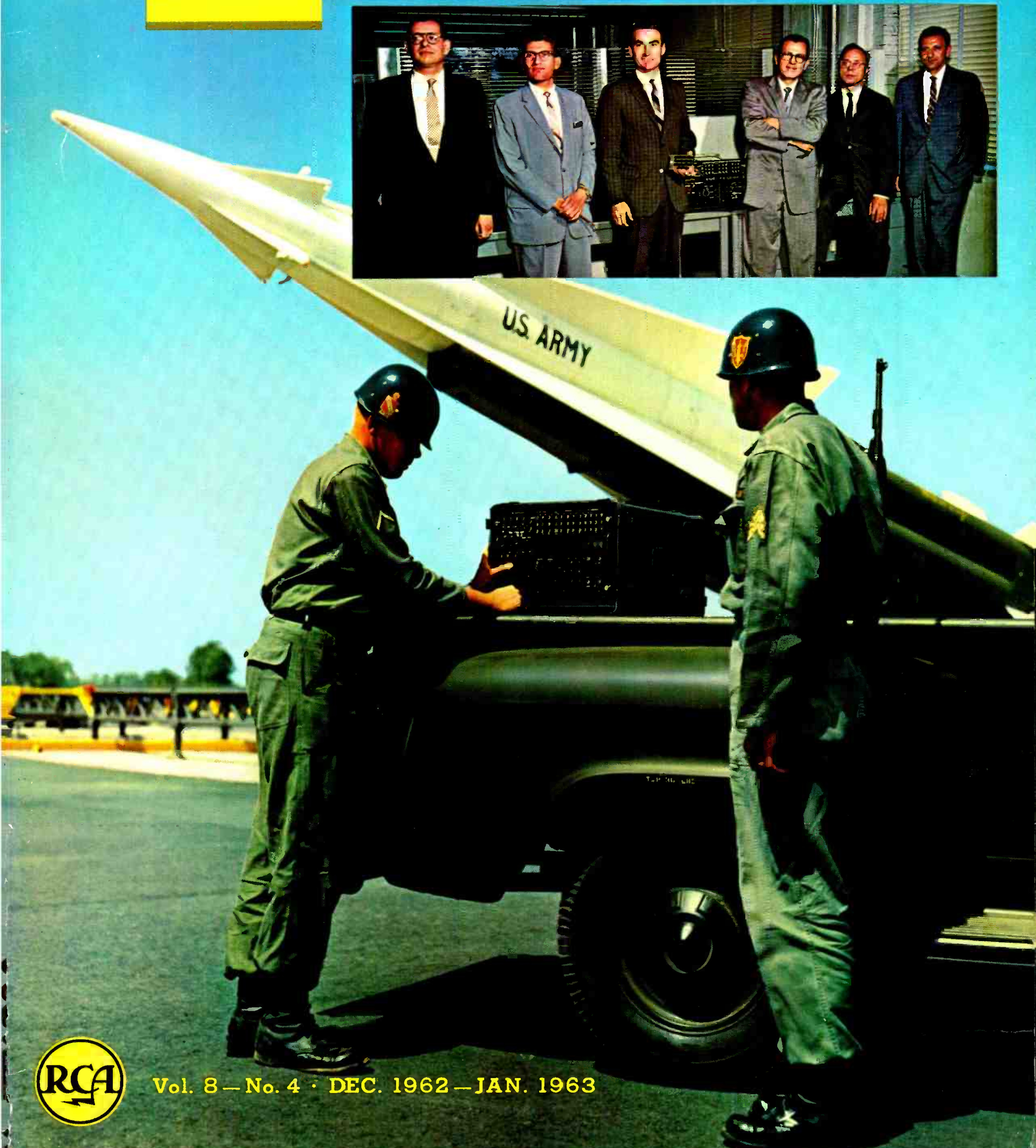
RCA ENGINEER



Vol. 8 — No. 4 · DEC. 1962 — JAN. 1963

OUR COVER

. . . The MICROPAC computer is shown against the backdrop of a NIKE-HERCULES missile. Although not a formal part of the NIKE system, the MICROPAC opens important possibilities for many types of military field equipment, since it is a portable general-purpose digital computer built with micromodules and designed for tactical military applications in the field. Inset are DEP Surface Communications Division engineers who led in development of the MICROPAC: (l. to r.) E. L. Schlain; A. S. Rettig; H. K. Sauer; A. H. Coleman; R. D. Torrey; and M. Gottlieb. *(See MICROPAC paper by Rettig, this issue.)*

Skill . . . Productivity . . . Flexibility

In the complex technological world today, the engineer must be aware at all times of three major factors:

First, he must realize that the age of automation poses new and serious challenges to technical personnel, requiring a level of productivity much higher than before. The current increased demand for sophisticated data processing and other electronic systems is constantly stepping up the technological pace—creating a need for the technical man to keep in stride by increasing his own rate of engineering innovation.

Second, the engineer who demonstrates ability to apply his skills toward greater productive efforts will find rapid advancement within his own scientific field—advancement opportunity matched by no other activity, including that of management. To increase his own productive efforts and at the same time stimulate greater effort from his associates is an invaluable combination. Professional recognition and success lie ahead in engineering and research for those who achieve such results.

Third, while the engineer must be an expert in his own field, he also must remain versatile and flexible in operational ability; he must not only keep fully abreast of developments in his own specialized area but also must be familiar with what is transpiring in related areas.

The function of the engineer, the very reason for his existence, is to solve the problems set before him—problems that are becoming technologically more difficult as the Space Age progresses and more and more important as national and international conditions continue as they are today. The measure of an engineer's productivity is his ability to find these solutions and, in the end, produce the highest quality products and systems. Machines may help him do so, but *the end product is his.*

By combining these attributes—*skill, productivity,* and *flexibility*—the engineer remains ready at any time to fit his skills to new programs that come to RCA.

A. L. Malcarney
Group Executive Vice President
Radio Corporation of America

RCA ENGINEER

VOL. 8, NO. 4

DEC. 1962-JAN. 1963

CONTENTS

PAPERS

NOTES

DEPARTMENTS

A TECHNICAL JOURNAL PUBLISHED BY **RADIO CORPORATION OF AMERICA,** PRODUCT ENGINEERING 2-8, CAMDEN, N. J.

● *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.*

An index to RCA ENGINEER articles appears annually in the April-May issue.

RCA AID TO EDUCATION

DR. DOUGLAS H. EWING
Vice President and Technical Director
Radio Corporation of America
Princeton, N. J.

RCA's PROGRAM for giving financial aid to education was initiated shortly after World War II. The Corporation recognized then, as it does now, that it has an obligation to assist the expansion and betterment of our institutions of higher learning and to provide help to students who are unable to finance their education completely. The reasons for this are not only those relating to good corporate citizenship but include the important need of assuring a continuing supply of men and women trained in science, engineering, and the other disciplines necessary to the growth and progress of RCA and its subsidiaries.

American business corporations' contributed over $130 million to colleges and universities in the academic year 1960-61. This represented about 16 percent of the total voluntary contributions received by schools; the dollar amount was 33 percent higher than in 1958-59 and 232 percent higher than in 1954-55 (totals were up 28 and 177 percent, respectively).

Money contributed for educational purposes comes out of corporate profit; it is money which, after providing for corporate income tax, would otherwise be disbursed as dividends to shareholders or reinvested in the business. Although contributions of this sort might be considered slightly peripheral to the business itself, Boards of Directors of U. S. corporations now generally recognize that their corporations have real obligations to educational institutions, and shareholders do not disagree.

As one would expect, there is wide variation in the amount of educational giving among U. S. corporations. One study of the donations of 30 major companies for the years 1956, 1957, and 1958 showed a *median* contribution of 0.7 percent of the individual net profit after taxes. 30 percent of these companies made donations of 1.0 percent or more of their after-tax profits.

THE RCA EDUCATION COMMITTEE

RCA's program for support to education is operated by the RCA Education Committee, whose first chairman was Dr. James Rowland Angell, retired president of Yale University. He was succeeded, in 1949, by Dr. C. B. Jolliffe, then Executive Vice President, RCA Laboratories and later Vice President and Technical Director of RCA. Dr. Jolliffe guided the Committee for ten years and was succeeded by Dr. Irving Wolff, who had retired as Vice President, Research, but remained with RCA on a part-time basis, at the request of the Board of Directors, in order to work on educational matters, until June 1962.

It will be seen from the listing in Table I that the Committee members include RCA and NBC officials concerned with education and related matters, as well as two distinguished members of the Boards of Directors of RCA and NBC. Both Mrs. Case and Dr. Newsom have lifelong interest and experience in educational matters.

The RCA Education Committee has the responsibility of maintaining and modifying, as appropriate, RCA's program for support to education, subject to approval by the President, the Contributions Committee and the Board of Directors. RCA's aim in providing aid to educational institutions and to individuals is to assist in the training of students for citizenship and careers in education and industry, and to encourage research in electronics and related fields.

It should be noted that all forms of corporate philanthropy come under the general authority of the RCA Board of Directors' Committee on Contributions. A brochure of this Committee, *Corporate Contributions Policies and Procedures*, guides the RCA Education Committee in carrying out its mission. One overriding principle set forth in this policy is *that all contributions should advance the interests of the Corporation*. Two policy provisions are particularly noteworthy at this point. They are in the nature of prohibitions. It is the general policy of the Corporation not to contribute to capital expenditures for educational institutions, and not to make gifts of RCA apparatus to an institution which is a customer or a prospective customer for such apparatus. Also, as a matter of practice, not specifically covered by policy, the RCA Education Committee has not contributed in any way to secondary or preparatory schools, but only to colleges and universities.

DR. D. H. EWING has been Vice President and Technical Director of RCA since January 1961. In this position he serves as the top technical liaison officer of the Corporation, providing counseling and advisory services to RCA licensees abroad and technical liaison between domestic and foreign research and engineering staffs. Instrumental in the establishment of RCA's basic research laboratory in Tokyo in June 1960, Dr. Ewing is a member of its Board of Directors. Dr. Ewing was recently appointed Chairman of the RCA Education Committee. Dr. Ewing graduated from Butler University, Indianapolis, Ind., with an AB in Physics, magna cum laude, in 1935. He received an MS degree in 1937 and a PhD in Physics in 1939 from the University of Rochester. In June 1955, Dr. Ewing received the honorary degree of Doctor of Science from Butler University. From 1939 to 1941, Dr. Ewing was Assistant Professor of Physics at Smith College, Northampton, Massachusetts. In 1941 he took a leave of absence from Smith College to join the Radiation Laboratory of MIT where government-sponsored development of radar systems was underway. He worked on radar research there throughout World War II, being named Chairman of the Overseas Office for the Radiation Laboratory. In 1945, Dr. Ewing joined the RCA Victor Division, in Camden, New Jersey, as Manager of the Teleran Engineering Section. (Teleran, was a pioneer electronic system for air navigation and traffic control.) In 1947, he was appointed Manager of Advanced Development at Camden. In 1949, Dr. Ewing was granted a leave of absence from RCA, at the request of the Civil Aeronautics Administrator, to serve as Director of Development of the Air Navigation Development Board in Washington, D. C. In 1951, Dr. Ewing returned to RCA as Director of Research Services of the RCA Laboratories in Princeton. Two years later he was appointed Director of the Physical and Chemical Research Laboratory, remaining in that post until his appointment as Administrative Director, RCA Laboratories, in June 1954. In November 1955, he was elected Vice President, RCA Laboratories. He was named Vice President, Research and Engineering, in January 1957. In January 1961, he was appointed to his present position. In addition to his RCA responsibilities, from 1956 to 1960 Dr. Ewing also served as a member of the Board of Directors of Industrial Reactor Laboratories, Inc., Plainsboro, New Jersey. He is a member of the Board of Directors and Vice President, Research and Development Division, of the American Management Association. He is a Fellow of the American Physical Society, a Fellow of the Institute of Radio Engineers, and a member of Phi Kappa Phi and Sigma Xi.

In developing its program, the Education Committee is mindful of the business interests of the Corporation and attempts to use the money at its disposal in ways beneficial to the Corporation as well as the recipient.

PROGRAM

The program of the RCA Education Committee for achieving the aims outlined above has three separate but interrelated parts: *Scholarships*, *Fellowships*, and *Grants*.

Scholarships

Two types of undergraduate scholarship grants are financed[2]: *First*, thirty-four scholarships are established at designated colleges and universities—thirty in Science and allied disciplines, and one each in Industrial Relations, Music, Dramatic Arts, and Television Training. *Second*, fifteen four-year scholarships are available each year to children of RCA employees under the recently announced Merit Scholarship Program.

Under the first program, candidates for the thirty-four scholarships (usually upperclassmen) are selected annually by the institutions on the basis of academic standing, character, and financial need, and are recommended to the RCA Education Committee for approval. Each of the scholarships carries a stipend of $800 which is paid to the college or university for the benefit of the scholarship recipient. In addition, an unrestricted grant of $500 is made to the institution itself, provided it is a private one not supported by taxes.

The unrestricted grant made to a private institution at which a scholarship (or fellowship) is placed is a relatively new form of corporate educational support and was originated by RCA. While a scholarship stipend is intended to cover tuition payment, it does not reimburse all institutional expenses connected with the scholar's education. The intent of the unrestricted grant is to cover those expenses not reimbursed by tuition so that the stipend and grant combined approximate an institution's total expenses in behalf of the scholar. Colleges and universities have been grateful for these grants, particularly since there are no restrictions on their use. Following RCA's lead, other corporate donors have adopted similar practices.

Table I—Current Members of the RCA Education Committee

Dr. George H. Brown
Vice President of Research and Engineering, RCA
Mrs. Everett N. Case
Member of RCA and NBC Boards of Directors
George H. Fuchs
Vice President, Personnel, NBC
Julius Haber
Director, Community Relations, RCA
George F. Maedel
President, RCA Institutes, Inc.
Frank L. McClure
Director, Organization Development, RCA
Harold Metz
Division Vice President, RCA
Carroll V. Newsom
Member of RCA and NBC Boards of Directors
Edward Stanley
Director, Public Affairs, NBC
Edward M. Tuft
Vice President, Personnel, RCA
John Q. Cannon, *Secretary*
Secretary of RCA
Dr. Douglas H. Ewing, *Chairman*
Vice President and Technical Director, RCA

In addition to the thirty-four scholarships at designated institutions, an RCA scholarship is awarded each year to an outstanding graduate of RCA Institutes, Inc. at an approved college or university. The award of $800 is made for one year but may be renewed for the period required for the student to achieve the baccalaureate degree. Thus, four RCA Institutes' scholarships may be in effect during each school year. Candidates apply for the scholarship to a committee consisting of engineers and educators selected by RCA Institutes. Final selection is subject to the approval of the RCA Education Committee.

The second of the two types of undergraduate scholarships, the Merit Scholarship Program for children of RCA employees, was announced in April 1962. Each year, a maximum of fifteen four-year college scholarships are awarded to RCA Merit Scholars. Recipients may attend the college of their choice, and may pursue any course of study leading to the usual baccalaureate degree. In contrast with the institutionally placed scholarships, which are on an annual basis, the RCA Merit Scholarships run for four years. Thus, beginning with the fourth year, as many as sixty scholars may be included.

All children (including those legally adopted) of regular employees of RCA and its divisions and subsidiaries in the United States who have completed at least two years' continuous company service by March 1 of the year in which the scholarship is granted are eligible to compete for these scholarships. Children of retired and deceased employees are also eligible.

The RCA Merit Scholars are chosen by the National Merit Scholarship Corporation (NMSC) from the children of RCA employees who reach the Finalist level of the annual NMSC competition. The selection is made on the basis of scholastic aptitude, leadership and good citizenship. The amount of each four-year scholarship is based on need and ranges from a minimum of $100 annually to a maximum of $1,500 annually. Additionally, grants are made to some of the colleges attended by the RCA Merit Scholars, based on recommendations from the NMSC.[3]

Fellowships

Aid to graduate students is given through two types of fellowships: the twelve RCA Fellowships, and the ten David Sarnoff Fellowships.

The twelve RCA Fellowships are established at designated universities in specified fields: five in Electrical Engineering, three in Physics, one in Science Teaching, two in Dramatic Arts, and one in Journalism. The Journalism fellowship, sponsored by RCA and the NBC Radio Network, is open to qualified newsmen (or women) associated with any of NBC's affiliated radio stations. The other fellowships are open to all qualified students.

The two awards in Dramatic Arts, known as RCA-NBC Fellowships, are among the very few industrially supported fellowships in this field. Available for prospective playwrights, actors, directors, producers, scenic artists, etc., these fellowships have furthered the careers of a number of young men and women.

Candidates for RCA Fellowships are selected by the university departments concerned, subject to approval by the RCA Education Committee. Each fellowship provides full tuition expenses and a stipend of $2,100. In addition, RCA makes an unrestricted grant of $750 to each university having an RCA Fellow.

The second type of fellowship, carrying the name of RCA's Board Chairman, is available to outstanding employees of RCA who are working toward graduate degrees at approved universities. Ten David Sarnoff Fellowships are awarded annually, six in Science, three in Business Administration, and one in Dramatic Arts or Journalism.

Employees are nominated for these fellowships by the department heads of RCA divisions and subsidiaries and final selection is made by the RCA Education Committee. Employees are chosen on the basis of academic aptitude, promise of achievement and character. They must be qualified for graduate study and be accepted in an approved school. Ph.D. candidates are given preference.

These fellowships are granted for one academic year. Each appointee is granted a leave of absence from the Corporation for the duration of the fellowship and is eligible for reappointment. The stipend includes payment of tuition, up to $50 for books, and $2,500 to $4,000 a year to the individual, depending on marital status. An unrestricted gift of $1,000 is made to the university attended.

RCA Scholars and Fellows who are selected by colleges and universities are completely free of obligation to RCA. Some have chosen RCA as their place of employment, but this has been a free choice.

Grants

RCA makes grants to educational institutions in a number of different ways. Prominent among these are the grants made to colleges and universities at which RCA employees have studied under RCA's Tuition Loan and Refund Plan. Since this plan may not be known generally, a summary follows.

This plan, administered by RCA's several plant and laboratory locations, not the RCA Education Committee, assists full-time employees to improve their performance in their present occupations and/or to equip themselves to perform in related occupations through after-hours study or training. Within specified limits and subject to certain general conditions, the plan provides for loans of tuition, budgeted repayment by the employees, and refund of tuition payments on satisfactory completion of courses. Details of this plan are available at local Personnel offices. Of particular interest to engineers is recent modification of the plan to provide additional assistance for employees in approved graduate degree programs.

The role of the RCA Education Committee in connection with the Tuition Loan and Refund Plan is to make grants to the institutions at which RCA employees have taken after-hours courses, again in recognition of the inadequacy of tuition to reimburse total costs. They are completely unrestricted as to use; the amount of each depends on (and is roughly proportional to) the number of employees taking courses at the particular institution. For the academic year 1961-62, grants in this category were made to 125 institutions, varying in amount from $100 to $2,500. Although many corporations have plans for assisting employees in payment of tuition for supplementary study, few have made contributions to the institutions at which the study is carried out. This type of grant was originated by RCA and has received favorable comment from many sources.

Grants are also made, to a limited extent, to certain organizations in the field of education whose activities are considered beneficial to the Corporation and to industry. Examples of such beneficiaries are the United Negro College Fund and the National Fund for Medical Education.

