almost no updating capabilities. They are limited to change through replacement. Electronic storage systems, which range from tiny core memories to very large magnetic disks and tapes, allow easy updating but with reduced storage densities.

The main drawback in all these systems as methods to stop the information explosion is the limited use they make of the characteristics of the storage materials. The capabilities of the materials have no strong influence on the achieved storage capacities.

Photographic films with resolution in excess of 2,000 lines/mm long have been available, but practical storage systems limit the useful resolution to the order of 100 lines/mm. Magnetic materials with submicron domain sizes are well within the state of the art, but actual stored bits occupy tens, even hundreds, of square microns.

The reason for this is "noise," either in the form of material defects, mechanical tolerances, dust, dirt, and scratches, or in the form of electrical cross-talk. Images cannot be made too small for fear of obscuration by dirt and defects. They cannot be too densely packed because the positional requirements become intolerable. Magnetic heads cannot be placed too close to the recording surface; wires cannot be placed too close together. As the speed of the retrieval mechanisms has been increased to satisfy the need for more data quicker, these problems have been magnified.

Modern systems have tried to compromise between the potentials of the storage media and the limitations of the storage techniques.

The brute-force approach has been to redesign the system so that the tolerances are easier to live with. Surfaces are polished flat, servomechanisms are added, and 2-μm resolution in a practical system is attained.

The elegant approach has been to convert all data, such as graphs, documents, and drawings, into digital form. The result then is treated with error-correcting codes and stored as spots, either optically, magnetically, or both. With this, commercial systems have been proposed (for example, the "Unicon" of Precision Instrument Co., Palo Alto, Cal.) with bit densities on the order of 10^6 bits/cm^2 and access times on the order of tens of milliseconds.

Holography's undegraded image

As commercially successful and technically interesting as these techniques are, new methods are under development that should go further, in terms of reduced cost and increased simplicity, towards an eventual total solution to the problem.

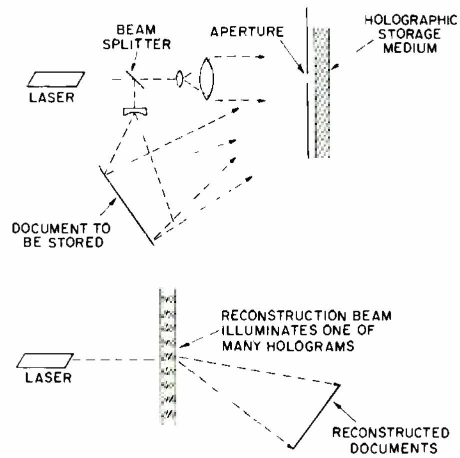


Fig. 1—Schematic view of holographic document storage and retrieval.

Holography, by virtue of its large storage capacities, its inherent redundancy, and its immunity to dirt and material defects, is perhaps the most exciting new method. It is through holography, as we shall see, that the full storage capabilities of existing storage materials can be realized without fear of image degradation.

Holograms are formed by the interference of two coherent light waves at a photosensitive medium (Fig. 1). One of these waves, the object wave, is obtained by letting part of a laser beam strike an object (such as a document, a drawing, or a graph) which then scatters light towards the film. The other wave, the reference wave, is obtained simply by letting part of the laser beam illuminate the film directly. No lenses need be used, and the light scattered by the object, as well as the reference wave, is spread over the entire recording film. Every part of the film records light from every part of the object.

After the film is exposed, developed, and re-illuminated by the reference beam, reconstructed wavefronts appear that are identical to those originally scattered by the object. The image may be viewed directly by simply looking through the hologram as if it were a window. Conjugate wavefronts (that is, wavefronts that appear to be converging on the object instead of diverging from it) are also produced by the hologram and the image may be projected onto a viewing screen. As a consequence of the way the hologram is formed (light from the object is simply scattered towards the film, not imaged by lenses) no single part of the hologram corresponds to any single part of the object, but rather the entire object can be reconstructed by illuminating any part, or parts, of the hologram. Great portions of the hologram can be destroyed with no resultant image degradation. The hologram is inherently redundant.

Making the most of the material

A detailed analysis would show that, given a certain material, no more information can be stored holographically than can be stored otherwise. The capacity of the hologram still is limited by the capabilities of the storage medium. In holography, however, the limits set by the medium can be approached in a practical system, the limit no longer is set by considerations of loss of detail due to defects, dust, or scratches.

In experiments performed at the RCA Laboratories, 8½ x 11 in. documents have been stored holographically on 1-to-2-mm^2 film and then subjected to a series of destructive tests, which resulted in little or no image degradation. (One such test was to rub the hologram with sandpaper. Another easier test was to run it on an automatic retrieval system, the RCA 70/3488.) There was no catastrophic loss of image detail and calculations indicated that as much as 50% of the hologram could have been destroyed without attendant image quality loss.

In addition to high storage capacity and inherent redundancy, holograms have other features that make them particularly attractive in image stor-

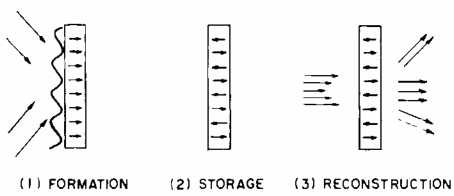


Fig. 2—Magnetic holography: 1) formation by curie-point writing, 2) storage as magnetic domain pattern, 3) reconstruction by magnetic-optic effects.

age applications—features that greatly simplify the problems of mechanical tolerances associated with automatic retrieval systems.

The first of these features is that the image is "locked" to the hologram; the image always appears at a certain distance from, and at a definite angle to, the hologram. This means that if the hologram moves by some amount during reconstruction, the image will move by the same amount.

Holograms, however, store the image at an effectively enormous reduction ratio. Yet if the hologram is mispositioned during read-out by a small amount, the image moves by only that small amount. This is to be contrasted with the situation in conventional recording, where every motion of the recording medium is multiplied by the reduction factor.

The second attribute of holography, depth of field, is realized when it is used for high-density storage. Because in many cases the hologram will be small, the depth of field with which it reproduces the image will be large.

Volume holography for data density

The chief disadvantage of holography would appear to be that a laser, and possibly a high-power laser, is needed. While it is true that a simple light bulb would be more convenient, and in some instances of holographic storage (such as reflection holography with thick materials) suffices, the need for a laser can be turned to advantage. Materials whose sensitivities previously were considered too low, or whose spectral response too limited, or whose thickness too great, can be used as storage media when a laser is employed, particularly when holography is the storage mode.

Thick photochromic crystals, in which it is difficult to record diffraction-limited spots, have been used successfully for very high density storage. Because these crystals are colored by light of one wavelength and bleached by light of another, erasable (thus updatable) storage is possible. Furthermore, as Dr. Emmett N. Leith,[1] professor of electrical engineering, and his colleagues of the University of Michigan in Ann Arbor suggested and demonstrated, more than one hologram can be recorded in a thick medium simply by tilting the crystal between successive exposures. The various stored images will not overlap; on reconstruction only one image will appear with each successive tilt of the crystal. Each image corresponds to the tilt of the crystal during the exposure.

This attribute of holograms in thick crystals—volume holography—is a consequence of the need to satisfy Bragg-angle conditions during reconstruction, and obviously results in a tremendous storage density per unit volume. In principle, as many as 500 high-quality images could be superposed in a 2-mm thick crystal, with no cross-talk between the images.

Holograms made in thick materials have great storage potential, even exceeding the capabilities demonstrated by Emmanuel Goldberg. Holograms made in thin storage media, however, allow somewhat simpler retrieval and the material already is in a form suited for conventional retrieval mechanisms.

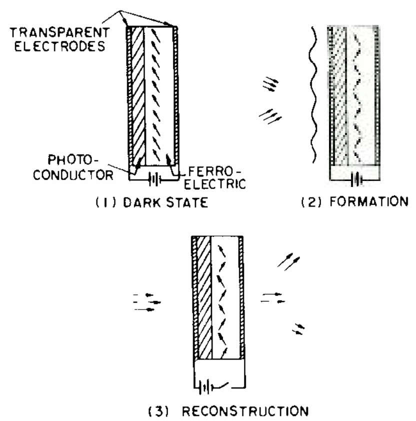


Fig. 3—Ferroelectric photoconductor holography: 1) initially voltage appears mainly across photoconductor, 2) optical pattern causes corresponding decrease in photoconductor resistivity—voltage appears across ferroelectric and causes switching of domain pattern, 3) hologram reconstructed by electro-optic effect.

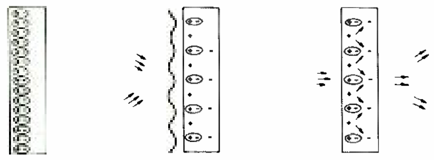
When an RCA 70/3488 transport mechanism (a system normally used with magnetic cards) was used in conjunction with the experiments mentioned earlier as a retrieval system for holograms stored on flexible film (Kodak 649, Eastman Kodak Co., Rochester, N.Y.), the feasibility of 0.5-second access to any of more than 12-million 8½x11 in. documents was demonstrated. For purposes of comparison, this corresponds to a multi-trillion-bit memory. Because holography was the storage mode, the scratches caused by the mechanism could be tolerated.

Fixed materials, such as films, polymers, or dichromated gelatins, would serve well in those applications where the need for change is not great—libraries for example. Other applications—business files, inventories, engineering reports and drawings, computer outputs—demand rapid updating and materials are under development that would allow this (one has been mentioned already).

By means of Curie-point writing, in which the domain pattern of a thin magnetic film can be made to correspond to an incident-light-intensity pattern, holograms in 600-angstrom-thick films of manganese bismuth have been stored.[2] The holograms are reconstructed by magneto-optic effects and erased by applying a magnetic field, as shown in Fig. 2.

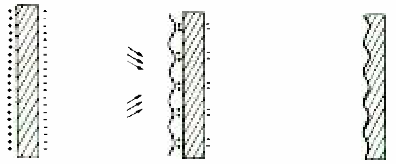
Ferroelectric crystals, such as bismuth titanate, coated with a thin photoconductor have also been successfully used for holographic storage.[3] The domain pattern in the ferroelectric crystal is made to correspond to a light pattern incident on the photoconductor by applying voltage to the structure; in regions of high light intensity, the applied voltage appears across the ferroelectric; while in regions of low intensity, the applied voltage appears across the photoconductor. (See Fig. 3) The pattern is reconstructed by electro-optic effects and erased electrically.

Optical damage, a thermally reversible effect in some crystals such as lithium niobate, can also be used for holographic storage.[4] (See Fig. 4.) In these, the internal charge distribution, and hence the internal electric field pattern, is modified in proportion to



(1) INITIALLY NEUTRAL (2) FORMATION (3) RECONSTRUCTION

Fig. 4—Electro-optic (optical damage) holography: 1) initially uniform charge distribution, 2) optical pattern causes corresponding charge distribution—which causes local high electric fields, 3) hologram reconstructed by electro-optic effects.



(1) CHARGED THERMO-PLASTIC (2) OPTICAL PATTERN DISCHARGES PATTERN (3) STORED PATTERN AFTER HEATING

Fig. 5—Thermoplastic holography: 1) photoconductive thermoplastic is charged, 2) charge pattern modified by optical pattern, 3) coulomb forces on hot thermoplastic forms hologram.

the incident optical pattern. Electro-optic effects, sensitive to the high local electric fields in the crystal, are used to reconstruct the pattern. When the crystal is heated, the charge pattern redistributes and the hologram is erased.

Thermoplastic deformation, in which the thickness of a plastic is modified in proportion to light, is yet another candidate for reversible holographic storage.[5] As shown in Fig. 5, the plastic is either mixed with, or overcoated by, a photoconductor and then charged. The light pattern then causes the charge to leak away in regions of high light intensity and subsequent heating of the plastic causes the deformation. Phase variations of light passing through the plastic, caused by the thickness variations, is used for holographic reconstruction. The pattern is erased by reheating the uncharged plastic.

At the extreme limit of thinness, holograms have been made in 75-ang-thick bismuth films. As demonstrated by Dr. J. Amodei, and the author at RCA Laboratories, the holograms were made using a Q-switched laser by evaporating the film to thicknesses inversely proportional to the incident illumination. Although not strictly updatable—they form the basis for a write-once, read-only, store—the holograms can be erased by evaporating the entire film and recoated for further use.

Recent experiments with selenium or tellurium films as the storage medium [both materials characterized by low melting points and very low thermal conductivities] have indicated that exposures of millisecond duration should be feasible, thus allowing the use of such non Q-switched sources as argon lasers.

Storage with an associative memory

A rather extensive list of storage materials and holographic techniques have been covered to give an indication of the research being pursued and the progress being made in this area of information storage and retrieval.

None of the storage materials discussed is without some drawbacks. The photochromic and optical materials exhibit thermal decay, the thermoplastic suffers from fatigue, the magnetic and ferroelectric materials have low reconstruction efficiency, and the metal films cannot be erased. Even so there is much optimism among workers in the field that these present drawbacks will be overcome and it seems reasonable to suppose that the goal of updatable, easily accessible, very high density storage—far in excess of what is available today—will soon be reached.

Holography is capable of more than just simple storage; it can serve as the basis for an associative memory. As described earlier in the paper the hologram produces an image wavefront when illuminated by the reference beam. However, when illuminated by the image wavefront, the hologram reconstructs the reference beam.

It is this attribute that makes the hologram a potentially perfect associative store: if the recording surface were made to store a multiplicity of holograms, each one made with different reference and object wavefronts, the illumination of the entire surface with a particular object wave would result in the reconstruction of the associated reference beam. The reference beam could be a plane wave or it could be the wave scattered by another object.

Thus, if one had a portion of the desired information, the remainder—or at least its location—could be found. With the title of an article in hand, one could recover the entire article, at least in principle.

If a transparency of the title were to be illuminated by a laser beam, the light scattered from it would act as the object wavefront that could recover (or reconstruct) the article. The difficulty with this technique at present is that similar, but different, wavefronts are confused by the hologram; the association is not perfect. Additional work, and some invention, still is required.

Concluding remarks

I have suggested that the parameters of an ideal image storage system would be: high storage capacity; immunity to dirt, dust, defects, and scratches; simple mechanical tolerances; and fast, easy retrieval. To a greater or lesser extent, existing storage methods attempt to approach this ideal, but due to inherent "noise" limitations these methods have to compromise between their potential and the practical realities.

The hologram can avoid these limitations. There still are problems to be solved before a holographic storage system can become a commercial reality, but the promise of holography would seem to make the effort needed worthwhile.

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Inside Romania, 1970

Dr. J. I. Pankove

This visit to Romania was sponsored by the scientific exchange program between the National Academy and the Academy of Sciences of Romania. I was already familiar with some of the scientific work of Professors Grigorovici and Constantinescu and of their coworkers in Bucarest; also I had already met two young Romanian semiconductor scientists who had spent ten months in the United States, one of them a former student of mine at Berkeley. Hence, I was looking forward to this three-week visit and expected a quick adaptation to the new ambiance. The transition was indeed very easy as the red-carpet treatment was extended throughout my stay. The main problem, that of communication, could be easily solved with French, English, and Russian, in that order. After a few days, if I knew the topic conversation I could follow what was said in Romanian where the vocabulary is of 70% Latin and 15% Slavic origin.

In what follows, I describe some impressions of the contrast between city and country and make general observations about life and work in Romania and how these were affected by the severe floods of June. I also touch on political considerations of Romanian socialism and the aspirations for independence from the USSR. Finally, I conclude with recommendations for possible improvements in the scientific exchange program.

Bucarest, with its combination of cobble-stoned curving narrow streets and very broad tree-lined boulevards, is a bustling city. Massive turn-of-the-century buildings mingle with miniature parks. There are many By-zantine churches, whose dark interiors are dotted with tiny electric candles. In the many churches I visited, people of all ages, including teenagers, were praying. On the periphery of Bucarest, large complexes of tall apartment buildings form new high-rise glomerations comprising all facilities for schools, shopping, theater and restaurants; however, some of the buildings seem to be half a mile from the nearest shopping center. The modern apartment houses are built of prefabricated concrete slabs forming partitions comprising doors or windows. The finish is much superior to similar modular buildings I had observed in Russia. Television antennas bristle not only from the rooftops, but also from the balconies. Apartments can be bought with a 30% down payment and a 6% mortgage.

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The moderate traffic consists of many busses, a few street-cars, and a great variety of cars from western as well as communist countries. Taxis are available as metered trucks, panel trucks, and the standard passenger cab—all with checker-board identification. Foot traffic is also heavy, especially after 4 p.m. Except at those intersections controlled by traffic lights, the pedestrian is never safe off the sidewalks. The population is divided into pedestrians and drivers, the latter being an overwhelmingly powerful minority.

Many cultural establishments—book stores, institutions, art galleries, museums, etc.—make Bucarest an intense intellectual center. Surrounding the city is a vast expanse of farms with small picturesque houses enclosed by neat fences. Many shallow wells can be identified by the tall, balanced piece of timber that can swing down to dip the bucket into the water. Along every road, all sorts of farm animals are seen, mostly on the grassy banks away from the hard surface. Usually single cows are guarded by either a child or an old man; obviously a milk factory is a valuable asset.

Most of the farms were tilled by hand by groups of people working the soil between plants with rounded hoes. Farmers cut hay with scythes. Many a horse-drawn wagon had a colt running alongside. One could see peasants trudging home for miles with a bundle of hay on their backs; men with pants tucked into their boots and wearing a black hat; women with long dark dresses and a scarf. Except for the presence of paved main roads, electricity, and TV antennas, one might get the impression that life has not changed for the peasant in several centuries.

Living conditions

Casual observations of life in Bucarest suggest long working hours. One can pass tailor shops after ten in the evening and still see people crowded elbow-to-elbow around a table, busily

Dr. Pankove (front row, arms folded) with a group of Dr. Grigorovici's semiconductor scientists in front of the Academy Club of Bucharest, Romania. Dr. Grigorovici, Director of the Institute of Physics of Bucharest, is the tall man, back row, left side.

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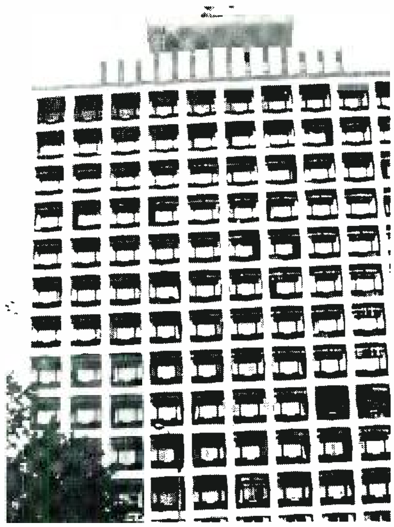
received the BSEE in 1944 and the MSEE in 1948, both from the University of California. In 1948 he joined the RCA Laboratories; in 1956, he received a David Sarnoff Fellowship to study at the University of Paris, France, where his doctoral topic was infrared radiation from surface processes in germanium. Since his return to RCA Laboratories, he has worked on superconductivity, where he has evolved several new device concepts and has done research on silicon carbide. He has investigated the optical properties of degenerate germanium and the electrical properties of tunnel diodes in germanium. Currently, he is concerned with interjection luminescence and the laser action in gellium arsenide and other compounds. Dr. Pankove has published over 20 papers and has over 30 issued patents. In addition to IEEE, he is a member of the APS, the Electrochemical Society, and Sigma XI.



Clockwise from upper left: a skiing resort in the Transylvanian Alps. Panorama of Iasi in Northern Romania. Paved roads, electrification, television antennae, and a very common mode of transportation in rural areas. TV Broadcasting building (lower right) in Bucharest. Sunday morning in the Moldavian village of Niemts. And (lower left) modern apartment buildings in Bucharest.

sewing. Cafeterias where standing people grab a bite seem jammed till closing time at 10:30 P.M. Manpower seems plentiful but not idle. Many women clean the streets or help pave the roads or tend the public gardens. The economy seems to require that everyone should work to support himself and the children. In almost all families both husband and wife work full-time. The salary of one individual is insufficient to maintain a whole family. In laboratories, people work from either seven AM to three PM or eight AM to four PM or for a longer period if there is a luncheon break. They work 6 days a week. Only those employed in hazardous jobs, e.g. in a laboratory where there is exposure to radiation, have shorter working days.

By our standards, working conditions are hard. The working schedule (7 AM or 8 AM starting time) is decided at the beginning of each month. Any change or absence must be explained in writing. There is a penalty cut in salary for for late arrival exceeding five minutes per month. Rewards in the form of bonuses are sometimes given, but the system is mostly punitive. When people work on contracts, there is a penalty clause of 15% which is deducted from the salary until the end of the contract period, at which time it is refunded if the contract has been performed satisfactorily. Every salary is public knowledge in each organization because on pay-day everyone must sign a register listing names and salary. Salaries of technical personnel range from $120 a month for a young physicist to about $300 a month for a group head. There is an additional payment of $6 a month for each child. When both parents are working and have young children, they often hire someone from the country to live in and take care of their child at the cost of $25 a month. A clerk's wage is a minimum for subsistence, spent mostly on food, $35 a month. To encourage population increase, abortion was abolished a few years ago for women having fewer than four children. Childless couples are taxed $6 a month. The very low wage scale which forces every adult to work implies an extremely high cost of living. Manufactured goods cost the same as in the US (according to the official currency value). Protein foods are also as expensive as in the US; however, vegetables and fruit are much cheaper. Rental is inexpensive, but private property per square foot costs the same as in the US. The monthly salary of a beginning physicist will buy a suit. A compact car, equivalent to a Volkswagen, is worth a year's gross income of a mature PhD.

Medical services are free, but many Romanians prefer to go to their favorite physician for which they pay. No allowance is made for sickness, not even for women, unless a person is sick enough to be hospitalized. A mother is not allowed a sick day even if her child is sick. Personal leaves for such reasons are taken without pay on a pro-rated basis. When a person takes time off for illness, his salary is reduced by 10% for that period. For serious cases, like tuberculosis or heart condition. a person is placed on a retirement pension.

The attitudes of these people, hard at work, busy surviving, varies with the personality. Some are resigned to a fate of hopelessness. Others spike their

The ornate castle of Sinaia.

life with a sense of humor. Common expressions are "Don't worry; life is short." Or "They pretend to pay us; we pretend to work." Or "Life is like raisin bread; sometimes you find raisins, but once in a while you find only the hole where the raisin used to be." The third class apartments are of such low cost that the small bathroom has only a toilet and a faucet. It is said that among the furniture designed for third-class apartments is a night pot with a handle on the inside to save space.

The major Sunday pastime all over Romania seems to be promenading along the main boulevard. In the villages, the main boulevard is also the highway. It is a colorful scene: people in gaily embroidered clothes milling about on both sides of the road.

Effect of floods

The floods of June have had a catastrophic impact on the nation's economy. It is estimated that the damage exceeds 15% of the national budget. As a result, people have been asked to contribute 15% of this year's salary towards relief. Many lotteries have been organized to raise additional funds, such as raffles on cars or art objects. In many industries people have been asked to work a seven-day week. Although immediate help has been pouring in from many countries, especially the United States, it is acknowledged that Russian help came after a long delay and after president Ceaucescu was called to Moscow. In the theater, documentary shorts before the main feature make a strong impact about the extent of the damage: demolished houses, flooded factories, homeless people, makeshift refugee camps. In traveling through the countryside, one can see the hastily-built dikes extending for miles along the edges of the highways.

Tourism

The Academy was very kind in arranging a number of weekend excursions, such as a trip along the valley of the Prahova to visit the famous castle of Sinaya—an exquisite jewel of a castle filled with art in all media, and the castle of Bran—a fourteenth century fortress with a labyrinthine sequence of rooms spiralling up to a high tower. A trip to Mamaia on the Black Sea gave some impression of the seaside in Romania. It is as well developed for vacationers as the Riviera. The monasteries of Moldavia (whose Romanesque churches are painted from top to bottom both inside and out) is Romania's equivalent of the French chateaux along the Loire. Many of these monasteries are still in operation for both monks and nuns. Everywhere there is evidence of an effort to promote tourism: new motels, good main roads, car rentals (including Hertz). In concluding this paragraph on tourism, it should be pointed out that some of their modern hotels could benefit from an exchange program of plumbers.

Attitudes toward Russia

Although Romania is a socialist country, one is quickly made aware of its spiritual independence from the Soviet Union. There is the impression that the Soviet Union exerts a drag on the economy. In traveling near the Russian border of Moldavia, I pointed to the wavy horizon and asked if those were Russian mountains, and received this reply: "Those are not Russian mountains; those mountains are in Russia." Someone else commented about his difficulty in communicating in Russian: "Russian is a very difficult language to learn, and an easy one to forget." Anecdotes making fun of Russia are abundant. Example: an American and a Russian are comparing their transportation. The American says, "We have 3 cars—a small, a medium, and a large one. I drive the small one; my wife drives the medium one, and when we go out visiting we take the large one." The Russian says: "I go to work by bus; my wife goes to work by bus, and when we go shopping we take the bus also." American: "And how do you travel to visit your friends." Russian: "To visit friends, we go by tank."

According to a Romanian emigre, the apparent cleavage between Romanians and Russians is only an act, a political game to give the free world an impression that Romania is independent; it is the only socialist country to deal with Israel and to have close rapport with western countries; people give the impression of free talk to western visitors. However, he contended that Romanians are more afraid of their government than Soviet citizens: there has been no Romanian Soljenitsin to criticize the system or to write letters abroad.

In contrast to the sophisticated attitude toward Russians, there is a genuine interest and curiosity about life in the United States. Yet Romanians always avoided topics which might lead to embarrassment or controversy.

Rapport with Israel

I left Bucharest to go to Tel Aviv. The lobby of the airport was crowded with many Jews. It was obvious that some were emigrating. Friends and relatives were on hand to say farewell. On hand were also cameramen with fancy large movie cameras photographing the scene. When the few passengers began boarding the bus going to the plane, one of the cameramen was again taking pictures. It was obvious that these were not pressmen but surveillance personnel. On the next day, I met a recent Romanian emigrant, an engineer, who told of a 12-year wait for permission to leave, of being allowed only 70 kg of luggage which arrived three months later, of all money being confiscated at departure (and one is supposed to manage on such a start in a new world.) Yet, even then, it is worth getting out and even non-jews yearn to get out. The import of citrus fruit and busses from Israel is a barter for immigrants. This I had also heard in Romania.

Science in Romania

The laboratory facilities at the Bucharest Institute of Physics are rather modest. Except for a few power supplies made in Romania, most of the equipment comes from different countries: France, England, East and West Germany, Poland, and Hungary. Very few pieces come from Russia. The most wanted apparatus is a high frequency oscilloscope. They regret the US embargo on scopes capable of displaying 50 MHz and higher. At the Institute of Atomic Physics, on the other hand, the facilities are more modern; the buildings are air conditioned.

Since the beginning of this year, the Academy of Sciences has dropped its support of the Bucarest Institute of Physics. This abandonment has forced all the physicists to seek out contracts from industry. The shift from fundamental to applied work has been disappointing to the scientists who feel inadequately equipped for applied work but better able to get fundamental work from available facilities. But mostly, it is a matter of professional snobbism.

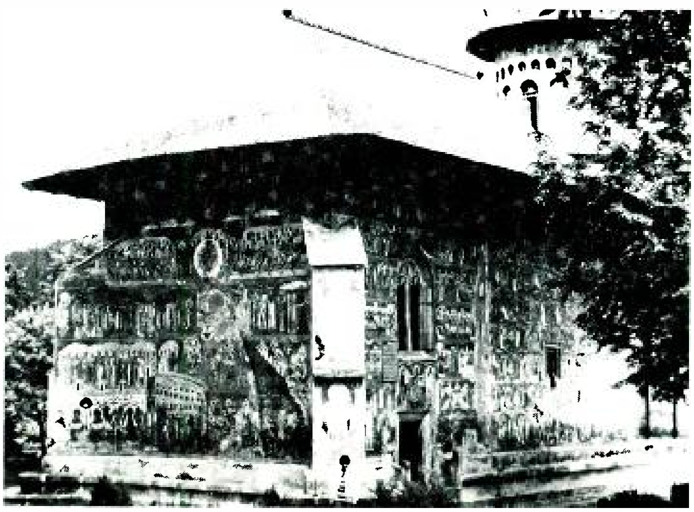
A plea was made to me that American corporations should make contracts for research at the Bucarest Institute of Physics. Research money would go much further there. They did not consider the problems of propriety of ideas, as if patents did not have value in Romania. They even suggested that payment could be made in obsolete equipment. Actually, the low cost of skilled labor in Romania could be a strong inducement for American industry to set up operations in Romania, instead of the Orient. The goods produced could be ear-marked for export, the investing firm and the Romanian government sharing the profits, thus bringing in hard currency which they need for import from the West and for economic independence from the USSR. By excluding these goods from home consumption, at least initially, there would be no competition with other firms that might produce similar goods with less efficient methods. The only problem may be securing a guarantee that the American investment will not be dispossessed at the whims of the Communist party. Yet, there is a Pepsi Cola plant, an American firm is building a huge hotel, and Hertz car rental has begun operating in Bucarest for credit card customers.

Recommendations

Romania is one of the few socialist nations where the majority of people are friendly to us and where the government's attitude is as favorable to us as their precarious ties to the Soviet Union will allow. These good relations should be cultivated, though with reasonable caution. The exchange program offers the possibility of closer ties and deeper people-to-people insight into comparative life on both sides. However, to make the most of the scientific exchange program, I think it should be up to the Romanian scientists to recommend fields in which they wish American visitors, and possibly they should invite individuals of their choice, rather than depend on random selection. Chances are that their most advanced departments would exert the most influence, and those are precisely the areas where our scientists stand to learn the most.

However, to be successful, such an initiative should be suggested to the head of their academy. Their scientists are so used to being told who is to go that they would not think to ask. Everyone would love to get out of the country, even for a short time. The conviction that there is no possibility of influencing the upper strata of administration can generate a tremendous inertia. The heads of the institutes make a selection and ask if the individual will accept the opportunity. In contrast to this top-to-bottom Romanian selection, in America the selection starts in reverse order. I suspect that in the US few individuals ask to go and, for those who do, tourism may be a prime reason. In this case, both academies have a small number of American scientists to choose from. Romanians tend to go to the US for long terms whereas Americans tend to go for a short stay. The advantage of the exchange program to Romanian science is evident. Their technology is far behind, and their experimental and financial means are very limited. They are conscious of this lag: "If we start now to work on *(GaAl)As* electroluminescence we may be only three years behind, but if we start with luminescence in *GaP* we will be fifteen years behind." Yet, with their limited means, they manage to find new areas of research where, with great ingenuity and a bit of luck, they can obtain noteworthy results.

For us, the advantage of the exchange program may be more political. It increases their friendship to the United States and helps them at a limited level in their effort to gain more independence from the USSR. The exchange program allows a better insight into life in Romania. One definitely gets the impression that a Western visitor is like a breath of fresh air.



Church painted top to bottom, inside and out, in the Monastery of Voronets.

RUDI: computer-controlled test-data acquisition and processing

B. Mangolds

RCA's Space Center, near Princeton, New Jersey, has extensive facilities for spacecraft environmental testing. To speed up and automate the measurement of variables produced during space-simulation tests, and to reduce the huge amount of measured data to a user-oriented format for the customer, a computer-controlled data-acquisition system is being used. The system, which has been in operation for more than a year, has been nicknamed RUDI, from its distinguishing characteristic: Rapid Universal Digital Instrumentation. In numerous applications, some involving 24-hours-a-day duty over a period of several months, the system has been accurate, fast, efficient, and reliable. The financial investment has been completely justified.

RUDI is intended principally for the measurement of slowly varying parameters; specifically, quasi-static, low-level signals of the type encountered in thermal-vacuum tests involving large thermal masses. This permits the use of a scan rate of 200 channels per second, which is perhaps slow in terms of computer technology, but is economical and adequate for this particular test environment. The advantages offered by the computer are, instead, utilized specifically in the areas of control of data integrity, and automation of data reduction.

RUDI is designed around a Systems Engineering Laboratories digital computer, model 810A, with a 16k core, a 16-bit process-word length and a 14-bit data-word length. The main-frame and the majority of its peripherals (a central control console, a 1.2-million-word disk file, a 400-LPM line printer, TTY, a high-speed tape reader and two magnetic tape decks) are located in an air-conditioned room called Data Central (Figs 1 and 2).

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Data sources

The data originates at a test site. Ten such sites, located in the Environmental Test Facility, are hardwired to Data Central, the main trunk consisting of only three RG-59U coaxial cables. Typical signal sources are analog devices: thermocouples, resistance transducers, strain gages, auto-collimaters, radiometers, thermistors, and pressure and vacuum transducers.

A set of three mobile instrumentation carts closes the link-up between transducer and computer. One of the carts is shown in Fig. 3, connected to a test chamber. Transducers mounted on the devices under test are connected to the input terminals of the carts. Each cart can process 250 channels of data and up to three can be connected to one site to provide a maximum capacity of 750 channels for a particular test. Each cart can, however, also be used individually, and the system is thus able to process up to three unrelated 250-channel tests simultaneously, each with different input configurations, scan rates, output format specifications and identifications, starting and terminating independently of the others. The cart equipment includes analog signal conditioners for transducer excitation and normalization, multiplexers, amplifiers, analog-to-digital converters, control logic, and line drivers. Information is transmitted to and from Data Central digitally, in serial format (Manchester II) over coaxial cables.

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studied electrical engineering at the University of Latvia in Riga and physics at Fairleigh Dickinson. Mr. Mangolds worked in the electronic components industry for ten years as a design engineer, then for six years as a senior test engineer for the Components Development Laboratory of Reaction Motors Inc. He joined AED in 1962 as instrumentation engineer in the Environmental Space Simulation Department, specializing in transducer technology and automation of data acquisition and presentation. He is a member of the IEEE and the IES.

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Data integrity

Many safeguards are incorporated in the system to ensure the integrity of the data. Since each cart includes four differential autoranging DC amplifiers which are integral to the analog portion of the front end, the effects of offset drift and gain changes must be particularly considered. These are monitored by having each data scan begin (as an integral part of the scan) with the checkout of all six gain ranges of each amplifier, taken at full scale (plus and minus) and at zero input. A reference voltage is applied to each amplifier input; the output is compared with the anticipated value, and the necessary corrections for each range of each amplifier are stored in memory.

If the required correction is within specified units, it is automatically applied (properly interpolated) to the data-acquisition portion of the scan. However, if a limit for the correction is exceeded, the warning message, DRIFT EXCESSIVE, appears on the teletypewriter, with an identification of the cart, amplifier, and range concerned.

The accuracy of the reference power supply voltage is verified at regular intervals by the Space Center's Standards Laboratory, which provides the documentary link to the National Bureau of Standards.

Actually, every data channel is interrogated four times per scan, the individual measurements being spaced in time at ¼-wavelengths of a 60-Hz period. Through digital filtering, an

Fig. 1—Environmental test center data central.

effective common-mode rejection of 120 dB is thus obtained at 60 Hz and 120 Hz. Furthermore, if the comparison of the 4 readings shows a spread of more than a pre-selected amount (in percent of full scale of present range), a DATA SCATTER ALARM message on the TTY alerts the operator to a possibly open channel, identified in the message by test and channel number. Finally, after common-mode subtraction, the four readings are averaged, and this value is now used as the actual single result of that particular scan of this channel.

To guard against excessive feedback current entering a transducer line from a defective amplifier, the operator can request a measurement of it, per amplifier. The multiplexer replaces the incoming data line with a fixed resistor, and the resulting voltage drop is printed out in terms of nanoamperes of feedback current.

The operator can request, at any time, a printout of the circuit resistance of every data line, and can thus keep watch on the sensors. A constant-current supply is switched sequentially across the channels, and the resulting voltage drop across the line plus sensor is printed out in ohms.

To obtain a more detailed statistical overview of the actual state of all amplifiers within a cart, a RUN RFC command initiates an action similar to that described earlier for initial scan-drift data acquisition. Each amplifier receives now a ±100% FS, ±50% FS and a zero signal per range, fifty times each. Each highest, lowest, and the average of these, as well as the variance, is printed out in uncorrected binary counts, per gain range per amplifier. This provides a good picture of the uncompensated status of the system.

Signal conditioning for resistance transducers and strain gages employs individual, highly isolated power supplies, selectable for constant-voltage or constant-current operation. Automatic R-CAL and/or substitution calibration is provided.

Thermocouple tables for copper-constantan and chromel-alumel are resident in core. No fixed reference junctions are necessary because the computer measures and corrects for the actual junction temperature.

Operation

In Data Central, the TTY functions as an interactive communications link between system and operator. Instructions are in abbreviated English mnemonics. Every entry is time-verified for log purposes. Under typical operating conditions, the specifics of a test such as channel identifications, scan rate, printout format selection, are entered during set-up time. Calibration curves of non-linear transducers are defined in terms of straight-line segments; only the break-points need to be defined through TTY-entry; the computer interpolates in-between. Data taken from the curve then may be presented to the customer directly in any required engineering units. Combinations of random groups of channels can be defined as dummy channels, and the high, low, or average calculated value of such a group can be printed out as if it were one channel.

The instantaneous value of any channel can be requested at random and displayed at the operator's console, again in engineering units. The main output device is, however, the line printer. Many fixed presentation formats are available. For example, each scan can be printed out singly after it occurs; or, in the cumulative mode, each new printout repeats all the previous ones, too. The columns of data listings grow with each printout until a page is filled, after which a new set is started. If desired, no print occurs, and all data is stored instead on the disk, until a full page is accumulated. Output can be in actual values, or can be the algebraic difference between the previous value and the present one. One can also define a target value and obtain printouts of the interval between present and target level. Level and rate-of-change alarms can be specified if desired. Printouts are uniquely identified by test number, title, date, time-of-scan, and engineering units. If several tests run simultaneously, the printout for each test is made on separate sheets.

The same information can be recorded on magnetic tape, all data terminating on the same deck. If one test terminates while others continue, the data from this test is copied selectively from the original tape onto a second deck, while acquisition of the other tests continues, their data being temporarily stored on the disk. After completion of the transcript operation, the accumulated data is dumped from disk to tape, providing uninterrupted service. This feature is used also during preventive system maintenance.

Accuracy

The accuracy of the system is ±0.22% (±½ least significant bit) on the 5mV range, representing the worst condition. Temperatures are measured within 0.2°C, excluding the transducer. A time-code generator acts as the main housekeeping device, and it is synchronized with National Bureau of Standards, over a direct link with AED's Standards Laboratory's time-signal distribution network.

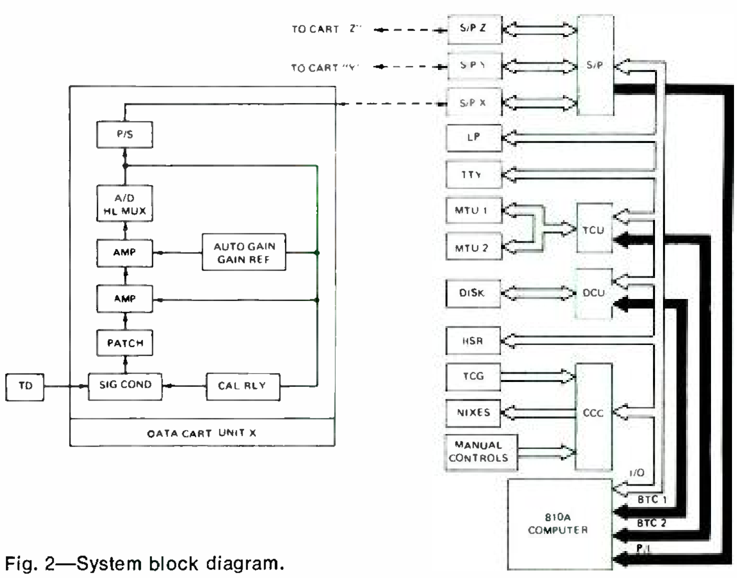

Fig. 2—System block diagram.

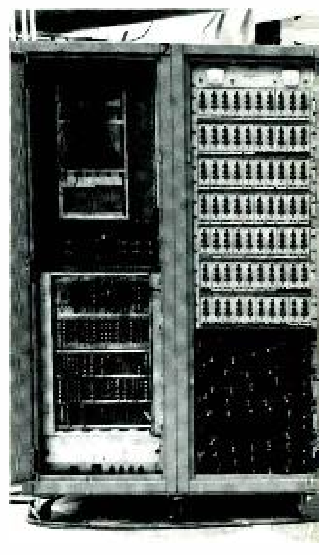

Fig. 3—Mobile Instrumentation cart in use.

ALSIM—microprogram simulator

S. O. Hong | S. P. Young

The increasing use of microprogramming both in read-only and writable memories, makes a microprogram simulator of particular importance. This paper will discuss some aspects of microprogram simulators with particular emphasis on one developed by RCA for use on their digital computers. The program is called ALSIM,* which stands for algorithm simulator.

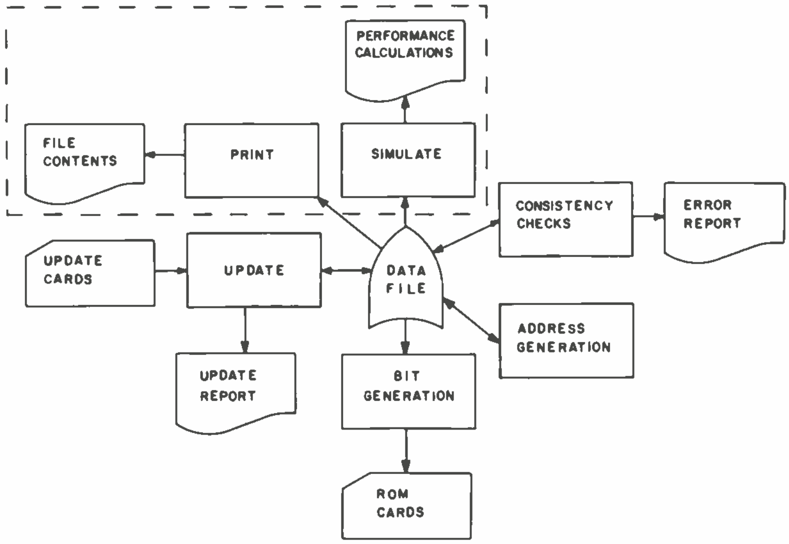

Fig. 1—Process flow of elementary-operation simulation system.

MICROPROGRAMMING is an orderly approach to the design of the control section of a computer using control signals organized in fixed-length words. The most elementary operation, such as a register-to-register transfer, is called a *micro-operation*. Each control word, or *micro-instruction*, contains one or more micro-operations which are performed in a fixed time interval. The set of micro-instructions required to execute one machine language instruction is a *microprogram*.

There are four ways in which a microprogram simulator can assist in developing a read-only control memory:

1) The simulator can be used to debug microprograms before they are manufactured. Since a read-only memory is often made with integrated-circuit technology, the early detection of each mistake represents a considerable savings in time and money.
2) Simulation can aid in the resolution of several alternative designs. A simulator can analyze trade-offs between the number and size of the control memory words, the segmentation of the control memory word, and the micro-operation repertoire associated with each segment.
3) It can be useful in the verification of fault-test procedures. Microdiagnostic procedures can be tested by analyzing a model in which faults have been selectively inserted.
4) The simulator produces a tested data base which can be used to provide block-diagram documentation and to produce input to a machine which manufactures the read-only memory.

The reasons for simulating a user-writable control memory are somewhat similar. Although a mistake does not involve redesigning a manufactured product, it can be very troublesome. The main problem is that field service engineers will find it very difficult to distinguish between faults in the delivered hardware and mistakes in the writable control memory.

The simulation program is part of a larger system for designing and manufacturing a control memory. The system contains programs to perform the following functions:

1) Create or update the data file describing the control memory.
2) Simulate the data file.
3) Make consistency checks to ensure that the simulated read-only memory (ROM) can actually be built.
4) Print the contents of the data file.
5) Sort the micro-instructions to match hardware requirements.
6) Punch the cards which are used in manufacturing each integrated-circuit.

Fig. 1 describes the information flow for the entire system. The portion within the dotted lines is the subject of this paper.

There are two broad categories of microprogram organization: direct control and encoded control. *Direct control* resembles ordinary machine

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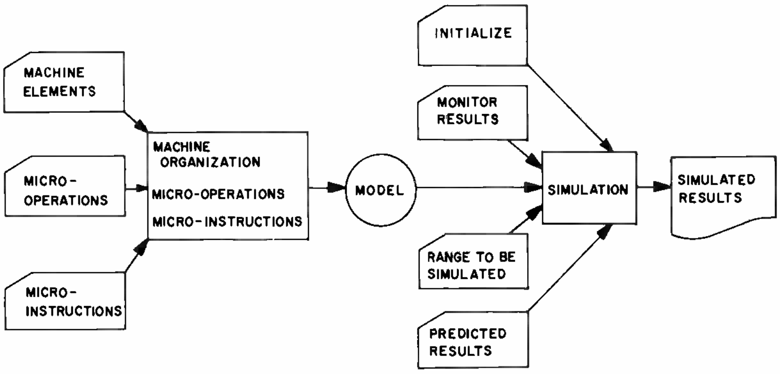

Fig. 2—System flow chart of elementary-operation simulator.

```
    $EODEF
    SPEC LSB=0
D---MAP A,T,F,F,F,F,F,F,F,G,G
    EQN EVAL,*T1 EXEC,*F1 EXEC,*F2 EXEC,*F3 EXEC,*F4 EXEC,*F5 EXEC,*F6
E---EQN EXEC,*F7 RTN,TEST INC,COUNT,COUNT,1
    RTN TEST GOTO,*G1,(*T1) GOTO,*G2,(*T1')
B---FUN MDR TF,DR,SUM
C---EQN X:UR07 X#UR07
    FUN O→DR RST,DR
    FUN %R1 TR,PSR,FMAD(5-6) RST,FMAD(4) TR,R1,FMAD(0-3)
    FUN BINADD      SET,RZ BADD,ADDER,UR,IR,SUM,SCAR,OV  RST,RZ,(SUMZ)
    FUN W4  TR,SUM,DUMMY WRITE,FM
    FUN SCCF2 COMP,OV,CC(0) AND,RZ,CC(0),CC(0) OR,RZ,OV,CC(1)
    FUN SCCF2 COMP,CC(1),CC(1) AND,S07,CC(1),CC(1) OR,RZ,OV,CC(2)
A---FUN SCCF2 OR,S07,CC(2),CC(2) COMP,CC(2),CC(2) TR,OVCC(3)
    FUN %IR TR,SUM,IR
    EQN SUMZ SUM=0
    FUN BINSUB SET,OV SET,SCAR
    FUN BINSUB COMP,UR,SUM BADD,ADDER,SUM,IR,SUM,SCAR,OV  RST,RZ,(SUMZ)
    FUN E1  END
    FUN END1  END
    EQN 2 OV#OV
    FUN Y TR,OV,OV
```

Fig. 4—Example of input for micro-operation section.

language coding in having one operation and several operands in one micro-instruction. This organization is simpler because each control gate has a unique control line. The other organization, *encoded control*, divides the micro-instruction into fields, each of which represents a micro-operation. This is more economical of gates because M control lines yield only $\log_2 M$ control gates. There are also various ways of controlling the sequence of micro-instructions. In the simplest case, a test determines whether the control passes to the next higher micro-instruction or to some other address specified within the micro-instruction. In the more complicated instance, control passes to one of a number of equally spaced successors.

A simulator consists of two parts. One part constructs a model of the object to be simulated and the other part exercises this model by setting initial conditions and monitoring the elements of the model. In the case of ALSIM, the model is a description of the computer being simulated. The model (see Fig. 2) includes:

1) A description of the machine organization,
2) A functional description of the available micro-operations, and
3) A description of the micro-instructions expressed as a sequence of the micro-operations from 2) above.

Machine organization

The machine organization section of the model describes the computer in terms of its physical features, e.g. registers and memories. The registers and busses are specified with REG and BUS cards. Each contains the name of the element, followed by the word REG or BUS, followed by the length of the register or bus. The main difference between the two devices is that a register is a storage device while a bus is merely a collection of data lines for transferring information between registers. Lines A and B of Fig. 3 are examples of defining cards for a one-bit register (A) and a 32-bit bus (SUM).

The FIELD command divides a register or bus into sections that can be called out separately. Thus, UR07 in line C is defined as bit 31 of register UR.

The ADDER card must specify the length of the adder and the name of the overflow and carry-in registers which are used. Line D of Fig. 3 describes a 32-bit adder with overflow register OV and carry-in register SCAR. A main memory is a storage device consisting of a number of bits divided into individually addressable words or bytes. Before a single memory location is read, its address must be put into the read address register. The definition of the memory must include the read-address and read-data registers, as well as the same information for write registers. In addition, memory access times must be specified. Fig. 3,

```
    $MCDEF
A---DEFINE   A,REG,1
    DEFINE AUD,REG,1
    DEFINE  BA,REG,2
    DEFINE  CC,REG,4
    DEFINE COUNT,REG,8
    DEFINE  DR,REG,32
    DEFINE DUMMY,REG,32
    DEFINE   E,REG,1
    DEFINE  EO,REG,72
    DEFINE FMAD,REG,7
    DEFINE FMAR,REG,32
    DEFINE ICAR,REG,1
    DEFINE ILC,REG,2
    DEFINE  IR,REG,32
    DEFINE   L,REG,8
    DEFINE MAR,REG,24
    DEFINE MMR,REG,45
    DEFINE  MR,REG,32
    DEFINE  NP,REG,1
    DEFINE  NT,REG,1
    DEFINE OCR,REG,2
    DEFINE OPR,REG,8
    DEFINE OV,REG,1
    DEFINE PMR,REG,4
    DEFINE PSR,REG,2
    DEFINE RZ,REG,1
    DEFINE SCAR,REG,1
    DEFINE   T,REG,1
    DEFINE UR,REG,32
    DEFINE  X,REG,1
E---DEFINE MM,MMEM,0-1023,8,MAR,MR,MAR,MR,R=3,W=2,C=3
F---DEFINE FM,FMEM,123,32,FMAD,DUMMY,FMAD,DR
B---DEFINE SUM,BUS,32
    DEFINE BUS,BUS,32
D---DEFINE ADDER,ADDER,32,0,OV,31,C,SCAR,0
    DEFINE R1,FIELD,L(0-3) R2,FIELD,L(4-7) I2,FIELD,L(0-7)
C---DEFINE UR07,FIELD,UR(31-31)
    DEFINE S07,FIELD,SUM(31-31)
    DEFINE FMADHI,FIELD,FMAD(5-6)
```

Fig. 3—Example of input for machine organization section.

line E, describes a memory MM, with 1024 8-bit words and address and data registers (MAR and MR). A fast memory is described in the same way as a main memory except that access is assumed to be immediate so that no timing information is needed. Fast memory FM is described in line F of Fig. 3.

Micro-operation section

The micro-operation section gives a description of the functions and tests which can be performed by a microprogram. Each function is expressed as a string of mini-functions which operate on the elements described in the machine organization section. A typical mini-function is the OR on line A of Fig. 4. It specifies that the first two elements are combined with a logical OR and the result is put into the third element. A hard-wired function is put in by a FUN card. Each FUN card contains a string of mini-functions which are executed only if certain tests are true. Line B shows a simple function, MDR, containing one mini-function.

The EQN card (line C) designates an elementary test which can be performed either by a micro-instruction or by a function micro-operation. A micro-instruction evaluates an equation to determine the next micro-instruction to be executed. A function micro-operation uses an equation to permit or inhibit the execution of a certain mini-function. An equation can be very simple, like line C of Fig. 4 which compares register X to field UR07, or it can be a sequence of simple comparisons combined by Boolean operators.

The micro-operation section has two more input cards which do not describe micro-operation. However, these cards give the simulator the

```
                                                    SYMBOLIC      EO      LISTING
EOFLOW      STORE
EO 2100,X:UR07,MIR,Y,Y,Y,Y,Y,Y,Y,2110,2114
EO 2104,X:UR07,MIR,Y,Y,Y,Y,Y,Y,Y,2114,2110
EO 2110,Z,O+DR,%R1,BINADD,%4,%IR,SCCF2,EI,0000,2100
EO 2114,Z,O+DR,%R1,BINSUB,%4,%IR,SCCF2,EI,0000,2100
EO 0000,Z,Y,Y,Y,Y,Y,Y,Y,2100,2100
```

Fig. 5—Input for micro-instruction section.

```
MAP A,T,F,R,R,G,G

EOM EVAL,*T1 EXEC,*F1 GOTO,*G1,(*T1) GOTO,*G2,(*T1')
```

Fig. 6—MAP and EOM card for direct control.

```
MAP A,T,F,F,F,F,G

EOM EVAL*T1 EXEC,*F1 EXEC,*F2 EXEC,*F3 EXEC,*F4 GOTO,*G1,(*T1) GOTO,*G1+1,(*T1')
```

Fig. 7—MAP and EOM card for indirect control.

```
MAP A,T,T,F,F,G

EOM EVAL,*T1,*T2 EXEC,*F1 EXEC,*F2 EXEC,*F3 EXEC*F4

   GOTO,*G1,(*T1·T2') GOTO,*G1+1,(*T1'·*T2)

   GOTO,*G1+2,(IT1·*T2') GOTO,*G1+3,(*T1·*T2)
```

Fig. 8—MAP and EOM for four-address branching.

```
EOM EXEC,*F1 EXEC,*F2 GOTO,*G1,(R1=0) GOTO,*G2,(R1=1)

   GOTO,*G3,(R1=2) GOTO,*G4,(R1=3)
```

Fig. 9—EOM card for branching based on register 1.

```
      JOB STARTED AT     084715

A---LOAD REG L,50
    LOAD REG PSR,2
    LOAD REG X,0
    LOAD REG COUNT,0
    LOAD REG DR,8
    LOAD REG IR,129876
    LOAD REG UR,456789
B---LOAD MEM FM,40,24
C---SNAP A FM,2110,=5
D---TRACE A 2110,0000
E---TERMS 0000
F   BEGIN  2100 T=5 E=30
```

Fig. 10—Input for exercising model.

flexibility required for modeling many different microprogram structures. The first is the MAP card (line D) that gives the format of the micro-instruction. A micro-instruction is written as a combination of the following elements:

1) The symbolic address of the micro-instruction (A).
2) The names of equations that determine the next address (T).
3) The names of functions which are performed during the execution of a micro-instruction (F).
4) The names of registers which are directly specified (R), and
5) The addresses of all possible successor micro-instructions (G).

The MAP card lists these letters to correspond to the format of the symbolic micro-instructions. The typical MAP card, shown in line D, indicates that each symbolic micro-instruction will contain a symbolic address, one equation name, seven symbolic function names, and four branch addresses.

The last card in the micro-operation section is the EOM card. This card gives the order in which events take place during one micro-instruction. That is, it tells when there is instruction overlap, and it specifies the order in which the tests are evaluated and the functions are performed. The expression *F2 refers to the second function in the current micro-instructions. Instruction overlap is accomplished by allowing the apiece symbol (@) to refer to a function in the previous micro-instruction. Line E specifies that the following actions take place for each micro-instruction:

1) Evaluate the test.
2) Execute the seven functions in the current micro-instruction.
3) Then go to the first or second branch address depending on whether the symbolic test is true or false.

Micro-instruction section

The micro-instruction section reads the data cards that specify the individual micro-instructions. The format of these micro-instructions follows the MAP card from the micro-operation section. As in the MAP card, the components are:

1) The symbolic address of the micro-instruction.
2) The names of the equations that determine the next address.
3) The names of functions performed during the execution of a micro-instruction.
4) The names of registers that are used as explicit operands, and
5) The address of all possible successor micro-instructions.