Special grants are made to educational institutions where instruction or research is of particular interest and value to RCA or where major use is made by RCA's employees of the institution's facilities. Such grants may be unrestricted or given for a particular project or program. Grants in this category are closely coupled to RCA's business operations, and are made usually to institutions in the vicinity of RCA plants or laboratories.

Although it is RCA's policy not to contribute equipment of RCA manufacture if the donee is a customer or prospective customer for that equipment, it is possible to make donations of surplus equipment. Apparatus, judged surplus by the division owning it, is offered to other divisions of RCA, and then is offered to the RCA Education Committee for possible use by colleges or universities. Frequently, test and measuring equipment and the like, no longer appropriate for use by RCA, fill a definite need in a college instructional laboratory and are accepted gratefully for that purpose.

OTHER CONTRIBUTIONS TO EDUCATION

In addition to the program outlined above which is carried out by the RCA Education Committee, there are many other direct or indirect contributions made by operating segments of the Corporation and coordinated by the Committee.

Network TV Classes

For three of the last four years, RCA was one of the substantial contributors in support of "Continental Classroom," the pioneering network television program for college credit. This program was broadcast five mornings per week by more than 180 stations of the NBC Television Network and was accredited by several hundred colleges and universities. Average daily viewing audiences were estimated to be in excess of 500,000. In 1958-59, Continental Classroom offered a course in *Contemporary Physics*; in 1959-60, a course in *Modern Chemistry*, broadcast in color; in 1960-61, *Contemporary Mathematics*, also in color, and in 1961-62, *American Government*.

Associates Programs

A number of American universities have so-called Associates Programs under which industrial concerns, in return for a contribution, receive certain benefits such as special seminars, consultation on general scientific problems, etc. In the normal course of business, RCA has joined some of these Associates Programs, through the operating divisions. In each case, the division concerned is responsible for liaison with the university, takes care of the contribution within its own budget, and reports its activities to the RCA Education Committee.

Fellowships, Scholarships, and Grants in Japan

Because of the unusual educational needs in Japan and because of RCA's business operations there, the RCA International Division initiated a program of educational aids in Japan in 1959. Prior to that time, most Japanese students chosen for Fulbright awards for study in the United States had been unable to accept them since they did not have the resources to cover tuition and living expenses. (Fulbright awards cover only transportation expense.) Through the United States Educational Commission in Japan (The Fulbright Commission), RCA makes available five fellowships for Japanese university graduate students to supplement their Fulbright awards. Awards are made to a maximum of five graduate students each year to provide assistance in meeting their tuition and living costs in the United States. Selection is made by the Fulbright Commission, and recipients have no obligation to RCA.

RCA's Educational Aid Program in Japan includes the award of scholarships to Japanese undergraduates studying in Japanese universities in natural sciences and electronics. Recipients of these scholarships are selected by the deans or presidents of universities which have been designated by the Japanese Ministry of Education.

RCA has also established a fund administered by the Japanese Ministry of Education to assist in providing Japanese secondary schools with laboratory apparatus and books.

Through RCA's Tokyo research laboratory, research grants are made annually to research investigators in Japanese universities to assist them in the prosecution of their programs. Limited to four in number, the research grants are made after review of detailed proposals and may be used for purchase of apparatus or supplies, salaries of supporting workers, etc. Although very modest in amount, by U. S. standards, the Japanese research grants have been well received and competition for them is keen.

Science Teaching Aid for Secondary Schools

Beginning this fall, RCA is initiating a pilot program of aid to science teaching in the secondary schools. Two junior and two senior high schools in Brooklyn, New York are involved. The program will include classroom lecture demonstrations in one junior and one senior high school and a series of seminar or after-school demonstration lectures in the other two. Twelve scientists and engineers from seven divisions and subsidiaries of RCA will participate as lecturers. Their contributions, in their fields of specialization, will be timed and paced to the curricula with which they will be associated. It is hoped that this participation by industrial scientists and engineers will supplement and enrich high school science courses to a considerable extent.

A LOOK AT THE FUTURE

The previous paragraphs have outlined RCA's present program in financial support of education and some of its history and philosophy. The program has reached its present form and proportion through an evolutionary process; it is to be expected that further modifications will be made as needs and interests are found to change. In the remainder of this paper I shall mention a few of the movements in education and its financial support which may have a bearing on the development of RCA's program.

The increasing costs of education, primary and secondary as well as collegiate, are of great concern to many thinking people. If educational methods and processes continue in their present form, many observers foresee that education will require a disproportionate share of our national resources a decade or a generation hence. Consequently much thought and discussion are being given to modifications in present practices and experimentation is underway. Examples abound: new curricula are being devised and new textbooks written; experiments are being performed on separating the expository and consultative phases of teaching with the view of accomplishing exposition more efficiently, e.g., through television. Audio aids are being used, especially in the teaching of foreign languages; teaching machines are being developed and, more importantly, programs are being written for them.

Likewise, there are many ideas on financial support. One suggestion is that colleges and universities should raise their tuition charges to equal total costs, providing loans for worthy, needy students, the loans to be paid off in later life. Radical though this suggestion may seem, it is certainly worth consideration and debate.

In this same vein, many colleges are already insisting that needy students, in order to obtain outright scholarship grants must take loans for a portion (typically, one-third) of their total needs. Such loans are long-term and bear low interest rates. In most cases repayment need not begin until several years after graduation. The theory behind these practices is, of course, that, through them, students have heightened incentive.

Personal giving, by non-alumni as well as alumni, is growing, possibly due to the increasing number of annual fund-raising campaigns. Historically, private universities used return on endowment to supplement tuition income and found this total sufficient to meet total expenses. Rising costs and shrinking investment income have produced serious deficits, and there is little hope for sufficient additional endowment to restore equilibrium. Thus institutions have resorted to solicitation of funds to meet current expenses. There seems to be no reason to believe this trend will do other than increase.

Corporate donors are constantly exploring novel means of educational support. One of these, initiated a few years ago by the General Electric Company, provides corporate grants to educational institutions, matching grants made to those institutions by corporate employees. Over 140 U. S. corporations now have matching grant programs. Among these there are wide variations in matching conditions, e.g., type of institution, amount contributed to a single institution per employee, total annual contribution per employee. One advantage of matching grant schemes frequently mentioned by their proponents is that they add incentive to regular personal giving through their multiplicative effect. Additionally, they stimulate colleges to more active and regular alumni solicitation. RCA has chosen not to adopt a matching grant program.

Other methods of corporate contribution include a scheme in which a corporation makes a donation, on behalf of each college graduate employed, to the appropriate college, after the employee has completed several years of service.

Certain it is that educational methods and processes and means of supporting them will be the subject of much discussion in the next few years. The RCA Education Committee will follow these discussions with great interest as it seeks to maximize the effectiveness of its educational assistance program.

BIBLIOGRAPHY

1. 1960-61 Voluntary Support of America's Colleges and Universities, Council for Financial Aid to Education, Inc.
2. Full details of the RCA Scholarship and Fellowship Program are contained in the pamphlet entitled *RCA Aid to Education.*
3. Full details of the RCA Merit Scholarship Program for children of RCA employees are found in the pamphlet entitled *Merit Scholarship Program — For Children of RCA Employees.*


SPACE TECHNOLOGY—Gary D. Gordon and T. Todd Reboul, Astro-Electronics Division, Princeton.

ACOUSTICS—Donald S. McCoy, RCA Laboratories, Princeton.

NUCLEAR PHYSICS—George J. Goldsmith, RCA Laboratories, Princeton.

ELECTRON TUBES—Markus Nowogrodzki, Electron Tube Division, Harrison, N. J.

RCA PIONEERS SCIENCE TEACHING PROGRAM FOR PUBLIC SCHOOLS

R. K. KILBON, Editor

Research and Engineering Information

Dept. of Public Affairs

Radio Corporation of America

New York City, N. Y.

ENERGY CONVERSION — William J. Helwig, Electron Tube Division, Harrison, N. J.

TELEVISION PRINCIPLES — Jarrett L. Hathaway, National Broadcasting Company, New York.

RADAR AND MICROWAVES — Richard M. Kurzrok, Surface Communications Systems Laboratory, New York.

CRYOGENICS—Benjamin Rabinovici, Surface Communications Systems Laboratory, New York.

PRACTICAL PROBLEM SOLVING — Lawrence Siegel, Surface Communications Systems Laboratory, New York.

COMPUTERS AND DATA PROCESSING — Harriet Bein, Surface Communications Systems Laboratory, New York.

SOLID STATE PHYSICS—F. L. Vogel, Semiconductor and Materials Division, Somerville, N. J.


COMMUNICATIONS THEORY AND SYSTEMS — R. K. Andres and James C. Hepburn, RCA Communications, Inc., New York.

Listed above are the technical fields and the fourteen RCA engineers and scientists who will teach them in the initial phase of the David Sarnoff Industry-Science Teaching Program—now underway for 275 students in four New York City high schools.

THE MOST COMPREHENSIVE APPROACH yet attempted to the enrichment of public school science teaching with the help of industry talent is now under way in a pilot program undertaken by RCA and the New York City Board of Education, proprietor of the nation's largest school system. Fourteen members of RCA's technical staff, four science teachers, and some 275 students in four schools are participating in the project, named the *David Sarnoff Industry-Science Teaching Program* in honor of its originator. During the 1962-63 school year, the RCA participants are presenting a series of more than fifty demonstration lectures in classrooms and after-school seminars.

Geared in both substance and timing to the regular science curricula of the participating schools, the presentations are designed to highlight current progress along the frontiers of science in the most challenging present fields of electronics. The subject matter, prepared and presented by specialists from seven of RCA's centers of technical activity, ranges from space technology and practical problem-solving to communications theory and nuclear physics. The theater of operations embraces two junior and two senior high schools in the Borough of Brooklyn, selected by New York school authorities as best representing the standard throughout the extensive system.

The objective of the pilot program, stemming from proposals made during the past six years by RCA Board Chairman Brig. General David Sarnoff, is to stimulate student interest in science as a career and to broaden the scientific understanding of those who will seek their careers in other fields. At the same time, the 1962-63 test in the New York City school system is conceived as a first run for a procedure which can be extended into communities throughout the nation by joint action of private industries and educational authorities.

For RCA, the experience represents a radical extension of a time-honored practice of cooperation with the communities in which it lives and works. In past years, there have been many examples of cooperation between RCA facilities and local school systems, as in Moorestown and Princeton. To a great extent, however, these—and most cooperative industry-education projects—have been local in concept and operation. The David Sarnoff Industry-Science Teaching Program has now gone beyond all of these by seeking to establish a procedure that can be widely adopted.

The program took shape early in 1962 following publication of an article by

General Sarnoff in a national magazine in which he urged specific steps to tap the technical talents of industry in order to help overcome the national shortage of qualified science teachers in public schools. The proposal, amplifying suggestions first made by General Sarnoff in 1956, struck members of the New York City Board of Education as a potentially useful approach to stimulation of student interest in science, even in a school system unaffected by a teacher shortage.

Following discussions between General Sarnoff and members of the Board of Education, the details of the pilot program were worked out by RCA representatives and the Office of Science Education of the New York City Schools. On September 27, 1962, shortly after the beginning of the new school term, the project was launched with opening ceremonies at the Board of Education headquarters in Brooklyn. On October 15, the program commenced with lectures on space technology in a physics class at Midwood High School and an after-school seminar at Erasmus Hall High School.

In its scope and concept, the David Sarnoff Industry-Science Teaching Program represents something new in the burgeoning field of industry-school cooperation. Among its most significant features are these:

1) A high degree of integration between the RCA presentations and the regular curricula, and between the RCA specialists and the public school science teachers in preparing and presenting the subjects;
2) The combination of classroom presentations and after-school demonstration lectures in a coordinated program running through the full school year;
3) The conception of the after-school seminar series for selected students as a supplementary course with credits, and as a source of further training for the science teachers of the participating schools;
4) The simultaneous operation of the program at both junior and senior high school levels;
5) The establishment by school authorities of techniques for evaluating the program at the end of the school year, including special test procedures and observation of any student tendencies to elect further science courses in following years; and,
6) The conception of the pilot program as a model for possible extension not only in New York but throughout school systems across the country.

The role of the RCA scientists and engineers in the program is basically one of sparking the imaginations of the students with first-hand accounts of recent and continuing advances in the laboratory. Picking up where the school curriculum stops, their presentations are designed to show how basic principles are being applied to the solution of major scientific and technological problems, and in what direction future progress is likely. In the course of the program, most of the RCA participants will introduce new or specially-designed visual aids, including simple demonstrations and actual laboratory models or prototypes.

The classroom phase of the project comprises one series of eight lectures in a twelfth-year physics class at Midwood High School, and another of seven lectures in a general science class at Andries Hudde Junior High School—one of the sources for the Midwood High School. All of these lectures are coordinated with the regular curriculum, coming at the conclusion of studies in the related subject. By close cooperation between the teachers and the RCA participants, the special presentations thus follow and enrich the regular program of instruction in the two classes.

The seminar phase of the program comprises a more extensive series of one-hour demonstration lectures to a group of about fifty selected "good average" students and the science teachers in each of the two other schools. Through the school year, the RCA specialists will give eighteen of these lectures to an audience comprised basically of eleventh-year chemistry students at Erasmus Hall High School, and another eighteen to a group of seventh- to ninth-grade students at Ditmas Junior High School—one of the sources for Erasmus Hall.

One of the more promising features of the pilot program from the standpoint of possible extension to other schools is the fact that no cost is involved for the educational systems. The RCA participants have volunteered their services, and their time and demonstrations are being paid for by their divisions and by the corporation. Seven different RCA facilities were approached in the preparatory stages of the program, and all extended willing cooperation in working out the list of subjects and selecting outstanding staff members from among those who expressed interest in the project. The result is the group of RCA "faculty members" (see list and photos) who will present demonstration lectures. As coordinator of the arrangements for the program through the year, RCA has named Jacob Brody, Superintendent of the Evening School, RCA Institutes, New York.

As it continues through the school year, the program is receiving close scrutiny from both educational and industrial organizations. And it appears at the same time to be arousing a lively interest among the students themselves because of the unusual opportunity to learn of the most advanced present-day activities in important fields of science and engineering from the people who are directly involved in the laboratories and the advanced development groups.

As General Sarnoff observed in the opening ceremonies on September 27, 1962:

"Out of a lifetime of collaboration with scientists, I have developed the deep conviction that if our young people in high schools could share my experience—and the similar experiences of many others—they also might be influenced in the selection of their life's work. I became convinced that student contact with scientists would stimulate intellectual curiosity and encourage the pursuit of further scientific knowledge.

"It does not require the rare mentality of a genius to produce a scientist. It requires only an alert and eager mind—a mind such as you youngsters possess—to absorb the technical knowledge that is the springboard to scientific innovation. If you are exposed to that knowledge when you are young, it can become your deposit on a lifetime of exciting and useful service to your country and the world."

RALPH KENYON KILBON graduated in 1938 from Wesleyan University, Middletown, Conn., with a B.A. degree with distinction in English. Joining the New York Herald Tribune after graduation, Mr. Kilbon was assigned to the foreign news desk and later to general reporting. Successively, he became makeup and picture editor, United Nations correspondent, financial writer, and, in 1949-1950, economic editor of the New York Herald Tribune European edition in Paris and Paris correspondent for the New York paper. From 1950 to 1952, he was Information Officer, Marshall Plan mission to the Netherlands, in The Hague, Holland. Returning to the United States in December, 1952, he entered the European office of the U.S. Information Service in Washington, D.C. Six months later he joined the RCA Department of Information in New York, and in September, 1954, was assigned as staff writer to the RCA Laboratories in Princeton. In January, 1958, he was named Coordinator, RCA Editorial and Press Services, Princeton and Camden. In October 1961, he was named Administrator, Public Affairs, for the RCA Laboratories. In February of 1962, he was named to his present post in the RCA Department of Public Affairs in New York as Editor, Research and Engineering Information.

SURFACE COMMUNICATIONS DIVISION ORGANIZATION AND FACILITIES

S. W. COCHRAN
Division Vice President and General Manager
Surface Communications Division
DEP, Camden, N.J.

Fig. 1—Program review in SurfCom Control Room. At tables (left to right): R. W. Greenwood, Manager, Operations Control; D. C. Koenitzer, Manager, Program Administration, M&SR; J. H. Sidebottom, Division Vice President and General Manager, M&SR; S. W. Cochran, Division Vice President and General Manager SurfCom; A. L. Malcarney, Group Executive Vice President; C. B. Jolliffe, Vice President and Technical Consultant; W. G. Bain, Vice President, Defense Electronic Products; T. J. Tsevdos, Manager, Programs Management. Facing them is P. C. Lindoerfer, Manager, Administration and Financial Control reporting on Minuteman Program. Seated against wall are (left to right): G. B. Di Girolamo, Administrator, Control Room; A. M. Burke, Leader, Engineering Systems Projects; C. A. Steuernagel, Plant Manager, Cambridge, Ohio Plant; and C. M. Ledig, Manager, Manufacturing Projects and Product Assurance. Standing are H. M. Groce, Jr., (left) Programs Coordinator, Control Room, and C. W. Fields, Engineering Editor.

The Surface Communications Division of RCA Defense Electronics Products is dedicated to the applied research, development, design, and production of modern communication systems and equipment for the military. From modest beginnings in 1956 in Camden, the Division has expanded to locations in four states, employing nearly 5000 people, of whom over 800 are engineers and scientists. The Division is now engaged on projects which will yield a 1962 sales total of approximately $85,000,000.

Much of the modern military communications problem is associated with *command* and *control*. The major elements of a command and control system are collection of information, processing of the collected data, distribution or communication of the processed data, decision making, and the implementation of the decisions. As a result of the tremendous developments which have taken place in the military equipment field over the past decade, it is now possible to collect vastly greater amounts of data, of a wide variety of types, from many more sources, bearing on a specific military situation, than ever before. The time, however, for performing the major command and control functions on the data has been drastically shortened. These conditions, then, lead to the basic requirement for modern, complex military communications systems.

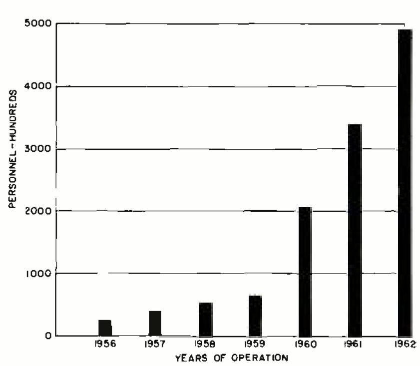


Fig. 2—SurfCom personnel growth.

SurfCom is organized for versatility in attacking a wide range of defense communications projects (Fig. 3). As Fig. 4 shows, these are now six basic product lines, and several major programs.

It was in 1957 that SurfCom successfully initiated its first major systems design and development effort—the North Atlantic Tropospheric Scatter System, a long-range high-frequency communications system. SurfCom has since participated in some of the most formidable military communications systems projects. Examples of this team effort are the Army's Unicom System with Bell Telephone Laboratories, the 480-L Communications System with IT&T, the 466-L Intelligence Study with IBM, and the Minuteman ground complex with Boeing.

The awarding of additional major systems contracts, including a quick-reaction design program for electronic warfare equipment, Data Link, and the Minuteman aerospace ground equipment programs to SurfCom in the 1960-61 period, accelerated division growth to a sales level of $75 million in 1961.

SURFCOM SUBDIVISIONS

SurfCom headquarters are, of course, located in the Camden RCA complex. The following are major outlying SurfCom activities.