Figure 5 gives an example of micro-instruction cards corresponding to the MAP card in Fig. 4. A micro-instruction card is identified by the letters EO (elementary operation) in the first two columns.

The capabilities described above enable ALSIM to model almost any microprogram format. Direct control requires the presence of one function (micro-operation) and two or more operands in the EOFLOW cards. Fig. 6 gives an example of the MAP and EOM cards which describe a direct-control memory with two operands. The function, F, operates on the two registers specified in the EOFLOW card. Indirect control requires several functions in the EOFLOW cards, and no operands. Fig. 7 shows the MAP and EOM cards required for indirect control with four micro-operations. The use of symbolic addresses gives ALSIM great flexibility in modeling various addressing schemes. The simplest scheme is the one in which each micro-instruction contains one branch which is executed when the test is true. Fig. 7 shows EOM and MAP cards which could represent this type of addressing. The NPL 500 uses an addressing scheme which is altogether different. The next address (Fig. 8) is calculated in two parts. The eleven high-order bits come from the control word itself, and the two low-order bits are the results of two tests. Thus, control can go to any one of four consecutive micro-instructions. In this case, the EOFLOW card contains the address of the first one, and the EOM card determines which branch to take. Finally, the next address could be determined by the contents of a particular register. Fig. 9 shows this with register R1.

Exercising the model

The microprograms are verified by exercising the model which was built

```
EOADDR A AUD BA CC COUNT DR       DUMMY    E EO                 FMAD FMAR     ICAR ILC IR       L
       0 0   0  0  00    00000008 00000000 0 000000000000000000 00   00000000 0    0   00129876 50
       NT OCR OPR OV PMC PSR RZ SCAR T UR       X SUM      BUS
       0  0   00  0  0   2   0  0    0 00456789 0 00000000 00000000



MEMORY PRINT FOR   MM
 000000   00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
*0003E0   00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00


MEMORY PRINT FOR   FM
 000000   00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
*000040   00000025 00000000 00000000 00000000 00000000 00000000 00000000 00000000
 000048   00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
*000078   00000000 00000000 00000000

*: *** SNAP   A  ACTIVATED     ******
MEMORY PRINT FOR   FM
*000040   00000025 00000000 00000000 00000000 00000000 00000000 00000000 00000000
 000048   00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
*000078   00000000 00000000 00000000
```

Fig. 11—Initial values of registers and memories.

up in the previous three program segments. This function is performed by the fourth segment which:

1) Initializes registers and memories by loading them with special values.
2) Monitors the intermediate values of registers, busses, and memories.
3) Specifies the address of the starting micro-instruction, along with conditions for stopping the simulation, and
4) Sets predicted values of memories and registers to be compared with the actual results.

The registers and memories are initialized by the use of LOAD cards. LOAD REG cards contain the name of the register and a right-justified hexadecimal number with which the register is initialized. An example is given in line A of Fig. 10 which puts hexadecimal 50 into register L. All registers which are not mentioned in LOAD cards are automatically set to zero. A fast or main memory is initialized by the LOAD MEM card. In addition to the name of the memory, this card contains a hexadecimal memory address. The rest of the numbers on the card are put into consecutive memory locations, starting with that address. Line B gives an example of the LOAD MEM card. It places the value 25 into location 40, memory FM.

Fig. 11 shows the computer printout that contains the initialized values of all the registers and memories in the model. The intermediate results are monitored by TRACE and SNAP cards. A TRACE card performs two functions. First, it specifies that, within a certain range in the microprogram, the contents of all registers are printed out. Secondly, it prints out the address of each micro-instruction executed within that range. The SNAP card prints out the contents of all memories within a certain range.

If many consecutive words contain the same information, they are skipped and their omission is indicated by an asterisk. Since the symbolic addresses of the micro-instructions are not printed, the TRACE instruction is usually included with a SNAP. The range of operation is specified by a starting and ending address or by a starting address and the number of micro-instructions which are to be traced. Fig. 10 gives an example of these two cards in lines C and D. The SNAP card starts its output at

```
****** TRACE  A  ACTIVATED     ******
EOADDR A AUD BA CC COUNT DR       DUMMY    E EO                 FMAD FMAR     ICAR ILC IR        L  M
2100   0 0   0  0  01    00000008 00000000 0 000000000000000000 00   00000000 0    0   00129876 50 0
       NT OCR OPR OV PMR PSR RZ SCAR T UR        X SUM      BUS
       0  0   00  0  0   2   0  0    0 00456789 0 00000008 00000000

MEMORY PRINT FOR   FM
*000040   0057FFFF 00000000 00000000 00000000 00000000 00000000 00000000 00000000
 000048   00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
*000078   00000000 00000000 00000000

EOADDR A AUD BA CC COUNT DR       DUMMY    E EO                 FMAD FMAR     ICAR ILC IR        L  M
2110   0 0   0  4  02    00000000 0057FFFF 0 000000000000000000 40   00000000 0    0   0057FFFF 50 0
       NT OCR OPR OV PMR PSR RZ SCAR T UR        X SUM      BUS
       0  0   00  0  0   2   0  0    0 00456789 0 0057FFFF 0000000C

MEMORY PRINT FOR   FM
*000040   0057FFFF 00000000 00000000 00000000 00000000 00000000 00000000 00000000
 000048   00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
*000078   00000000 00000000 00000000

EOADDR A AUD BA CC COUNT DR       DUMMY    E EO                 FMAD FMAR     ICAR ILC IR        L  M
0000   0 0   0  4  03    00000000 0057FFFF 0 000000000000000000 40   00000000 0    0   0057FFFF 50 0
       NT OCR OPR OV PMR PSR RZ SCAR T UR        X SUM      BUS
       0  0   00  0  0   2   0  0    0 00456789 0 0057FFFF 00000000

****** TRACE  A  DEACTIVATED  ******
```

Fig. 12—Printout from TRACE and SNAP cards.

micro-instruction 2100 and prints out no more than five times. The TRACE card starts tracing at micro-instruction 2100 and stops at micro-instruction 0000. Fig. 12 shows the output produced by these cards. There are three instructions that specify which portion of microcode should be simulated. These are the BEGIN, TERM and TERMS cards. The first micro-instruction to be simulated is always specified in the BEGIN card. The simulation is terminated either by reaching a certain address or by fulfilling a certain condition. The TERMS card in line E of fig. 10 specifies that the simulation stops when it reaches address 0000. Execution can also be terminated when either a predefined (EQN from EODEF section) or a symbolic equation is true. The BEGIN card contains three ways to stop the microprogram in case there is an endless loop. The simulation stops for a maximum number of output lines, a maximum number of micro-instructions executed, or a maximum time exceeded.

Additional output

In addition to the TRACE and SNAP output, there is also some output which appears with all simulation. In the beginning of the simulation, the initial values of all memories and registers are printed out. Fig. 13 shows an example of this output that corresponds to the initializing cards in Fig. 10. The final values are also printed out at the end.

Conclusion

ALSIM has proved to be a significant help in the development of some of the RCA computers. It has simulated control logic and diagnostics on machines with widely differing organization. The machines include direct and indirect control as well as read-only and user-writable control memories. In addition to simulation, the system has produced documentation and fabrication aids.

Acknowledgment

The authors would like to acknowledge important contributions made by Mr. Avijet Ghosh in formulating ideas and implementing the design. They are also grateful to Mr. E. H. Cope for valuable assistance in checking out the system.


```
ROM PROGRAM COUNTER  0000     NORMAL TERMINATION
EOADDR A AUD BA CC COUNT DR       DUMMY    E EO                 FMAD FMAR
0000   0 0   0  4  03    00000000 0057FFFF 0 000000000000000000 40   00000000
       NT OCR OPR OV PMR PSR RZ SCAR T UR        X SUM      BUS
       0  0   00  0  0   2   0  0    0 00456789 0 0057FFFF 00000000

MEMORY PRINT FOR   MM
 000000   00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
*0003E0   00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

MEMORY PRINT FOR   FM
 000000   00000000 00000000 00000000 00000000 00000000 00000000 00000000
*000040   0057FFFF 00000000 00000000 00000000 00000000 00000000 00000000
 000048   00000000 00000000 00000000

CHECK REG IR,500
******  SUPPLIED VALUE  ******  00000500
******  ACTUAL   VALUE  ******  0057FFFF

CHECK REG DR,0

CHECK MEM FM,40,16
******  SUPPLIED VALUE  ****** 00000016
******  ACTUAL   VALUE  ****** 0057FFFF
```

Fig. 13—Initial and final values corresponding to LOAD cards (Fig. 10).

Ceramic integrated circuit development

R. D. Snyder | J. W. Stephens

The following Consumer Electronics articles present the characteristics of resistors,[1] capacitors,[2] conductors and printing inks,[3] and flip-chip semiconductors[4] which may be packaged on a single alumina substrate and joined[5] with certain discrete devices such as multi-layer capacitors, inductors, diodes, transistors, and monolythic integrated circuits to make up a ceramic integrated circuit. This article describes the development process of a ceramic circuit from the selection of a circuit design to the final production circuit.

Since the early 1960's, Consumer Electronics has been actively involved in an effort to interface hybrid ceramic circuit technology with its product lines. This effort has evolved through the inventive stages of determining basic theoretical fundamentals for hybrid circuit fabrication into the establishment of an efficient manufacturing facility. Production of thick film or ceramic integrated circuits began on April 1, 1970 at the Rockville, Ind., plant. This facility contains equipment specifically designed for high-volume automatic fabrication and computer-controlled test and process capabilities.

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The process of developing a ceramic integrated circuit from an initial concept to a final circuit moving in high volume production is a lengthy one. It also requires coordination and teamwork among the many disciplines and individuals involved to minimize production lead times. Technical areas represented in this development cycle encompass electrical engineering, mechanical engineering, computer aids, drafting, photography, and laboratory analysis.

Committing a circuit design to such a complex process can be costly, and careful initial business and technical decisions are mandatory to ascertain if a given circuit design lends itself economically to thick-film technology. This planning must be achieved with insight toward the final performance requirements of the circuit and a view toward the capabilities and limitations of the development process.

Initial development

The developmental process begins with a circuit designer, who has assembled preliminary performance specifications for his design, including electrical and mechanical measurements, circuit component tolerances, and circuit partitioning requirements. This latter requirement is extremely important at this point, for it carefully defines the boundaries which will contain the circuit(s) to be considered. Next, one who is extremely familiar with hybrid components and their application to thick-film development must assemble a data package containing circuit component specifications including essential semiconductor parameters; resistor tolerances; power ratings; noise characteristics; capacitor tolerances; voltage ratings; temperature coefficient; and inductor

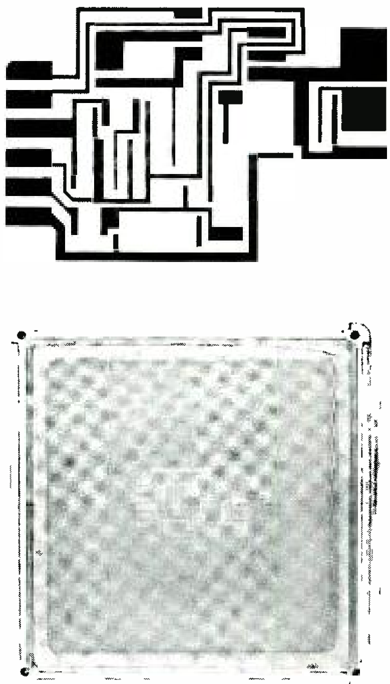

Fig. 1—Rubylith (a, top) and finished screen (b, bottom) for the metalizer pattern on a kinescope driver circuit for color television.

requirements. Specially developed computer programs are available to automatically reduce screened resistor and capacitor specifications to mechanical dimensions for use in drafting a circuit layout. The resistor program examines ink resistivity, maximum voltage and power ratings, power density, and maximum and minimum aspect ratios. The capacitor program examines dielectric constant and dielectric thickness to produce screened capacitor dimensions. Where capacitor physical sizes become unwieldy, discrete units requiring less surface area such as multiple layer ceramic chip and/or tantalum chip capacitors are carefully selected. Inductors require special attention, since good-quality, low-cost inductors with a broad range of values and high volumetric efficiency have been difficult to obtain.

The next step in the development cycle is completed with the aid of a draftsman, who is keenly familiar with circuit layout guide lines and substrate size considerations. With the guidance of an engineer, particularly where extremely critical circuits are involved, the draftsman becomes a key man in determining the final layout and package configuration. With the minimum spacing guidelines, the draftsman must now complete a series of routines in placing each component from the circuit schematic diagram on the layout for each circuit component involved. These minimum mechanical dimensions have been compiled essentially by experience gained from manufacturing considerations, and limitations and are absolutely necessary if automated high-volume production is to be expected at high yield levels. As the circuit is developed on the layout by the draftsman, the engineer simultaneously weighs his circuit performance limitations against compliance with mechanical layout guideline limitations until an optimum set of compromises is resolved.

At this stage of development, a master layout drawing of the circuit exists in a 10:1 ratio of drawing size to finished circuit size. This high ratio is used to assure extremely high definition, or resolution, and reduced effective dimensional errors in the final circuit screens.

Rubylith and screen preparation

In fabricating a circuit, the typical manufacturing sequence is as follows: substrate preparation, metalizer (conductor) pattern screening, capacitor dielectric screening, capacitor top electrode screening, resistor screening, insulator coat screening, solder material screening, discrete component attachment, and encapsulation. A photo-rubylith (Fig. 1a) is prepared from the master layout drawing of the circuit for each of these screening steps. For each process step, the rubylith positive is photographically reduced and used to prepare a negative film. A high-quality screen mesh, which is chosen consistent with the material to be screened, is used in conjunction with the photographic negative to produce a finished screen (Fig. 1b) for each manufacturing step.

Prototype sample preparation

Now that all screens for a given circuit have been carefully defined and prepared, the next important stage in the development cycle is sample circuit preparation. Small quantities of finished circuits are fabricated by the sample circuit facility for immediate electrical circuit performance checks, physical and chemical analysis of materials, and early life test data. These samples initially simulate what will be produced in high volume later in manufacturing. The circuit performance is reviewed carefully with the circuit designer at this time, before committing further work on the circuit. If the performance specifications are not met, changes in the layout require iteration of the previous development steps until the performance specifications are achieved. It is extremely important that the time involved here be minimized; this requires close coordination and cooperation of all people involved. At this point, the plans are complete for a circuit which will give the customer

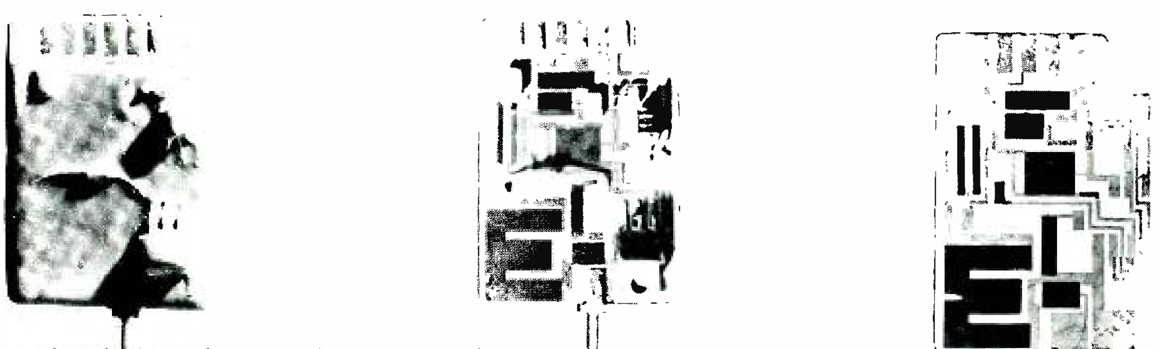

Fig. 2—Manufacturing stages for a color kinescope driver circuit.

high perfoimance levels at low costs.

As the circuit development becomes finalized, specifications and drawings relating to purchased components and materials are formalized to assist purchasing and manufacturing people in the procurement and use of these items in production. Hybrid component specifications for screened-printed resistors and capacitors are translated to "inputs" to a computer-controlled measurement system which monitors the electrical values of components on substrates emerging from firing furnaces.[6]

When a final packaged circuit has achieved satisfactory electrical, mechanical, and environmental performance requirements, approval samples are selected which represent what the customer can expect from production quantities. After these samples are given approval, manufacturing proceeds to fabricate the quantities specified by the customer on a high-volume basis. Fig. 2 typifies three important manufacturing process stages for the color kinescope driver circuit and the color demodulator circuit presently used in television receivers.

Test considerations

At a pre-determined time before production of a circuit, final electrical test equipment is simultaneously developed and used in final production as a rapid check of manufacturing output on certain important electrical specifications, which assure the customer that he is receiving a functionally acceptable product. The production output is also sampled on a quality basis with the use of specially designed test equipment, indicating not only acceptability but also more detailed information on the quality level of the product. This function is an invaluable aid to improved manufacturing process control and a definite key to building customer confidence levels.

Conclusion

Ceramic integrated circuits offer the circuit designer a hybrid manufacturing and device technology which is applicable to a broad spectrum of circuit applications. Examples of applications which have been developed (or are in the developmental process) for Consumer Electronics include chroma, video, audio, VHF, UHF for television; and audio driver and power output circuits for radio. These designs include a wide variety of hybrid and discrete components that have been designed or selected to be compatible with both ceramic circuit manufacturing technology and the circuit application.

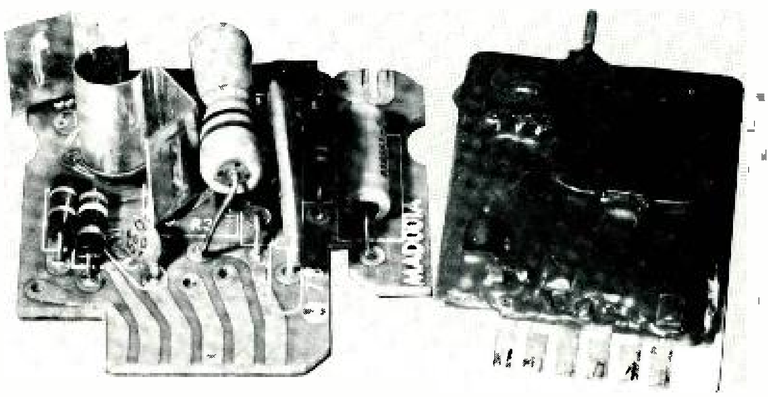

Fig. 3—Ceramic integrated circuit and discrete versions of the kinescope driver circuit.

While the development process itself is an expensive operation (as is always the case for preparing prototypes), the high-volume manufacturing capability with consistent repeatability and excellent performance provide economic advantages over other manufacturing techniques. There are other characteristics which also provide for physical and cost advantages, such as the elimination of the encapsulation and packaging of each individual component which reduces size, weight, and cost; and yet, overall circuit encapsulation provides environmental protection for the entire circuit. As an example, the ceramic kinescope driver circuit shown in Fig. 3 requires considerably less volume in the final product, does not require a heat sink on the power transistor, and is almost half the weight of the discrete version.

A unique manufacturing versatility is also realized with RCA's ceramic integrated circuit technology which includes three very important considerations: 1) The process is consistently repeatable. In-process testing of components, adjustment capabilities, and final functional testing maintain high quality levels throughout the process. 2) Design changes in many cases can be made without the necessity of the utilization of old parts and with little or no material loss. Also, different subparts for which only component value or tolerance differences are required for different product models may be made during the same production run by simply using different test and adjust conditions. 3) The capability of having different layouts for the same circuit, quick production changeover capabilities, and the standardization of package design provide the ability to have second sources both for materials in the process and for the complete ceramic circuit. Modular packaging concepts also are consistent with both conventional soldering operations and plug-in socket designs.

The process of developing a ceramic integrated circuit from initial concept to final production model involves, like most finished marketable products, a delicate balance of business and technical decisions and compromises to arrive at a product having low cost, good quality, and consequently providing high customer satisfaction.

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Joining operation for ceramic circuits—state of the art

E. R. Skaw

The ceramic circuit process engineer has several techniques available to him when it comes to joining discrete components and leads to thick-film ceramic circuits. However, considerations of reliability, strength, and electrical parameters generally limit him to only one technique—soldering. In many cases, this is a very unfortunate circumstance. Selection and application of solder and the control of the related parameters are discussed in this paper.

PROCESS ENGINEERS in both printed circuit and ceramic circuit fabrication are faced with at least one common problem—how to economically and reliably join discrete components and leads to the circuit. The ceramic circuit offers further restrictions due to its very complex metallurgy and strict processing requirements.

Thermal compression bonding, conductive epoxy, solder, and brazing are all candidates for joining components to the ceramic circuit. Thermal compression bonding works well for very small (0.010 diameter or less) wires—gold preferably—but fails for large devices and leads. Conductive epoxy is effective in applications requiring a large-area bond, and its use does not require that additional processing techniques be added to the sequence of fabrication of a thick-film circuit. However, conductive epoxy bonds do not appear to be as strong as bonds achieved by other means (e.g., solder); they are questionable as to reproducibility, especially when used for very small-area connections, and they impart high resistances in certain frequency ranges (compared to solder bonds). The complex metallurgy of the ceramic circuit and the extreme sensitivity of its many components to sudden increases in temperature completely rule out the joining technique of brazing with its high temperature requirements. Solder, at first look, appears to be the answer to all problems related to joining. It forms a strong, reproducible bond which does not impart additional resistance to the circuit. It can be applied by a variety of techniques, each of which is amenable to high-speed production. Also the use of such an old stand-by as solder makes the process engineer and electrical engineer feel a little more at home in the new and often exasperating world of thick-film ceramic circuits.

However, the use of solder is not without its problem areas, and these will be discussed in detail. This paper will review the selection of a solder, the technique of its application, and the control of the parameters employed to make the solder joint. The discussion and conclusion of this paper are a result of the author's experience with thick-film ceramic circuits which employ an 85% alumina substrate and a silver-palladium conductor system.

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Solder selection

Criteria for the selection of solder alloy include the following:

1) Wettability—does the alloy under consideration "wet" (or react with) the conductor in a controllable manner?
2) Conductor adhesion—does the application of the solder in any way disrupt the conductor-to-substrate bonding mechanism and cause a loss of adhesion?
3) Temperature selection—is the melting point of the solder sufficiently high so as to not be affected by temperature excursions to which the circuit will subsequently be subjected and yet sufficiently low so as to not degrade the circuit during its application?
4) Solder-conductor reaction—what is the nature of reaction of the solder with the conductor, i.e., is there solid solution or are intermetallic compounds formed? If compounds are formed, do they degrade the circuit or the solder connection?

Wettability

When we think of the phenomena of "wetting" we generally think of the interfacial forces as between water and glass. These forces give rise to an entire family of phenomena including capillary rise which is characterized by a characteristic interfacial angle known as the wetting angle. For solder systems, the same considerations are valid at least in a qualitative manner as they are modified* somewhat by the

*The wetting of solder systems is directly related to many other phenomena such as substrate cleanliness and particularly the nature and type of flux employed. The cleaning processes and selection of fluxes each constitute areas of investigation too large to be included in this discussion. The reader is referred to the many works which have already been published in these fields.

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A hot-plate system for reflow joining.

nature of the reaction between the solder and the basis metal which results in the formation of either a solid solution or an intermetallic compound, or both. However, the wetting phenomena applies sufficiently well to solder systems that the wetting angle can be used as a criteria for the selection of a solder alloy for any application including thick-film circuits.

The procedure for measuring the wetting angle for a thick-film circuit requires (1) the application of solder to a circuit, (2) preparation of a cross-section of the circuit, and (3) measurement of the angle between the solder and conductor. A test which is more readily performed employs a small sphere (or disk) of known diameter of the solder alloy under question. The solder sphere is placed upon the conductor and the circuit brought to a suitable temperature (30 to 50° C above the melting point of the solder) for a suitable period of time then cooled. The change in diameter of the solder sphere is determined and provides a suitable barometer of wettability for most applications.

Temperature selection

The temperature selected plays an important role in the measured wetting angle in that higher temperatures reduce the surface tension of the solder and promote the reaction between the solder and basis metal. Higher temperatures also increase the formation of oxides (tin-based solders) which tend to increase the surface tension of the solder and limit the extent of the reaction with the basis metal. Therefore, a compromise temperature must be selected.

It soon becomes obvious that the selection of the proper solder alloy offers the process engineer a fairly large degree of freedom in choosing processing parameters. For example, if a solder is chosen which has a very low wetting angle—very large change in diameter of solder sphere—then extreme control of the time-temperature cycle required for the soldering process must be achieved. On the other hand, if a very large wetting angle is selected, then, within the limits of the system, the time-temperature cycle for the soldering process is non-critical. Wetting angles in the medium to high range offer the process engineer many advantages; the time-temperature requirements are not too demanding and it is possible to selectively solder small areas without having to produce artificial "dams" to limit solder spread.

Conductor adhesion

Adhesion of the conductor to the substrate consists of many contributing factors. A physical contribution to adhesion results from the surface roughness of the substrate alumina. A chemical contribution to adhesion results from diffusion of the metal atoms into the substrate. A chemical-mechanical contribution to adhesion is a result of flux and frit partially diffusing into the substrate and bridging back to the flux and frit remaining in the conductor. A further contribution to the total adhesion may be found in oxide bridging between the conductor metal and the alumina substrate. All the mechanisms of bonding with the exception of the purely mechanical one are subject to disruption by an improperly applied soldering process or by a wrongly selected solder alloy. (Subsequent portions of this paper will pursue this matter in greater detail.)

Measuring adhesion becomes an important process control technique. It is therefore necessary that a standard procedure be established. Such a procedure—with slight modifications— is found in ASTM F1 Document 7D10 Method B. It is this author's opinion that this procedure meets all requirements of being readily and reproducibly applied to adhesion testing for ceramic circuits.

For reasons of control it is advantageous to use a solder alloy which does not have a large "plastic" region, i.e., a large spread between liquidus and solidus temperature. A few degrees centigrade are manageable, and eutectic systems are preferred.

The working temperature (melting point plus 30 to 50° C, sometimes referred to as pot temperature) should be high enough that the assembled circuit is not subject to degradation during subsequent soldering operations. A minimum melting point in the range of 180 to 200° C is necessary for most circuits as tin-lead eutectic mixtures (melting point equal to 180° C) are most commonly used for joining the thick-film circuit into the system in which it is to be used. Additionally, the circuits produce heat during operation. The melting point of the solder, and in fact, the nature of the reaction of solder with basis metal should be such that it is not affected or accelerated by the temperature of operation (adhesion values should not be reduced by more than 10% during 1000 hours of operation).

On the high end, the circuit and its components become sensitive to temperatures in excess of 500° C. Further restrictions may be found in the use of silicone or related types of insulating overcoats which may be present on the circuit.

Solder-conductor reaction

Finally the nature of the reaction of the solder with the basis metal is important. Nearly all the more common solder compositions rely upon tin being one of the major constituents. Tin forms intermetallic compounds with palladium and with gold. These intermetallic compounds tend to be hard and brittle and in the case of palladium, they are non-solderable (at least with all the more common solders). Formation of these intermetallic compounds completely destroys all chemical contributions to the adhesion mechanism, and while it is possible to control their formation during the actual soldering operation, their rate of formation at temperatures as low as 125° C is sufficiently high that complete loss of chemical adhesion is found in periods as short as four hours at that temperature.

Application of solder

Once a solder alloy has been selected as a best compromise for the criteria discussed above, the process engineer must decide how he is going to apply it to the circuit. Time-honored methods of dip or wave soldering introduce several problems including handling in volume, masking, and dissolution of the basis metal into the molten solder. The latter becomes a critical area of control since the components of the basis metal are readily soluble in the solder.