New York Systems Laboratory: In 1956, Dr. Richard Guenther was assigned to creating a systems and techniques engineering laboratory in New York City. Today the group comprises over 300 engineers and support personnel occupying two floors at 75 Varick Street. Dr. Guenther directs the engineering and scientific talent in the development of new concepts and techniques in military communications and the integration of these concepts into improved military communication systems. This laboratory is the backbone of the division. In addition to supporting all of the major systems operations with systems and techniques talent, a substantial portion of the laboratory staff are concentrating on forward-looking developments associated with masers, parametric amplifiers, high-speed switching, etc.

Tucson, Arizona, Systems Laboratory: The Tucson branch of the SurfCom N.Y. Systems Laboratory was established in 1955 with three engineers and a small contract with the Army's Electronic Proving Ground at Fort Huachuca, Arizona. Until 1960 the major effort of this activity was devoted to a single system study of Army Communications systems. In that year the scope of the laboratory was diversified. In January 1960, the laboratory was moved from Tucson, 23 miles south to Vail, where a new 13,000-

Fig. 3—SurfCom Organization. (Mr. Cochran reports to W. G. Bain, Vice President, Defense Electronic Products.)

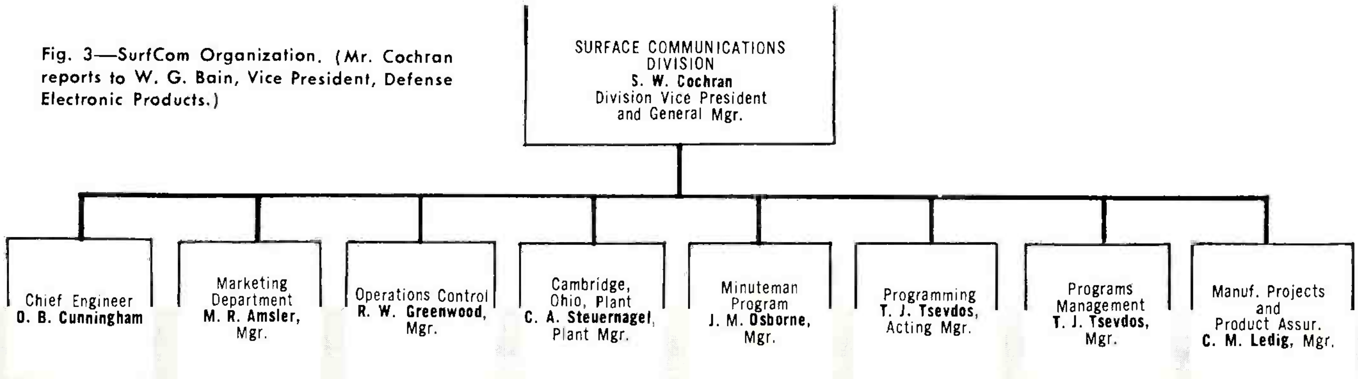


Fig. 4—Basic SurfCom product lines.

COMMUNICATIONS SYSTEMS
- Program Management
- Systems Studies
- Design and Development
- Manufacture and Installation

ADVANCED TECHNIQUES
- Micromodules and Integrated Circuits
- Tunnel-Diode and Parametron Circuitry
- TDM, FDM, PCM

DIGITAL COMMUNICATIONS
- Data Transmission Systems
- High-Speed Switching Devices
- Input-Output Equipment
- Data Modems
- Tactical Data Processing Equipment

ELECTRONIC WARFARE
- System Studies
- Quick-Reaction-Projects

MAGNETIC RECORDING
- Recorder-Reproducers
- Radarlog Equipment
- Tape Storage Devices
- Magnetic Drum, Thin Film Memory, and Random Access Devices

GROUND COMMUNICATIONS
- Tropospheric Scatter Communications
- Microwave Communications
- Parametric Amplifiers
- Military Television
- Combat Radio

S. W. COCHRAN, Division Vice President and General Manager, DEP Surface Communications Division, received his BSEE from the University of Washington in 1927. After graduation, Mr. Cochran spent three years with the General Electric Company at Schenectady. In 1930, he joined RCA, Camden, as a design engineer. In Special Devices Engineering, under his guidance, sound-powered telephones, battle announce equipment, and shipboard sound motion picture equipment were developed. In 1940, Mr. Cochran became a product manager of government sound equipment at the Indianapolis plant. He returned to Camden in 1945 as Manager of Special Devices Engineering. In 1949, Mr. Cochran was appointed Manager of Advanced Development Engineering, specializing in system development work. During 1950, under RCA sponsorship, Mr. Cochran took the Advanced Management Program at Harvard Graduate School of Business Administration. During the years 1953-1956, Mr. Cochran was Manager of Engineering Administration, Standards and Services for the Engineering Department, Engineering Products Division. In 1956, Mr. Cochran became Manager, Surface Communications Department. Later, when that department grew to Division status, Mr. Cochran was appointed Division Vice President and General Manager.

Fig. 5—Some major SurfCom programs.

MINUTEMAN—The system synthesis, equipment design and hardware production of the MINUTEMAN Sensitive Command and Support Information Networks has been a major effort in SurfCom since 1959. These networks process and transmit command and status signals between 50 launch sites and five launch control centers using advanced solid state switching and alternate routing to achieve ultrareliability and survivability under nuclear attack. Digital data transmission is employed and is based upon the RCA-developed "Modified Diphase" technique of modulation-demodulation: that is, converting digital data signals to a form suitable for handling by telephone lines. Unique and stringent reliability and security measures are incorporated.

DYNASOAR Ground-to-Air Transmitter—This project, begun in early 1961 under subcontract to the DEP Aerospace Communications and Controls Division, covers the development and design of a high power transmitter operating in the high x-band frequency range to supply ground-to-air command and voice communications. The amplifier and RF circuitry delivering 2 kw of x-band power was a major development. This is, to our knowledge, the first transmitter generating 2 kw of continuous-wave power in the SHF range.

MAVAR Pump—Development of an RF amplifier to provide "pumping" power to a series of parametric amplifiers for the NIKE ZEUS missile tracking system.

COMLOGNET Global Message and Data Switching Network—Providing the 75- to 4800-band service, a new tape-search unit and a unique broadband circuit switchboard utilizing dry-reed relays were developed, under subcontract to RCA Electronic Data Processing.

MICROMODULE Program—This was one of the earliest microminiaturization programs in the industry, now in the fourth year of development and application. Major SurfCom applications are the MICROPAC military digital computer, the PRC-25 pack radio set and the newest application, the "MICRORAC." The MICRORAC (MICROmodule Random Access Computer) will be a large-scale, high-speed, general purpose, militarized digital data processor and computer for the U.S. Army. It will operate at an equivalent speed of 160,000 instructions per second when equipped with a memory overlap feature and will provide an instruction repertoire of 55 orders automatically decoded and executed. All logic and memory circuitry will be packaged in micromodules. The high-population logic circuits may employ integrated semiconductor circuitry packaged within micromodules. The maximum computer system will be mounted within a standard 24-inch rack containing approximately 10,000 micromodules and four 16,384-core memory stacks.

AN/GRC-50 Microwave Radio Relay System—SurfCom developed, designed, and is now producing a large quantity of this UHF radio set used in multihop systems as the "backbone" of the U.S. Army's midrange communication networks. The AN/GRC-50 provides line-of-sight communication at 601.5 to 999.5 Mc, and at 1350.5 to 1949.5 Mc. A total of 899 discrete operating channels are available, using 1-Mc channel separations. The equipment can provide either terminal or patch repeater operation in intermediate or forward area military communications systems of up to 8 hops in tandem. It can be operated by relatively unskilled personnel in 24-hour-per-day continuous communication. It provides voice transmissions for a maximum of 24 channels of frequency division multiplexing, or 24 channels of time division multiplexing, utilizing the pulse-code-modulation method. The basic equipment can be handled by two men and can be stacked to form a compact operating group in a truck or adapted for installation in fixed plants.

AN/PRC-25 "Backpack" FM Combat Radio—SurfCom has a production contract to supply a large quantity of these "GI" radios. Included in the program are design and production of a number of units using micromodule circuitry. The PRC-25 is a 17.5-pound man-pack or vehicular-mounted (tank or jeep) tactical two-way radio transmitter-receiver operating at 30 to 75.95 Mc. Both transmitter and receiver can be instantly tuned by digital means in increments of 50 kc to any one of 920 channels within this frequency range, in two bands. Each channel provides crystal-controlled frequency accuracy and stability under all environmental conditions. The equipment is completely transistorized with the exception of a tube in the transmitter power output stage. Under man-pack conditions, the radio equipment is powered by a self-contained battery which provides up to 24 hours of life under a 9-to-1 transmit-to-receive ratio. Communication range is 3 to 5 miles, using a short 3-foot whip antenna or 8 to 10 miles using a 10-foot whip antenna.

AN/WIC Submarine Intercom System—This system, now in production at the Cambridge Plant, is a prime example of an RCA engineering-study-through-production project. SurfCom engineers were asked to modernize and expand submarine intercommunications systems in 1954. The study task group traveled aboard fleet submarines observing submarine intercom problems, and then designed and installed a pilot system. In turn, this led to a large-scale design-development-production contract to equip the new POLARIS missile submarines as well as the standard fleet attack types with all-new intercom and paging systems. The AN/WIC is a completely integrated system providing the equivalent of eight independent intercom and public address sets. Alarm signals for general alarm, collision, diving, missile malfunction, missile jettison and nuclear power plant failure are electronically generated. All amplifiers and alarm signal generators are completely transistorized and semiconductor rectifiers are used in the power supplies. The power supply is backed up by a nickel-cadmium battery which will supply several hours of full-scale system operation in case of AC power failure.

square-foot facility was dedicated. Located conveniently to the great western military bases, including Fort Huachuca, this facility employs approximately 150 engineers and support personnel who work on a variety of military projects including the support information network for MINUTEMAN, a Marine Corps communications receiver development and design project, and a communications study for the U. S. Navy.

Cambridge, Ohio: In 1961 the RCA Victor Home Instruments Division plant in Cambridge, Ohio, was rapidly transformed into a defense production plant. A "white room" was constructed inside that plant. This new controlled-atmosphere, contamination-free facility is the largest of its kind in the world. It enables RCA to make equipment meeting the MINUTEMAN reliability requirements which are undoubtedly the highest, currently, in the military equipment field. Cambridge employs 2500 personnel working in a 350,000-square-foot facility. Present manufacturing projects include MINUTEMAN, DATA LINK, POLARIS submarine intercoms, GRC-50 and PRC-25 combat radios, and COMLOGNET switchboards.

THE BUSINESS PICTURE

During the last five years, the Surface Communications Division has grown at an average rate of over 30 percent per year (Fig. 2). Deliveries during 1963 are expected to be 70% higher than in 1962. This growth has enabled the division to satisfy the major communications requirements of the defense establishment. In the years ahead, SurfCom plans to maintain a position of leadership through continued growth and expanded capability.

During the coming years the defense communications market is expected to change rapidly. New techniques are being developed which will make present communications equipment obsolete, new requirements and applications will arise, cost competition will increase as the percentage of fixed price contracts increases, and increased emphasis on integrated military communications networks will vest greater responsibility in a smaller number of centralized defense procurement agencies. The Division is making every effort to visualize and project the military communications requirements of the future and is taking steps now in the areas of engineering, manufacturing, and management which will assure its competency to compete for and obtain a substantial portion of the market.

ENGINEERING

To assure that SurfCom retains its technological leadership in the future, the division is presently carrying on over twenty applied research and development programs designed to advance the state of the art in many technological areas. Each of these programs has ambitious goals which, when achieved, will make a substantial contribution not only to SurfCom but to all of RCA and to the electronics industry in general.

In the area of digital switching, development is under way to increase switching speed while decreasing the error rate by an order of magnitude. Smaller, lighter weight equipment with higher reliability will be developed. In lasers, which have many potential uses in both communications and weapons systems, SurfCom plans to explore new applications which show exceptional promise; and in magnetic recording, where, with the assistance of DEP Applied Research, significant advances have been made, major effort will be exerted to advance the state of the art still further.

These and many other applied research and development programs will make a substantial contribution to technological growth in the coming years. Of great importance are customer-sponsored programs which enable the further development of techniques which show unusual promise. An example of this is the micromodule program, which is being carried out under the sponsorship of the Signal Corps. This program has proven so successful that, according to a recent statement by Major General Earle F. Cook, Chief Signal Officer, the production of modules will increase to an annual rate of 250,000 by March of 1963, to a million a year by June of 1964, and to three to five million a year by 1965.

MANUFACTURING

Shifts in manufacturing techniques and methods will be evident in the years ahead. With the increasing use of micromodules, more and more equipment will be manufactured by linking together standard module circuits on standard module boards rather than by assembling individual components. This will require new high-precision, high-speed connection techniques presently under development by SurfCom.

The modern defense electronics facility of the future will be considerably more mechanized than at present. The streamlining of the defense electronics industry has been retarded in the past by the large number of small-volume production runs and by rapidly fluctuating manufacturing requirements as old contracts reached completion and new contracts began. These factors will be much less of a limitation as new developments in production techniques provide equipment which can be used on a large number of contracts with varying requirements. SurfCom is continuously exploring these developments, such as automatic wire-wrap, in order to continuously improve the Division's production capability.

MANAGEMENT

Advances in management must keep pace with advances in other technical areas. As technology becomes more advanced and weapons systems become more complex, the need to develop and utilize new management techniques becomes increasingly more important.

Extensive design-review, product-assurance, and value-engineering programs are under way. Personnel are being retrained and new cost estimating techniques are being developed to handle an increasing number of cost estimate requests with speed and precision. These are necessary to support new cost incentive type contracts.

In planning, SurfCom has developed and is presently implementing a Business Planning and Reporting System, nicknamed "BUPAR", which will utilize data processing equipment to sort, collate, and present the increasing volume of planning information used as the basis for management decisions. When implemented, this SurfCom development will be made available to all DEP divisions.

The advantages of PERT/COST, a new program scheduling and control technique, have been recognized. The system has been implemented on several large programs in the division. An RCA 501 computer program is being written to develop within RCA an in-house capability to utilize this important tool.

A labor utilization program has been implemented to assure effective manpower utilization in all areas of manufacturing. In the near future the division plans to implement a similar technique for indirect and supporting personnel.

An increasing portion of our business consists of large projects. In order to manage these programs effectively, Program Management Offices have been established which utilize all of the above management techniques. Top management periodically reviews progress on each program (Fig. 1).

CONCLUSION

The management tools described above result from constant efforts to develop better management methods and techniques. Through the application of constantly-improving management methods in all parts of the operation, the personnel of the division propose to foster its rapid growth and obtain its full share of the military communications business.

SOME DEFINITIONS AND A BIBLIOGRAPHY

. . . of digital communications terms and recent SurfCom papers in this field—a supplementary reference for the papers in this issue on digital communications. (Credit is due C. W. Fields, Engineering Editor, SurfCom, for compiling this information.)

DEFINITIONS OF SOME DIGITAL-COMMUNICATIONS TERMS

baud—A unit of telegraph signalling speed. The speed in bauds is the number of equivalent code elements (pulses and spaces of standard width) per second.

baudot code—A teleprinter code employing a start space of one baud interval followed by data marks and spaces, each mark or space being of one baud interval duration followed by a stop interval equal to or greater than one baud.

buffer—A device used to hold temporarily information being transmitted between external and internal storage units or input-output devices and internal storage.

compandor (compressor-expander)—A system for improving the signal-to-noise ratio by compressing the volume range of the signal at the transmitter or recorder by means of a compressor, and restoring the normal range at the receiving or reproducing apparatus with an expandor.

delta pulse code modulation—A modulation system that converts audio signals into corresponding trains of digital pulses to give greater freedom from interference during transmission over wire or radio channels.

dipulse—An information bit interval in which a pulse of one polarity follows an equal pulse of the opposite polarity.

edit—To arrange or rearrange digital computer output information before printing it out. Editing may involve deletion or selection of data, insertion of invariant symbols such as page numbers and the application of standard processes such as zero suppression.

Fieldata code—Standard code used in U. S. Army and Marine Corps digital equipment. It is an alphanumeric code providing 64 data and 64 control characters in binary form.

frequency division multiplex (FDM)—A multiplex system for transmitting two or more signals over a common path by using a different frequency band for each signal.

frequency shift-keying (FSK)—A form of frequency modulation in which the modulating wave shifts the output frequency between predetermined values corresponding to the frequencies of correlated sources.

matrix—A computer logical network consisting of a rectangular array of intersections of input-output leads, with diodes, magnetic cores or other circuit elements connected at some of these intersections.

modem (modulator-demodulator)—A carrier terminal panel containing a modulator and a demodulator, some circuits of which may be in common.

off-line operation—Operations carried on independently of the main computer, such as transcribing card information to magnetic tape or magnetic tape to printed form.

on-line operation—Operations carried on within the main computer system such as computing and writing results onto a magnetic tape, printed report, or paper tape.

pulse-amplitude modulation (PAM)—Amplitude modulation of a pulse carrier.

pulse code—A code consisting of various combinations of pulses, such as the Morse Code, baudot Code and the binary Code used in computers.

pulse code modulation (PCM)—A method of converting a continuous message into a signal of coded on-off pulses by: 1) sampling the amplitude of the message at discrete intervals; 2) measuring the amplitude of each sample to the nearest one of a finite number of amplitudes into which the message range has been divided; 3) expressing each measured value as a train of on-off pulses, the pattern of which is in accordance with binary number notations.

pulse duration modulation (PDM)—A form of pulse-time modulation in which the duration of a pulse is varied.

pulse position modulation (PPM)—A form of pulse-time modulation in which the position in time of a pulse is varied.

pulse-time modulation (PTM)—Modulation in which the time of occurrence of some characteristic of a pulse carrier is varied from the unmodulated value.

quantization—Division of the range of value of a wave into a finite number of smaller subranges, each of which is represented by an assigned or quantized value within the subrange.

quantization distortion — Inherent distortion introduced in process of quantization. Also called quantization noise.

random access—Access to computer storage under conditions wherein the next store location from which the information is to be obtained is chosen at random.

real time—The performance of a computation during the time of a related physical process so the results are available for guiding the physical process. (An example is computer guidance of a missile.)

time division multiplex (TDM)—A device or process for transmitting two or more signals over a common path by using successive time intervals for different signals.

vocoder—A bandwidth compression device which analyzes and synthesizes speech.