Fortunately in the last few years, solder has become available in paste or cream forms. Applications of solder in this form employs screening equipment and technology already present in a thick-film manufacturing area. Further it simplifies the application of solder to selected areas. It is critical that a sufficient volume of solder be available to adequately wet the surface being joined and form a good fillet—the strength of the solder joint being derived largely from the fillet. Ordinary stainless-steel mesh screens as currently available do not provide sufficient volumes of solder paste to accomplish a good solder joint. It is necessary to provide a backing for the screen some 0.008 to 0.010 inch in thickness. Since the application of the solder is—with few exceptions—a non-critical operation due to the flowing and wetting action of the molten solder, a perfectly acceptable solder paste mask can be prepared by machining 0.015 to 0.020-inch-thick steel sheet. Such masks are inexpensive and very durable.

Joining

The method of joining—accomplishing the actual solder joint—is one which has been widely cussed and discussed. Since the solder joining operation is the penultimate processing step in the fabrication of a circuit, it is imperative that it be an operation which has 100% yield. To accomplish this goal, it is necessary to:

1) Pre-solder the circuit,
2) Pre-solder all components and reject those which do not properly accept solder.
3) Accomplish the actual joint by a simple solder-to-solder reflow, and
4) Recognize that each component is different in mass and heat capacity and, therefore, join each separately using parameters which are optimum for each.

While all of this may sound easy, it is at this point that the real problem-child of present-day soldering techniques rears its cute little head—namely, in what form do you apply the required heat and, worse yet, how do you control it?

Conventional heating techniques consist of one form or another of resistance heated tool, (e.g., solder iron, parallel-gap, and formed resistance tool) infrared—either focused or blanket-type, convection oven or furnace or a modified hot plate. In some cases combinations of these are employed. Control of these systems is limited to varying the power level of the tool and the dwell time of the tool on the part or of the part in the hot zone. For most production purposes, it is necessary that a soldered joint be accomplished in 1 second or less which requires that the melting, holding, and cooling of the solder occupy less than 0.5 second. These requirements of time are outside the controllable response time of present-day soldering systems. Many factors come into play here. Among these are; substrate camber, tool cleanliness, and, most importantly, there is no way to measure the solder temperature at these rates.

Because of these limitations, systems have evolved which tend to treat components as equals and which attempt to ignore effects such as camber, etc. These systems involve a batch operation concept in which solder is placed on the substrate either by dipping as preform or paste. Multiple components—generally differing greatly in mass and solderability—are assembled on the circuit, which is then placed in an oven, passed through a furnace, set under an infrared lamp, or put over a glorified hot plate. In desperation, some systems have infrared lamps added to the hot plate to try and compensate for camber and differential mass effects.

Needless to say, these methods have been at best only marginally successful. However, there seems to be no alternative without better detection and control systems.

But all is not lost. In June 1970, Vanzetti Infrared and Computer Systems, Dedham, Mass., announced what most certainly will prove to be the harbinger of new concepts for ultra-high speed heat detection and control. This system combines fiber optics, solid-state infrared detectors and logic controls. The use of fiber optics permits the monitoring of very small spots—less than 0.010-inch diameter—without the necessity of making physical contact. The system as it now stands has a total response time of the order of one millisecond, a lower detection limit of about 125° C and an accuracy of 1 to 3° C. (Future improvements in fiber optic technology and in the logic circuit controls will extend the limits of this system even further.)

With the new detector-control system in mind, it is now possible to conceive a joining system which will allow each connection to be made as a separate operation with the main limit now being in the mechanical handling systems. A high-speed joining system which makes each connection separately and employs not one but two or even three heat sources—the source being chosen to provide optimum control for each component—is thus feasible. Extremely high yields are a real possibility since the proper heating parameters can be set and controlled for each individual component. It will still prove a must to pre-solder both the circuit and the components where possible as this guarantees the proper wetting of all parts and the proper volume of solder for fillet formation. And in certain critical cases, pre-soldering facilitates removal of harmful flux residue.

Acknowledgment

The author wishes to acknowledge the help of his co-workers E. Kovac and B. Terry of Consumer Electronics.

Components being placed on circuit boards. Flowing of the paste and component joining are accomplished in one operation in the infrared oven.

Capacitors for ceramic integrated circuits

J. H. Shelby

Any technology chosen to replace the present printed circuit board, discrete component technology must be capable of offering a wide range of circuit functions. The circuit functions required for consumer electronics equipment use a wide variety of capacitors. Ceramic integrated circuits now being applied to RCA's line of consumer electronic equipment can be manufactured using these capacitors as an integral part of the circuit. The required capacitors are discussed in this paper.

ELECTRONIC CIRCUITS designed and manufactured by Consumer Electronics for home entertainment products contain a variety of capacitor types. These range from small values (1 to 1000 pF) for temperature compensating capacitors to high values (0.5 to 50,000 μF) for bulk-type filter capacitors.

Capacitors for consumer electronic equipment can generally be categorized into two classes: 1) capacitors that are small enough to use on miniaturized circuits and 2) capacitors too large for miniature circuitry.

The latter group generally consists of metal canned aluminum electrolytic capacitors, and polystyrene, polyvinyl chloride, mylar, polycarbonate, and mica electrostatic capacitors.

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The capacitor requirements of miniaturized circuits cover roughly the capacitance range of 1 pF to 100 μF. The capacitors are used in bypass, coupling, and tuned circuit applications. Since there is little probability that consumer electronic circuits in the near future can be designed without these capacitors, any technology chosen to replace the present printed circuit board technology must be capable of satisfying these basic capacitor requirements.

Ceramic integrated circuit technology as developed by Consumer Electronics' Ceramic Circuit Department is capable of manufacturing circuits with capacitors in the required range of 1 pF to 100 μF. No other single technology can at present do this.

Capacitor requirements of miniaturized circuits

What general type of capacitors are used on ceramic circuits to fulfill the capacitor requirements? Table I defines and categorizes the capacitor requirements for design of miniaturized consumer electronic circuits. To meet the requirements outlined in Table I, three types of capacitors are presently used on RCA ceramic circuits: screen-printed ceramic; multilayer ceramic chip; and unencapsulated solid-tantalum chip.

Each of the three types has certain advantages over any other available type; these advantages will be examined in the following paragraphs.

Screen-printed capacitors

The American consumer electronics industry has steadily lost sales to foreign competitors over the last decade. To compete effectively with low-price foreign goods, it is necessary to lower the manufactured cost of our products. Hybrid ceramic integrated circuits produced in large volume can help lower these manufacturing costs.

Screen-printing techniques are used in ceramic circuit technology to place most passive components and conductor patterns onto ceramic substrates. Screen printing is a high-speed, highly automatic, and therefore, potentially low-cost means of making electronic circuits. It is only natural then that screen-printed capacitors have received much emphasis at CE.

The manufacturing of screen-printed capacitors requires basically four steps: 1) the bottom electrode is screen printed, dried and fired; 2) the dielectric is screen printed and dried; 3) the top electrode is screen printed and dried; and 4) the top electrode and dielectric are co-fired. Firing temperatures for capacitor dielectrics vary from +850 to +1050°C. The resultant structure consists of ceramic and metallic particulates held together by a glassy matrix. This type of monolithic structure, when constituent materials are chosen wisely, gives reliable performance. A cross section and top view of the resultant capacitor is shown in Fig. 1.

Screen-printable dielectric materials are now commercially available with dielectric constants from approximately 6 to 1000. Materials with dielectric constants up to 2000 are now being evaluated. In ceramic circuit engineering the term capacitance per square inch is used rather than

Table I—Capacitor requirements for miniaturized circuits.

Type	*Description*	*Capacitance Range*	*General Characteristics*
A	Temperature compensating	1 pF to 1000 pF	Predictable temperature coefficient Drift on life 2% or less Q greater than 1000 for N1500 or less Q greater than 500 for greater than N1500 Insulation resistance (IR) greater than 10^{11} ohms
B	General purpose	5 pF to 0.1 μF	Drift on life 10% or less IR greater than 2×10^{10} ohms Dissipation Factor (DF) less than 3%
C	General purpose	0.1 μF to 100 μF	Drift on life 10% or less DF less than 8% IR greater than 10^{8} ohms

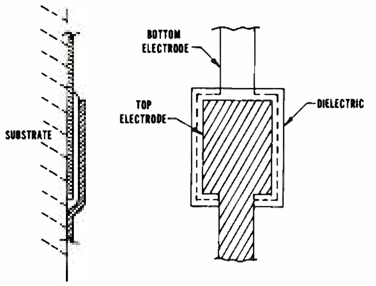

Fig. 1—Screen printed capacitor structure

dielectric constant. This term is derived as follows: $C=KA/4.45d$ where 4.45 consists of permittivity of free space and conversion factors from MKS to FPS system; C is capacitance (pF : K is the relative dielectric constant; A is mutual electrode area (in.^{2}); and d is dielectric thickness (in.).

$$C/A=K/4.45d$$

A constant dielectric thickness of 0.0022 inches was chosen after evaluation of empirical data showed insulation resistance (IR) and dissipation factor (DF) were adversely affected by thinner dielectrics. Therefore, if given a specific dielectric constant, the related capacitance per square inch would be given by $C/A=103K$. This formula is used to calculate the needed top electrode area for a capacitor. For example, a material with a dielectric constant of 1000 gives a design factor of approximately 100,000 pF per square inch. Thus, a top electrode area of 0.01 square inch would be needed to make a 1000 pF capacitor.

There is no maximum size for a screen-printed capacitor except the dimension of the substrate. However, a capacitor of dimensions 0.250 × 0.250 inch is a realistic large-size capacitor. Using this maximum area of 0.0625 square inch and a design factor of 100,000 pF per square inch, we can make a 6250 pF capacitor. Now under evaluation is a paste with a dielectric constant of 2000. This would double the present maximum capacitance to 12,500 pF. Also, a designer when using screen-printed capacitors is not restrained by standard shapes or sizes. He may choose almost any shape, e.g., square, rectangular, trepezoidal circular, or combinations of each, and within certain limits—any size.

The electrical properties of dielectric materials vary. Generally, the dissipation factor, temperature coefficient of capacitance, frequency sensitivity, and drift with life are directly proportional to relative dielectric constant. Therefore, a designer who requires low loss and stable performance should use the material with the lowest possible dielectric constant. Screen-printed ceramic capacitors have been evaluated against discrete component specifications and results show equal or, in most cases, superior performance.

Some low dielectric constant (10 to 60) materials show great promise as extremely low loss (high Q or low DF) temperature compensating capacitors. Q in excess of 1000 at 1 MHz is now obtainable. These materials are available with various capacitance coefficients of temperature, e.g., NPO, N750. Thus we can predict that Type A (see Table I) capacitors will be available in the near future as screen-printed capacitors.

A disadvantage of screen-printed capacitors has been the lack of a production means of trimming fired capacitors to obtain specific ranges of capacitance, and hence, increase yields. This production tool has been available for screen-printed resistors for many years. Either aluminum oxide abrasive powder or a laser is used for trimming resistors. Recently, glass bead abrasive powder, in conjunction with a 1 MHz capacitance bridge, successfully trimmed screen-printed capacitors to as low as 1.5 pF. This system or a laser trim system will probably be in wide production use soon.

Wide use is now made of inductor-capacitor tuned circuits in the consumer electronics industry using discrete components. Setting the tuned frequency by manually adjusting the ferrite core of an inductor has historically been a costly job. When capacitor trimming becomes a viable production tool, it is conceivable that these circuits could be manufactured using screened capacitors and the desired frequency obtained by trimming the capacitor. Thus a now costly manufacturing step could be done automatically and cheaply. This is an example of dynamic trimming.

Capacitors for tuned circuits and other applications frequently have very small values (5 to 50 pF). Since capacitance is directly proportional to electrode area and since dielectric thickness must stay relatively con-

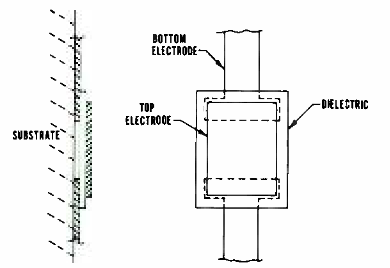

Fig. 2—"Planar" Capacitor structure

stant at approximately 0.0022 inch, top electrode areas for these capacitors become quite small. They become so small (0.01 × 0.01 inch) that they are difficult to screen print and obtain high yields. To overcome this problem, a special type of screen-printed capacitor was designed. The top and side view of this capacitor is shown in Fig. 2. Basically two capacitors are placed in series. The equivalent capacitance is given by the equation.

$$C_{eq}=C_1C_2/(C_1+C_2)$$

and for the special case where $C_1=C_2$

$$C_{eq}=C_2/2$$

This design allows us to screen print sizable top electrode areas and yet obtain very small capacitance; it allows the printing of four times the normally required top electrode area for identical capacitance values.

Multilayer ceramic capacitors

Multilayer ceramic capacitors are used on ceramic integrated circuits to fill the Type B (see Table I) capacitance requirements above approximately 0.006 μF or whenever it would be more desirable from a cost standpoint to use ceramic chips rather than screen-printed ceramic capacitors. If other chip components (discrete transistors or diodes) are placed on a circuit, the cost of placing a multilayer ceramic chip capacitor along with the other discrete chips may be less than screen printing a single capacitor. However, if the circuit uses more than one capacitor and can be designed using one dielectric paste, the screen-printed capacitor will probably be less expensive than ceramic chips even if other chip components need to be placed on the circuit. The RCA Ceramic Integrated Circuit Department has an in-house development program for multilayer chip capacitors in progress.

Multilayer ceramic chip capacitors are manufactured by stacking layers of "green" (unfired) dielectric materials that have been metalized by screen printing in such a way that every other metal layer can be joined electrically. The parallel plate structure is fired at temperatures ranging from 1200C to 1800°C. The resultant capacitor is a parallel combination of individual capacitors whose values add according to the expression $C_{eq}=C_1+C_2+C_n$, where n is the number of dielectric layers.

With this structure, very high capacitance per circuit board area can be achieved by stacking several layers. Height of these components (0.018 inch to 0.060 inch) varies depending upon the number of layers used to achieve the required capacitance. The circuit board area needed varies depending upon the manufacturer. The multilayer capacitors which we use have pads on each end of the chip as shown in Fig. 3. These pads are the electrical connections to the capacitor and are solderable. They are attached onto our metallizing system by using an RCA-designed solder flow system.

The materials used in multilayer ceramic chip capacitors give dielectric constants up to approximately 20,000. Materials with this high dielectric constant can be used in multilayers, but not in screen-printed capacitors, because multilayers can be fired at higher temperatures. Typical firing temperatures are from 1200 to 1800°C. while screen-printed dielectrics are fired below 1100°C. Electrical characteristics of multilayers are greatly dependent upon the material used and, as in screen-printed capacitor materials, electrical performance generally degrades with increasing dielectric constant. For this reason multilayer ceramic chips manufactured to meet the requirements of Type B capacitors usually contain materials of dielectric constant 2500 or less. The high dielectric constant materials are used in Type C capacitors.

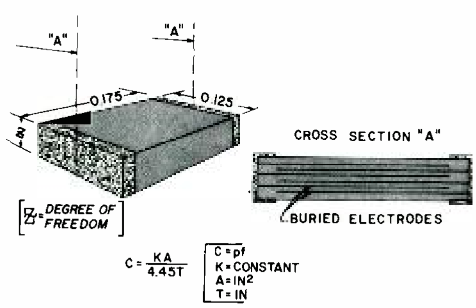

Fig. 3—Multilayer Capacitor structure

Multilayer ceramic chip capacitors which fill the requirements of Type A temperature compensating capacitors are commercially available.

Solid tantalum chip capacitors

Solid tantalum unencapsulated chip capacitors fill the requirements for Type C capacitors. Generally, if the capacitance value needed is between 0.5 and 100 μF, a solid tantalum chip will be used because it is the only commercially available capacitor in that range with a size which will fit our circuits. Although multilayer ceramic chip capacitors are available in ratings up to 10 μF, size and cost are generally prohibitive.

Solid tantalum capacitor chips are manufactured using the following general steps: slug pressing, presintering, sintering, electrochemical dielectric formation, pyrolytic deposition of MnO_2, copper plating, and solder coating. The resultant capacitor has the greatest volumetric efficiency for a capacitor (with the exception of some wet-slug tantalums) on the commercial market. It has a low profile and small over-all size (typically 0.110×0.050×0.025 inch) which makes it usable on ceramic integrated circuits. Fig. 4 is a cross sectional view of a tantalum chip.

Since these tantalum chips are unencapsulated, they are quite susceptible to physical damage. One tantalum manufacturer has designed a carrier-strip-type package in which the capacitors are shipped and handled until placed on the circuit.

Another problem is that these bare chips are susceptible to moisture absorption. The moisture absorption rate varies according to chip size and manufacturing efficiency. Moisture absorption even varies in lots supplied by the same vendor. It is important that these parts be stored in dry boxes and shipped in cartons with desiccant. Attention also should be given to the humidity level in the chip placement area. In the ceramic integrated circuit manufacturing area at CE, the relative humidity is kept below 40%.

The tantalum chip capacitor is placed on the circuit in essentially the same manner as the multilayer ceramic chip, using a solder flow technique (see Fig. 4).

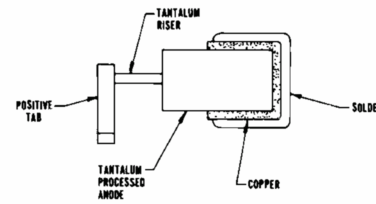

Fig. 4—Solid tantalum capacitor structure

Summary

Screen-printed capacitors provide a highly reliable component while allowing high-speed, large-scale production. Thus, screen-printed capacitors are capable of being low-cost components. Screen-printed capacitors now can meet the requirements of Type B (see Table I) capacitors through 0.006 μF and in the near future should go up to 0.012 microfarads. Screen-printed capacitors soon will have the capability of supplying all the requirements for Type A capacitors. Screen-printed capacitors can be printed to very small capacitance values with high yields and they lend themselves, coupled with trimming capability, to dynamic circuit trimming.

Multilayer ceramic chip capacitors are commercially available to fill our needs for Type A capacitors; Type B capacitors above 0.006 μF and below 0.006 μF, if there is a cost advantage over screen printed capacitors; and Type C capacitors up to approximately 0.5 μF.

Unencapsulated solid tantalum chip capacitors are used to fill the requirements for Type C capacitors. The bare chip is physically delicate and must be handled with care. Until they are finally encapsulated they must be protected from moisture.

Unencapsulated tantalum chip, ceramic multilayer chip, and screen-printed ceramic capacitors are all being used on present production circuits. Each have distinct advantages for specific applications. All three have proved to be reliable components when subjected to testing in extreme environments.

The advantages of screen-printed resistors

T. R. Allington

Thick-film technology has led to the development of the improved glaze resistor which equals the characteristics of the best composition resistors normally used in the manufacture of consumer products. The flexibility in electrical characteristics offers the circuit designer an unparalleled tool never available before with the discrete component. This paper briefly describes some of the more important advantages to be gained from using the screen-printed resistor.

THE SCREEN-PRINTED RESISTOR is made from a resistive ink, consisting of a glass frit, organic binders and solvents, and a resistive phase. The resistive phase generally consists of an oxide of either palladium, thallium, or ruthenium combined with other precious metals. In the manufacturing process, the ink is "squeegeed" through a stainless steel screen which has a photographic emulsion in the mesh where no ink (or paste) is required on the ceramic substrate positioned below the screen. The pattern then is allowed to settle, dried at an elevated temperature (125 to 150°C), and fired at temperatures between 500 and 1000°C, depending on the metal system used.

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*Since writing this article, Mr. Allington has left RCA.

If a close tolerance value is needed, e.g., ±2%, the resistors are normally adjusted to the required value by removing part of the resistive film. This is generally accomplished by using an abrasive powder or by laser evaporation of the film in an isolated area.

The electrical characteristics of the resistors depend on the metals and metal oxides used and the firing conditions. The work described in this paper is based on extensive studies of pallidium oxide/palladium/silver systems.

Test circuits

Many test circuits for evaluating screened resistors have been developed; the most frequently used one is shown in Fig. 1. This circuit provides for a range of aspect ratios (length/width) from 10 to 1 down to 1 to 5. Resistor sizes vary from 0.500 x 0.050 inch to 0.060 x 0.180 inch. A life-test facility was automated with this test circuit, the data being recorded by computer. Any effect due to changing sizes and geometry of the screened resistor also showed up on this circuit.

Also, the effect of processing on the electrical characteristics of the resistors was observed. However, this aspect of the work will not be discussed here, except to note that all resistors processed at the Indianapolis location are processed to optimize their properties and for the best possible yield for production.

Other test patterns were used to investigate effects of geometry on noise, temperature coefficient of resistance, and voltage coefficient of resistance.

All testing was carried out according

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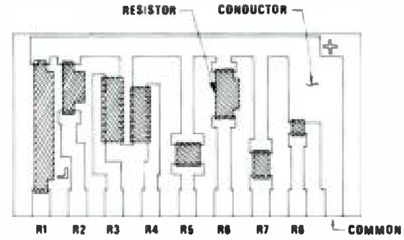

Fig. 1—Eight-resistor test circuit.

to an internal purchasing specification", which is used for evaluation of traditional discrete resistors. The target was to meet or exceed the performance of the best known components. This goal was achieved or exceeded in nearly every characteristic.

Costs

The expense of screen printing a resistor is mainly in labor and overhead, the material cost being small. Therefore, the second and subsequent resistors printed at the same time from any ink are obtained at little extra cost over printing a single resistor. A circuit with several resistors printed together then becomes very economical.

The performance of the thick-film resistor is good enough in many applications to serve as a replacement for more expensive types.[1,2,3]

Resistor value

Most carbon composition resistors with wide tolerances of ±10% or ±20% are sorted by the manufacturer from a production batch targeted around the nominal value. However, the narrow-tolerance (such as ±5%) resistors, have already been removed from the batch. Thus, a circuit designer specifying a ±10% resistor does not generally get a typical gaus-

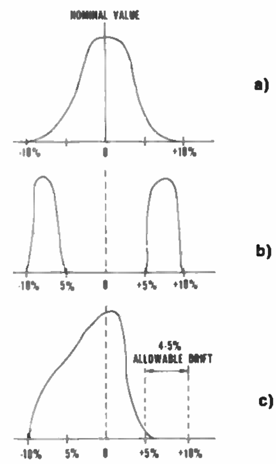

Fig. 2—a) Normal distribution; b) typical bi-modal distribution of a ±10% carbon component resistor; c) typical screen-printed adjusted distribution.

sian distribution (see Fig. 2a) around the nominal value. In fact, he gets +5 to +10% and −5 to −10%, or a bimodal distribution (see Fig. 2b).

With the screen-printed thick-film resistor, the designer gets a mixture of adjusted and unadjusted resistors and his ±10% resistor is now more truly distributed around the nominal value as shown in Fig. 2c. (The figure shows drift in the direction of increasing resistance. This is the normal drift direction.)

The thick-film resistor can be made to any value and any tolerance a designer may specify to suit his application; e.g., 96.3 kΩ±5% instead of 100 kΩ±5% as is the normal practice.

Often, a designer has to specify a more expensive ±5% resistor because a tolerance of ±10% is too wide; but the thick-film resistor can be any intermediate tolerance such as 7 or 8%; the wider the tolerance, the better the yield; the better the yield, the cheaper the resistor.

Load Life

All testing is carried out using intermittent DC load (or drift as it is commonly called). The use of DC is essential to determine any ionic drift in either resistor or substrate. Even protective coatings in direct contact with the resistor may have a deleterious effect on the resistor under load. Intermittent load is desirable to simulate typical consumer usage.

General drift of the screen-printed resistor is of the order of +2% or less in 1,000 hours, dependent on resistivity, ink supply, protective coating, and resistor geometry.[4]

The carbon composition resistor is highly reliable. However, high resistance values (over 1 MΩ) having a limiting voltage specified, operate under light DC load conditions, i.e., very low wattages such as 0.02 watt. When high humidity conditions exist with this light DC load condition, open circuits can occur with the carbon resistor. This does not happen with the screen-printed resistor. The glass/

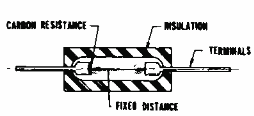

Fig. 3—Typical construction of a carbon composition resistor showing fixed interterminal length.

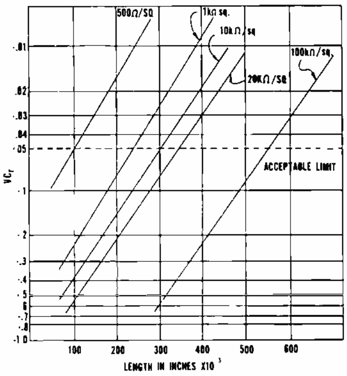

Fig. 4—Voltage coefficient of resistance and length of resistor.

metal/metal oxide resistors may change up to 6% in ohmic value but they do not open-circuit. No resistors tested at CE in Indianapolis have exhibited catastrophic failure after millions of hours of component testing under normal load conditions.

The screen-printed thick-film resistor may be designed to give any required stability. A long, thin resistor, e.g., 0.500 x 0.050 inch wide will give about 1/5 of the drift of a 0.050 x 0.050-inch resistor, all other test parameters being equal.

As with all resistors, screen-printed components also have a limiting voltage not to be exceeded. This is specified by voltage per unit length of resistor. Hence, it is only necessary to lengthen the screened resistor to increase its voltage rating. This flexibility is not available when using the limited patterns of discrete resistors. Typical composition resistors have a fixed interterminal distance (see Fig. 3).

Drift is partially a function of adjustment-nozzle height and powder flow from an air abrasive system. When this adjustment technique is optimized, most of the overspray is eliminated and a further reduction in the amount of drift and lower noise levels may be realized.[5]

The wattage rating applied to the resistor also determines the drift on load. The higher the wattage, the greater the drift. The designer may utilize this property and select the minimum size required for the power to be dissipated. This will provide a savings in material.

Overload

The testing procedure requires that all resistors used in CE must withstand an overload of 2½ times their normal wattage rating for 5 seconds without burning or changing from the initial value by more than ±2½%. In

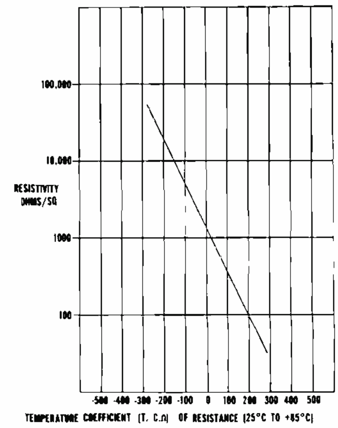

Fig. 5—Distribution of temperature coefficient of resistance with resistivity.

contrast to carbon resistors, screen-printed resistors are entirely inorganic and cannot possibly burn or even support combustion under normal atmospheric conditions. The drift on this overload test when applied to the screened thick-film resistors is generally less than 0.2%. It has been found that resistors can be overloaded by 150% and 200% for 1000 hours with changes under 3%.[6] A large safety factor may therefore be built into this type of resistor.

High-temperature aging

This test is performed with no load applied, but is carried out at 150°C for 1000 hours. Again, the screen-printed resistor remains well within 2% of its initial value and is within 3% after 4000 hours. This is a far superior performance than attained by the discrete carbon resistor. Furthermore, the drift can be reduced even further by selecting the optimum thickness of resistor. Generally, the thinner resistors perform better.[7]

Voltage coefficient

Voltage coefficient of the resistor (VC_r) is generally unimportant with low value resistors, as high voltages are not applied with normal wattage ratings. However, with values above 1000 ohms, this is a very important characteristic. Most screened materials evaluated have shown negative voltage coefficients. This characteristic is a very useful "tool" in selection of vendor materials, as varying VC_r values are available dependent on the ink system used.