BIBLIOGRAPHY

Selected SurfCom Papers Relating to Digital Communications

1. Abbott, G. F., "A Four-Wire Electronic Circuit Switching System for Analog and Digital Transmission," IRE 2nd Winter Convention on Military Electronics, February 1961; *Convention Proceedings*.
2. Abbott, G. F., "Application of Circuit Switching to Communications Systems," IRE 7th National Communication Symposium, October 1961; *Symposium Proceedings*.
3. Abbott, G. F. and Groth, W. B., "Application of Switching to Communications Systems," RCA ENGINEER, February-March, 1962.
4. Anzalone, P. J. and Schlain, E. L., "How Shared Loading in Decode Matrices Reduces Driver Requirements," RCA ENGINEER, August-September, 1962.
5. Atzenbeck, C., "An Error Detection and Correction Technique For the RCA Modified Diphase Modem," *MSEE Thesis*, Brooklyn Polytechnic Institute.
6. Bayer, I., "Fixed Interval Timer Gates Random Pulse Stream," *Electronic Design*, September 13, 1962.
7. Caplan, D. I., "Data Processing For Communication Network Monitoring and Control," Fall Joint Computer Conference, Dec. 4, 5, 6, 1962, Philadelphia; *to be published*.
8. Coleman, A. H., "Digital Microelectronic Systems: Problems and Potential," West Coast AIEE Meeting, May; 5th National Convention IRE-PGPEP, June 1961, *PGME Trans.*, July 1961.
9. Coleman, A. H., Sauer, H. K., "Digital Micromodular Equipment Design Concepts," International Electronic Circuit Packaging Symposium, Boulder, Colorado, August 15-17, 1962.
10. Coleman, A. H., "Solid State Interconnection Problems," 1962 International Solid State Circuits Conference, Philadelphia, February 14, 1962.
11. Curtin, K., "A Monte Carlo Simulation of the Operational Effectiveness of Multi-Moded Systems," IRE 3rd National Symposium on Reliability and Quality Control, New York, October 15, 1962.
12. Dietz, J. C. and Swyler, J., "Design and Application of Dry Reed Relays to an Electronic Switching System," National Conference on Electromagnetic Relays, April 1961; *Conference Proceedings*.
13. Douglas, D., Aaronson, G., and Meslener, G., "A New Digital Communications System — Modified Diphase," IRE 5th Global Communications Symposium, May 1961, *Symposium Proceedings;* 5th National Convention on Military Electronics, June 1961.
14. Dutka, J., "On Synchronization of Pulse Trains," *RCA Review*, September 1961.
15. Groth, W. B., "Design and Application of Message Switching to Communication Systems," IRE 7th National Communications Symposium, October 1961; *Symposium Proceedings*.
16. Kaplan, S. and Stambler, L., "Parametron Applications in Military Switchboards," IRE 5th Global Communications Symposium, May 1961; *Symposium Proceedings*.
17. Kishi, J. J., Cohen, J. and Rosenthal, M. P., "Self-Verification of System Status," RCA ENGINEER, August-September, 1962.
18. Klapper, J. and Rabinovici, B., "Digital Circuits with a Minimum Number of Tunnel Diodes," Northeast Research and Engineering Meeting (NEREM), November 1961; *NEREM Proceedings*.
19. Klapper, J. and Rabinovici, B., "Tunnel Diode Digital Circuits Using Composite Characteristics," *Electronics*, February 16, 1962.
20. Kolarcik, J. J., "Versatile Zener Diode Array Forms High-Speed Quantizer," *Electronics*, August 20, 1962.
21. Kritz, A. M. and Roberts, H., "Alternate Routing Computer," IRE 5th Global Communications Symposium, May 1961; *Symposium Proceedings*.
22. Lysobey, M., "Microminiature Crystal Oscillator Using Wafer Modules," *Electronics*, April 31, 1962.
23. Meeker, W. F., "Speech Coding and Automatic Speech Recognition," Acoustical Society of America, November 9, 1962.
24. Mertens, L. E., "Military Digital Communications," RCA ENGINEER, October-November 1961; University of Pennsylvania, March 1962.
25. Rezek, G. and Taylor, P. K., "Thermal Design Solutions for Micro-Modular Equipment," IRE PGPEP National Conference and Exhibition, June 1961: *Transactions of PGPEP*.
26. Rabinovici, B., "Tunnel Diode Shift Register," *IRE Proceedings*, April 1962.
27. Rabinovici, B. and Renton, C. A., "Full Binary Adder With One Tunnel Diode," *IRE Proceedings*, July 1961.
28. Rabinovici, B. and Renton, C. A., "Tunnel Diode Full Binary Adder," *IRE-PGEC Transactions*, April 1962.
29. Straube, H., "Dependency of Cross-talk on Upper and Lower Cut-off Frequencies in PAM Time-Multiplexed Transmission Paths," *IRE-WESCON Proceedings*, Aug. 1961.
30. Tepfer and Rabinowitz, "Communications Error Rate Instrumentation System," IRE 5th Global Communications Symposium, May 1961; *Symposium Proceedings*.
31. Wald, S., "Comparison of Analog-To-Digital Conversion Techniques," *Electronic Design*, August 2, 1962.
32. Weinstock, D., "Mathematical Analysis of Redundant Systems Solving the Problems With Matrix Algebra," IRE 8th National Symposium on Reliability and Quality Control, January 10, 1962; *Symposium Proceedings*.
33. Winkler, M. R., "Chirp Coding, Correlation Detection and Side Lobes," Navy Research and Development Clinic, September 1961.
34. Winkler, M. R., "Chirp Signals For Communications," *IRE-WESCON Proceedings*, August 1962.
35. Yao, Y. L., "Generating a Worst-Case Noise Pattern In Coincident Current Memories," *Electronic Design*, May 10, 1962.
36. Zabronsky, H., "Statistical Properties of M-ary Frequency-Shift Keyed and Phase-Shift Keyed Modulated Carriers," *RCA Review*, September 1961.

SURFCOM ENGINEERING PHILOSOPHY AND STRUCTURE

O. B. CUNNINGHAM, Chief Engineer
Surface Communications Division
DEP, Camden, N. J.

UPON VIEWING Surface Communications Engineering in total, with its large population and extensive facilities, I am reminded of this organization as it existed in 1953 (then known as Radiation Engineering) when I joined the group. Then, there was a dedicated staff of about 70 engineers, leaders, and managers, with a handful of draftsmen and technicians and a minimum of office support. Occupying one floor in Building 13, Camden, Radiation Engineering was engaged principally in the Navy receiver, sonar, and combat radio business, with a small group working on mine firing devices.

The organization principles used to build this small nucleus were, simply stated: *put people with similar skills, interests and, most importantly, mutual technical respect, together in product-line groups and give them the job of building that product line into a going business.* Potential growth items in the form of new projects and techniques have always been put into each group, so that the group might broaden its skill base not only by attracting competent technical people but also by diversifying the skills of all its members. (Remember that new techniques and new systems, or a major project, are just as much separate product lines as are, say, magnetic recording or digital communications.)

Continuity of skills in a product line is of particular importance. Many of the design teams in our division have been together for a number of years, and have an intense devotion to their product lines. They have developed a long succession of products and services that have earned the respect of our customers. By thus establishing a history of successful designs, such teams never seem to lack a new and challenging assignment in their particular field of deavor—indeed, many times the customer comes to them first for help.

Most of the original members of Radiation Engineering are still on the SurfCom staff and constitute much of the backbone of the product-line teams. Charged with broadening their product and skill base, they have changed the entire complexion of our division, utilizing the skills of sister divisions and subcontracts from them wherever possible to increase the volume of business. As a contrast, at one time early in the life of the division, 45 percent of the engineering, drafting and technician load was in essence "subcontracted" to other divisions (including the commercial operations) to keep pace with our rapid business growth. Conversely, we have sent our personnel into other divisions many times to work with and learn from them and to bring new skills vital to our growth back to the parent product group. We are particularly grateful to DEP Applied Research and other Divisions in the Camden-Moorestown complex for making it possible for us to enter areas which would have been impossible to develop without their understanding, assistance, and training.

By design, the SurfCom Engineering organization has been kept very flexible and does not follow any standardized, orthodox, textbook pattern. We believe in tailoring the organization and the people to the exact job to be done, and we attempt to give the manager of that job freedom to organize to that end. Note that the same basic principles of organization still apply in SurfCom, although we have grown over ten-fold, and have spread our technical staff from Camden to Tucson, Cambridge, and New York. We have concentrated many of our systems-and-techniques specialists in the Systems Labs in New York and Tucson, but surprisingly enough we have also a product design group in New York which reports to Camden. Similarly, we have a Systems group in Camden, for on-the-spot support of the product groups, which reports to New York. Our Programs Management operation has branch offices in New York, Cambridge, and Tucson to give manage-

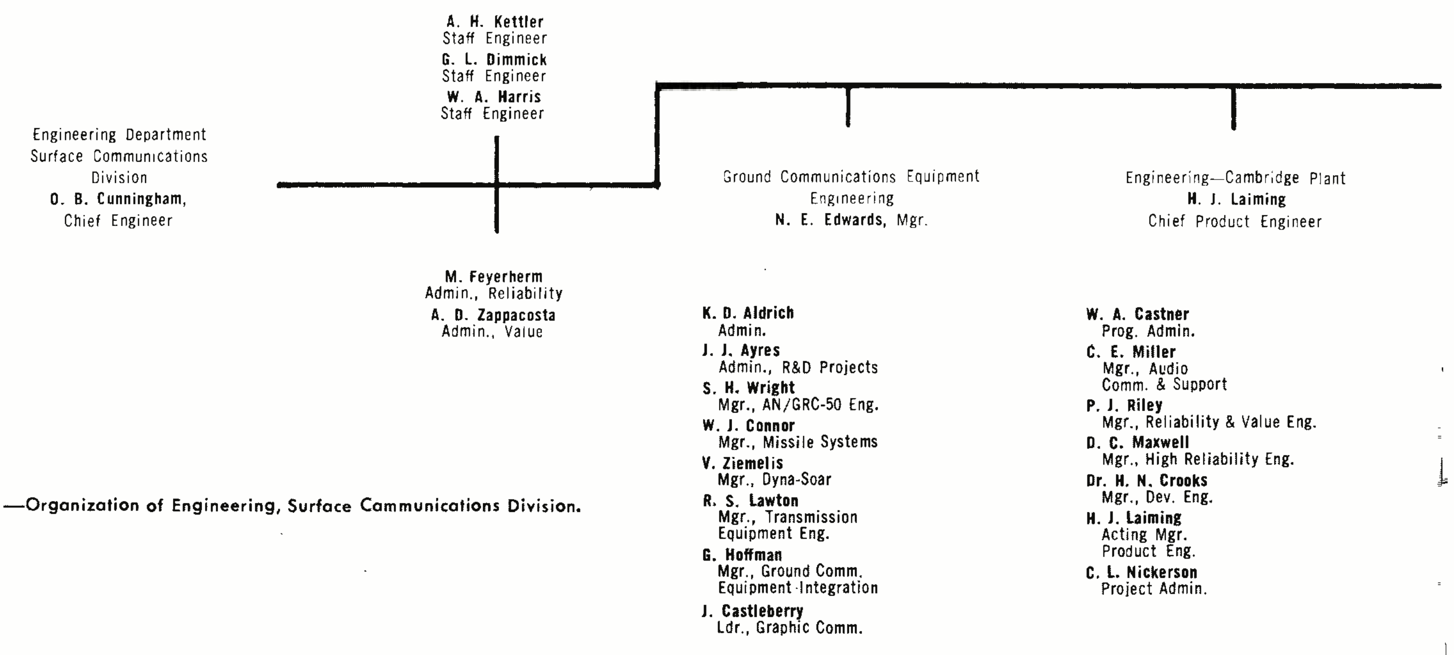


Fig. 1—Organization of Engineering, Surface Communications Division.

ment support, strength, and guidance to these operations. In addition to the three Camden design groups, we have established product design activities in Tucson and, more recently, in Cambridge to utilize the skills in those areas to further increase our capacity to engineer products and systems for our customers.

We believe an engineering department should be able to service its customers all the way from the conceptual period through the system-and-design plan phases, into production, and finally follow the product out into the field. On our MINUTEMAN program, we were fortunate enough to have this complete responsibility—from devising the system to following its successful implementation and operation in the field. Frankly, we could not have handled a MINUTEMAN system when this division was first formed; and it has taken a lot of doing on the part of every member of our division, plus contributions from people throughout RCA, to make it possible today.

While there are many factors that have influenced the progress of SurfCom, I believe that when you put competent people together who like, respect, and trust each other, keep them together as a team and give them a charter to grow with, then growth is inevitable. Our job in management has been to keep these groups in constant, effective communication with one another. But that's easy; after all, *Communications is our business.*

O. B. CUNNINGHAM, Chief Engineer, Surface Communications Engineering, received his BSME at the University of Kentucky in 1935. Mr. Cunningham began his radio career as an operator in the U. S. Navy in 1929. He joined RCA the summer of 1935, and served as a special tester on receivers, transmitters, and television equipment for two years and then transferred to the Engineering Department. As an engineer, he handled a wide variety of mobile, shipboard and airborne communication and navigation equipment design, both Government and commercial. He entered supervision in 1941, and served as Leader, Unit Supervisor, and Manager of Aviation Communications until May 1953, when he assumed duties as Chief Engineer of Surface Communications Engineering. He is a Senior Member of IRE, a civil member of ASNE, and a member of Tau Beta Pi, Sigma Pi Sigma, and the American Management Association.

Fig. 2—Chief Engineer's Staff Meeting (clockwise from left foreground): M. P. Feyerherm, Administrator, Reliability; A. D. Zappacosta, Administrator, Value Engineering; M. C. Meyers, Manager, QRC Programs; J. L. Grever, Manager, Magnetic Recording; C. M. Ledig, Manager, Manufacturing Projects and Product Assurance; J. E. Eiselein, Manager, Engineering Support and Administration; O. B. Cunningham, Chief Engineer, SurfCom; J. M. Osborne, Minuteman Program Manager; R. L. Rocamora, Manager, Digital Communications; A. H. Kettler, Staff Engineer; M. L. Graham, Manager, Projects Administration, Digital Communications; J. D. Sellers, Manager, Systems Projects, Program Management Section; K. R. Thompson, Manager, Facilities Engineering; C. A. Rammer, Manager, Micromodule Engineering; B. F. Wheeler, Leader, Systems Engineering; J. R. Dziel, Manager, Mechanical Coordination and Drafting; G. L. Dimmick, Staff Engineer; E. F. Bailey, Manager, Communication Equipment Programs.

Eng. Support & Admin.
J. E. Eiselein, Mgr.

- **J. Kaurloto** Mgr., SurfCom Eng. Servs.
- **J. Dziel** Mgr., Mech. Coord. & Draft.
- **H. Fesq** Acting Mgr., Configuration Records Control
- **R. E. Patterson** Mgr., Publications
- **L. Dommel** Admin., Tech. Manpower Coord.
- **E. E. Moore** Mgr., Des. Support Coord.

Magnetic Recording Equipment Eng.
J. L. Grever, Mgr

- **H. R. Warren** Mgr., Des. & Dev. Eng.
- **A. Lichowsky** Mgr., Des. & Dev. Eng.
- **J. L. Grever** Act. Mgr., Product Line Controls
- **L. S. Cranmer** Admin., Facilities and Services

Digital Comm. Equipment Eng.
R. L. Rocamora, Mgr.

- **R. D. Torrey** Staff Consultant Digital Circuits
- **D. I. Caplan** Admin., Tech. Proj. Coord. Digital Comm. System Projects
- **M. L. Graham** Mgr., Proj. Administration
- **G. T. Ross** Mgr., Automatic Switching & Checkout
- **R. L. Rocamora** Acting Mgr., Data Comm. Eng.
- **A. H. Coleman** Mgr., Tactical Data Processing Eng.
- **M. L. Touger** Mgr., Speech & Military Data Link Eng.

SurfCom Systems Labs., NYC and Tucson
Dr. R. Guenther, Mgr.

- **E. M. Bradburd** Mgr., Advanced Comm. Techniques
- **A. P. Brogle** Mgr., Comm. Intelligence & Intercept Eng.
- **M. L. Ribe** Mgr., Systems Projects
- **A. M. Creighton** Mgr., Tucson Systems Lab.
- **A. Mack** Mgr., Systems Integration

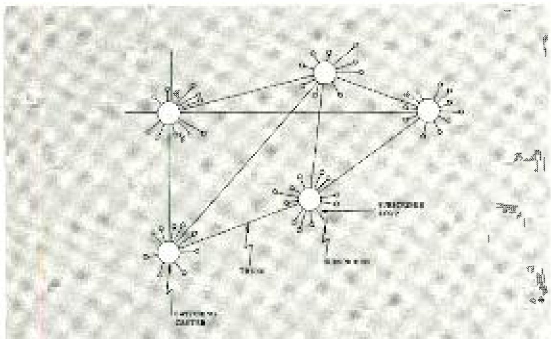


Fig. 1—Basic elements of a long haul communications network.

SOME TRENDS IN MILITARY COMMUNICATIONS SYSTEMS

This paper outlines briefly some of the urgent and unique problems that our modern globe-spanning military capability poses for military communication systems and indicates some of the major approaches used in solving these problems.

Dr. L. E. MERTENS and D. I. CAPLAN

Surface Communications Division

DEP, Camden, N. J.

COMMUNICATIONS, always crucial to military operations, have recently become complicated by several new factors:

1) Dispersion of forces due to the threat of atomic weapons
2) Increased mobility of military units
3) Vulnerability of many communications links to nuclear effects
4) Growth of computer-to-computer data communication
5) Increase in crypto-secure traffic

Despite these problems, the military user must be provided with adequate and reliable communications, even during periods of extreme stress brought on by wartime conditions.

The problems noted above have posed a requirement for vast new military communications capabilities. Providing these new capabilities has been a vital and important challenge to the engineering skills of the Surface Communications Division[1] as well as in many other divisions of RCA.

There exists, of course, a wide variety of military communications systems, each with its own unique applications and problems. It is convenient to consider these systems in the following categories: *long-haul networks, tactical-communication network systems, command and control communications*, and *telemetry systems.*

LONG HAUL NETWORKS

The backbone of military communications is the long-haul network. Covering continents and serving thousands of subscribers, the long haul network is essential for coordination and control of military operations throughout the world. The size and scope of military long haul networks are indicated by the following statistics:

Service	*Telephone Channels*	*Teletype Channels*
Army	1600	1900
Navy	300	1000
Air Force	4350	5500
	6250	8400

The military communications mission requires rapid reaction to enemy interference, acts of nature, traffic overload, or equipment failure. Possible remedial actions include use of spare channels, transfer of traffic to alternate routes, and preemption of channels by high priority users. For optimum effectiveness, a central control facility must direct these actions from an over-all network viewpoint. Otherwise, remedial action at network stations may alleviate local problems at the cost of global effectiveness. Computers can be used for central control of a long haul network.[2]

The basic elements of a long-haul communications network are shown in Fig. 1. The users, or subscribers, are connected to nearby switching centers by subscriber loops. Switching centers are interconnected by trunks. The trunks are made up of channels, where each channel may carry a single voice communication or a single teletype communication. Communication between subscribers served by different switching centers can take place over any of several paths through the network. This network redundancy is essential for network operation when some switching centers or trunks are inoperative.

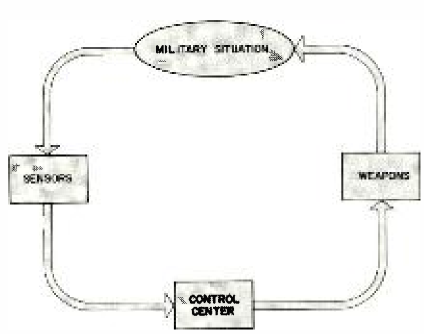


Fig. 3—Command and control communications system.

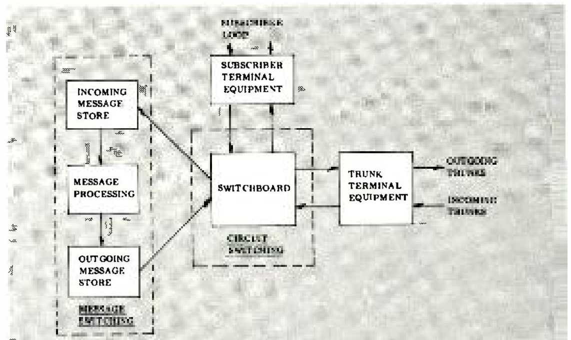


Fig. 2—Switching center block diagram.

The switching center is shown in Fig. 2. Trunks and subscriber loops are terminated in a switchboard. The circuit switching function consists of making a connection between two loops (local call), between a loop and a trunk channel (toll call), or between two trunk channels (tandem connection). Switchboards may be manual, with operators, or may be automatic for use with dial telephones.[3]

To provide immediate service to important subscribers, two special circuit-switching procedures are used. First, some of the connections can remain in effect full time. These connections, called allocated circuits, are used to provide continuous service between subscribers. The Air Force SAC "hot lines" are examples of allocated circuits. Second, certain subscribers can interrupt calls of other subscribers to preempt the circuits being used. This feature must be based on a series of preassigned subscriber priorities.

Teletype messages and digital data, unlike voice, can be stored at a switching center for later retransmission. This operation is called *message switching;* the descriptive term *store and forward* is also used.[4]

Message switching provides several network advantages. First, messages can be transferred part of the way to the destination, even when no straight-through connection is available because one or more trunks are busy. Second, multiple-address messages can be sent as single messages to the destination switching center and broken down there into multiple copies for subscribers served by that center. This feature saves trunk transmission capacity. For these reasons, message switching is preferable for all traffic which can tolerate the inherent delay involved.

The trunks use many communications media to transfer information. The commonly used media are HF radio, microwave, land line, submarine cable, and tropospheric scatter. In each case, terminal equipment is required to modulate the transmitter. The growth of data communications has resulted in development of specialized digital terminals.

Security may be provided in several ways for teletype traffic in the network. Some of the traffic is link-encrypted; that is, the messages are encrypted as they are transmitted from the switching center and decrypted as they are received at the next center. They pass through the switching center in the clear. Critical messages are end-to-end encrypted, and cannot be read in any switching center along the way.

COMMAND AND CONTROL COMMUNICATIONS

Modern military weapons systems use a command and control concept which involves a closed loop. The military situation is observed by sensors and data gathering equipment, and data from these sources is transferred back to control center. Here, digital computers filter the incoming data. Either automatically, or in conjunction with man-machine subsystems, the operations decisions are made and translated into commands. These commands are then transmitted through the system to operational weapon units such as missiles, aircraft or ships. The weapons exert an effect on the military situation, thereby closing the loop. A flow diagram illustrating this concept is contained in Fig. 3.

DR. L. E. MERTENS received his BS and MS and Doctor-of-Engineering Science all in Electrical Engineering from Columbia University. In 1953, he joined RCA's Advanced Development Section in Camden, working on mathematical analyses, and circuit design. In 1954, Dr. Mertens transferred to Aviation Systems Department and was responsible for systems analysis and planning on airborne fire control, missile guidance, and bombing and navigation systems. In 1957, he joined the ASD Chief Engineers' staff to become responsible for initial feasibility studies on a new approach to interception of satellites in orbit. In 1958 Dr. Mertens joined the staff of the Chief Defense Engineer and assumed coordination of applied research and advanced development programs. In 1959, he transferred to the Surface Communications Division to become Manager of Digital Communications Equipment Engineering. Recently, he moved to the RCA Servce Co. as Staff Scientist at Cape Canaveral. Dr. Mertens is a member of IRE; American Ordnance Association; the New York Academy of Sciences; Sigma XI and Tau Beta Pi.

Special problems faced by the command and control communications system include minimizing the reaction time, insuring high accuracy data, providing security, and meeting certain environmental requirements. These are considered in the following paragraphs.

The advent of supersonic aircraft and, more recently, ballistic missiles placed stringent requirements on minimizing reaction time in both offensive and defensive weapon systems. High speed digital data transmission employing automatic handling and processing is an important method in reducing the system's reaction time. An attempt is made to permit as far as possible the various computers and data processors in the system to communicate directly with each other. Only highly condensed and processed data is generally presented, either visually or aurally, to human operators. Special techniques for providing priority interrupts, nonblocking switching, and hot lines are often provided in the system.

Important defense functions depend on the accuracy of the data transmitted and processed in the command and control systems, and there can be severe penalties for system errors. Small data errors in timing or position can completely destroy the effectiveness of an air-to-air interception, for example. Perhaps even more serious might be the inadvertent launching of nuclear warheads because of incorrect system signalling. In order to achieve the high accuracy required, various techniques of error control are employed. The degree of error protection employed is determined by the type of transmission channel employed as well as the system requirements for error free transmission.

DAVID I. CAPLAN graduated from MIT in 1951 with a BS in Mathematics and in 1952 with an MS in Mathematics. He received the MSEE from the University of Pennsylvania in 1957. From 1952 to 1957, Mr. Caplan worked at the Burroughs Corporation, Paoli, Pennsylvania, on digital computers for various military applications. He joined the Navigation Computer Corporation in 1957 as Chief Engineer, responsible for the development of special purpose data processing equipment. In 1958, Mr. Caplan joined the EDP Division of RCA, where he worked on magnetic core memory and transfluxor development. He then transferred to Surface Communications where he was responsible for the digital ground terminal of the AGACS data link system. During the past three years, he has directed work on the design of communcations systems such as Unicom, 480L, and the Minuteman Launch Control System. He is presently Leader of a group in the Systems Integration and Advanced Programs Activity of Digital Communications Engineering.

Many of the command and control systems will be prime targets for the enemy, and hence must survive attack by nuclear and conventional weapons. This means that the communications system must be able to operate under conditions of shock, heat, radiation, and fallout from nuclear weapons. In addition to the brute-force approach to equipment "hardening" by improved structures and approved underground locations, etc., there are a number of other approaches for the system designer. These approaches include the use of redundant networks, and provisions for alternate routing and restoration of the communication channels.

The security of important command and control messages is essential in many applications. Security in the broad sense can have many meanings and interpretations. The objective may be to keep the enemy from becoming aware of any information transfer, or it may be simply to prevent him from understanding or interpreting the information that is being transmitted. In other cases the objective may be merely to prevent the enemy from "spoofing"—putting false messages into the command-and-control system to confuse it. Data processing can, of course, play a major part in achieving objectives automatically and at high speed. As with other systems, the degree of performance required generally has had a great influence on the required equipment and complexity. Hence, detailed analysis must be made to determine the degree of protection required and the allowable system complexity. An important factor in these studies is often, of course, the time delay to the enemy in breaking the protective system. Details of methods of achieving these objectives are generally carefully protected to make it as difficult as possible for the enemy to break the system.

Many of the command-and-control systems have special requirements for message compatibility and message format standardization. This is necessary to permit communications to controlled vehicles from any operational commands and to interchange information between the various systems and various echelons in the command area. (Message standardization is further discussed at the end of this paper.)

TACTICAL COMMUNICATIONS NETWORKS

Tactical communications networks are required by all the services and may have communicating ranges varying from a few miles to over 1000 miles, depending on the specific applications. In general, there is a common problem of mobility and transportability of equipment as well as the ability to operate under adverse physical environments. The equipment mobility requirement stems from the basically high mobility of the modern military services and the dispersion requirements dictated by atomic warfare. The mobility requirements may vary from requirements for small pack-size equipments to jeep-mounted and small aircraft-mounted equipments—and to even larger systems that are equivalent to fixed-plant systems but are readily transportable by airlift or van.

Communication switching, control, and connectivity are important problems in providing communications to many highly mobile subscribers. Methods of establishing suitable channels, keeping track of the subscriber locations, security clearance and priority, and providing rapid, automatic switching are complex problems. Data processing plays an important part in achieving many of these capabilities.

Security and anti-jam requirements of tactical communications equipment are particularly challenging. The particular problem faced in many tactical situations is that the operating equipments are often located in much closer proximity to enemy jammers than to the equipment with which they must communicate.

It should be pointed out that the economics of providing sophisticated communications capabilities to the large number of subscribers necessitates that equipment not only have high performance but also be extremely simple to use and relatively inexpensive. Tactical equipments often are procured in units of 1000 to 10,000, and even a few-dollars-per-unit differential can lead to important economic problems—or advantages.

TELEMETRY

The rapidly growing developments in aerospace vehicles and systems have greatly increased the requirements for telemetering of data. At present, most of the telemetry systems transmit data using FM-FM. In this system (Fig. 4), each analog signal is modulated onto an individual FM subcarrier. All the subcarriers are mixed and the sum is modulated onto an FM carrier for transmission to the ground station.

When many signals must be telemetered down, the FM-FM system described above becomes inefficient and expensive because of the large number of subcarrier modulators required. For that reason, the digital telemetry system (Fig. 5) has come into use. The analog signals

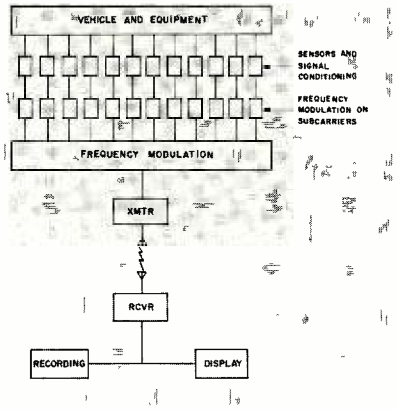


Fig. 4—Analog telemetry system.

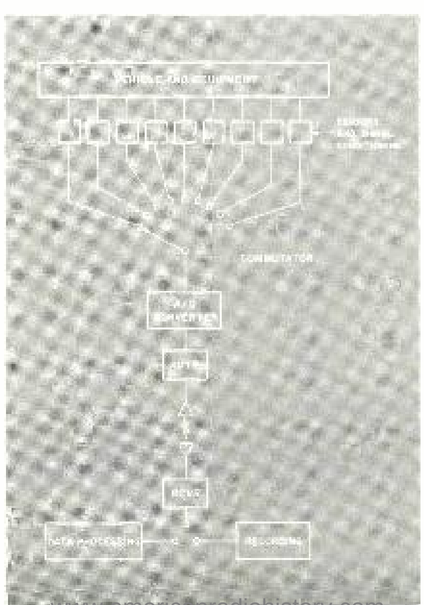
are commutated, one at a time, to the analog-to-digital converter where they are transformed to pulse-code-modulation (PCM) format.[5] The PCM data is transmitted to the ground stations, where it can be recorded or entered directly into digital data processing equipment.

The major problems involved in modern high-performance telemetry systems are associated with long-range operation, the large amounts of precision data to be transmitted, and extreme limitations on size and weight. Special digital coding techniques have already been demonstrated for telemetry applications on long-range space probes. These coding approaches provide a powerful tool to improve performance under low signal-to-noise ratios.

STANDARDIZATION OF RATES, CODES, AND MESSAGE FORMATS

In any system involving a large number of users the problem of standardization usually appears. To optimize the performance of their subsystems, individual users or groups of users will often tailor equipments to their specific requirements. While this procedure may result in the highest performance or cheapest system for a given user, it generally runs into problem areas when the users must communicate with each other. As a result of these interface and compatibility problems, the military have attempted to standardize on various message characteristics.

Fig. 5—Digital telemetry system.



It is convenient to consider the standardization problem in three areas: *rates*, *codes*, and *formats*. Data rate has been very largely standardized at 75×2^n bits per second (where n can be any integer). The standardization on these rates principally affects the data transmission channels and associated equipments. In recent years, most services have tended to standardize new systems on the FIELDATA code, although there still remain considerable military communications employing the Baudot code. The selection and standardization of codes principally affects the buffering and translation portions of the communications system. Message formats have been much less standardized than rates and codes. The format standardization principally affects the end user in such items as tab functions, paragraphing, line shifting, and related synchronization between input-output equipments and communications systems.

At first glance, it may appear relatively simple to standardize on given rates, codes, and formats, but the practical problems usually turn out to be rather difficult. This is particularly true when the technical problems of operating with existing systems and the economic constraints are considered. The problem of standardization on data rates can be appreciated by considering a transmission system which employs standard input data rates, but which employs for transmission additional framing and order wire pulses. In this case, the transmitted data will be slightly higher in rate than the information data rate, and hence the modems and channel characteristics will be somewhat different from those of the systems transmitting at the standardized bit rate. The further one investigates the detailed compatibility between equipments and channels, the more difficult the standardization becomes.

Many modern systems have solved the compatibility problem by using stored program code, and format converters. While this is an expensive approach as far as hardware is concerned, it does permit intercommunication between a wide variety of users and the use of existing tributary equipments. In many cases, this may be the most economical immediate over-all solution to the standardization problem.

FUTURE TRENDS

The communications systems described above are closely interwoven with military operations. Therefore, as the nature of warfare and military operations changes, the communications systems must also change. Some of the expected future trends are covered in this section.

In the area of long-haul communications, one of the most dramatic changes will occur in chanel capacity. Typical present HF radio links provide 3 voice and 16 teletype channels. They are being replaced with wideband tropospheric scatter trunks providing 36 to 72 voice channels over a suitable wideband system. Satellite communications will also provide wideband capabilities. These newer systems will eliminate the present dependence on ionospheric conditions and the resultant communication blackouts caused by nuclear weapons.

In the long-haul central office, new switching is beginning to become available with solid state techniques and major improvements in speed and accuracy. Reed relays and electronic control circuits are used to make circuit connections in a few milliseconds, to provide compatibility with high-speed data transmission. The newest message switching centers, such as the RCA ComLogNet,[4] actually are built around a digital-computer complex. High-speed electronic circuits, core memories,. and magnetic drums perform the necessary data transfer and processing operations. Special off-line digital processors are required at these message switching centers. An example of such a processor is the ComLogNet tape search unit.[6]

In command and control systems, the future emphasis will be on automation of functions now performed manually. Certain command decisions are always the prerogative of the human commander, but the implementation of command decisions will be performed by sophisticated computers. The detailed commands to subordinate units will be developed by the computer, which will perform many of the communications functions in addition to its other tasks. The computer will provide data buffering, message switching, and communications error control.

Command and control communications systems must in most cases meet normal military requirements for environment, RF interference, and reliability. In the reliability area, special ultra-reliable components and techniques have been employed in such programs as the Minuteman Launch Control System.[7,8]

In the tactical-communication area, the newest differences are based on reductions in size and weight provided by microelectronic packaging. The general trend during the past decade has been to put more and more data processing in the forward echelons. To this end, small computers and tactical processing equipments have been developed, such as the Fadac and Micropac. Communicating with these processors requires high-performance data communications equipments at the forward echelon. Advanced digital techniques are being applied to data communications to achieve security, anti-jam, and other features. The recent advances in microelectronics have made feasible the packaging of complex digital processing systems in extremely small volumes, thus meeting tactical requirements.[9]

Improvements in speed and accuracy will mark the telemetry field. Accuracies of 0.1 percent will be exceeded and sampling rates in the megacycle range will be accepted in operational equipment. Telemetry systems of this type will be required for the new generations of complex missiles and space vehicles presently being developed. (A PCM telemetry instrumentation unit having an accuracy of 0.2 percent has been developed by Surface Communications Division engineers.)

In the past, brute force techniques have been largely employed for communication error control. The brute force approach might include the use of higher power transmitters, lower noise or equalized channels, etc. More recently, however, more sophisticated approaches have been employed, including redundancy, ARQ (automatic error correction) and adaptaive and variable-rate systems. Redundancy may be applied as simple parity bits, more-complex error-detection coding, or error-correcting coding. The amount and type of redundancy is a function of the noise statistics and the error-rate requirements. The more efficient and effective error-protection systems at present require rather complex mechanization and are resorted to only when such performance is essential. This complexity comes about because code efficiency generally increases as the block of data to be protected is increased in size. There has been a general trend recently toward the use of systems[10,11] which employ feedback and request retransmission of erroneous data, i.e., ARQ. These systems are particularly advantageous when the channel characteristics include brief periods of almost complete "outages." Noise strikes on telephone lines are good examples of this situation.

It should be pointed out that the need for high accuracy data is generally required under all operation conditions, and hence must be insured in spite of enemy countermeasures and jamming. Sophisticated modulation and coding techniques have been considered for these applications in addition to the brute force approaches of higher gain and higher power. The so-called "spread" spectrum techniques provide a good example of data processing approach to providing high performance in the face of countermeasures and jamming.

Security can be provided for teletype transmission using digital encryption devices. These devices can be applied to any digital data, but not to analog signals. Therefore, analog voice communication cannot easily be made secure. To overcome this limitation, many recent developments have been directed toward digital voice communications.[12]

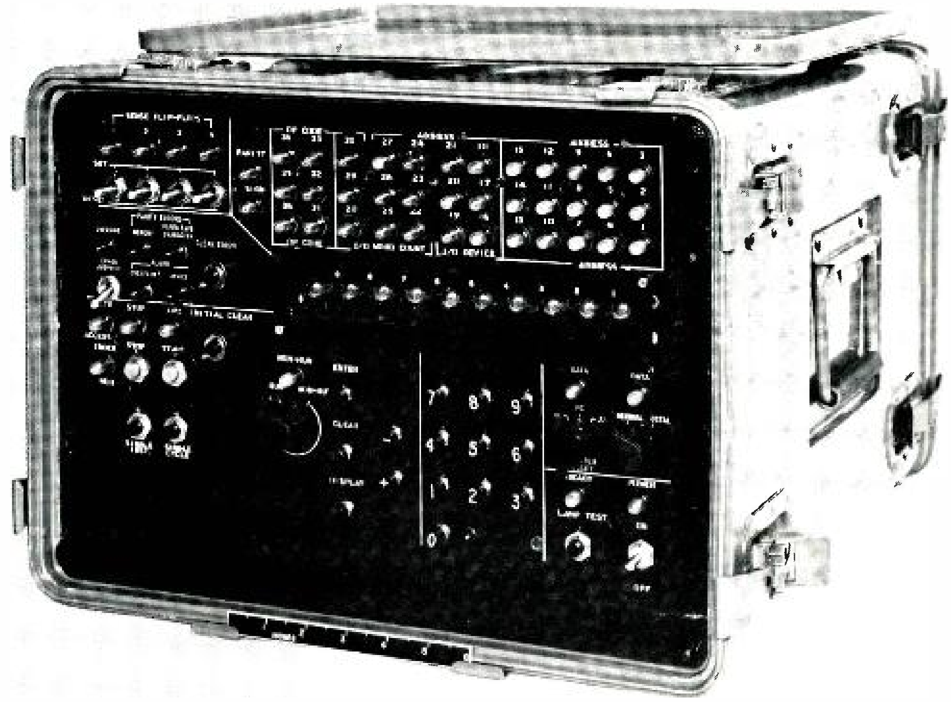
SUMMARY

The breakdown of military communications into long haul, command and control, tactical, and telemetry is only one way of analyzing the technical problems, which include security, redundancy and survivability, reliability and maintenance, noise, jamming and countermeasure, accuracy and error control, mobility, size, weight, power, and cost. All these problems are present in any communications system. This paper has reviewed those problems that are most significant for each type of application.