The designer can also chose the VC_r needed by selection of resistivity and correct aspect ratio. Since the VC_r is inversely proportional to the length of the resistor[8] (see Fig. 4) and directly proportional to the resistivity, the lower the resistivity, the lower

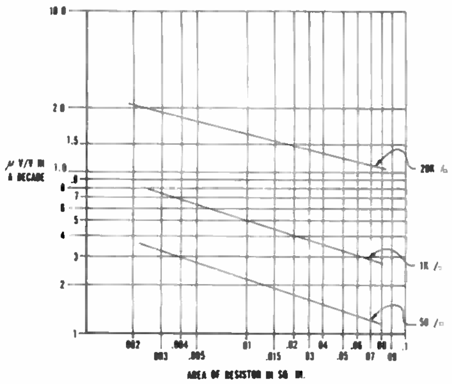

Fig. 6—Noise variation with area of resistor.

the VC_r. The discrete resistor has a fixed VC_r, whereas the screen-printed resistor can be "tailored" by changing the geometry.

Soldering effect

The effect on resistance of soldering a finished circuit containing screen-printed resistors is so negligible (less than 0.2%),[9] it can be ignored in most cases. No longer need the circuit designer worry about his parameters exceeding specification limits due to a resistor changing tolerance when it is soldered into a chassis.

Storage life

The storage life of these resistors is phenomenally good. Shelf life over 2 years show changes to be within the resistor bridge error. This may be an advantage to a buyer who has to exercise close control of his stock for fear of his resistors drifting out of tolerance as shown in Fig. 2c.

Temperature coefficient

The normal range of temperature encountered with consumer products is +25 to +85°C; hence, the work on temperature coefficient of resistance (TC_r) has been concentrated in this range.[10] The target values of TC_r of the best composition resistors available together with typical screen-printed resistors is shown in Table I. The TC_r depends largely on two factors; the processing of the resistor and its composition (or resistivity). The higher the resistivity, the more negative the TC_r (see Fig. 5). Here then is a mechanism for giving the circuit designer the TC_r requirements he needs. However, when several resistors on a circuit can be produced by screening a single ink, the TC_r for all of these resistors on that circuit will "track" together within 15 to 25 ppm. Excellent TC_r tracking is available at no extra charge when the thick film is used.

Table I—Allowable TC_r with temperature.

Nom. resistance (ohms)	*Maximum temp. coeff. (PPM/°C) averaged over indicated temp. range*
	+25 to +85°C
Thru 10	−135 +335
Over 10 thru 100	−165 +435
100 thru 1k	−215 +550
1k thru 10k	−250 +650
10k thru 100k	−300 +765
100k thru 1 meg	−335 +865
1 meg thru 10 meg	−385 +985
10 meg thru 100 meg	−415 +1100

Noise

It is well known that the least noisy resistors are the wire-wound and thin-metal-film types. It would be a logical assumption to expect the best screened resistors to be those made from the lower resistivity inks with the higher metal contents. This holds true. However, screen-printed resistors can be designed to give varying noise levels.[11] The larger the volume (or area, with constant thickness), the lower the noise (see Fig 6). The longer resistors also give lower noise levels.

New inks are being introduced which approach the low noise levels of the high-stability metal-film resistors with the added advantage of not being subject to catastrophic failure as can occur with the thin-film resistors (i.e., those with thicknesses of about 200 to 500 angstroms).

Radio frequency characteristics

The RF characteristic is the frequency at which the resistor impedance is 90% of its DC resistance. This characteristic is rarely mentioned by vendors, yet it is important to manufacturers of RF equipment. Investigation of this phenomena has led to some interesting observations.[12] The position of the resistor on the ceramic substrate, length of conductors, composition of the resistor ink, and the geometry of the resistor all interact. Measurements of RF characteristics were made on an RX meter, Boonton Model 250 A have indicated that for a typical composition resistor, the higher values rapidly deteriorate in performance. The screen-printed resistor has been designed to minimize this effect, especially for values over 50 kΩ where the discrete component behaves very poorly.

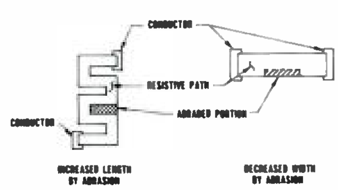

Fig. 7—Method of adjustment to improve voltage gradient effect.

Voltage limitation

This characteristic is well recognized with the discrete resistor, but has only recently been described for the thick-film resistor by Herbst.[13] Knowing the voltage limitation of the screen-printed resistor ink, the resistor can be designed to give the circuit engineer the voltage stability required by simply increasing the length of the resistor. This can be done by modifying the resistive path of the screened resistor to increase the length as shown in Fig. 7, rather than decreasing the width as is the normal practice.

New materials are already on the market with greatly increased voltage gradients from 250 volts/inch of length with the PdO/Pd/PdAg systems up to 1,000 volts/inch and more from the newer systems.

Summary

The advent of the screen-printed thick-film resistor has introduced a tool of tremendous flexibility to circuit designers. The importance, however, of good liaison between circuit designers and the materials scientist working with the screen-printed resistor inks cannot be overemphasized.

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The use of small computers for ceramic circuit production

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J. W. Stephens | L. L. Tretter

Small computers are used to provide process control in the manufacture of ceramic circuits for Consumer Electronics. This article describes the evolution of the computing facilities and the development of the present production system at CE. Independence and reliability of hardware and software are stressed, together with a description of typical problems encountered in setting up this type of new operation.

In 1966, a group of engineers were assembled at Consumer Electronics (CE) to develop ceramic-based hybrid circuits suitable for use in consumer electronic devices. (A hybrid circuit consists of a ceramic base upon which layers of conductive metalizer are screen printed, with resistors and capacitors added in successive operations. After each printing operation the circuit is fired in a traveling-belt furnace as shown in Fig. 1.) Although hybrid circuits had been in use in the electronics industry for some years, the problems facing this engineering group were unique.

During development, thousands of circuits, each with several devices, were printed and fired in tests to optimize variables such as ink viscosity, screen mesh, and firing temperature and time which influence the final value. Work was begun first with resistors and later with capacitors.

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The foremost problem was to measure test batches, recording a value for each resistor so that mean value and distribution of values could be easily compared. The solution was to lower test probes onto the circuit and take readings from a scanner and digital resistance meter; the value of the readings then were transferred to paper tape. This tape was fed through a Teletype to a time-shared computer and processed by Fortran programs. These early results proved very successful, and this work ultimately determined the evolutionary path of test equipment utilizing computers. The next step was to develop a means to handle the bulk of data analysis; for this task the Ceramic Circuit Department obtained a small computer.

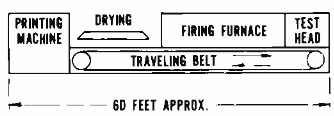

Fig. 1—Relationship of printing, drying firing, and testing.

Engineering system

The engineering measurement system incorporated a Digital Equipment Corporation's PDP8 computer which since 1967 has been the "work-horse" of the Department. With this equipment, numeric values are taken in digitized form via an interface and stored on magnetic tape for future analysis. Seven pieces of equipment have been interfaced including a semiconductor tester. Since work proceeded simultaneously in all areas of device development, the system was designed to time-share its data collecting service among them.

The software in this system is typical of that used in special purpose, small computer systems. It was written in assembly language and expanded as new measuring devices were added. All basic software for the system, such as floating point and arithmetic routines, were written as required.

A background mode was provided for simultaneous analysis of data previously stored. Fortran language analysis programs were developed to calculate mean and standard deviation of data batches, draw histograms on a plotter, and calculate percentage change in devices resulting from life testing.

As the volume of data collected daily on this system grew, attention turned to the possibility of using the computer at night. This was considered feasible since analysis routines were run in a batch mode, and reliability of the machine was high. So, unattended computer operation was developed and christened, "Fly-by-Night."

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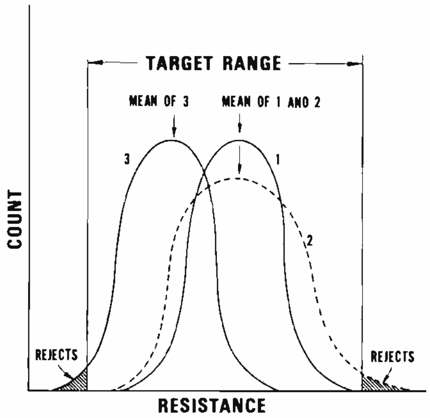

Fig. 2—Distribution of resistance value.

To get into the system, each engineer with measurements awaiting analysis prepared a short punched-paper-tape. These individual tapes were combined on a single tape and conveyed to the computer operating system (1) the name of an analysis program which is loaded from magnetic tape, and (2) the location of data.

A high-speed punch output contains the results of the analysis and, on completion, each program exits to the operating system which loads the next program. Embodied in this system are error-detection and recovery procedures which prevent the computer from halting until all programs have been executed, after which the operating system shuts off the computer and the external input/output devices. This system is still in use for engineering development.

Process control

It was found from printing and firing test batches of resistors that plotting a histogram for a single device produces a distribution as in curve 1 of Fig. 2. Repeating the same test at a later time might produce histograms resembling those in curves 2 or 3, when either mean value or distribution have changed. It was obvious, therefore, that although all the known variables were optimized, there are still many unknown factors.

It was customary to specify a nominal value for a component and its tolerance; this corresponds with the Target Range in Fig. 2. It required planning to keep the bulk of the population within this range. A single parameter which could be changed late in the printing and firing sequence was needed to control the final value. It was found that the value of a resistor varies with temperature and time of firing as shown in Fig. 3. Since firing is the last operation in the sequence, changing the belt speed of the furnace provided the necessary control tool.

During an extended printing trial, consecutive samples of circuits were measured and appropriate changes made in the belt speed to keep the mean value within a previously chosen range. For best results, the time interval between evaluating the mean value and deciding how much to change the belt speed had to be small.

Production requirements

It was necessary to calculate yield and reduce losses in production by removing circuits which could never be good at early stages in the process.

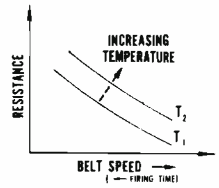

Fig. 3—Influence of firing temperature and time in resistance value.

This required testing every component on a circuit at key points—clearly a job for a computer, but of what size?

By late 1968, the initial concept envisaged a system having one furnace for producing resistors and one for capacitors with provision for an additional furnace for each. This immediately determined that there would be four measuring stations. The planned production rate required processing two circuits per second, i.e., one at each furnace with a component density of twelve resistors and four capacitors. The system would be required to make over 60 measurements per second and sort each circuit.

Another consideration was that the system had to have high reliability; This meant back-ups for the computer, also, a high degree of independence was needed between furnaces. If one stage of the production were to have problems, the others must not be interrupted.

The feature of storing data had proved useful and was to be incorporated. The rates of measurement envisaged required automatic handling and probing of each substrate with the computer issuing the necessary control signals and deciding

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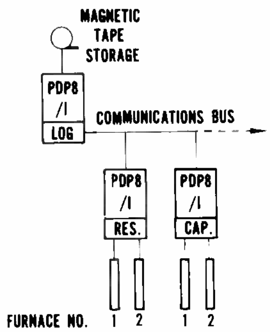

Fig. 4—Interconnection of computers on the communication bus.

where to sort the circuits when unloading. The measuring equipment was to use a programmable scanner and bridge which requires the computer to issue a command to initiate measurement of each device. Production data was needed quickly and in real time, hard copy being a prerequisite.

Computer selection

One medium-size computer was considered but found lacking in three crucial respects:

1) The whole system would have to be finished, debugged, and put into operation simultaneously.
2) The requirements of "modular-independence" would not be met.
3) The interrupt and data processing rate would nearly saturate a single computer.

The engineering machine (PDP8 computer) had proved reliable, and considerable software and hardware experience had been accumulated; therefore, three Digital Equipment Corporation PDP8/I computers were chosen and interconnected as shown in Fig. 4.

Each computer has a standard capacity of 8,192 twelve-bit words. To implement the second furnace in the case of the resistor and capacitor systems, requires the addition of 4,096 words. All three computers have an optional extended arithmetic element which consists of circuits that perform integer multiply and divide operations. The engineering PDP8 computer is the same configuration as the production computers except it has discrete circuit logic instead of integrated circuit logic. The PDP8 and all the PDP8/I's have ASR 33 Teletypes for output of hard copy.

System hardware

Both the resistor and capacitor systems are located in the production area near the measuring stations and are packaged in RFI shielded cabinets to eliminate noise problems. Each system is totally independent, but connected to a common communication bus allowing the data collected to be transmitted to a central computer which records the data on magnetic tape for later evaluation. All three computer systems were designed to allow interchangeability between computer main frames. If a computer failure occurs in either the resistor or capacitor system, the main frame of the data collection system can be removed from that system and interchanged with the malfunctioning computer in approximately thirty minutes. During the period of time required to repair the faulty computer, only the ability to log data is forfeited.

The hardware for both the resistor and capacitor systems is the same (see Figs. 5 and 6) except for the actual measurement device and its associated interface to the PDP8/I computer. Each system has circuit handlers moving and sorting measured circuits on command from the handler interface. Associated with each handler is the test head with as many as 24 probes for testing of a circuit. Under control of the computer, the test and scanner interface can connect through the scanner any two of these probes to the test instrument input and perform a measurement on the component being probed.

Each system has instrumentation for the measurement of the belt speeds of the two furnaces under control. These measurements are entered to the computer by way of the belt-speed interface. Both systems have interfaces for output of fixed error and information messages to a system display, which provides a quick method of communication with the operator.

All three of the production computers have interfaces which allow each to communicate with any other computer under program control. The communication system allows the connection of additional computers to the communication bus without having to modify any of the existing hardware or software.

One of the uses of the communication system is the loading of the test and production programs for use by the resistor and capacitor systems. If a failure occurs in the communication bus, each of the computers can interface with a portable high-speed paper-tape reader for loading these programs.

System self test

One very important capability of the test system is being able to rapidly check its own test accuracy and system operation. Each system has a test module which contains a set of standard components and control circuits to check the test accuracy of each range of the test instrument and each channel of the scanner. A special computer program controls the operation of the system and checks each function for operational malfunctions and measurement errors. This program and a complete set of computer diagnostic routines are run daily as a routine system test and can also be used as a valuable trouble-shooting aid.

In addition to the test module, each system has a set of basic standard components which are measured after every twenty circuits during production testing. This capability constantly monitors the general operation and accuracy of the system.

Component measurement accuracy and speed

The test equipment for the resistor system is a Vidar 521 integrating digital voltmeter and a Vidar 531 ohms-to-volts converter. The system measures resistors from 1 ohm to 10 megohms with an accuracy of 0.1% and a system speed of about 40 milliseconds per measurement.

The test instrument for the capacitor system is a General Radio Co. Type 1680-A automatic capacitor bridge. The bridge measures both capacitance and conductance values ranging from 1 picofarad to 100 microfarads and 1 nanomho to 1 mho, respectively. Basic measurement accuracy is 0.1% of the reading; however, for measurements made at the extremes of each range the accuracy decreases de-

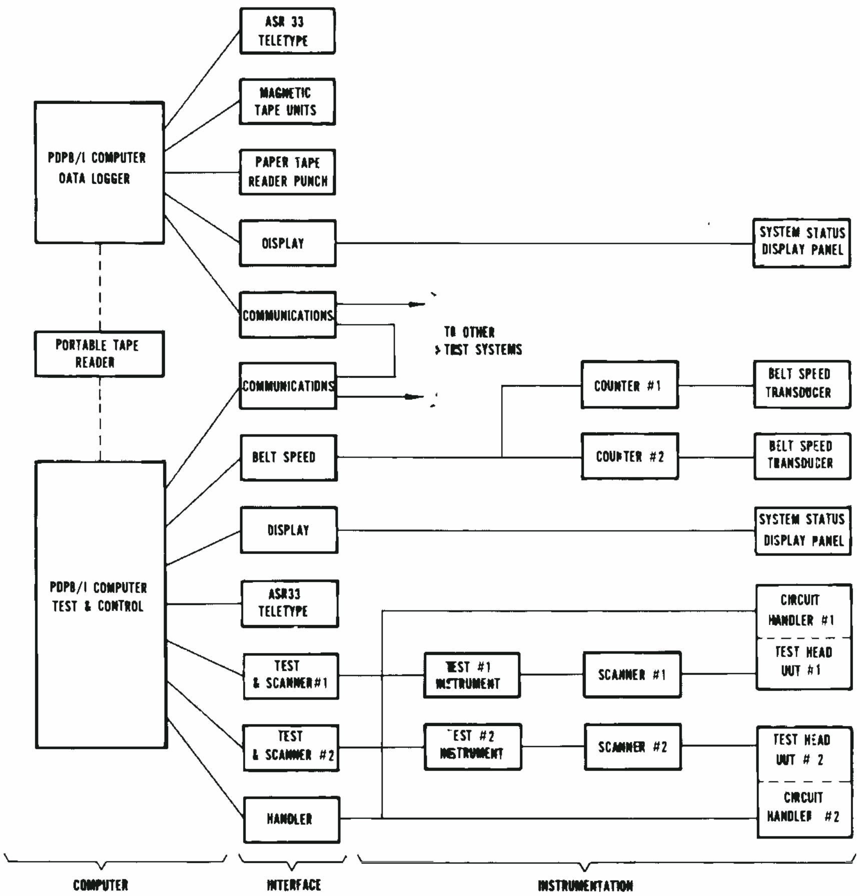

Fig. 5—Block diagram of system used for measuring and logging data.

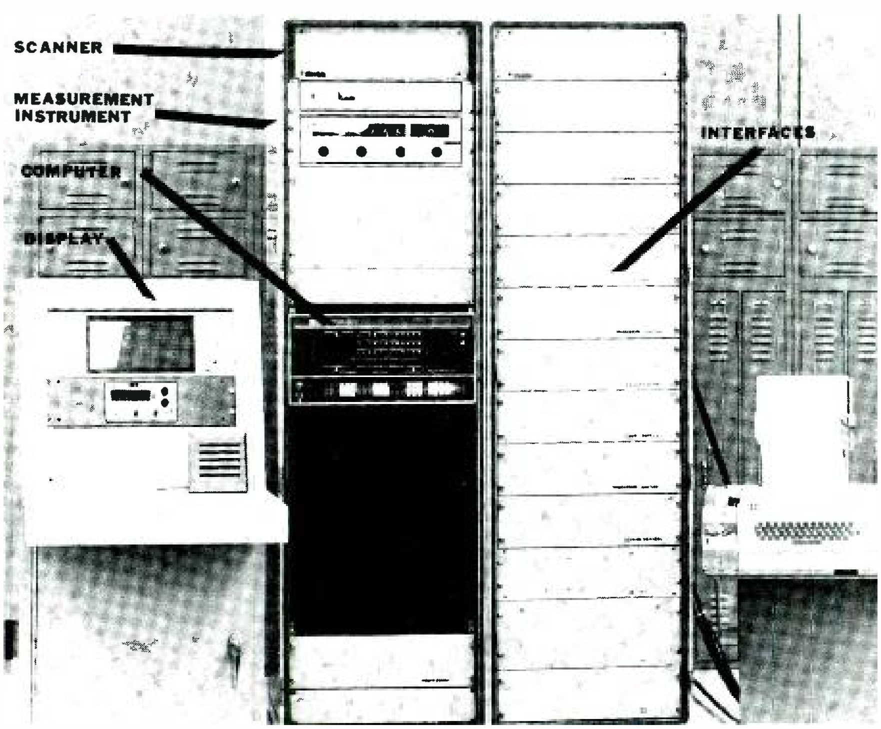

Fig. 6—The assembled measuring system.

pending on the range and ratio of capacitance to conductance. Typical measurement speeds are 300 to 600 milliseconds per capacitor depending on range changes and value.

Production software concepts

When planning the production system, it was decided to use the Fortran programming language as much as possible. Some efficiency in program size and speed were sacrificed in order to take advantage of the higher level language. These advantages include the following:

1) Less overall time required in program development and later modifications,
2) Availability of previously written arithmetic functions,
3) Formatted input/output operations, and
4) Use of a language understood by engineering personnel.

The resulting software structure consists of one 4-K bank of memory containing Fortran language programs and one 4-K bank of memory containing assembly language routines. In general, the assembly language routines are the input/output and related basic "system" programs while the Fortran routines perform process control calculations on the data, checking that it is within limits, and generating information for the system operator as required.

Measurement system software

The resistor measurement system controls the following functions:

1) Measurement of each resistor on a circuit, comparison of the individual values with sets of limits, and sorting of the circuit as either "good", "adjustable" (by reworking one or more components), or "reject".
2) Transmission to the logging computer for recording on magnetic tape the value of each resistor on a circuit.
3) Periodic typing out of a running mean value and histogram for each resistor, for observation by the operator.
4) Displaying to the operator the status of the system, including any information requiring his attention.
5) Typing specific process control instructions for the operator.
6) Typing out the value of each resistor on a specific circuit upon request.

A flow chart for these operations is shown in Fig. 7. All information required to setup the measurement sys-

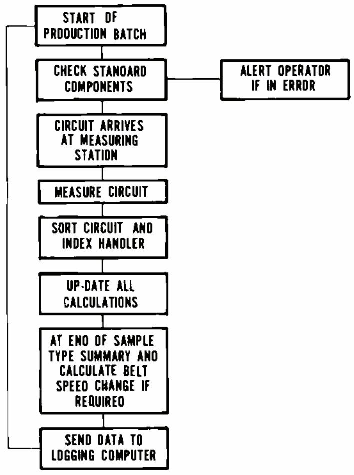

Fig. 7—Operations required to test circuits.

tem for a particular circuit is entered on a circuit parameter tape through the teletypewriter. When production personnel change circuits, only a new circuit parameter tape and test head are required.

Process control involves keeping the mean value of one selected resistor on the circuit, called the control resistor, within a pair of limits designated "action" limits. This control resistor is usually chosen to be the one with the least tolerance. Since the value of each of the resistors on the circuit varies in the same way as a function of furnace belt speed, changing the belt speed to keep the control resistor within its action limits also keeps the other resistors on the circuit within their ranges. Fig. 8 shows the relationships of the limits with which each resistor is compared and the action limits, which apply only to the control resistor. If the mean value of the control resistor drifts outside the action limits during a sample, at the end of the sample a new belt speed is calculated. The operator is alerted and the new target belt speed setting is typed. Presently, belt speed changes are implemented manually; however,

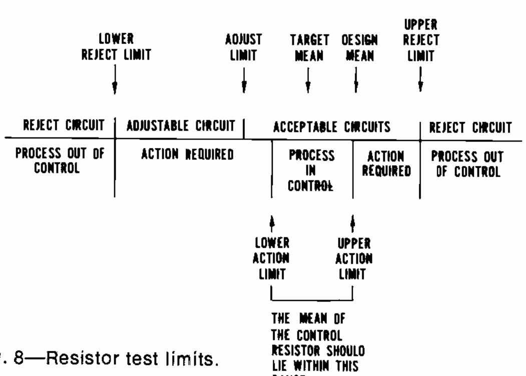

Fig. 8—Resistor test limits.

in the future this can be converted to a computer controlled operation.

The relationship between belt speed and resistance is described by a second degree polynomial, which for small changes can be approximated by a linear function. Thus the calculations are based upon the linear relationship $y=mx+b$, where y is the control resistor value, x is belt speed, and m and b are values initially entered from paper tape. Actually m and b may vary from their predetermined values due to changes in the production environment and properties of the resistive inks. At the end of each sample, new values for m and b are computed and used for a closer approximation.

The running mean values are computed for a group of consecutive circuits called a sample. Also a six-cell histogram is kept for each of the resistors and typed out with the mean at the end of the sample.

All of the data required for initializing the system for a particular circuit is entered into the computer by reading a paper tape with the teletypewriter. During initialization, the time and date are typed in. The time is used to set a clock which is thereafter updated by the system. The time and date are printed with certain of the output data to provide a time reference. They are also sent along and stored with each block of data logged to provide an easy method for identifying the data when it is subsequently retrieved for analysis.

The capacitor measurement system performs the same functions as the resistor system except that at this time, no process control information is provided to the operator. For capacitors, both capacitance and dissipation factor are compared with limits before sorting.

The programs for both measurement systems are stored on magnetic tape at the logging machine. Before production commences each day, the programs are sent from the logging machine via the communication system to the measurement systems.

Data logging system software

The main function of the logging system is to record, on magnetic tape, data received from the measurement systems via the communication system. Features of the logging system include the ability to initialize new tapes while data is being recorded and automatic switching between tapes when one becomes full. The logging machine is located in the computer room where a display shows the status of the entire production system. The logging computer utilizes a multi-programming scheme permitting routines to be called from magnetic tape on demand and executed while data collection continues.

Off-line circuit parameter tape preparation

To minimize the time required to enter the circuit parameters into the measurement systems, a compressed data format is used for the data tapes. To aid in preparing the tape, a Fortran program is run on a computer time-sharing system. The operator enters the data from the master layout drawing into the program which makes certain validity checks on the data, converts the tolerances taken from the drawing into absolute limits as required by the measurement systems, and punches out at the teletypewriter the compressed format parameter tape. The generated tape is then read back into a verification program to ensure that no transmission errors occurred during the process.

Conclusion

The system described in this paper is used for a special purpose, but a number of basic concepts are used which would be important to any production control scheme. Those concepts are:

1) Dividing a large system into a number of subsystems tied together by a communication bus so that they are still independent. This independence provides both inherent reliability and the capability to build up and expand the system in modular steps.
2) Using a high-level language for much of the software to conserve the time required to implement or modify a system.
3) Implementing a system such that intervention by the programming staff is not required when routine production changeovers occur.
4) Developing hardware and software within the department which provides engineering support to production. Thus, additional features can be added to the system after a period of use in the production facility.

Flip-chip semiconductor devices for hybrid circuits

B. A. Hegarty

Ceramic modules using thick-film processes are becoming increasingly important as a circuit manufacturing method. The design, manufacture, and attachment of active devices compatible with such modules is discussed. The author concludes that solder reflow flip-chips form the most attractive system and will have far-reaching implications in the circuit manufacturing field.

In the manufacturing of thick-film modules, of critical importance is the question of how to add *active* components. This paper describes the current approach of Consumer Electronics (CE) to this problem. It will be seen that, at least for transistors and diodes, the preferred technique is the use of solder reflow flip-chip devices. The processing of such chips is discussed as well as aspects of the bonding to the ceramic circuit boards.

Why flip-chips?

Some aspects of existing thick-film processing at CE and its future volume predictions should first be considered. The three-year forecast for circuit production is approximately 10 million modules per year. To process these through the various printing and trimming steps, each individual circuit module has to be handled at a rate of one per second. This is achieved by expensive precision automatic equipment. All modules are automatically placed in precision alignment under various screen-printing heads and then conductors, resistors, and capacitors are successively printed. This use of automatic equipment rather than hand labor is, of course, an important point in the overall economics of circuit manufacture. To fit this rate of module processing, active components (assuming four per circuit), must be placed at roughly the same rate.

To examine the question "Why flip-chips?" an evaluation of the following possible alternative components is necessary:

1) Conventional aluminum chips.
2) Conventional plastic encapsulated chips.
3) Beam-lead chips.
4) Solder reflow flip-chips.

Each of these have to be evaluated against the ultimate yardstick composed of overall circuit cost, reliability, and flexibility.

Given the above mentioned volume and rate requirements, a comparison can be made of the various alternatives as they apply to this particular thick-film manufacturing technology (see Table I).

As might be expected, the status quo represented by current manufacturing, (conventional chips and plastic encapsulated chips), gives the greatest immediate flexibility. However, its inherently poor showing on overall cost and reliability demands that other answers be found.

CE has critically investigated single-step bonding processes, particularly solder reflow which appears to be the best system, at least for transistors and diodes. Pilot facilities have been setup to process wafers to the conventional aluminum stage and then finish with solder bumps.

In spite of the good rating given to flip-chips in Table I with regard to their adaptability to IC's, sourcing and second sourcing may be difficult. Beam-leaded devices offer the next most attractive alternative and as the relative volume of IC's will be smaller, so problems associated with their slower placement capability are not immediately serious.