BIBLIOGRAPHY

1. For a bibliography of recent Surface Communications Division papers on digital communications, see p. 11 *this issue*.
2. D. I. Caplan, "Data Processing for Communication Monitoring and Control," Fall Joint Computer Conference, Dec. 4-6, 1962, Philadelphia, Pa.; *to be published*.
3. G. F. Abbott and W. B. Groth, "Switching in Communications Systems," RCA Engineer, Feb.-Mar. 1962.
4. R. J. Segal and H. P. Guerber, "Automatic Store-and-Forward Message-Switching Centers for ComLogNet," RCA Engineer, Feb.-Mar. 1962.
5. H. M. Straube, "Pulse Code Modulation," *this issue*.
6. A. W. Muoio, "A Stored-Program Magnetic-Tape Search Unit," *to be published*.
7. I. K. Munson, B. H. Rosen, S. Schach, and A. J. Schwartz, "High-Reliability Component Parts Program," RCA Engineer, Aug.-Sept. 1961.
8. H. J. Kishi, M. P. Rosenthal, and J. Cohen, "Self-Verification of System Status," RCA Engineer, Aug.-Sept. 1962.
9. A. Rettig, "Micropac—A Micromodule Digital Computer for Tactical Military Use," *this issue*.
10. J. E. Palmer, "Transistorized MUX-ARQ-2," RCA Engineer, Feb.-Mar. 1960.
11. E. D. Becken, "MUX- ARQ Equipment at RCA Communications," RCA Engineer, Feb.-Mar. 1960.
12. W. F. Meeker, "Speech Coding and Automatic Speech Recognition," *this issue*.

Fig. 1—MICROPAC case and controls.



MICROPAC

. . . A Micromodule Digital Computer for Tactical Military Use

A. S. RETTIG, Leader
Systems and Projects
Surface Communications Division
DEP, Camden, N. J.

MICROPAC is a general-purpose digital computer in a rugged 90-pound package, designed for many mobile tactical applications—battery fire control, missile guidance control, weather or surveillance data reduction, etc. Micromodules (over 1600 are used) make possible this miniaturization of circuitry. MICROPAC uses FIELDATA 38-bit word formats, and has a complement of 21 mechanized instructions. It is a binary synchronous computer operating in serial mode at 1.6-Mc clock frequency, with random-access ferrite-core memory of basic 2048-word capacity, expandable to 8192 words.

MICROPAC is a general-purpose, militarized digital computer designed for tactical applications where high reliability, small size and weight, and low power requirements are of major importance. It employs the micromodule, which provides high packaging density with high reliability (a predicted failure rate of 0.04 percent per 1000 hours per two-circuit micromodule). The MICROPAC, as a whole, has a mean-time-before-failure of over 1000 hours (at a 60-percent confidence level).

Much of the equipment in the machine is used for more than one function (i.e., *time shared*) to further reduce the amount of circuitry needed. Developed under the Signal Corps micromodule program, MICROPAC (*Micro*module Data *P*rocessor *A*nd *C*omputer) was designed for compatibility with the U.S. Army's FIELDATA family of automatic data-processing equipment.

MICROPAC was selected as the vehicle to demonstrate the capability of micromodular digital equipment. The high packaging density gained with micromodules (approximately 150,000 components per cubic foot in the circuitry section) permits the effective employment of a single-case design (Fig. 1) of 2.7 cubic feet that weighs 90 pounds. MICROPAC requires 250-watt DC power and 270-volt-ampere generator power.

The diode-transistor logic circuitry was designed for use within encapsulated micromodules of variable packaging density and for reliable operation over an ambient temperature range of −30°C to +90°C within the computer. The equipment is packaged for extreme environmental conditions.

SYSTEM ORGANIZATION AND LOGIC DESIGN

The MICROPAC computer accommodates a wide variety of problems with its versatile complement of 21 mechanized instructions, listed in Table 1, and index register provisions. It is a binary synchronous computer operating in a completely serial mode at a clock frequency of 1.6 Mc, which permits a reasonably short execution time per instruction.

The clock pulses drive a timing-level generator which produces a sequence of gate levels of varying lengths within a 63-clock pulse period. This 63-clock pulse period of approximately 40 μsec is called a *minor cycle*. The minor cycle is abbreviated during certain instructions in order to decrease operation time. An instruction is executed in one or more minor cycles plus a minor cycle for instruction access.

The various FIELDATA 38-bit word formats are provided. Fig. 2 illustrates the format of a binary word, an alphanumeric word, a computer instruction word,

Table I—MICROPAC Instruction Catalog and Timing

Instruction	*Approximate Time μsec (including IAC)*
Arithmetic:	
1. *Add*	80
2. *Subtract*	80
3. *Multiply Fast* (18 bits)	325
4. *Multiply*	1035
5. *Divide*	1075
Transfer:	
6. *Transfer Unconditional*	40
7. *Transfer and Load Pcs.*	120
8. *Transfer on Negative*	40
9. *Transfer on Zero*	40
10. *Transfer on Index*	200
Logical	
11. *Shift Right*	280, max.
12. *Shift Left*	280, max.
13. *Store*	80
14. *Logical Multiply*	80
15. *Load*	120
16. *Halt*	40
Sense	
17. *Sense*	40
18. *Sense and Set*	40
19. *Sense and Reset*	40
Input-Output	
20. *Read Alphanumeric*	variable
21. *Write Alphanumeric*	variable

or an input-output instruction word. The basic random-access ferrite-core memory of 2048-word capacity is expandable in multiples of 2048 to a maximum of 8192 words.

MICROPAC is divided into five major subsystems (Fig. 3), as follows: *high-speed memory, central processor, program control unit, input-output, and major transfer bus.*

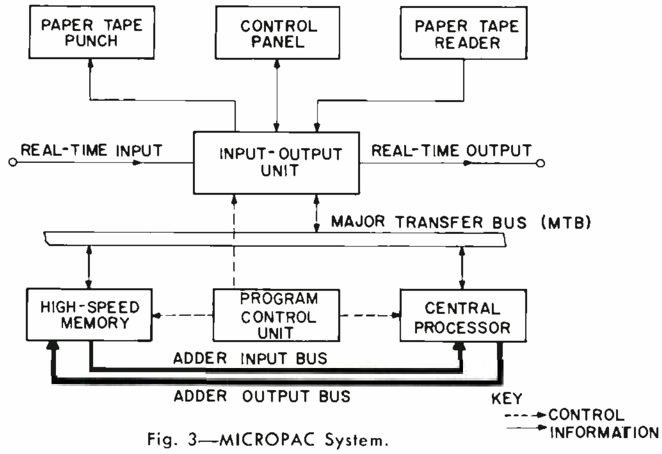


Fig. 3—MICROPAC System.

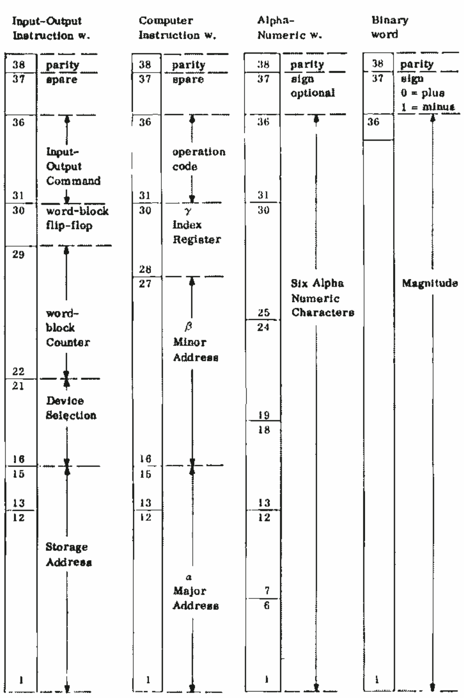
High Speed Memory

The high-speed memory contains the core memory and associated registers for data storage, and controls for reading, writing, and word selection. The memory operates with coincident-current selection (destructive read-out with regeneration) having a duty cycle of 40 μsec between *read* interrogations.

The memory array consists of 20 double planes, each containing two 64 x 32 core matrices; also included in the stack are a diode board, a heater assembly, and a header board containing connectors for external connections (Fig. 4). The 20 double planes are used (rather than 19) to provide two spare bits per word. These spare bits can be utilized by connecting the sense winding output to any input circuit, and connecting the digit winding to the digit drive of the corresponding regenerative loop. The memory module (bank) is a completely self-contained plug-in unit. Up to four memory banks may be used with the computer.

A 13-bit address generated by the central processor determines which one of four memory banks and which one of 8192 words will be selected and sent to the two memory output registers. Two memory output registers are associated with the memory: register *1* is a temporary buffer for parallel data flow to and from the memory; register *2* is both a buffer effecting parallel-to-serial conversion of data, and an additional operand register for several instructions.

Fig. 2—FIELDATA word format.



Central Processor

The central processor performs the internal data-processing functions. It contains a one-bit adder; various shift registers which, among other functions, are used with the adder to form the arithmetic unit; gates to transfer data between registers and adder; and control and timing logic.

All arithmetic operations are performed in binary-serial form using a one-bit adder. Subtraction is accomplished by two's-complement addition; multiplication is performed by successive addition of partial products; division is executed via a nonrestoring algorithm. Computer operands are fixed-point, signed magnitude.

The accumulator, instruction, and program-counter registers are contained within this section. The accumulator contains first the operand and then the result of the arithmetic instructions. In *divide*, the remainder is stored in the accumulator and the quotient in the *Q*-register (a register simulated in high-speed memory). In *multiply*, the high-order result is stored in the accumulator and the low-order result in the *Q*-register. The instruction register holds the instruction as it is being executed in the computer. The program counter stores the address of the next instruction to be executed in the program sequence. Other registers required for the central processing functions are simulated in the memory.

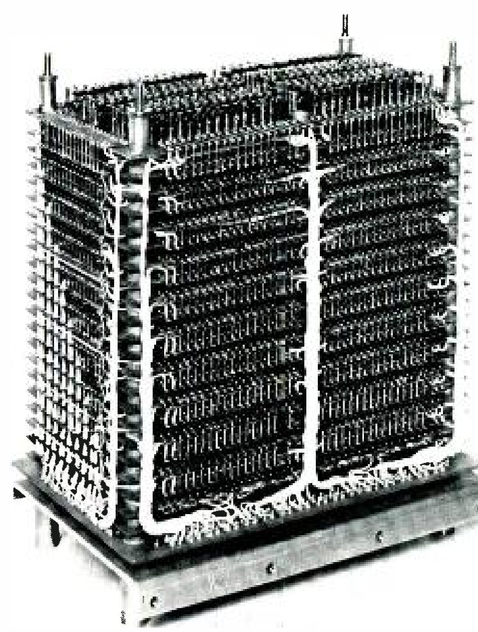
Program Control Unit

The Program Control Unit generates the various controls required by the high-speed memory, central processor, and the input-output sections. It comprises the various decoders (e.g., *operation, address, device select*), signal generators (e.g., *status level, function, gating, clock pulse, timing level*), and control flip-flops.

Input-Output Devices and Functions

The input-output section controls the exchange of data between the central processor and the control panel, a paper-tape reader and printer-punch, and a real-time channel. The standard FIELDATA intercommunication conventions (8-bit characters, *ready-busy* line, and *strobe* line) are used for all input-output operations. On-line insertion of information may be accomplished via a paper-tape reader at 300 characters/sec or a programmed instruction re-

Fig. 4—Memory stack.



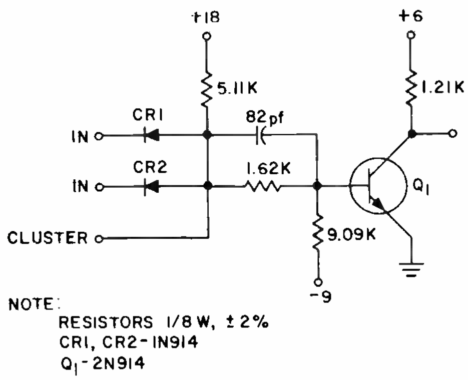


Fig. 5—Standard gate circuit.

questing operator input at the console. In the latter, the computer waits until a specified quantity of information has been inserted and then automatically continues program execution.

Similarly, on-line output of information may also be accomplished via a paper-tape punch-printer at 30 characters/sec. or via the control panel. In the latter case, the computer waits until the operator has requested the display of the instruction-specified number of words, and then automatically continues program execution.

MICROPAC can communicate with other computers via real-time input and output channels on a *computer-interrupt* basis at a maximum rate of 300 characters/sec.

The computer may concurrently perform real-time input, real-time output, and data-processing functions. When a character has been received from the real-time input unit or when the real-time output unit signifies that it is ready to accept a character, the computer temporarily interrupts its data processing function, services the character, and then resumes data processing from the point of interruption. One- to seven-character storage or retrieval operations are implemented by computer interrupts until a complete data word or a single *control* character has been stored or retrieved. A program interrupt will then transfer the completed word to the message storage section of the high speed-memory, or retrieve a complete word from the message-storage section for output.

Major Transfer Bus

Most transfers are accomplished via a major transfer bus; some transfers to and from the adder, which occur concurrently with transfers of data via the major bus, are executed via minor transfer buses.

MICROMODULE CIRCUITRY DESCRIPTION

The requirements of +90° C maximum internal ambient temperature (to permit reliable circuit performance within the high-density micromodule packaging), made silicon semiconductor components mandatory. For the bulk of the micromodule logic circuits, the type 2N914 switching transistor (in wafer form, for incorporation into the micromodule) was selected for its relatively high-speed switching and good record of reliability. Also, it is reasonably priced and available from several manufacturers.

The basic circuit is the standard logic gate (Fig. 5) with the following main characteristics:

fan-in: 20, maximum
fan-out: 4
power dissipation: 75-mw average
pair delay: 60 nsec (nominal)
rise time: 30 nsec (nominal)

This standard gate is the most frequently used micromodule in the computer. Low-power gates are provided when the speed and power capabilities of these standard gates are not required. Several micromodule configurations of the standard and low-power gates were designed. Gates are packaged two to a micromodule. Several gate micromodules were designed with different input-diode arrangements so that the micromodule's 12 pins (standard) would be adequate to handle the input-terminal requirements of a number of different logical configurations. Diode cluster micromodules are provided to take care of unusual cases.

Although the gates comprise the bulk of the micromodules in the computer, many other special-purpose circuits are required. All logic micromodules are compatible and use common supply voltages and signal-voltage characteristics. Line receivers and drivers are provided for the transition from computer signal voltage to FIELDATA operation requirements.

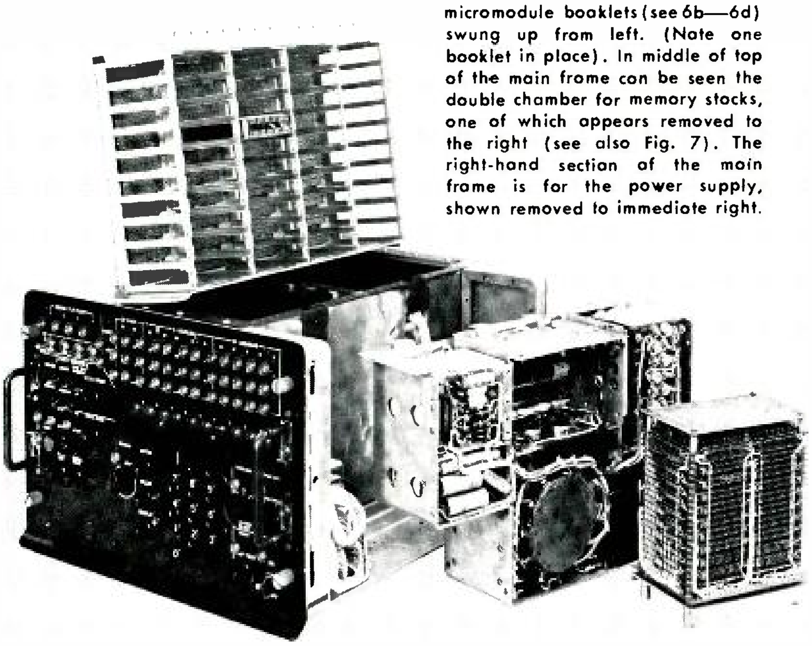


Fig. 6a—Disassembled MICROPAC. Center: main frame, with rack for micromodule booklets (see 6b—6d) swung up from left. (Note one booklet in place). In middle of top of the main frame can be seen the double chamber for memory stacks, one of which appears removed to the right (see also Fig. 7). The right-hand section of the main frame is for the power supply, shown removed to immediate right.

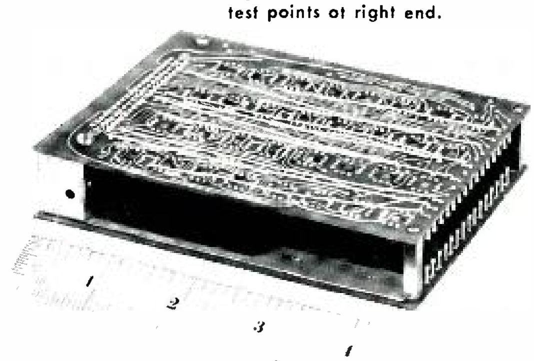


Fig. 6b—Micromodule booklet, showing test points at right end.

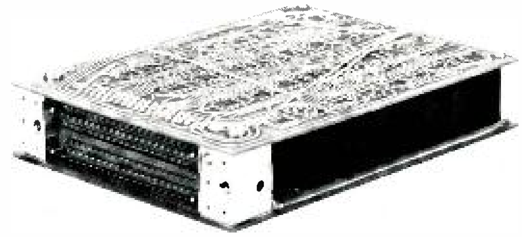


Fig. 6c—Opposite end of Fig. 6b booklet, showing connector.

All electronic components are operated well below rating to insure maximum reliability. Resistors are operated at a maximum of 20 percent of rating. The silicon transistors are junction-temperature limited to 100°C maximum in operation, although circuits were designed and tested for 125°C operating temperatures.

POWER SUPPLY

The MICROPAC power supply is operationally typical of digital computers in that it furnishes a fairly large number of well-regulated output voltages with low source impedance. However, it differs from the usual computer power supply in two major respects which complicated the design: the requirement for small over-all size, and poor regulation of the primary power source.

The primary power source for the computer may range from a poorly regulated field-type power supply to a well-regulated commercial power line. The DC power supply has been designed for the following input power conditions:

Voltage: 120 volts, ±10% single phase
Frequency: 50-60 cps ±10%
Transient voltage range (5 sec): 75.6 to 138.6 volts
Transient frequency range (5 sec): 31 to 86 cps

The required DC output of the power supply for MICROPAC with two memory packages (4096-word capacity) is a total of 250 watts, consisting of 13 different voltages. The wide range of input voltage and frequency, coupled with the requirement of minimum size and weight, made unsatisfactory the conventional design approach using a power transformer, with individual rectifiers and regulators for each voltage.

Instead, a power supply incorporating the following features was designed:

1) Controlled bridge rectifiers operating directly from the AC line, to achieve rough regulation in the order of 15%.
2) Single section LC filter to reduce ripple to less than 10% after 60-cycle line input rectification.
3) Morgan regulator circuit, using a silicon-controlled rectifier and a square loop core, to achieve regulation of the order of 2%.
4) Single-section LC filter to reduce ripple to less than 1% after high frequency rectification.
5) Silicon-controlled rectifier parallel inverter operating at 1000 cycles, using a power transformer with separate output windings for individual supplies.
6) Individual rectifiers and regulators for each output voltage, where required.

MECHANICAL DESIGN

The MICROPAC mechanical design is in accordance with the Signal Corps specifications for tactical data processing equipment to achieve a high functional utility, high reliability, and simplified maintainability while satisfying requirements of human factors engineering. MICROPAC is adaptable for rack and panel mounting, bench-top operation, or vehicular mounting utilizing a case specifically designed for this purpose. It is a self-contained equipment of four major sections: *control panel*, *micromodule circuitry*, *memory*, and *power supply* (Fig. 6a). It has the following dimensions:

Exterior: 17.75″ wide x 12.625″ high x 21″ deep
Usable Interior: 16″ wide x 11.25″ high x 20.25″ deep

All sections are plug-in units, with the exception of the circuitry section because of the large amount of connections required.

Control Panel

The control panel provides for manual insertion of information into the computer and for monitoring and selecting the various operational modes (Fig. 1).

Information may be entered manually via the keyboard on the control panel. Input or output data may be displayed in digital and binary forms by 10 nixie tubes and 38 neons, respectively. The neon bulbs are arranged in octal code groups for ease of interpretation. The nixie tubes provide a binary-coded-decimal indication (9 decimal digits) of the contents of various computer registers. This decimal indication is primarily for use by the operator. The neon-tube indication is provided for use by the programmer or maintenance personnel in debugging. Other lamp indicators are provided to indicate

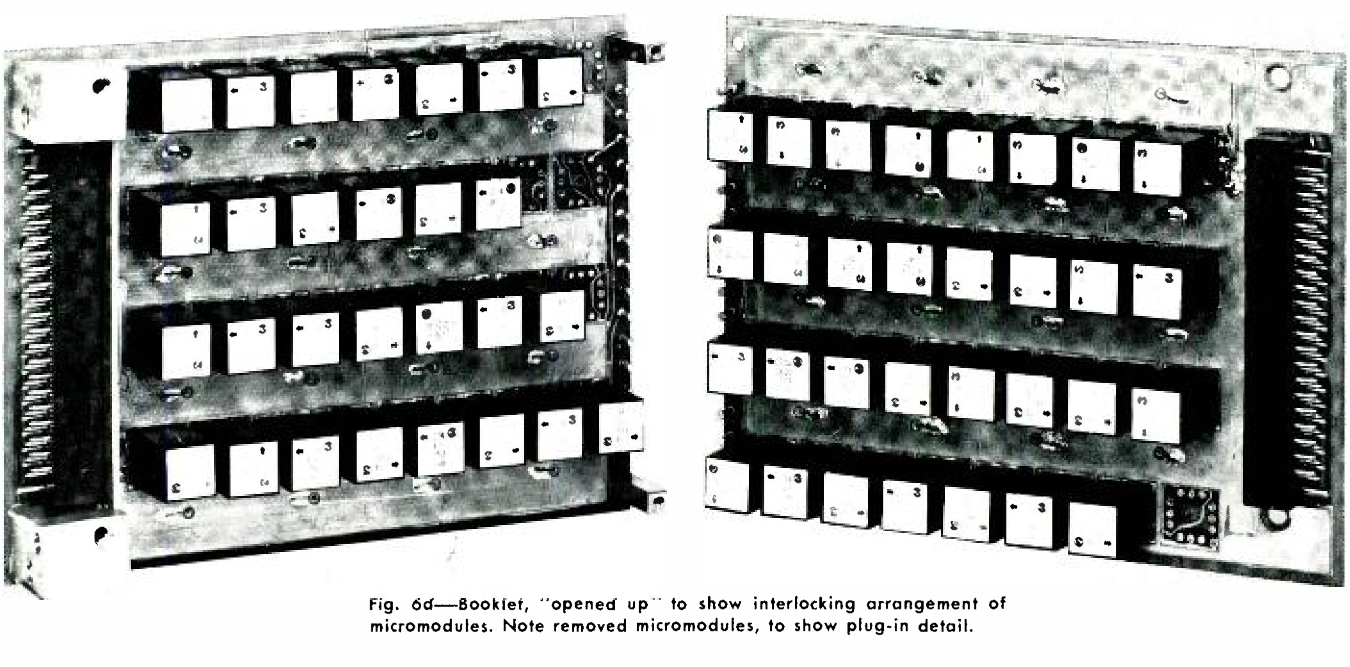


Fig. 6d—Booklet, "opened up" to show interlocking arrangement of micromodules. Note removed micromodules, to show plug-in detail.

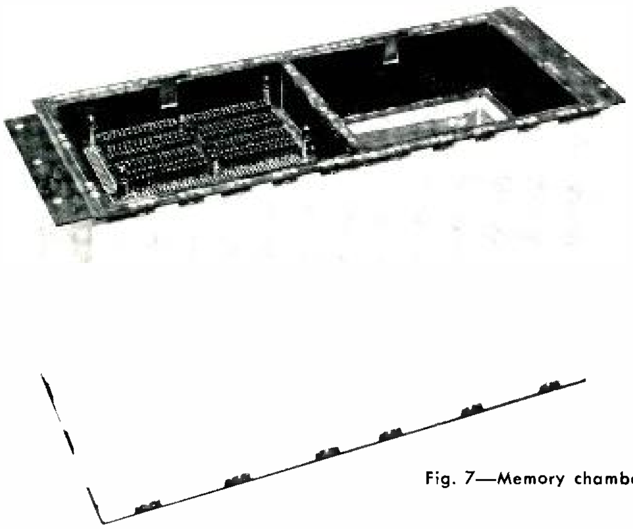


Fig. 7—Memory chamber.

computer status and to alert the operator to abnormal conditions.

Micromodule Circuitry

The micromodule section (Figs. 6b, c, d) contains the logic and memory controls and functions required for computer operation. It consists of 39 "booklets" (each booklet consists of two printed-circuit cards) mounted within four columns, ten booklets per column. Each printed card provides for the mounting and interconnection of a maximum of 32 micromodules mounted in 4 x 8 grid to permit interleaving of two cards to form a compact and densely packed unit designated as a circuitry booklet. A 63-pin connector is mounted on each card providing connection with associated panel-mounted connectors located on a single, common backplane and interconnected to form the backplane wiring. Approximately 1650 micromodules are required for operation with a 2048-word, high-speed memory, and 1785 modules with a 4096-word, high-speed memory.

Memory Section

The memory section provides space for two ferrite-core stacks as shown at the top of Fig. 6a. The memory stacks are packaged in a molded fiberglass housing (Fig. 7) to provide maximum structural rigidity and minimum heat loss without disturbing the weight-to-volume ratio. Each memory stack is individually temperature-stabilized with a network of heaters and thermoelectric units to maintain a temperature gradient of ±2°C within a range of 40°C to 60°C internally in an environmental ambient range of −31°C to +52°C. The temperature control of the memory is accomplished in a closed-loop system, thus maintaining a comparatively dust- and moisture-free environment.

Power Supply

The power supply is designed as a fully self-contained plug-in unit. Because of the unique electrical design approach, the supply consumes only 730 cubic inches—approximately 15½″ x 4½″ x 12″. The gross weight—including casework—is 31 pounds. The choice of electrical connectors and mechanical fasteners ensures compact size and rapid, simple power supply replacement. This rapid access is achieved while still maintaining reliable, low impedance continuity with the computer power distribution system.

The supply is also mounted so that it can be extended from the computer proper and its casework removed to permit field maintenance and repair.

COOLING

To keep the air flow at a maximum, the use of exhaust and intake ports on the same plane was avoided. The intake area includes filters, fans and plenums, requiring space that makes it impossible to place the intake on the front panel. Therefore, the rear panel housed the inlet area. With the requirement of operation in rain, louvers, filters and drip opening were provided in the rear of the unit. Based on information as to the power dissipation of the micromodules and of the power supply, coupled with a preliminary layout, the use of two blowers was chosen, one for each of the two major sources of heat, namely the power supply and the circuitry section. The smallest blowers with a capacity greater than the predicted load were Rotron Aliximax 2, each capable of supplying air flow at the rate of 30 cfm. The output of the two blowers each feed a plenum chamber which then directs and allocates the proper amount of air for the load. The air, having cooled the power supply and the circuitry area, then wash-cools the front panel and exhausts through screened openings in the lower part of the front panel.

CONCLUSION

Because of MICROPAC's reduced size and weight which permits ease of handling and offers maximum mobility, this versatile computer could be used for a broad range of tactical applications including battery control in a fire support, guidance control in other weapon support systems and, data reduction in weather and surveillance systems. Its real-time duplex communication operational capability affords the means for remote access and control.

ACKNOWLEDGMENT

The work described in this article is the product of a joint effort by the Tactical Data Processing activity of the Digital Data Communications Department. Credit is due to the following individuals for their part in this work: A. H. Coleman, Program Manager; E. L. Schlain, Logic Design; R. D. Torrey, Circuit Design; W. Miller, Memory Design; and H. K. Sauer, Mechanical Design.

A. S. RETTIG is a graduate of the College of the City of New York (BEE) and of the University of Pa. (MSEE). From 1950 to 1954, at Raytheon Mfg. Co., Mr. Rettig participated in and was responsible for several digital design and development projects. From 1954 to 1955, Mr. Rettig was a senior engineer at Computer Control Co. and was responsible for the maintenance of the RAYDAC computer at Point Mugu, California and for the systems integration and installation of additional peripheral equipment and internal memory capacity. Since 1955 he has been active in several major RCA electronic data processing projects, including logic design and development of the File Control Unit of the RCA 501; system and logic design of the Communication Data Processor, a major element of the ComLogNet switching center. He has had project responsibility for the MICROPAC and MICRORAC computer programs. He is a member of Eta Kappa Nu, Tau Beta Pi, IRE, PGEC, and ACM. He has co-authored several papers and has filed patents for computer logic design techniques and diode-gating circuitry.

PULSE CODE MODULATION

Reviewed here are the basic processes of generation, transmission, and detection of PCM—a communication technique in which the analog signal of speech, television, or other information is converted to a sequence of coded constant-amplitude on-off pulses for transmission. PCM is today finding important applications in military digital communications systems and in commerical telephony—and is a promising technique for space communications systems.

H. M. STRAUBE
Systems Laboratory, Surface Communication Division
DEP, New York, N. Y.

PULSE CODE MODULATION (PCM) is a method for converting speech, television, or other messages to a signal of coded *on-off* pulses. Conceived about 1939 and researched for more than two decades, this type of analog-to-digital conversion has finally become a practical technique—PCM has "come of age."

Because it is a simple sequence of *on-off* constant-amplitude pulses, a PCM signal:

1) has great immunity to noise, interference, crosstalk, and distortion associated with the transmission path;
2) lends itself to "regenerative repeating" which avoids multi-link accumulation of transmission impairments; and
3) is amenable to error detection, error correction, cryptography, and numerous other data processing techniques of interest.

In addition, in multi-channel communication systems, time-multiplexed PCM often:

4) provides lower-cost terminals than do competing techniques (such as frequency-division-multiplex).

In view of these advantages, PCM finds rapid acceptance in military digital communication systems wherein needs of accuracy, reliability, and security are well met by transmitting a succession of simple "yes or no" decisions. Such an application is currently being engineered by RCA for UNICOM (Universal Integrated Communication System) through joint efforts of the New York Systems and Camden Digital Communications Sections of SurfCom.

Not only military, but also civilian applications of PCM are emerging, as witnessed by a recent Bell System announcement that a PCM system for short-haul exchange-area telephony is nearing the production stage. Space communication systems, military or civilian, also constitute a fertile field for PCM application.

GENERATION AND DETECTION OF PCM

Ten fundamental processes are often involved in the generation and detection of pulse code modulation, namely: band-limiting, sampling, quantizing, coding, decoding, framing, filtering, companding, multiplexing, and demultiplexing. Although the first seven of these appear in all PCM terminal equipments, the last three may or may not be required. Companding (or the equivalent) is employed only when certain messages of large volume range must be encoded with good quality. Multiplexing and demultiplexing are performed only when two or more message channels must be encoded for transmission over a single pair of wires.

Let us first examine the seven most basic processes that must be performed. Thereafter we can consider the added complications of companding, multiplexing, and demultiplexing.

Band-Limiting

As shown in Fig. 1, the message channel is first band-limited. This not only eliminates noise that may occur at frequencies outside the message band, but also defines the highest significant frequency that must be processed.

Sampling

The message wave is then converted to a pulse amplitude modulated (PAM) signal by taking narrow uniformly-spaced samples of the message waveform, as depicted in Fig. 1. If the samples are taken at a rate slightly higher than twice the highest message frequency, it may be shown[1] that all the information in the message waveform is still present in the envelope of the amplitude samples. Note that the information content is critically dependent on the exact amplitude, as well as the time of appearance, of these pulses. Also significant is the fact that, for typical nondiscrete messages, these samples may take on an infinite number of values within their given volume range. Like the original message, the PAM signal is still very "amplitude conscious."

Quantizing

The amplitude of each sample is then quantized, that is, measured in terms of a discrete number of quanta into which the PAM volume range is intentionally divided (see Fig. 1). Each result is "rounded off" to the nearest calibration, thus each quantized value may be in error by as much as ± ½ quantum. The integrated effect of such errors is called *quantizing distortion* or *quantizing noise* and is the inevitable result of approximating an infinite number of possible values by a finite number of discrete values. Although quantizing distortion is an inherent weakness of PCM, it may be made negligibly small by suitable choice of the number and size distribution of the quanta.

Coding

Each quantized value is next converted to a group of *on-off* pulses, the pattern of which is in accordance with binary notation. As indicated in Fig. 1, and further detailed in Fig. 2, this constitutes pulse code modulation. Significant is the fact that the information content of these

Fig. 1—Generation of pulse code modulation.

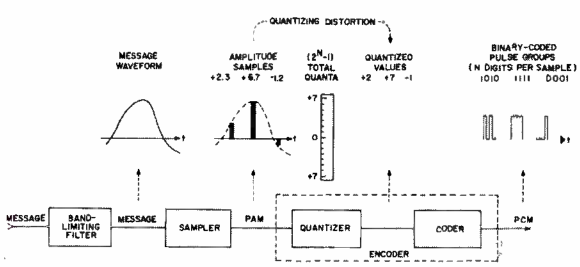


Fig. 2—Meaning of binary-coded pulse groups.

QUANTIZED VALUE →	+2	−1
BINARY NOTATION →	SIGN 1, FOURS 0, TWOS 1, ONES 0	SIGN 0, FOURS 0, TWOS 0, ONES 1
MEANING →	PLUS [(0x4) + (1x2) + (0x1)]	MINUS [(0x4) + (0x2) + (1x1)]
EQUIVALENT PULSE GROUP →	PULSE SPACE PULSE SPACE	SPACE SPACE SPACE PULSE

pulses is invested in their time of appearance, not their exact amplitude. As a result, PCM (unlike PAM) has a high immunity to amplitude disturbances such as are contributed by noise, interference, crosstalk, and distortion during transmission.

Although the zero-center quantum scale assumed in the example leads to a *sign* first-digit in the code, other arrangements are often practiced. For example, if zero were placed at the bottom end of the quantum scale in Fig. 1, all quantized values would be of one polarity and the resultant code would necessarily contain an *eights*, rather than *sign*, first-digit. The first sample in Fig. 1 would then have a quantized value of 9 and a code of *1001*, meaning $(1 \times 8) + (0 \times 4) + (0 \times 2) + (1 \times 1)$. The latter technique is attractive when there is no need to vary the size of the quanta symmetrically about the message average value. However, when such a need exists (as in one "companding equivalent" applied to speech) the zero-center quantizer is a natural choice.

Decoding

After the generated PCM has been transmitted to another location, it will normally be detected in a manner that recovers the original message. As depicted in Fig. 3, the received PCM is first decoded, that is, each binary-coded pulse group is converted to an equivalent amplitude sample. In essence, the decoder merely adds up the binary-weighted values of pulses present to obtain the equivalent quantized value (see Fig. 2). To do this correctly, the decoder must necessarily know when to look at the incoming data so that pulse groups, rather than partial pulse groups or idle time slots, will be decoded. To satisfy this need, timing information is supplied to the decoder by appropriate framing circuitry, as indicated in Fig. 3.

Framing

Although timing synchronous with the incoming pulse rate can be derived by simple filtering of the input signal (in path *a* of Fig. 3, for example), more sophisticated techniques must usually be applied to derive timing indicative of the start of each pulse group ("for framing").

HAROLD M. STRAUBE received his BSEE from the University of Michigan in 1939. He thereafter studied at Northwestern University for the M.S. degree, serving as Graduate Assistant in the E.E. Department from 1939 to 1941. He spent the following 19 years at Bell Telephone Laboratories, Inc. engaged in design, development and research of electronic devices, circuits, and systems for both transmission and switching applications. His most recent activity at the Laboratories involved both technical and supervisory responsibilities in the development of an all-semiconductor pulse-code-modulation exchange carrier telephone system. In 1960, Mr. Straube joined the RCA Surface Communications Systems Laboratories in New York City, where (as Senior Project Member Technical Staff) he has been primarily concerned with the development of digital communications systems associated with MINUTEMAN and UNICOM. Circuit and system problems, both analog and digital, occupy his attention, which is currently focussed on PCM, differential PCM, and delta modulation. Mr. Straube is the author of eleven publications and holds nine patents. He is a member of Sigma Xi, a Senior Member of the Institute of Radio Engineers, and a member of the IRE Professional Group on Communication Systems.

One common framing technique requires transmission at the beginning of each frame of a unique signal which is seldom, if ever, encountered elsewhere in the pulse train. For example, addition of a single digit that alternately takes on binary values of *1* and *0*, just previous to each pulse group in Figs. 1 and 3, would suffice. Rather simple framing circuitry can detect such information (on path *a* in Figure 3) and utilize it to "frame" the decoder readout.

Other framing techniques exploit some statistical characteristic of the message (such as the high probability of "zero rate of change" intervals in speech) to give indication of correct decoder framing. One such scheme involves translation of the generated code to a special code before transmission, such that lack of correct framing may be detected on path *b* in Figure 3. Techniques of this sort are attractive in that they do not require addition of special framing digits (or addition of bandwidth to transmit such extra digits).

Filtering

The message is finally recovered by merely detecting the envelope of the PAM delivered by the decoder. This is accomplished by passing the amplitude samples through a low-pass filter with cut-off slightly above the highest message frequency (but usually below half the sampling frequency). This filter may often be made identical to the band-limiting filter utilized in generating PCM.

In principle (assuming ideal implementation and errorless transmission), the recovered message should be a perfect copy of the original message except for quantizing distortion. The latter can never be eliminated but can be reduced to an acceptable value by appropriate design of the quantizer. Clearly, increasing the number of quanta (and therefore the number of digits per code group) will increase the accuracy of quantization and reduce the granularity of the recovered signal. Although for many messages this is the only good way to reduce quantizing distortion, for some messages (such as speech) improved results can be obtained through appropriate size distribution of a moderate number of quanta. The latter technique, one form of which is termed "companding," is worthy of further consideration.

Companding (or the Equivalent)

As shown in Fig. 4a, when a linear (equal-step) quantum scale is utilized, the weak signals suffer the most serious quantizing distortion. In the example shown, for weak samples that traverse only a single quantum step, a half-step error amounts to approximately a 50 percent error! Fortunately, strong samples suffer only slight distortion, so the diffi-

Fig. 3—Detection of pulse code modulation.