Flip-Chip processing and bonding

Wafer processing

CE has developed an inexpensive process, outlined in Fig. 1, for making

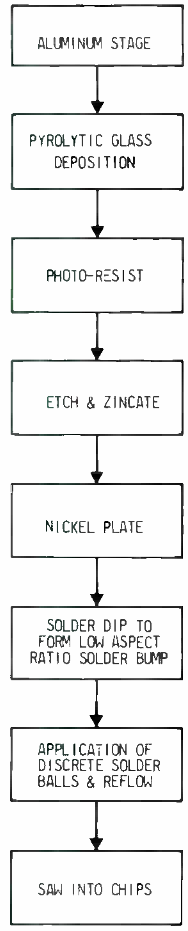

Fig. 1—Flip-chip wafer processing.

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received the B. Sc. (Honors) from National University of Ireland in 1960. He first worked at Westinghouse Physical Research Labs in England on high-voltage, high-power diodes and diffusion techniques. In 1964, Mr. Hegarty began work at S.T.C. Semiconductors on four-layer devices, thyristors, gate-controlled switches, and bi-directional switches. In 1967, he joined the Ceramic Circuits Department of Consumer Electronics, Indianapolis and has since investigated single-step bonding processes for semiconductor devices, especially solder reflow flip-chips for low-cost, high-volume circuits.

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Table I—Comparison chart to show device compatibility with thick-film manufacturing technology.

	Cost					*Reliability*				*Flexibility factors*					*Total Rating*
	Basic cost	*Placing cost*	*Placing Speed*	*Repair-ability*	*Overall Rating*	*Bond strength*	*Hermet-icity*	*Handling Rugged-ness*	*Overall Rating*	*Avail-ability*	*Variety*	*Power Handling*	*Expand-able to I.C.'s*	*Overall rating*	
Aluminum chips (wire bond)	V. Good	V. Poor	V. Poor	Poor	V. Poor	Poor	Poor	Poor	Poor	V. Good	V. Good	Fair	Good	Good	Poor
Plastic encapsulated (solder reflow)	Good	V. Poor	V. Poor	Good	Fair	Fair	Fair	Good	Fair	V. Good	V. Good	Fair	† Poor	Good	Fair
Beam-lead (T.C. bond)**	* Poor	Fair	Fair	Good	Fair	Good	V. Good	Poor	Good	Poor	V. Poor	Fair	V. Good	Poor	Fair
Flip-chips (solder reflow)	* Good	V. Good	V. Good	Fair	Good	Good	Good	V. Good	Good	Poor	Poor	Good	Good	Fair	Good

* Includes cost of masks, etc. for new design.
† Takes up too much real estate on circuit board.
** Thermal compression bond.

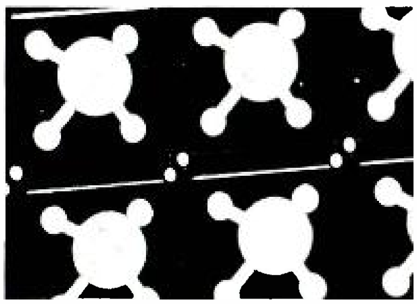


Fig. 2—Wafer at aluminum stage.

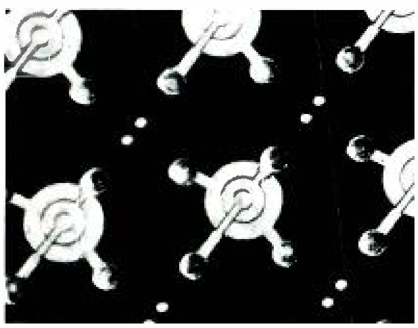


Fig. 3—Wafer after solder dipping.

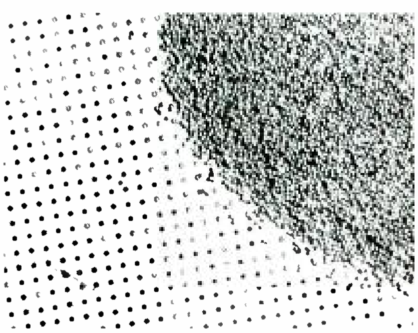
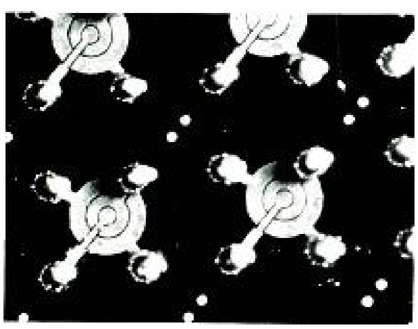


Fig. 4—a) Application of discrete solder balls; b) wafer with high aspect ratio solder balls.



glass-encapsulated solder-bump semiconductor devices. Basically the steps are as follows:

1) Conventional planar processing to the aluminum stage using relatively thick aluminum, 16kÅ, (see Fig. 2).

2) Pyrolytic deposition of a thick (2-3 μm) boro-silicate glass of such a composition to closely match the expansion coefficient of silicon. This allows the deposition of such a thick film without cracking. This glass is then densified in steam at 450°C for two hours.

3) Photo-resist masking of the glassed wafer to allow etching of selective holes over the aluminum contact pads.

4) Using an hydrofluoric acid mixture containing a zinc ion, the glass is etched to the aluminum pads; preferential plating of zinc now takes place on the aluminum.

5) Displacement of zinc by nickel in an electroless nickel bath.

6) Dipping of the wafer in a solder bath to form low-aspect-ratio solder bumps; 5 mils diameter by 1 mil high, 1:6 (see Fig. 3).

7) Application of discrete solder balls through a metal mask to the fluxed wafer so as to provide one solder ball over each bump. On reflowing, a large aspect ratio solder bump (1:1) is formed which is necessary for self-registration bonding (see Figs 4a and 4b).

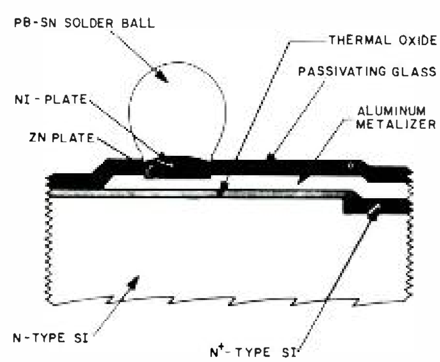


Fig. 5—Cross-section through solder bump (not to scale).

This method for wafer processing results in a well-passivated structure with a thick dense glass, completely protecting the aluminum against scratching and metal corrosion. It also adequately protects the substructure consisting of the diffused junctions. A cross section of the completed structure is shown in Fig. 5.

Chip handling

In this method, the wafer is diced using a slurry saw to provide chips with regular vertical sides, allowing it to be used in conventional vibratory feeders. The chips are fed along an inclined grooved track which discards those with the bumps facing upward.

Commercially available chip handlers are now used to test and classify each chip. An attractive feature of flip-chips is their handling ruggedness, enabling them to be sorted and resorted many times.

Good chips are now transferred to a similar piece of handling equipment, which has a station where circuit boards can be placed. The prototype shown in Fig. 6 requires only that the boards be manually placed in receiving nests. The chips are automatically placed, with coarse alignment, on various programmed points on the circuit. This type of placement head or multiple heads may be attached to an automatic substrate handler such as is used in the printing operations.

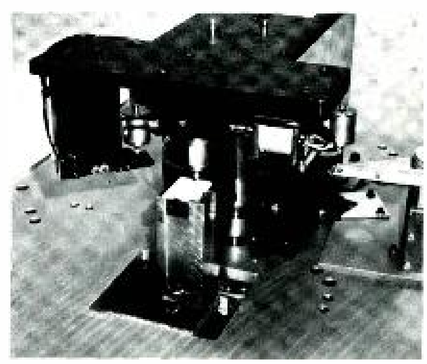


Fig. 6—Prototype placement equipment.

Chip-to-circuit bonding

By a combination of the solder-bump aspect ratio and the geometry of the metallizer pattern on the substrate, a unique chip self-registration process is obtained. See Figs. 7a and 7b.

The circuit is fluxed and the chip placed in a coarse alignment position. To achieve complete wetting by the four bumps, all that is necessary is for the chip to be placed such that just two bumps touch the metallizer pads anywhere within the 9-mil-diameter circle. See Figs. 8a and 9.

The circuit is now reflowed on a hot plate or other heat source until the solder melts. The wetting of the first two substrate pads then brings the chip down as the solder spreads to fill the whole pad. The tendency for the solder to form a minimum surface area vertical column while liquid, causes the chip to move into precise alignment and the remaining bumps to solder. The confining shape of the lead-out pattern (5 mils, see Fig. 7b) constricts the flow of solder away from the pad area during the short reflow cycle. This maintains the chip 2 to 3 mils off the substrate after reflow. See Fig. 8b.

This self-registration phenomenon, as demonstrated in Fig. 9, greatly reduces the need for ultra-precise placement of the chip on the circuit board by mechanical equipment and is an outstanding feature of the solder reflow process.

In Fig. 10, the chip is shown sheared from its mounting. The failure mechanism in this case is the disruption of the metallizer-ceramic interface. Shear strengths up to 100 gm/bump are standard.

Device design

As is clear from Table 1, there is a strictly limited range of flip-chip devices presently available to a circuit designer. Devices currently available within CE in flip-chip form include a wide range of general purpose NPN planar epitaxial transistors and diodes. In development are high voltage and PNP general purpose devices. All are planar structures, have four bumps and are on chips of identical mechanical size and shape.

Flip-chips properly designed, are in no way inferior to conventional back side contact devices and in many cases are superior. With optimum base collector design, saturation voltages are not a problem.

One interesting and extremely useful innovation using flip-chips is to place the emitters directly under the solder bumps. In this way, heat generated in the collector-base junction under the emitters is transmitted directly to the substrate, resulting in a very low thermal resistance from junction to substrate. A few devices using this principle are in the design and evaluation stages (see Fig. 11). So far, thermal resistances as low as 10°C/watt from junction to substrate have been obtained for devices with 320-sq. mil emitter areas.

Circuit crossovers can also be designed in many varieties on flip-chips and can be more attractive economically than printed crossovers when only a few are required.

Conclusions

Hybrid circuit manufacture, using solder reflow flip-chips, provides an excellent technical and economical system for high-volume, low-cost circuits. Many basically different types of devices can be placed on the same circuit allowing the designer wide freedom of choice. Flip-chips, with their inherent ruggedness, and the ease with which they can be handled due to their regular shape, combined only with the need for coarse placement accuracy because of the self-registration mechanism, will add a new dimension to linear circuit design manufacture and reliability.

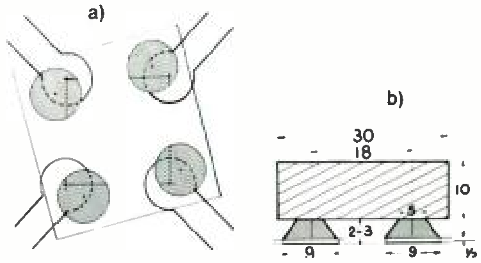


Fig. 8—a) Chip placement (view through chip); b) chip and circuit after reflow.

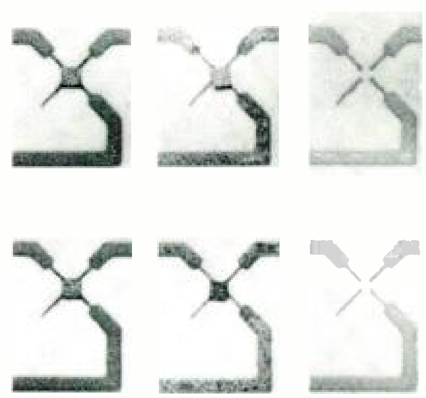


Fig. 9—a) Actual test circuit; b) with coarse replacement of chip; c) after reflow.


Fig. 10—Chip sheared from substrate.

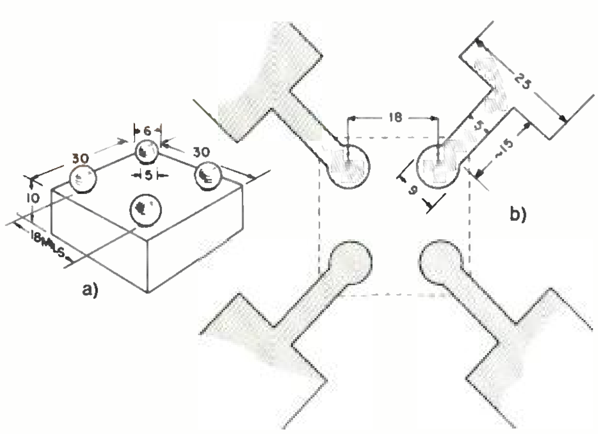


Fig. 7—a) Chip outline; b) metallizer pattern on ceramic.

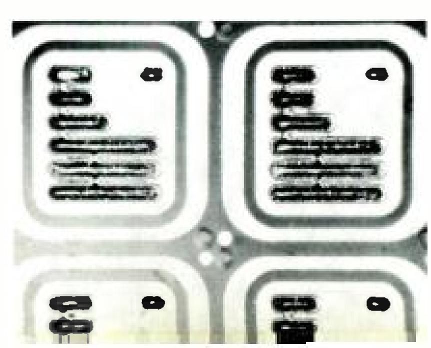


Fig. 11—Experimental device with solder stripes on the emitters.

Rheological properties of printing inks

Y. H. Wang

In an investigation conducted at CE, a Ferranti-Shirley cone and plate viscometer was utilized to characterize the rheological properties of thick-film inks. Rheograms were obtained for structural breakdown during repetitive runs at constant shear. An attempt was made to relate rheological differences among the various inks investigated. A feasibility study for the establishment of process control criteria is also discussed.

THICK FILMS are layers of conductive, dielectric or resistive inks that are deposited on a substrate. The ink contains the necessary polycrystalline solid ingredients having various electrical characteristics—high metal content for conductors, a proportion of high dielectric constant glasses for capacitors, and various resistivity oxides and metals for resistors. These solids are suspended in liquids forming a highly viscous suspension. To keep the solids in suspension, gel forming materials may be utilized.

The flow properties, or rheology, of inks are among the factors that determine the amount of ink deposited on a ceramic substrate by screening. Rheology interacts with other factors of the screening process such as mesh size, squeegee pressure, speed and direction of screening, and line width. Therefore, an understanding of the rheological properties of inks is necessary not only to explain the mechanism of ink transfer, but to predict a screened thickness and to increase uniformity and precision of screened images.

In a project at CE, a Ferranti-Shirley cone and plate viscometer was used to characterize the rheological properties of conductive, dielectric, and resistive inks. Rheograms and data have been obtained showing changes in flow properties with repetitive cycling. A uniformity evaluation was also performed at constant shear. An attempt is being made to determine rheological differences among all types of ink.

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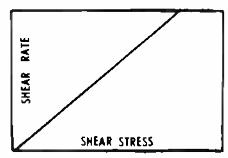
General principles

Rheology is the science dealing with the deformation and flow of matter. Deformation is a movement of parts or particles of a material or body relative to one another, such that the continuity of the body is not destroyed. If under the action of finite forces the deformation of the body increases with time continuously and indefinitely, the material is said to flow.[1]

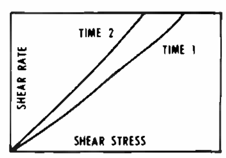
Ideal viscous bodies display flow, with the rate of flow being a function of the stress. The coefficient of viscosity is defined as the ratio of shear stress to shear strain rate. The coefficient of viscosity is measured in terms of "poise" and is generally called simply viscosity. Many fluids do not exhibit simple viscosity. In some cases an elastic deformation may occur before true flow begins. In other cases the shear strain rate is not directly proportional to the shear stress; the viscosity is not constant but varies with shear rate. Another effect may be manifest as a decrease of viscosity with time under constant shear rate. Where these effects occur, they are usually combined in various degrees, i.e., they usually occur in combination and are known as viscoelastic effects.

Elastic deformation is always held to be a function of stress, where the rate of deformation for flow is a function of shear. Differential equations describing combined viscoelastic effects are generally setup with three basic terms: an elastic one involving deformation, a viscous one involving rate of deformation, and an inertial term involving acceleration.[2]

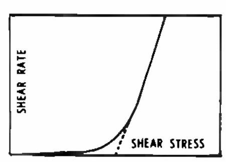
Flow is also described as being



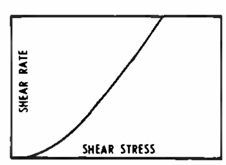
a) Newtonian: the resistance of newtonian systems is independent of rate of shear and time.



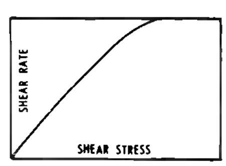
b) Non-newtonian thixotropic: the resistance to flow of thixotropic materials decreases with time and/or with increased rate of shear.



c) Non-newtonian plastic: beyond a given rate of shear, permanent physical deformation will result and resistance to flow will be independent of rate of shear.



d) Non-newtonian pseudo-plastic: the resistance to flow of pseudo-plastic materials decreases with increasing rate of shear, but stabilizes at comparatively high rate of shear.



e) Non-newtonian dilatant: the resistance to flow increases with rate of shear due to increased friction between internal particles.

Fig. 1—Typical viscosity graphs.

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received the MS in Mathematical Statistics from Purdue in 1959. In 1959, he joined the Television Picture Tube operation at Marion, Indiana as design and development engineer. In 1961, he worked at the Chemical and Physical Laboratory of Record Engineering. His primary responsibilities were in experimental design, system engineering related to control and operational systems, and consultation in the fields of mathematics and statistics at divisional level. In 1967, he joined the Ceramic Circuit Development group and has been working in the area of material engineering, evaluation, and process system. He is a member of the American Statistical Association, Operations Research Society of America, Institute of Mathematical Statistics, and is listed in American Men of Science.

*Since this article was written, Mr. Wang has left RCA.

either Newtonian or non-Newtonian. In Newtonian flow, viscosity is independent of time or rate of shear, and is exhibited by true liquids and dilute solutions. If the shearing rate is plotted against shearing stress, a straight line results passing through the origin. Non-Newtonian liquids or liquids with non-linear viscosities, exhibit viscoelastic properties. These can be characterized by several types of flow including plastic, pseudo-plastic, dilatant, and thixotropic flow (see Fig. 1).

Instrumentation

Because of the non-Newtonian viscosity of inks, the use of "steady-state flow" viscosity determination is not adequate for correlation with printing characteristics. Among the instruments which lend themselves to non-steady-state measurement of viscosity is the cone-plate viscometer.

One such instrument currently in use is the Ferranti-Shirley cone and plate viscometer shown in Fig. 2. This instrument has a number of advantages. By properly choosing the angle of the cone, the shear rate can be made uniform in the gap. The gap narrows with decreasing radius to compensate for the slower linear velocity, and thus the shear rate is independent of radius. The instrument uses very small quantities of ink for each test, a small fraction of a milliliter.

To obtain a rheogram of a substance from the Ferranti-Shirley viscometer, a sample of ink is placed between the stationary plate and the cone making a very small angle to insure uniform shearing of the entire sample. The ink under test is sheared in the space formed when the apex of the upper cone just touches the lower plate. The cone is rotated to a programmed schedule and driven by a variable speed motor through a gear train and torque spring. The variable speed motor shears the sample from zero r/min to a predetermined maximum at a uniformly increasing rate and then uniformly reduces the shearing to zero again. The torsion, due to viscous drag, is measured by a potentiometer arm coaxial with the spring, the voltage being plotted on an X-Y recorder.

In addition, a water circulating bath is attached to the equipment to maintain a constant temperature. The desired speed is selected and the torsion noted on the indicator. Various speeds and sweep times may be manually selected, and five ranges of shear stress indications are available using scale factors from X1 to X5.

A wide range of non-Newtonian inks can be evaluated by choosing the proper cone, spring time interval, and speed combination. A detailed explanation of the instrument may be found in Refs. 2 and 3.

Experimentation

The viscometer for this investigation was equipped with an 1120 gm-cm torque spring and regular small cone. All inks involved in this investigation exhibited non-Newtonian flow characteristics, i.e., a change in shear rate (Y) will cause a non-proportionate change in shear stress (X). The original rheograms obtained from the Ferranti-Shirley viscometer for various conductor, dielectric, and resistor inks are reproduced in Figs. 3a through 3i. Table I presents an analysis of these rheograms.

Discussion of rheological investigation

Inks for electronic application are composed of more than one ingredient including a large proportion of finely divided powders of metal, glass, or both, which, after firing, form the permanent film. Because of the nature of gels and the large proportion of solids, the viscosity of the inks are subject to non-linear effects.

In most cases, the viscosity decreases with shear rate. Because, when at rest, these polymeric substances are randomly oriented and matted together. The lack of order is also true at low shear rates. At a high rate of shear, breakdown of the random orientation occurs and the linear molecules tend to align with a linear orientation in the direction of flow. The overall resistance to flow is thereby reduced, and as a result, the viscosity of the ink decreases with increasing rate of shear. This is the so called pseudoplastic effect. A typical flow curve for pseudoplastic material is shown in Fig. 1d.

Another characteristic of the high molecular weight, linear polymer gel is the time required to revert to a random orientation system after the shearing action is removed. If the orientation of the linear polymers is cumulative, the viscosity may decrease with time at a constant rate of shear. This is known as the thixotropic effect. The solid particles or pigments of various shapes, will also contribute to non-linearity of viscosity due to orientation. Anisotropic particles randomly oriented offer resistance to flow. Under shear, the particles tend to orient in a direction with the smallest cross section perpendicular to the shear plane. With such orientation, the resistance to flow is minimal.

Fig. 2—The Ferranti-Shirley cone and plate viscometer: A) X-Y recorder, B) control and indicator unit, C) measuring unit, D) automatic gap-setting unit, E) amplifier unit, F) constant temperature water bath.

Some interesting rheological differences among various inks have been demonstrated in this investigation. In most cases, they are complex and may involve more than one type of flow in a single ink system. Ink rheology is therefore theoretically fascinating, but interpretation of data is frustrating.

Establishment of evaluation criteria

The use of the Ferranti-Shirley cone and plate viscometer is relatively recent. The method has been found attractive to some extent, because it is easy to use and requires only small quantities of ink. In addition, the rheological information can be read off directly from the rheogram with little calculation. In general, this viscometer is suitable for demonstrating differences in rheological properties of inks used for electronic circuits. Thixotropic effects and plastic effects can be readily seen. One of the steps is to reduce the information contained in the rheogram to numerical value or indices, thus the process control and the criteria for evaluation of thick-film ink can be established by utilizing the mathematical and statistical techniques.

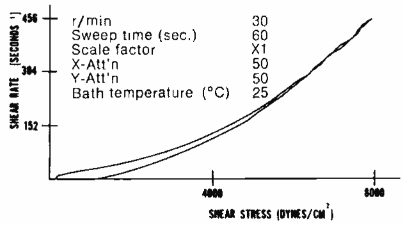

Fig. 3a—Rheogram of conductor ink DP 8318, a standard silver.

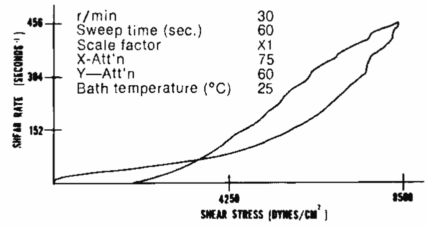

Fig. 3b—Rheogram of conductor ink DP 8261.

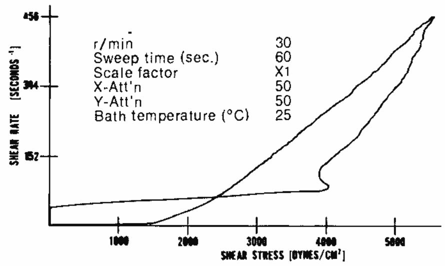

Fig. 3c—Rheogram of conductor ink 01 6121-S.

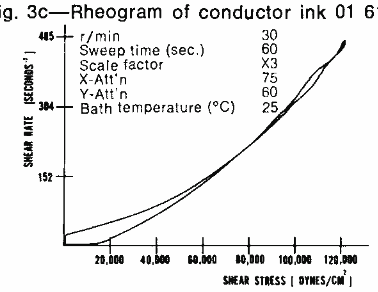

Fig. 3d—Rheogram of dielectric ink DP 8315.

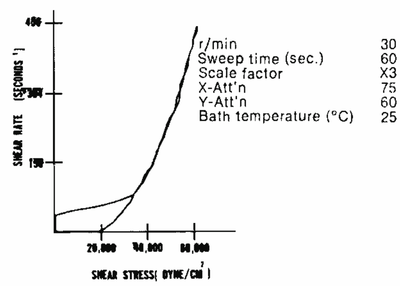

Fig. 3e—Rheogram of dielectric ink DP 8315 ESL 4640.

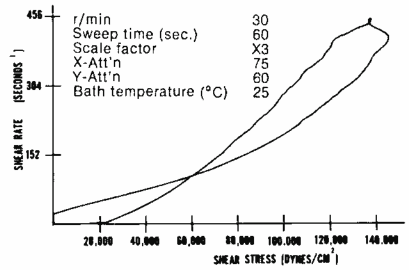

Fig. 3f—Rheogram of dielectric ink DP 8289.

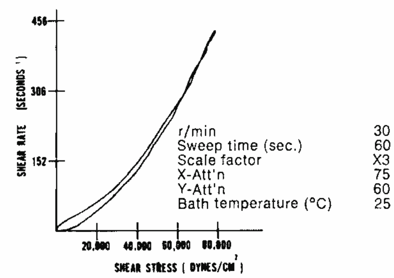

Fig. 3g—Rheogram of dielectric ink ACI 0001.

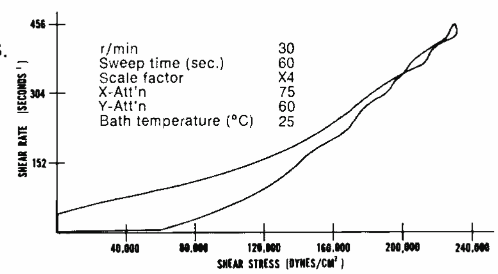

Fig. 3h—Rheogram of resistor ink DP 8584.

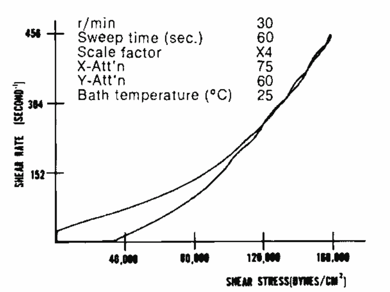

Fig. 3i—Rheogram of resistor ink DP 8089.

Index of reproducibility

Rheological properties of thick film ink may change from lot to lot. A rationalized index is needed to measure and compare the change in rheological properties under working conditions of the process system. For example, it is proposed that the index can be defined as the ratio of t_i (first sample or standard value from the previous run) to $t_{(i+1)}$ (second sample). Such an index can be readily determined by the expression $t_{(i+1)}/t_i, t_{(i+2)}/t_i, \ldots$

It is felt that this method offers a simplified approach to the evaluation of inks. It certainly permits a straightforward method of measurement and provides a rational expression for any variation that may exist. A Shewhart control chart technique may be applied to determine the average of the average indices (X) and average range ($\bar{R}$), so that projected limits can be established. Then, any calculated index, beyond the limits, may be considered an abnormal or questionable lot.

Thixotropic loop

Thixotropic breakdown is fostered by an increase in the shear stress, by extending the shear time, or by both. The thixotropic effect is a valuable property, for at high shear rates (during screening operation) the low viscosity that is produced facilitates ink flow and insures uniform thickness. At low shear rate (after a screening operation) the restoration of structural viscosity prevents undesirable ink sagging and running.

For any given ink, the amount of thixotropy present can be evaluated in terms of area enclosed by the so-called "thixotropic loop," and can be defined as the thixotropic index. The thixotropic index may be obtained by measuring the area under the curve; the greater the area, the greater the thixotropy. Desirable thixotropic properties are:

1) That the dispersion of the solids is not significantly changed by thixotropic breakdown at the specified shear rate, and
2) That quick recovery of the structure should occur when active shearing is removed to prevent running or secondary flow of the image.

Ratio of two rates of shear

Rheology is primarily concerned with the deformation of cohesive bodies. The viscosity of inks exhibit considerable changes with time and shear rate. By theoretical calculation and empirical data, it is possible to determine the squeegee speed of a printer in relation to the shear rate of the viscometer. If a particular screening operation is performed at a rate of 2000 second^{-1} in a Presco Printer, then the corresponding shear rate on the Ferranti-Shirley viscometer requires 132 r/min with the present regular small cone.

The ink is subjected to two rates of shear during screen printing. The ink must not resist being pushed between

Table I—Rheological properties of printed inks graphed in Figs. 3a through 3i.

Rheogram	*Ink type*	*Results and analysis of rheological investigation*
Fig. 3a	DP 8318, a standard silver-palladium conductor ink	The rheological properties of this ink can be considered close to Newtonian. There is some plastic effect as shown by the initial rise. There is also some nonlinearity as shown by decreasing viscosity with shear rate.
Fig. 3b	DP 8261, a new conductor ink developed by Du Pont	The dominant feature of this ink is the thixotropic effect. This is shown by the "hysteresis loop" which is due to the decrease of viscosity with time. There is some plastic effect as shown by the relatively initial portion of the curve.
Fig. 3c	OI6121-S, a new conductor ink developed by Owens-Illinois, now under engineering evaluation	This ink shows a pronounced plastic effect. Appreciable flow does not occur until the applied shear stress exceeds 4000 dynes/cm^2. Associated with this is also a pronounced thixotropic effect.
Fig. 3d	DP 8315, a standard low K dielectric ink for screen-printed capacitors	This ink displayed a similar flow to that shown in Fig. 3a. There is some thixotropic effect with a small yield value. However, the viscosity of this ink is one-third higher compared with the ink type shown in Fig. 3a, if both rheograms are converted to the same scale.
Fig. 3e	ESL 4640, a substitute ink for DP 8315	This ink has a gel-type flow with strong pseudoplasticity. A higher yield value and a lower viscosity were obtained, if compared to the same type ink shown in Fig. 3d (dielectric ink DP 8315). There is a pronounced thixotropic effect in this ink.
Fig. 3f	DP 8289, a medium K dielectric for screen-printed capacitors	For this ink, a large thixotropic loop was formed by the crossing area of the up and down curves. The second and third run on the same sample show a continuing decrease in viscosity. Each run was made within a few minutes of the preceding run. Although there was some relaxation of the material, the relaxation was not complete. The viscosities at the selected maximum shear rate were 31,494; 28,236; and 24,616 centipoises for the first, second, and third runs respectively. In contrast to this ink, the sample of the other type of ink showed only a small decrease in viscosity at the same shear rate on a second run of the same sample. For verification purposes, a fresh sample was taken from the same jar, and rheograms were obtained under the same running conditions. The viscosities were 31,494; 27,512; and 26,064 for the first, second, and third runs respectively. These viscosities are nearly the same as the first sample. The cause of this effect is probably due to a breakdown of some loosely knit structure resident in the system.
Fig. 3g	ACI 0001, a dielectric ink developed by American Components, Inc., now under engineering evaluation	The shear-stress/shear-rate relationship graphed in Fig. 3g shows a sort of hybrid flow; it simulates Newtonian flow at high rates of shear with slight pseudoplastic effect at low rates of shear. The change from one type of flow to the other is not sharp but rather gradual.
Fig. 3h	DP 8584, a standard low resistivity ink	This ink shows a small degree of plastic effect and thixotropy. The higher viscosity, 50,197 centipoises, occurs at the assigned maximum shear rate of 456 second^{-1}. However, the thixotropic effect is confirmed by the viscosity decrease to 47,301 centipoises on the second run. The coefficients of thixotropic breakdown (X) at constant shear rate can be calculated by using the formula: $X = Y_1 - Y_2/\ln\frac{t_2}{t_1}$ where Y_1 and Y_2 are the viscosity of the down curve.[4]
Fig. 3i	DP 8089, a standard high resistivity ink	A slight thixotropic and plastic effect are also shown in the rheogram. This ink has a lower viscosity, in general, compared with the graph of Fig. 3h. The viscosity was 34,750 centipoises at the assigned maximum shear rate (456 second^{-1}), which decreased to 33,300 centipoises on the second run. The rate of viscosity changes from the first run to the second run is smaller compared with low resistivity ink, DP 8584.

the mesh of the screen onto the substrate during printing, and it should not flow beyond the original dimensions of the screen under the force of gravity. In an experimental run, the viscosity of a particular ink was five times higher when run under a shear rate of 5 r/min compared with the same ink under a shear rate of 100 r/min. Thus, an appropriate ratio and projected limit should be established.

Simulation model for continuous screening

The rheological properties of ink exhibit prolonged changes under continued shear, as encountered while screening in the printer. If we assume the change under continued screening to be the same as those under continued shearing in the viscometer, then a simulation model can be established. In an experimental run for a particular ink, the data showed there was not a great change of viscosity during the first two minutes of shear. It then gradually decreased with time, and maintained a relatively constant viscosity level after 20 minutes of shearing time. The viscosity value was 10% lower than that of the beginning. A regression equation can be established to describe this relationship.

Summary

The requirements and problems of the thick-film ink system have been mentioned and the importance of shear-stress/shear-rate curves in depicting the flow properties of non-Newtonian inks has been emphasized. Such curves provide a key to the molecular structure and give information as to the rheological properties of plastic viscosity, yield value, and thixotropy on which the practical performance of the ink depends. Inks serving the same function have been shown to have widely different rheological behavior. As a sequel to this work, it is to be determined what characteristics are most desirable for screening operations. In the meantime, it is apparent that a single viscosity specification is inadequate to characterize an ink. The viscosity of these inks is not only time dependent but also dependent upon shear rate.

Acknowledgment

The author thanks Dr. A. M. Max of Purdue University for acting as a consultant in this work. He has made invaluable suggestions and provided helpful background material for discussion.

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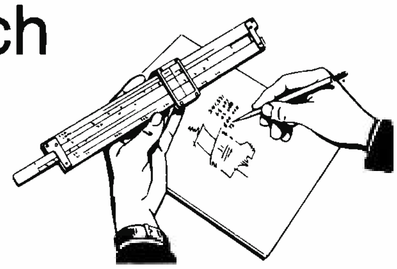
Engineering and Research Notes



Brief Technical Papers of Current Interest

Procedure for making triboelectric measurements

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The method described for making triboelectric measurements on powders is simple and appears to be accurate. It not only allows for the determination of the position in a triboelectric series of one material with respect to another but it also provides a means for measuring the magnitude of the generated charge. In addition, the method allows one to determine the percent concentration of one material with respect to another especially in developer mixtures used in electrophotographic printing.

Procedure

Pulverized samples of the two materials which are to be measured are placed in a shielded metallic container. The container has two screens so that compressed air can be blown through it. The particle sizes of the samples are chosen so that one will be retained and the other removed from the container by the passage of air. If the container is connected to an electrometer, both the sign and magnitude of the charge residing on the particles retained in the container can be determined.

The device is shown in Figs. 1, 2, and 3. Referring to Fig. 3, the procedure for making a measurement is as follows:

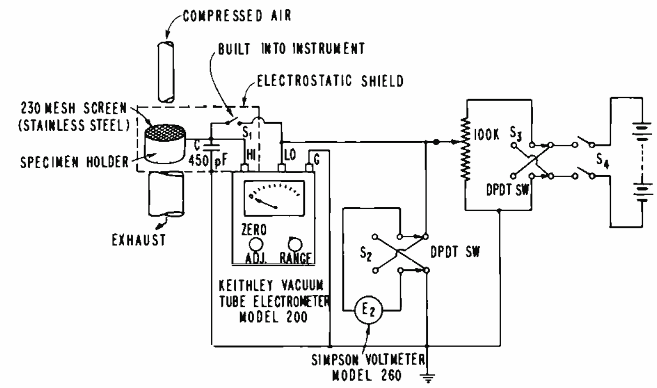

Fig. 3—Electrometer circuit for triboelectric measurements.

1) The materials to be tested are pulverized, mixed together, and inserted in the screened specimen holder.

2) E_2 is set to zero after closing switch *S4*.

3) Switch *S*1 is closed in order to discharge the capacitor *C*.

4) E_1, the electrometer reading, is set to zero by the "zero adjust" knob on the Keithley Vacuum Tube Electrometer (Model 200).

5) The compressed air supply is turned on carefully and the deflection of the meter on the electrometer is observed. Switch S3 is thrown to such a position that the polarity of E_2 will be proper to keep E_1 at zero as E_2 is increased during the buildup of charge on the capacitor *C*.

6) The air is allowed to flow until the voltage E_1 ceases to change.

7) At this time, the value of E_2 is noted.

Fig. 1—Device for making triboelectric measurements.

Fig. 2—Measurement system.

By following the above procedure, the electrometer is used as a null indicator so that no charge is withdrawn from the sample under test. As a result, the generated charge can be measured. The input resistance of the instrument is greater than 10^{14} ohms under these conditions.

The values of E_2 obtained can be used directly to obtain the relative positions in a triboelectric series of various materials with respect to a reference material. On the other hand, if one wishes to determine the magnitude of the charge generated in each case, the relationship $q = CE_2$ can be used.

There are certain precautions that should be observed to obtain accurate data. First, adequate electrostatic shielding is necessary around the specimen holder and the "Hi" terminal of the electrometer to eliminate the influence of extraneous fields. Second, the value of C should be large enough so that the electrometer input is not driven too far positive. If this should happen, the large forward grid current that would flow might dissipate some of the charge. Driving the electrometer down scale, on the other hand, has no deleterious effect for the electrometer tube is driven into the cutoff region, no forward grid current can flow, and the charge will be conserved.

Results

To classify several electroscopic toners with respect to their triboelectric activity in the presence of carrier iron, a series of tests were made using the procedure outlined above. The series is based on Ferrum Iron Powder, Type V, Commercial Grade, obtained from Charles Hardy, Inc. Before use, the iron was screened and only that which did not pass through a 200 mesh screen was kept for testing. The toners classified above iron acquire a positive charge when mixed with the powder while those below iron acquire a negative charge. The numbers after each toner listed in Table I are averages of three voltage readings. Each value taken did not deviate from the average by more than 5% in the worst case.

Table I—Triboelectric classification of several electroscopic toners.

Material	*Voltage generated across 450 μμF*	*Wt. of sample tested (gm)*	*% Toner concentration by wt. in iron*
RCA toner P342 (experimental)	66	0.2	2
RCA toner P648 (experimental)	34	0.2	2
Experimental toner #5640-35-2	33	0.2	2
Experimental toner #5640-38-2	30	0.2	2
RCA toner P664	28.5	0.2	2
Fe	0.3	0.2	0
A commercial toner	7.8	0.2	2

As a representative, RCA toner P648 was chosen for determining whether the method and apparatus were suitable for making toner concentration measurements. Table II and Fig. 4 indicate that the method works satisfactorily. Each value of voltage listed and plotted is an average of three readings which did not differ from the mean by more than 5% in the worst case.

The graph helps to confirm a previous observation that the upper limit on toner concentration should be in the vicinity of 4% in order to realize clean background in electrophotographic prints. The drooping characteristic observed is due probably to a saturation effect. An iron particle of a given size and shape can only retain a finite number of toner particles. All other toner particles in excess of this number acquire no charge and are only held in the mixture by mechanical forces.

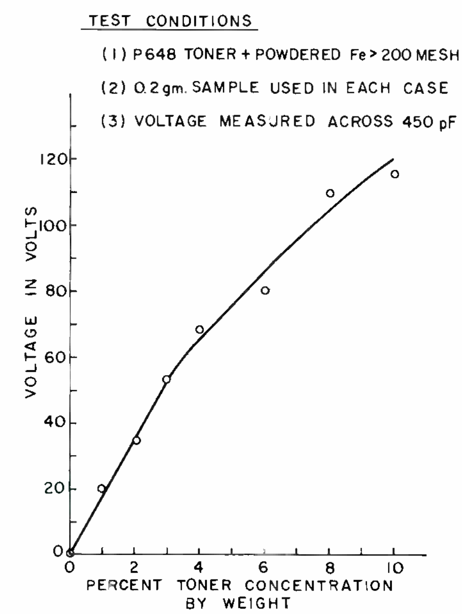

Fig. 4—Voltage vs. percent of toner concentration.

Table II—Toner concentration measurements on P648 toner in the presence of iron.

% Toner by wt.	*Wt. of sample*	*Average voltage*
0	0.2 g	−0.3
1	0.2 g	20
2	0.2 g	34
3	0.2 g	53
4	0.2 g	69
6	0.2 g	80
8	0.2 g	110
10	0.2 g	116

The following Triboelectric Series was determined using the method and apparatus described herein:

Material	*Nature of material*
RCA toner P342	Toner powder
RCA toner P648	Toner powder
Experimental toner #5640-35-2	Toner powder
Experimental toner #5640-38-2	Toner powder
RCA toner P664	Toner powder
Glass	Carrier powder
Iron	Carrier powder
Commercial toner	Toner powder
Nickel	Carrier powder

All materials above a particular one are positive with respect to it.

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Classical unijunction oscillator with a bootstrap T^2L output

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A unijunction oscillator incorporates current clamping and hysteresis to produce a stable, wide-frequency-range, T^2L compatible oscillator.

The range of *R1* (Fig. 1) is from 3.9 to 510 kilohms, and the range of *C1* is from .01 to 33μF. The approximate frequency of oscillation is given by $f=1.55/RC$. The minimum and maximum frequencies of oscillation, which correspond to the maximum and minimum values of *R1* and *C1*, are 0.1Hz and 40.0kHz, respectively.

When *R1* is split into a fixed resistor and a variable resistor, the initial component tolerances can be adjusted out. To guarantee the ability to set the oscillator frequency, the sum of the fixed and variable resistors should be 1.5 times the calculated resistance and the value of *R1P* should be twice that of *R1*.

Current-clamping circuit *R3-CR1* stabilizes the valley point of *Q1*, as well as insuring that *Q2* is biased off during the charging of *C1*; *R2* provides temperature compensation for *Q1*. If temperature stability is desired, a 1% film resistor and a wirewound variable resistor should be used for *R1*; and a low-leakage, temperature-stable capacitor such as mylar or metalized polycarbonate should be used for *C1*. Using these stable timing components guarantees a frequency drift of less than 3% over the temperature range of 0 to 70°C.

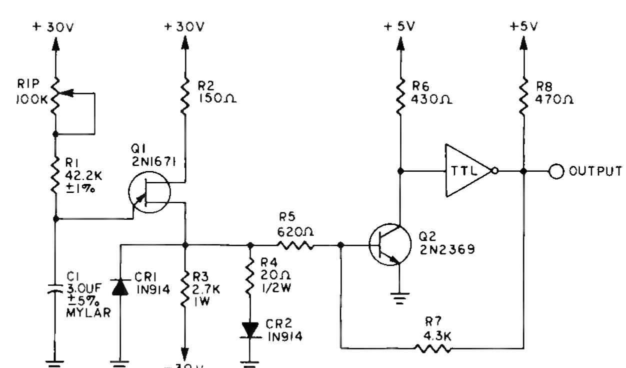

Fig. 1—Unijunction oscillator.

CR2 prevents *R4* from sinking current from *CR1* while *C1* is charging, and *R4* provides a low-impedance discharge path for *C1*. The typical waveform at the junction of *R3*, *R4*, and *CR1* has rise and fall times in the microsecond range. Hysteresis circuit *R5-R7* supplies positive feedback to the base of *Q2*, when *Q2* is switching.

As *Q2* starts to turn ON (or OFF) the T^2L gate goes high (or low) and this feedback speeds up the switching of *Q2*.

The hysteresis guarantees that the collector voltage of *Q2* passes through the threshold of the T^2L gate fast enough to preclude multiple switching. *R6* and *R8* were selected as low-value resistors to enhance the switching speed of the circuit. This circuit will drive edge-triggered counters without incurring any false counts.

With the component values shown in Fig. 1, the circuit will function as a 6-Hz oscillator with less than 3% drift and an output drive capability of two T^2L loads.

The unijunction oscillator circuit is useful in applications requiring T^2L compatibility or a low-frequency oscillator (chiefly in computer peripheral devices).

Simple photo alarm does double duty

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The simple circuit in Fig. 1 is very effective for detecting missing light pulses. The new, low-cost RCA CA3062 light sensor and amplifier integrated circuit is used to detect light pulses that are synchronized to the 60-Hz line frequency. Its amplifier output momentarily grounds diode *CR1*, when *S1* is in position A. This continuously resets the timing network of a unijunction transistor every 16.7 ms. Since the network reaches peak-point voltage in 20 ms, the transistor does not fire.

If an object interrupts the light beam, the UJT will reach its peak-point voltage and fire the SCR, turning on an audible alarm (e.g. a sonalert alarm).

The CA3062 was placed at the focal point of a typical condensing lens and operated successfully at a distance of over 60 feet, using the RCA 40736R and a similar lens as the infrared emitter.

When *S1* is in position B the circuit now detects interruptions in a steady light beam, sounding an alarm only when an interruption does *not* occur (e.g., in monitoring items on a conveyor belt).

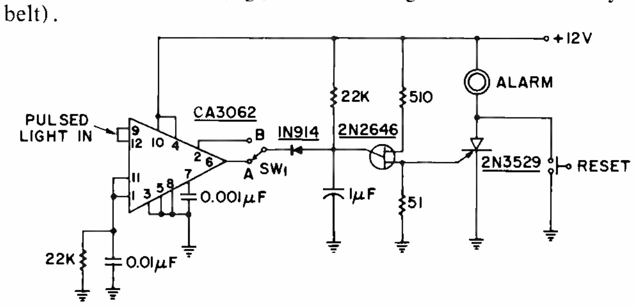
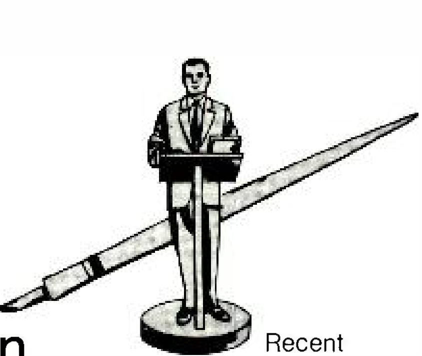


Fig. 1—Photo alarm circuit.



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COMPUTERS AND AUTOMATION—Are They in Your Future?—W. B. Varnum (CSD, Camden) NAB, Chicago, Ill., 3/31/71; *NAB Technical Papers*

ERTS [Earth Resources Technology Satellite] RBV [Return Beam Vidicon] IMAGERY, Simulation of—B. P. Miller, J. M. Barletta, O. Weinstein (AED, Pr) Remote Sensing Meeting: Univ. of Michigan; 5/15/71; *Proceedings.*

HOLOGRAPHIC MOVIES, Embossed—W. J. Hannan (Labs, Pr) SPIE Seminar-in-Depth on Holography, Boston, Mass.; 4/14-15/71

HUM-BUCKERS, Television—J. L. Hathaway (NBC, N.Y.) *J. of SMPTE,* Vol. 80; 2/71

INTERPHONE AMPLIFIER, A New High Impedance—J. L. Hathaway (NBC, N.Y.) NAB Convention, Chicago, Ill.; 3/30/71

SIGNAL-LOSS DETECTOR Suitable for Audio and Video System—S. Atwood (NBC, N.Y.) NAB Convention, Chicago, Ill.; 3/31/71

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CARD READERS, Photoconductive Sensor for—F. V. Shallcross, W. S. Pike, P. K. Weimer, G. M. Gryszman (Labs, Pr) *IEEE Trans. on Electron Devices* Vol. ED-17, No. 12; 12/70

COMPUTER MEMORIES—State of the Art and Remaining Challenges—J. A. Rajchman (Labs, Pr) American Physical Society Mtg., Cleveland, Ohio; 3/29/71

MAGNETIC MEMORIES—Present Status and Future Trends—R. Shahbender (Labs, Pr) IEEE International Convention, New York City, 3/22-25/71

MASS MEMORY'S PROMISE: Megabits Accessible in Microseconds, Holographic—R. D. Lohman, R. S. Mezrich, W. C. Stewart (Labs, Pr) *Electronics,* Vol. 44, No. 2; 1/18/71

OPTICAL MEMORIES, Holographic—R. D. Lohman (Labs, Pr) Rutgers University, New Brunswick, N.J.; 2/24/71

STORAGE AND MEMORY DEVICES and the Promise of Recent Research, The Hierarchy of—J. A. Rajchman (Labs, Pr) IEEE Int'l Convention, New York City, 3/22-25/71

SYNCHRONIZATION OF TWO PROCESSORS, Sequential Machine Design for—M. Kleidermacher (GCS, Camden) Univ. of Pennsylvania; 4/2/71

365 Computer Programming & Applications

. . . languages, software systems, & general applications (excluding: specific programs for scientific use)

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CACHE System Studies—K. R. Kaplan (Labs, Pr) SIGOPS Workshop on System Performance Evaluation, Cambridge, Mass.; 4/5-7/71

COMPUTERS AND AUTOMATION—Are They in Your Future?—W. B. Varnum (CSD, Camden) NAB, Chicago, Ill., 3/31/71; *NAB Technical Papers*

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VIEWGRAPHS, Designing Presentation—G. F. Fairhurst (EASD, Van Nuys) STWP, LA Chapter *Technograph;* 2-3/71

Author Index

Subject listed opposite each author's name indicates where complete citation to his paper may be found in the subject index. An author may have more than one paper for each subject category.

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RCA Laboratories

National Broadcasting Company

Patents Granted

to RCA Engineers

As reported by RCA Domestic Patents, Princeton

Laboratories

Apparatus for Monitoring and Controlling the Concentration of Toner in a Developer Mix—H. C. Gillespie, R. Herman, M. M. Sowiak (Labs, Pr) U.S. Pat. 3,572,551; March 30, 1971

Vacuum Evaporation Apparatus—A. Harel (Labs, Pr) U.S. Pat. 3,562,672; March 30, 1971

Apparatus for Developing Electrostatic Images—R. G. Olden (Labs, Pr) U.S. Pat. 3,572,922; March 30, 1971

Photochromic Device Based Upon Photon Absorption—Z. J. Kiss (Labs, Pr) U.S. Pat. 3,572,941; March 30, 1971

Electrical System and LSI Standard Cells—H. R. Beelitz (Labs, Pr) U.S. Pat. 3,573,488; April 6, 1971

Stroboscopic Display Apparatus—J. C. Miller, C. M. Wine (Labs, Pr) U.S. Pat. 3,573,785; April 6, 1971

Method of Electrostatic Recording on a Thermoplastic Recording Element—F. H. Nicoll (Labs, Pr) U.S. Pat. 3,574,613; April 13, 1971

Room Temperature Electroless Nickel Plating Bath—N. Feldstein (Labs, Pr) U.S. Pat. 3,574,664; April 13, 1971

Turn-Off Method and Circuit for Liquid Crystal Display Element—E. O. Nester, B. J. Lechner (Labs, Pr) U.S. Pat. 3,574,492; April 20, 1971

Decreasing Response Time of Liquid Crystals—G. H. Heilmeier (Labs, Pr) U.S. Pat. 3,575,491; April 20, 1971

Fast Self-Quenching of Dynamic Scattering in Liquid Crystal Devices—G. H. Heilmeier (Labs, Pr) U.S. Pat. 3,575,493; April 20, 1971

Field Effect Transistor, Content Addressed Memory Cell—J. R. Burns (Labs, Pr) U.S. Pat. 3,575,617; April 20, 1971

Cathode Ray Tube With Screen Comprising Laser Crystals—F. H. Nicoll (Labs, Pr) U.S. Pat. 3,575,627; April 20, 1971

Color Advertising Display Employing Liquid Crystal—L. A. Zannoni (Labs, Pr) U.S. Pat. 3,576,364; April 27, 1971

Television System for Transmitting Auxiliary Information During the Vertical Blanking Interval—W. D. Houghton (Labs, Pr) U.S. Pat. 3,576,391; April 27, 1971

Semiconductor Vidicon Target Having Electronically Alterable Light Response Characteristics—S. R. Hofstein (Labs, Pr) U.S. Pat 3,576,392; April 27, 1971

Circuit Producing Output Pulse of Polarity Dependent on Relative Times of Occurrence of Input Pulses—J. J. Amodei (Labs, Pr) U.S. Pat. 3,576,448; April 27, 1971

Photochromic-Photoconductive Memory—P. M. Heyman, Z. J. Kiss (Labs, Pr) U.S. Pat. 3,576,546; April 27, 1971

Retrieval of Holographically Recorded Data—W. J. Hannan (Labs, Pr) U.S. Pat. 3,578,836; May 18, 1971

Method of Making a Semiconductor Article and the Article Produced Thereby—A. I. Stoller (Labs, Pr) U.S. Pat. 3,579,057; May 18, 1971

Coupling and Driving Circuit for Matrix Array—P. K. Weimer (Labs, Pr) U.S. Pat. 3,579,189; May 18, 1971

Low Inductance Interconnection of Cryoelectric Memory System—R. A. Gange (Labs, Pr) U.S. Pat. 3,579,206; May 18, 1971

Single Crystal Zinc Oxide and an Electrophotographic Plate Made Therefrom—R. Williams (Labs, Pr) U.S. Pat. 3,579,332; May 18, 1971

Consumer Electronics

Selective Anodization Apparatus and Process—W. H. Laznovsky (CE, Som) U.S. Pat. 3,573,176; March 30, 1971

Color Killer and A.C.C. Circuits—P. R. Ahrens (CE, Som) U.S. Pat. 3,573,354; April 6, 1971

Video Muting Circuits—G. E. Anderson (CE, Som) U.S. Pat. 3,573,365; April 6, 1971

Noise Immunity Circuit—T. A. Bridgewater (CE, Ind) U.S. Pat. 3,573,492; April 6, 1971

Oscillator Circuit with Series Resonant Coupling to Mixer—D. J. Carlson (CE, Ind) U.S. Pat. 3,573,631; April 6, 1971

FET Control System Employing a Storage Capacitor and Switching Tube Means—L. M. Lunn (CE, Ind) U.S. Pat. 3,575,612; April 20, 1971

Automatic Frequency Control Apparatus—J. Craft (CE, Som) U.S. Pat. 3,577,008; May 4, 1971

Integrated Circuit Biasing Arrangements—J. Avins (CE, Som) U.S. Pat. 3,577,167; May 4, 1971

Automatic Chroma Control Circuit—J. M. Yongue (CE, Ind) U.S. Pat. 3,578,899; May 18, 1971

Video Amplifier Circuit—D. H. Willis (CE, Ind) U.S. Pat. 3,578,900; May 18, 1971

Video Amplifier for Driving a Delay Line Between Grounded Collector and Grounded Base Stages—D. F. Griepentrog (CE, Ind) U.S. Pat. 3.578,901; May 18, 1971

Control Circuits for Preventing Kinescope Color Saturation During Blooming—D. H. Willis (CE, Ind) U.S. Pat. 3,578,903; May 18, 1971

Circuits Using Transistors to Provide Variable Phase Shift—R. R. Norley (CE, Ind) U.S. Pat. 3,579,095; May 18, 1971

Automatic Gain Control Systems—J. R. Harford (CE, Som) U.S. Pat. 3,579,112; May 18, 1971

Signal Translating Stage—J. R. Harford (CE, Som) U.S. Pat. 3,579,133; May 18, 1971

Solid State Division

Counter or Shift Register Stage Having Both Static and Dynamic Storage Circuits—R. W. Ahrons (SSD, Som) U.S. Pat. 3,573,498; April 6, 1971

Phase Splitting Amplifier—C. F. Wheatley, Jr. (SSD, Som) U.S. Pat. 3,573,645; April 6, 1971

Method of Making a Phosphorus Glass Passivated Transistor—A. P. Storz, F. P. Chiovarou (SSD, Som) U.S. Pat. 3,575,743; April 20, 1971

Repair of Thin-Film Structure Such as Cryoelectric Memory—R. A. Gange (SSD, Som) U.S. Pat. 3,576.551; April 27, 1971

C-MOS Dynamic Binary Counter—A. K. Yung (SSD, Som) U.S. Pat. 3,577,166; May 4, 1971

Circuit for Starting and Maintaining a Discharge Through a Gas Discharge Tube—R. W. Longsderff (SSD, Lanc) U.S. Pat. 3,577,174; May 4, 1971

Transistor Package for Microwave Stripline Circuits—E. F. Belohoubek (SSD, Som) U.S. Pat. 3,577,181; May 4, 1971

Pulse Width Stabilized Monostable Multivibrator—R. C. Heuner (SSD, Som) U.S. Pat. 3,578,989; May 18, 1971

Method of Making Ohmic Contact to Semiconductor Devices—E. Wonilowicz, H. F. Machnacz (SSD, Som) U.S. Pat. 3,579,375; May 18, 1971

Graphic Systems

Compensation Circuit for Electronic Photocomposition System—J. C. Schira (GSD, Dayton) U.S. Pat. 3,573,786; April 6, 1971

Constant Velocity Vector Generator—S. A. Raciti (GSD, Dayton) U.S. Pat. 3,576,461; April 27, 1971

Communications Systems Division

Speech Synthesizer Providing Smooth Transition Between Adjacent Phonemes—J. F. Schanne (CSD, Camden) U.S. Pat. 3,575,555; April 20, 1971

Switching Regulator Having a Diode Connected to an Intermediate Tap of a Choke—F. L. Putzrath, C. A. Michel (CSD, Camden) U.S. Pat. 3,577,065; May 4, 1971

Sequence 'And' Gate with Resetting Means—T. B. Martin, H. J. Zadell (CSD, Camden) U.S. Pat. 3,577,087; May 4, 1971

Spring Actuated Sequential Color Filter for Image Tubes—E. Hutto, Jr., P. F. Joy, Jr. (CSD, Camden) U.S. Pat. 3,572,229; March 23, 1971; Assigned to U.S. Government

Relaxation Oscillator Gated by Transistor Switch—M. Rotolo, Jr. (CSD, Camden) U.S. Pat. 3,579,144; May 18, 1971

Push Button Mechanism—H. J. Mackway (CSD, Camden) U.S. Pat. 3,579,160; May 18, 1971

Aerospace Systems Division

Circuit for Detecting a Change in Voltage Level in Either Sense—D. J. Barth (ASD, Burl) U.S. Pat. 3,575,608; April 20, 1971

Digital Computer Controlled Test System—W. E. Bahls, R. E. Benway, A. C. Grover, J. Regnault, D. M. Priestley, L. M. Whitcomb (ASD, Burl) U.S. Pat. 3,576,494; April 27, 1971

Astro-Electronics Division

Apparatus for Generating Test Signals Useful in Measuring Television Transmission Performance Without Affecting Receiver Synchronization—D. S. Bond, A. C. Schroeder, D. H. Pritchard (AED, Pr) U.S. Pat. 3.576,390; April 27, 1971

Vehicle Road Guidance System—G. W. Gray (AED, Pr) U.S. Pat. 3,556,244; January 19, 1971

Process for Manufacturing Microminiature Electrical Component Mounting Assemblies—S. P. Knight (AED, Pr) U.S. Pat. 3,554,821; April 23, 1971

Gas Environment for Recorder-Reproducer Systems—H. Esten (AED, Pr) U.S. Pat. 3,569,637; March 1971

Apparatus for Generating Test Signals Useful in Measuring Television Transmission Performance Without Affecting Receiver Synchronization—D. S. Bond (AED, Pr) U.S. Pat. 3,576,390; April 27, 1971

Computer Systems

Priority Circuit—T. D. Floyd (CS, Fla) U.S. Pat. 3.576,542; April 27, 1971

Patents and Licensing

Decimal to Binary Conversion—C. M. Wright (P&L, Pr) U.S. Pat. 3,579,267; May 18, 1971

RCA Limited

Light Probe Circuit for Persistent Screen Display System—R. J. Clark (RCA Ltd, Canada) U.S. Pat. 3,579,225; May 18, 1971

Dates and Deadlines

As an industry leader, RCA must be well represented in major professional conferences . . . to display its skills and abilities to both commercial and government interests.

How can you and your manager, leader, or chief-engineer do this for RCA?

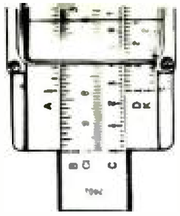
Plan ahead! Watch these columns every issue for advance notices of upcoming meetings and "calls for papers". Formulate plans at staff meetings—and select pertinent topics to represent you and your group professionally. Every engineer and scientist is urged to scan these columns; call attention of important meetings to your Technical Publications Administrator (TPA) or your manager. Always work closely with your TPA who can help with scheduling and supplement contacts between engineers and professional societies. Inform your TPA whenever you present or publish a paper. These professional accomplishments will be cited in the "Pen and Podium" section of the *RCA Engineer*, as reported by your TPA.

Dates of upcoming meetings

Date	Conference	Location	Sponsors	Program information
AUG. 2-6, 1971	**Intersociety Energy Conversion Engineering Conference**	Boston Hilton Hotel, Boston, Mass.	G-ED, G-AES, Solar Energy Society, AIAA et al	F. A. Creswick, Battelle Mem. Inst., 505 King Ave., Columbus, Ohio 43201
AUG. 9-11, 1971	**AIAA/ASMA Weightlessness and Artificial Gravity Meeting**	Williamsburg, Va.	AIAA/ASMA	AIAA Editorial Offices 1290 Ave. of the Americas, New York, N.Y. 10019
AUG. 11-13, 1971	**Joint Automatic Control Conference**	Washington Univ., St. Louis, Mo.	IEEE Control Society AACC/AIAA	R. W. Brockett, Pierce Hall, Harvard Univ., Cambridge, Mass. 02138
AUG. 16-18, 1971	**Guidance and Control and Flight Mechanics Conference**	Hofstra University, Hempstead, N.Y.	AIAA	AIAA Editorial Offices 1290 Ave. of the Americas New York, N.Y. 10019
AUG. 17-19, 1971	**Astrodynamics Conference**	Ft. Lauderdale, Fla.	AAS/AIAA	AIAA Editorial Offices 1290 Ave. of the Americas New York, N.Y. 10019
AUG. 23-28, 1971	**European Microwave Conference**	Royal Inst. of Tech., Stockholm, Sweden	G-MTT, Region 8, Swedish Academy of Engrg. Sci., IEE, et al	H. Steyskal, European Microwave Conf., Fack 23, 104 50 Stockholm 80, Sweden
AUG. 24-27, 1971	**Western Electronic Show & Convention (WESCON)**	San Francisco Hilton & Cow Palace, San Francisco, Calif.	Region 6, WEMA	WESCON Office, 3600 Wilshire Blvd., Los Angeles, Calif. 90005
AUG. 25-27, 1971	**Int'l. Geoscience Electronics Symposium**	Marriott Twin Bridges Motor Hotel Washington, D.C.	G-GE	M. T. Miyasaki, John Hopkins Univ., 8621 Georgia Ave., Silver Spring, Md. 20910
SEPT. 6-10, 1971	**4th IFAC Symposium on Automatic Control in Space**	Dubrovn k, Jugoslavia	AIAA	AIAA Editorial Offices 1290 Ave. of the Americas, New York, N.Y. 10019
SEPT. 6-10, 1971	**London International Symp. on Network Theory**	City University, London, England	G-CT, IEEE UKRI Section, IEE, IERE, City Univ. coop	G. S. Brayshaw, City Univ., St. John St., London E. C. 1 England

Calls for papers

Date	Conference	Location	Sponsors	Deadline Date	Submit	To:
DEC. 6-9, 1971	**Ultrasonics Symposium**	Carillon Hotel, Miami Beach, Florida	G-SU	9-1-71	abstract	Herbert Matthews, Sperry Rand Res. Ctr., Sudbury, Mass. 01776
DEC. 16-18, 1971	**1971 IEEE Conference on Decision and Control (including the 10th Symposium on Adaptive Processes)**	Americana of Bal Harbour, Miami Beach, Florida	IEE Control Systems Society, ITG, GoS, Man and Cybernetics	6-1-71 8-1-71	short paper paper	Prof. S. K. Mitter Program Chairman Dept. of Elec. Engrg., Room 35-229, Mass. Inst. of Tech., Cambridge, Mass. 02139
JAN. 17-19, 1972	**AIAA 10th Aerospace Sciences Meeting**	Town and Country Hotel, San Diego, Calif.	AIAA	8-17-71 12-7-71	abstract papers	General Chairman: R. H. Korkegi, Director, Hypersonic Research Lab., Aerospace Research Labs.— Bldg. 450, Wright-Patterson AFB, Ohio 45433
JAN. 30— FEB. 4, 1972	**IEEE Power Engineering Society Winter Meeting**	Statler Hilton Hotel, New York, New York	IEEE Power Engineering Society	9-15-71	paper	IEEE Office, 345 East 47th Street, New York, N.Y. 10017
FEB. 14-16, 1972	**AIAA Strategic Offensive/ Defensive Missile Systems Meeting**	Monterey, California	AIAA	7-14-71	abstracts	Clement F. Heddleson General Electric Co. Room U3230, P.O. Box 8555, Philadelphia, Pa. 19101
APRIL 11-13, 1972	**Conf. on Industrial Measurement & Control by Radiation Techniques**	Univ. of Surrey, Guildford, Surrey, England	IEE, IERE, IPPS, IMC, IEEE UKRI Section et al	6-21-71 11-8-71	synopsis paper	IEEE Office, Savoy Place, London W. C. 2 England
APRIL 24-26, 1972	**1972 International Conf. on Speech Communications and Processing**	Boston, Mass.	IEEE Group Audio Electroacoustics/ Air Force Cambridge Research Labs.	1-15-72	paper	Mr. Charles Teacher, Philco-Ford Corp. 3900 Welsh Road, Willow Grove, Pa. 19090
MAY 21-24, 1972	**IEEE Power Engineering Society Tech. Conf. on Underground Transmission**	Pittsburgh Hilton Hotel, Pittsburgh, Pa.	IEEE Power Engineering Society	1-7-72	paper	E. D. Eich, Anaconda Wire & Cable Co., Hastings-on-Hudson, N.Y. 10706

Engineering  News and Highlights

Staff Announcements

New top level appointments

At its meeting on June 2, the Board of Directors of the RCA Corporation, upon the recommendation of its Chairman, **Robert W. Sarnoff,** has elected **Anthony L. Conrad,** President of the RCA Corporation to be effective August 1, 1971.

The Chairman of the Board remains the Chief Executive Officer of the Corporation.

As President, Mr. Conrad will be Chief Operating Officer of the Corporation and, subject to the direction of the Chairman, will direct and supervise the operations of the Corporation and perform such other duties as may be assigned to him from time to time by the Chairman. In this capacity, Mr. Conrad will be responsible for all Divisions and Subsidiaries of the Corporation, except the National Broadcasting Company, Inc. which will continue to report to the Chairman of the Board. In addition, Mr. Conrad will have responsibility for the RCA Staff International activity and the Manufacturing Services and Materials activity.

Effective July 1, 1971, the following RCA Staff organizational changes will take place:

Chase Morsey, Jr. is appointed Executive Vice President, Finance and Planning. In addition to his present responsibility for Corporate Planning, Mr. Morsey will assume responsibility for the Corporate Financial activity.

Robert L. Werner continues as Executive Vice President and General Counsel. In addition to his present responsibilities, Mr. Werner will assume responsibility for Patents and Licensing and the Office of the Corporate Secretary.

James J. Johnson continues as Vice President, Marketing. In addition to his present responsibilities, Mr. Johnson will assume responsibility for Distributor and Commercial Relations.

Howard L. Letts continues as Executive Vice President and, until his retirement on January 1, 1972, will carry out special assignments for the Chairman of the Board.

The following executives will continue their present RCA Staff responsibilities:

Kenneth W. Bilby, Exec. V.P., Public Affairs

Herbert T. Brunn, V.P., Consumer Affairs

George H. Fuchs, Exec. V.P., Industrial Relations

James Hillier, Exec. V.P., Research and Engineering

Charles M. Odorizzi, Exec. V.P.

Messrs, Bilby, Brunn, Fuchs, Hillier, Johnson, Letts, Morsey, Odorizzi and Werner will report to the Chairman of the Board and Chief Executive Officer.

Solid State Division

William C. Hittinger, Vice President and General Manager has appointed **Ben A. Jacoby,** Division Vice President, Solid State Power and **Bernard V. Vonderschmitt,** Division Vice President, Solid State Integrated Circuits.

Government and Commercial Systems

Irving K. Kessler, Executive Vice President, has appointed **Maurice G. Staton,** Division Vice President, Advanced Space Programs; and **Kassel K. Miller,** Manager, Underseas Long-Range Missile Systems Programs.

Dr. Harry J. Woll, Division Vice President, Government Engineering, has appointed **Dr. Jack Hilibrand** as Staff Engineer, Government Engineering.

Corporate Planning

George C. Evanoff, Vice President, has announced the organization as follows: **James M. Alic,** Director, Corporate Projects; **Eugene J. Dailey,** Staff Vice President, International Planning; **Charles A. Passavant,** Manager, Planning Coordination; **Frank H. Erdman,** Staff Vice President, New Business Programs; **Edward J. Sherman,** Manager, New Business Programs; **Robert L. Krakoff,** Staff Vice President, Strategic Planning and Acting Director, Strategic Plans; **Peter B. Jones,** Director, Venture Studies; **Arthur C. Martinez,** Manager, Venture Planning, **Katherine B. Teale,** Venture Research Associate; **Jerome B. York,** Director, Operations Planning; **Thomas J. Aycock,** Manager, Project Assessment; **Alexander MacGregor,** Manager, Operations Planning; and **Paul Potashner,** Manager, Operations Planning.

Research and Engineering

Dr. James Hillier, Executive Vice President, has appointed **Arnold S. Farber** to RCA Corporate Engineering Staff.

Laboratories

Paul Rappaport, Director, Process and Materials Applied Research Laboratory has announced the organization as follows: **Glenn W. Cullen** continues as Head, Materials Synthesis; **Eric F. Hockings** continues as Head, Recording Materials and Glass Research; **Richard E. Honig** continues as Head, Materials Characterization; **Paul Rappaport** is appointed Acting Head, SelectaVision Processing; **George L. Schnable** is appointed Head, Process Research; and **Karl H. Zaininger** continues as Head, Solid State Device Technology.

Awards

Missile and Surface Radar Division

Miles Johnson was the recipient of the Annual Technical Excellence Award for 1970. Mr. Johnson was cited for his outstanding technical achievement in proposing, developing, and implementing the AEGIS/MFAR circuits and modular packaging.

Six engineers have been cited for their Technical Excellence in 1971:

J. J. Campbell accomplished an electromagnetic field analysis of the MFAR phased array radiating aperture. This analysis accurately describes the characteristics of the array elements as a function of scan angle and frequency.

J. A. DiCiurcio displayed a high degree of ingenuity and engineering excellence in the design of the AN/TPQ-27 Range Tracker subsystem.

A. G. Griffiths was cited by Drafting Operations in recognition of his outstanding accomplishment on the AEGIS/MFAR Antenna Array Assembly and Integration.

C. Moir, Technical Director for the TRADEX L/S Radar program, singularly provided all technical guidance for this effort, producing a second generation radar which will be the premier re-entry measurements radar for many years to come.

Dr. T. Murakami developed the fundamental time, energy and loss constraints which form the basis of control of the MFAR radar. He has provided the analyses leading to both the understanding and development of the non-linear signal processing used throughout the system.

W. J. Pratt developed and designed a 10-MHz 7-bit analog-to-digital converter for the MFAR Signal Processor. This design is compact, low in weight and meets the full range of environmental specifications imposed on the AEGIS-MFAR system.

Communications Systems Division

Norman Hovagimyan and **Mark Meer** of Digital Communications Equipment Engineering, Government Communications Systems, have received a Technical Excellence Award for their dedicated efforts and technical creativity in designing, building, and demonstrating state-of-the-art performance of a solid state semi-

Astro-Electronics Division

George J. Brucker and **Thomas J. Faith** of the Advanced Development Activity received the Engineering Excellence Award in recognition of their interdependent efforts in determining the feasibility and design of radiation-resistant solar cells. The most significant contribution was the technical skill involved in setting up two complex and complimentary sets of experiments on a poorly-characterized device and making technical and theoretical sense from a similarly complex array of experimental results.

Woll named Division Vice President

Irving K. Kessler, Executive Vice President, Government and Commercial Systems. Moorestown, N. J., announced the promotion of **Dr. Harry J. Woll** to Division Vice President, Government Engineering.

Formerly Chief Engineer, Dr. Woll has headed RCA Government Engineering since 1969. He will continue to be responsible for the Government Staff Engineering, Central Engineering, Microelectronics Technology and the Advanced Technology Laboratories organizations of G&CS.

Dr. Woll joined RCA in 1941 in Indianapolis, Ind., and transferred to Camden, N. J., in 1946. During that time he was engaged in developing advanced electronic circuitry for military and commercial applications. In the early 1950's he did pioneering work in transistor applications and was leader of the group that built RCA's first transistorized digital computer. In 1958 he was named Manager, Applied Research, and five years later became Chief Engineer at the Aerospace Systems Division.

Dr. Woll received the BSEE from North Dakota State University. He enrolled at the University of Pennsylvania as the first recipient of RCA's David Sarnoff Fellowship for continued graduate study, and earned the PhD in engineering in 1953. Dr. Woll is a member and officer of several major engineering societies and is a Fellow of the IEEE. He is a contributing author of the *Handbook of Semiconductor Electronics* and holds 20 patents in electronics.

Shore named Division Vice President

Irving K. Kessler, Executive Vice President, Government and Commercial Systems, Moorestown, N. J., announced the promotion of **David Shore** to Division Vice President, Government Plans and Systems Development.

Formerly Manager of Government Plans and Systems Development since 1969, Mr. Shore will continue to direct the planning activities for G&CS and its systems development function. He is also responsible for supporting the research efforts of the five operating divisions of G&CS.

Mr. Shore joined RCA in 1954 as a staff engineer for the Missile & Surface Radar Division. He progressed through a series of managerial posts involving the design and development of guided missile, radar, and aerospace systems. His positions included Program Manager of the Satellite Inspector project, Chief Engineer for the Communications Systems Division and Chief Defense Engineer for Defense Electronic Products. Previously Mr. Shore was Civilian Chief, Systems Liaison Office, Air Force Wright Development Center, Dayton, Ohio, where he served for 13 years.

Mr. Shore received the BS in Aeronautical Engineering from the University of Michigan and the MS in Physics from Ohio State University. He is a member of the American Institute of Aeronautics and Astronautics, American Ordnance Association, IEEE, Air Force Association, Armed Forces Communications and Electronics Association, and Association of the U. S. Army.

Kleinberg named Manager, Corporate Standards Engineering

A. Robert Trudel, Director, RCA Corporate Engineering Services, has appointed **Harry Kleinberg** as Manager, Corporate Standards Engineering.

The RCA Corporate Standards Engineering activity works with engineering groups in RCA's product division in setting engineering standards for all RCA products and services. In addition, Corporate Standards Engineering provides liaison between RCA and the national and international professional and governmental institutions dealing with engineering standards, such as the American National Standards Institute.

Mr. Kleinberg received the BS in Engineering Physics from the University of Toronto in 1951. After graduation, he worked as a Research Engineer for the Ferranti Electric Co. in Toronto before joining RCA in Camden, N. J., as a Computer Engineer in 1953. While at Camden, Mr. Kleinberg was an Engineering Group Leader on the RCA 501, the first transistorized computer, and served as Project Manager for the development of the RCA 301 Computer. In 1962, he was promoted to Manager, Engineering, at the RCA computer plant in Palm Beach Gardens, Fla. He returned to Camden in 1969, as Manager, Camden Engineering, and in November, 1970 was named Manager, Advanced Development Programs, for RCA Computer Systems, the position he held until he was appointed Manager, Corporate Standards Engineering.

Promotions

Electronic Components

D. G. Garbini from Supt. Super Power Products Mfg. to Mgr., Mfg. and Production Engineering (G. E. Yingst, Lancaster, Pa.)

W. M. Sloyer from Supt. Regular Power Products Mfg. to Mgr., Mfg. & Production Engineering (H. W. Sawyer, Lancaster, Pa.)

D. M. Weber from Engineering Leader, Manufacturing (Lancaster) to Mgr., Production Engineering (N. Menna, Marion, Ind.)

Solid State Division

S. Graf from Engr. to Engr. Ldr., Product Development (R. A. Santilli, Somerville, N.J.)

K. Orlowsky from Engr., Mfg. to Engr. Ldr., Mfg. (R. A. Santilli, Somerville, N.J.)

D. Ressler from Sr. Engr. to Engr. Ldr., Product Development (J. C. Miller, Somerville, N.J.)

Electromagnetic and Aviation Systems Division

P. Archbold from Prin. Mbr., D&D Engrg. Staff to Ldr., D&D Engrg. Staff (E. A. Cornwall, Van Nuys, Calif.)

Communications Systems Division

C. R. Horton from Sr. Member Engr. Staff to Ldr., Design & Development (J. S. Griffin, Camden)

Systems Development Division

H. W. Robinson from Sr. Mbr., Tech. Staff to Ldr., Tech. Staff (S. L. Muir, Marlboro)

RCA Service Company

S. B. Davis from Ldr., Engrs., to Mgr., Telemetry Sys. Engrg. (K. F. Wenz, MTP, Cocoa, Florida)

S. H. Elliott from Ship Instrumentation Engr. to Mgr., Radar Shipboard (C. Mendez, MTP, Patrick AFB, Florida)

Sayford named Manager Medium Systems, Palm Beach

Richard B. Sayford has been appointed Manager, Medium Systems at the RCA Palm Beach Gardens, Computer Systems plant. Mr. Sayford reports to **V. O. Wright**, President, Systems Development Division.

Mr. Sayford received the BA in Economics from the College of William and Mary in 1952, and the MBA from Harvard University in 1954. For 12 years he was with the IBM Data Processing Division where his responsibilities covered marketing functions as systems engineer, salesman, and Manager of Industry Development. In this latter position, Mr. Sayford was involved with the projection of 2- to 5-year industry requirements. His final assignment with IBM was as DP Branch Manager in St. Louis. In 1968 he joined Computer Technology, a firm developed in Dallas by Ling-Temco-Vought (LTV). As vice president of Computer Technology, Mr. Sayford was responsible for a 900-man facilities-management organization which provided full-range computer services to LTV and other customers in the Dallas area. His next association was with Xerox Corp. in Rochester as Manager, Industry Sales, prior to joining RCA Computer Systems at Palm Beach Gardens in April 1971.

Professional activities

Astro-Electronics Division

Dr. A. G. Holmes-Siedle was appointed to membership in the Component Response and Prediction working group of the Defense Atomic Support Agency.

Consumer Electronics

A successful newly organized Midwest Electronic Materials Symposium was conducted on June 4 and 5, 1971 at Notre Dame. The registration of about 100 people covered an area from the Midwest to the East Coast. RCA personnel were prominent in the planning as typified by **Bob Hurley** and **Bill Liederbach** of Indianapolis. RCA Engineers on the program included **Paul Schnitzler**, RCA Somerville; **Irwin Gordon**, RCA Laboratories; **Abraham Max**, former RCA of IUPUI Indianapolis; and **E. R. Shaw** and **R. A. Vogel**, RCA Indianapolis.

Systems Development Division

H. N. Morris, Manager, Palm Beach Product Laboratory, has been elected President of the Florida Engineers in Industry which is a practice session of the Florida Engineering Society. The installation took place at the 55th annual meeting of the FES, a branch of the National Society of Professional Engineers. Mr. Morris is a registered Professional Engineer in the State of Florida.

Missile and Surface Radar Division

George J. Branin, Manager, Product Assurance, has been named Chairman of the Philadelphia Section of the American Society for Quality Control. The National Group has approximately 25,000 members. The Philadelphia Section, the fifth largest, has 650 members.

Degrees granted

D. Biko, AED, Pr	BS in Physics, LaSalle, 6/71
D. E. Bowser, EC, Lanc	MS in Engineering Science, Penn State, 6/71
D. P. Cunningham, EC, Lanc	MS in Engineering Science, Penn State, 3/71
T. Lewis, EC, Lanc	MS in Engineering Science, Penn State, 6/71
R. E. Reed, EC, Lanc	MS in Physics, Franklin and Marshall, 6/71
R. Shaffer, EC, Lanc	MS in Engineering Science, Penn State, 3/71
J. Werntz, EC, Lanc	MS in Physics, Franklin and Marshall, 6/71
B. J. Gullege, SDD, Palm Beach	MS in Computer Science, U. of S. W. Louisiana, Lafayette, 5/71
R. M. Rodrick, EC, Hr	MSME, Newark College of Engineering, 6/71
S. Gaskell, M&SR, Mrstn	PhD in EE, Univ. of Penn., 5/71
J. F. Sprinkle, M&SR, Mrstn	BA in Math, Temple Univ., 5/71
G. R. Field, M&SR, Mrstn	MSEM, Drexel Univ., 6/71
S. Halpern, M&SR, Mrstn	Drexel Univ., 6/71
K. B. Rooney, M&SR, Mrstn	BS in Bus. Adm., LaSalle 5/71
F. J. Galvin, M&SR, Mrstn	BS in Bus Adm., Temple Univ. 5/71
J. S. Spencer, M&SR, Mrstn	MS in EE, Penn State, 12/70
D. J. Smaldone, M&SR, Mrstn	MSE in Sys. & En. Op., U of P, 5-71
S. R. Bastianelli, M&SR, Mrstn	MS in EE, Penn State, 12-70
S. Eisig, M&SR, Mrstn	BEE, City Col. of New York, 6/71
L. K. Smith, M&SR, Mrstn	MSEE, Univ. of Delaware, 5/71
H. Miller, Jr., M&SR, Mrstn	BS in Mgmt, Rutgers Univ., 6/71

Smiley named Resident Patent Counsel, Information Systems group

Raymond E. Smiley has been named Resident Patent Counsel in the Information Systems group of Patent Operations. He will be located at Computer Systems Headquarters, Marlboro, Massachusetts. In this position Mr. Smiley will be responsible for liaison between the Marlboro System Development Division personnel and Patent Operations. Mr. Smiley received the BSEE from Case Institute of Technology, Cleveland, in 1960 where he was elected to Eta Kappa Nu. He also received an MBA in Industrial Management from the Wharton School of the University of Pennsylvania in 1965 and the JD degree from Temple University Law School, in 1969. Prior to joining RCA in 1969 as a member of the Patent Staff, he was employed by Univac as a Systems Engineer responsible for design and development of computer peripheral equipment and by Honeywell. He is a member of the bars of the District of Columbia and New Jersey and is registered to practice before the U. S. Patent Office.

Metchette is new TPA for EASD

C. S. Metchette has been appointed Technical Publications Administrator for the Electromagnetic and Aviation Systems Division at Van Nuys, California. In this capacity, Mr. Metchette is responsible for the review and approval of technical papers; for coordinating the technical reporting program; and for promoting the preparation of papers for the *RCA Engineer* and other journals, internal and external. Mr. Metchette joined RCA in 1962 as a technical writer. As Leader of Production Services since 1967, he supervises reproduction typists and technical editors in the preparation of equipment manuals, contract reports, and technical proposals. Prior to joining RCA, Mr. Metchette was engaged in the design and development of telemetry simulators and decommutators. Mr. Metchette served with the US 7th Cavalry during the Korean War. He received his BSc from Pacific States University, Los Angeles.

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