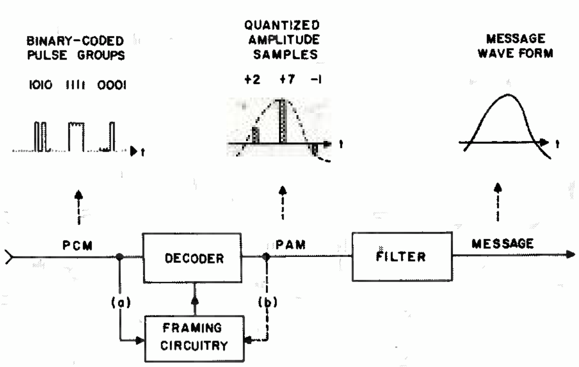
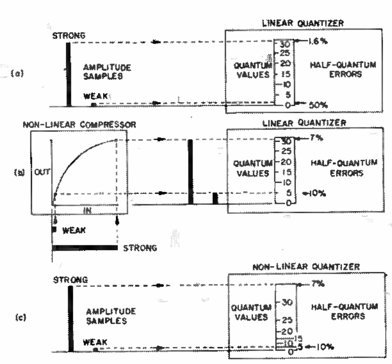


Fig. 4—Reduction of weak signal quantizing distortion: (a) no reduction; (b) reduction via tapered signal (companding); (c) reduction via tapered quantum scale.



culty can be alleviated by, in effect, shifting some of the strong-signal steps to the weak-signal region.

This may be done by tapering the signal in the manner shown in Fig. 4b before linear quantization.[2] The tapering device has a modified logarithmic compression characteristic that yields quite an equitable distribution of percent quantizing error. Of course, once the signal has been compressed in transmission, it must be expanded in reception if the overall transmission is to be linear. Therefore, in the receiving terminal, a linear decoder must be followed by an expander having an inverse characteristic to the compressor. The combination of compressor and expander are called a *compandor* and the function they perform is termed *companding.*

Although the compandor illustrated is "instantaneous" in the sense that it must respond to instantaneous values of narrow pulses, somewhat similar results may be had with slow-acting *syllabic compandors* placed in the message (rather than PAM) path. In either case preferential amplification of weak signals prior to encoding and preferential attenuation of weak signals after decoding, achieves the desired end.

A more direct but equivalent approach to the problem involves tapering the size of the quantum steps in the manner depicted in Fig. 4c. Electronic switching of resistors is usually employed to achieve the required unequal steps. (This method of reducing weak-signal quantizing distortion is being applied in a speech analog-to-digital converter now under development in SurfCom.)

Companding (or the equivalent) is particularly beneficial when applied to messages (such as speech) in which the major intelligence is conveyed by amplitudes near zero.[3] However, some messages do not take kindly to companding, whereupon the only solution is to increase the total number of quantum steps (which unfortunately increases the required transmission bandwidth).

Multiplexing and Demultiplexing

When two or more message channels must be encoded for transmission over a single PCM transmission path, advantage is taken of the time that is otherwise wasted between samples of a single channel. Thus, in Figs. 1 and 3, the clear time may be occupied by samples from other message channels, thus permitting multiplex operation with many channels.

Fig. 5 shows how the samples from four message channels may be interleaved to provide such a time-division multiplex system. Although only those elements needed for transmission in one direction are indicated, it will be understood that two-way transmission may be provided by appropriate duplication of the equipment shown. Multiplexing is accomplished by sampling the channels in a recurrent sequence and delivering the samples to a common PAM path. Each of the PAM samples is then encoded, and the resulting succession of pulse groups is transmitted to a receiving terminal. At the receiver, the incoming pulse groups are decoded, the resulting samples are demultiplexed (distributed to their appropriate channels), and each channel is filtered to yield its original message.

Synchronization and framing of the demultiplexing commutator, as well as the decoder, can be accomplished in the manner previously described wherein a special *framing digit* is transmitted once every frame. In the multiplex system, a *frame* comprises one complete commutation cycle, not the interval between successive coded pulse groups, so only a small fraction of the total time slots need be utilized for framing. Accordingly, only very little additional bandwith is required for transmitting framing information.

Note that the system of Fig. 5 contains a high percentage of common equipment, that is, equipment that is shared by the several message channels. Although all multiplex systems show this tendency, the per-channel needs in a PCM system are particularly small. As a result, PCM terminals serving a reasonable number of channels (say 24) are often less costly than competing terminals (frequency-division-multiplex, for example).

TRANSMISSION OF PCM

Thus far we have casually skipped over the problem of transmitting PCM from one communication terminal to another. Since the PCM signal contains an intermittent succession of narrow pulses, one might wonder whether inherent transmission difficulties might overshadow the "low cost per terminal" advantage claimed above. On the contrary, the transmission characteristics of PCM are its "crowning glory." It is true that the *quantity* of bandwith necessary to transmit PCM is greater than that required for more conventional analog and "carrier" signal forms. However, the *quality* of bandwidth required for PCM transmission is significantly lower than that demanded by competing analog techniques. This follows from the fact that PCM, unlike analog signals, lends itself to so-called *regenerative repeating*, whereby noise, interference, crosstalk, and distortion effects on the transmission path can be nearly eliminated. A brief discussion of these transmission features follows.

Bandwidth

If the highest message frequency is f_c and the number of digits per sample is N, it may be shown that PCM transmission of a single channel requires at least Nf_c cycles per second of bandwidth. Furthermore, if n channels are multiplexed, at least nNf_c cycles per second of total bandwidth is required. When these figures are compared with bandwidths necessary to transmit either baseband or single-sideband frequency-division-multiplex signals, it becomes evident that PCM requires at least N times as much bandwidth. This represents the price that must be paid for PCM immunity to noise, interference, crosstalk, and distortion associated with the transmission medium.

Actually the transmission medium need not be perfectly flat over this bandwidth. Reasonable deviations from flatness (several decibels) can be compensated by appropriate equalizer circuitry within the regenerative repeaters typically employed at appropriate intervals along the transmission path (see Fig. 5).

Regenerative Repeaters

Conventional analog repeaters attempt to reproduce at their output an amplified version of the signal *and noise* which arrives at their input. As a result, in multi-link analog -repeatered systems, noise and distortion accumulate from link-to-link.

Regenerative repeaters[4] attempt to regenerate or reconstruct at their output a replica of the original transmitted pulse signal (not a replica of the noisy, distorted signal which arrives at their input). Hence multi-link regenerative-repeatered systems substantially avoid accumulation of transmission impairments. Fresh new pulses are delivered at the output of each repeater, including the final repeater located at or near the receiving terminal.

Binary PCM, in which a simple "yes or no" decision occupies each time slot, is particularly well-suited to regenerative repeating. In essence, when handling such a signal, a regenerative repeater merely looks (in each time slot) for the presence or absence of a pulse. If it concludes a pulse is present, it generates an output pulse of the shape, amplitude, and duration *known* to have been transmitted originally.

Some basic features of regenerative repeating are illustrated in the idealized example of Fig. 6. As the original transmitted signal at *a* proceeds through the transmission medium to the first repeater, it will typically undergo amplitude and phase distortion. Though not shown, the weak distorted signal that arrives at the repeater may often appear to be unrecognizable. However, after passing through a simple equalizer and amplifier within the repeater, the signal (if noise-free) will take on the more meaningful waveform shown at *b*. The latter signal (peak value E) is then submitted to an appropriate threshold-triggered pulse regenerator (threshold $E/2$) which is enabled to "look" for the presence or absence of a pulse at only times t_1, t_2, t_3, and t_4 near the center of the assigned time slots. Timing information for the latter purpose may be extracted from the signal of b in a number of ways. During those "looks" in which the signal of b exceeds the threshold, a pulse is regenerated, thereby yielding the reconstructed signal of c in which shape, amplitude, duration, and spacing are a near-replica of a.

If the signal is not noise-free but contains some such form of interference as implied at b' and b'' of Fig. 6, the regenerator may make errors. However, inspection of b', b'', and c'' reveals that the idealized repeater requires little more than a 2-to-1 6-db peak-signal to peak-noise amplitude ratio for error-free transmission. Clearly such a regenerative repeater is remarkably tolerant of noise.

It is also interesting to note what tolerance such a repeater will have to "white" noise (i.e., noise with a uniform power spectrum and Gaussian amplitude distribution, such as thermal noise). It can be shown that if signal pulses are present in about half the time slots, the idealized repeater requires little more than a 17-db average-signal-power to average-noise-power ratio to yield a negligible (10^{-8}) error rate. For comparable performance, conventional analog-repeatered speech transmission links require a signal-to-noise ratio on the order of 65 db or more. Even taking account of the N-fold increase in bandwidth (hence N-fold increase in "white" noise power) demanded by PCM, one still concludes that PCM requires much less signal power (about 40 db less) than a comparable analog-repeatered speech link.

Obviously the bandwidth expenditure demanded by PCM is well worth the signal-to-noise advantage it buys via regenerative repeating. Although bandwidth may be traded for signal-to-noise ratio in frequency modulation and certain other pulse systems, the trade is less favorable. In these systems, the information capacity is proportional to the logarithm of bandwidth, instead of directly proportional to bandwidth as in PCM. Thus, for a sufficiently wide band, PCM is certain to be less susceptible to the ravages of noise, interference, crosstalk, and distortion—in essence, PCM is a "rugged" signal.

Processed PCM

Although the preceding examples have concerned classical unipolar PCM, some applications encourage special processing of such signals before transmission. For one thing, most transmission systems are AC-coupled and hence suppress DC.

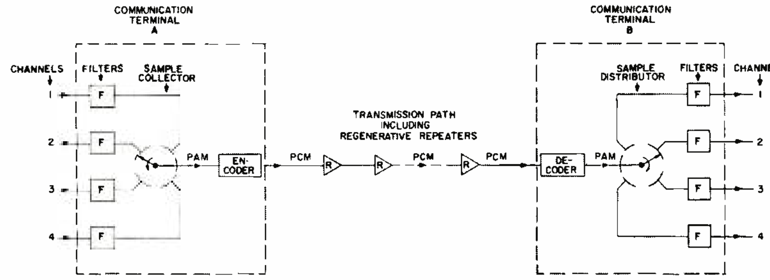


Fig. 5—Elements of multiplexed PCM system.

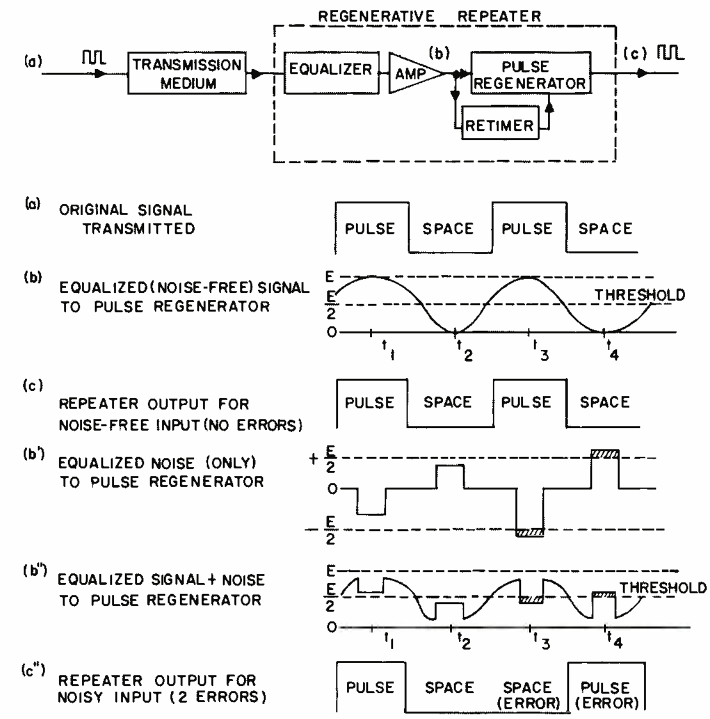


Fig. 6—An ideal regenerative repeater commits no errors if the peak-signal to peak-noise amplitude ratio at decision times is greater than 2 (6 decibels).

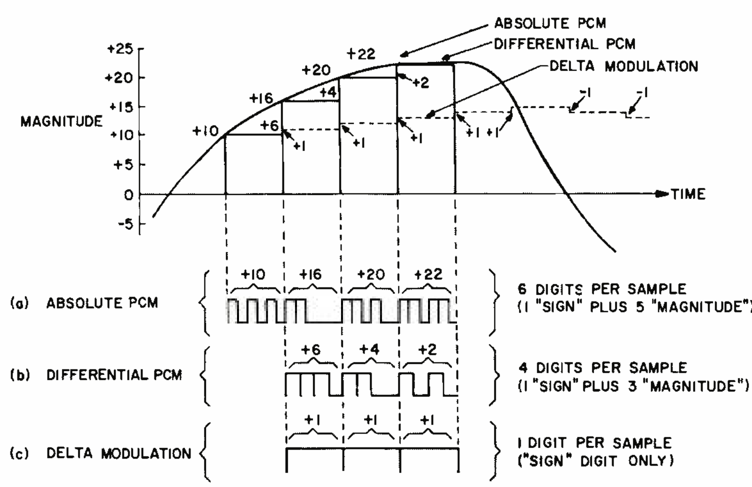


Fig. 7—Absolute PCM, differential PCM, and delta modulation.

When unipolar PCM (the spectra of which contains discrete lines at DC) is transmitted over such systems. difficult transient problems arise. Although a host of techniques have been applied to minimize low-frequency suppression effects, in some cases it is preferable to prepare the signal for the transmission path. rather than to tailor the transmission path to the signal.

One approach involves transmitting a "dipulse" (positive pulse followed by an equal negative pulse) every time a pulse is present in the PCM format. Another more attractive method[5] involves transmitting the PCM in a manner that makes successive pulses have opposite polarity. whenever they occur. Other techniques utilize the PCM pulses to modulate the frequency or phase of a sinusoidal carrier in a manner that yields a desirable spectrum for transmission.

By and large, such conversions fall in the broad category termed *data processing*. Their detailed description is far beyond the scope of this paper, but their merit is unquestionable. In general, they treat each PCM "bit" of information the same as any other "data bit." and they make every effort to utilize regenerative repeating to the best advantage. Special data processors are often introduced at sending and receiving points in the PCM system to accomplish message security (through cryptography). error detection. error correction, etc. The simple *on-off* constant-amplitude nature of the PCM signal is especially favorable to such techniques.

DIFFERENTIAL PCM

The previous discussion has dwelled on what might be termed "absolute PCM." wherein the *absolute* amplitude of a message is sampled, quantized, and coded. Some messages (such as speech) lend themselves to a variation of this technique called "differential PCM," wherein the *differential* amplitude of the message is sampled, quantized, and coded. The latter is briefly discussed below.

Example

The conceptual differences between *absolute* PCM, *differential* PCM, and *delta modulation* (a special case of differential PCM) may be grasped by inspection of Fig. 7. A simple numerical example is shown in which a specific message wave. sampled at a specific rate, is to be approximated by coded pulses. The absolute-PCM codes, utilizing a polarity digit and five magnitude digits to approximate absolute magnitudes, are shown at *a* for several successive samples. The differential-PCM codes, utilizing a polarity digit and three magnitude digits to approximate inter-sample amplitude *changes*, are shown at *b*. The delta-modulation codes shown at *c* utilize a single polarity digit to describe whether a unit magnitude differential shall be added to or subtracted from accumulated past differentials to approximate the message wave.

Although (in Fig. 7) both absolute PCM and differential PCM define the message equally well during the interval studied, differential PCM does so with *two less digits per sample*. This is a strong hint that differential PCM can be used to transmit a given message with *less bandwidth* than required for absolute PCM.

Delta modulation yields a very poor representation of the message when constrained to the sampling rate assumed in Fig. 7. However, if the sampling rate for delta modulation were increased by a factor appropriately *greater* than six. an approximation comparable to the others would obtain. This hints that delta modulation (with one-sixth the number of digits, but more than six times the sampling rate) will require somewhat more bandwidth than absolute PCM to yield *high* quality. Of course, the simplicity of the delta-modulation code strongly suggests that its implementation will be simple and inexpensive.

General Comments

Although the example given is an oversimplified. special case, the general tendencies shown actually apply to messages (such as speech) in which the spectral amplitude falls off with increasing frequency.[6]

In particular, when low-frequency preemphasis and tapered-step quantizing are applied to differential PCM,[7] approximately a 2-digit advantage may be gained over absolute PCM, even though the latter is similarly refined. This comes about partly because in tapered-step differential PCM both large and small quantum steps are utilized in *all* regions of the message absolute amplitude, rather than being restricted to particular regions as in tapered-step absolute PCM.

Also, (as implied in Figure 7), delta modulation actually requires higher transmission bit rates than absolute PCM when *high* quality performance is desired. However, when *medium* quality speech is acceptable. and low transmission bit rates (of the order of 20,000 bits per second) are demanded, delta modulation yields better signal-to-quantizing noise performance than absolute PCM. In fact, at such low bit rates. syllabic-companded delta modulation competes favorably with 3-digit tapered-step differential PCM. When minimal terminal equipment is of prime importance and medium quality is acceptable (as in certain military tactical equipments), companded delta modulation is a natural choice.

In multiplex systems, differential PCM tends to require more "per-channel" equipment than absolute PCM. However, as long as its inherent bandwidth savings outweigh its increased "per-channel" equipment tendencies, multiplexed differential PCM is still attractive. The outcome of this conflict will vary, of course, with specific applications.

Some messages may require very accurate transmission of absolute values. By definition, absolute PCM is inherently fit for such applications. However, if *approximate* absolute value transmission is permissible, differential PCM or delta modulation can sometimes satisfy the need through application of certain "clamping" or "limited integration" techniques.

CONCLUSION

Conversion of an analog message to pulse code modulation (a digital signal) requires the performance of many basic functions to create a signal with several times the bandwidth of the original message. Superficially, this seems like a wasteful operation, but actually it results in a signal that is very "rugged"— a signal that can stand large amounts of noise. interference, crosstalk, and distortion in the transmission medium. Realization of this advantage depends on the use of regenerative repeaters at appropriate intervals along the transmission path. When so transmitted, PCM takes full advantage of transmission media that offer "large-quantity" but "poor-quality" bandwidth. In addition, multiplexed PCM tends toward less-expensive communication terminals than are offered by competing techniques.

BIBLIOGRAPHY

1. H. S. Black, *Modulation Theory*, D. Van Nostrand Company, Inc., New York (1953), pp. 37-58.
2. H. Mann, H. M. Straube, and C. P. Villars, "A Companded Coder System for an Experimental PCM Terminal," *The Bell System Technical Journal*, New York, Vol. 41, No. 1, January 1962, pp. 173-197.
3. Bernard Smith, "Instantaneous Companding of Quantized Signals," *The Bell System Technical Journal*, New York, Vol. 36, No. 2, May 1957, pp. 653-709.
4. J. S. Mayo, "A Bipolar Repeater for Pulse Code Signals," *The Bell System Technical Journal*, New York, Vol. 41, No. 1, January 1962, pp. 25-97.
5. M. R. Aaron, "PCM Transmission in the Exchange Plant," *The Bell System Technical Journal*, New York, Vol. 41, No. 1, January 1962, pp. 99-141.
6. H. van de Weg, "Quantizing Noise of a Single Integration Delta Modulation System with an N-Digit Code," *Philips Research Reports*, Vol. 8, 1953, pp. 367-385.
7. R. L. Miller, "The Possible Use of Log Differential PCM for Speech Transmission in UNICOM," *Proceedings of the National Electronics Conference*, Vol. 17, 1961.

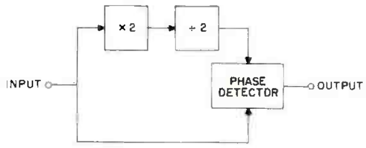


Fig. 1—Binary PSK demodulator.

USE OF A PHASE LOCKED OSCILLATOR IN PSK DEMODULATORS

Phase locked oscillators (PLO) have proven to be valuable additions to digital communication links. The PLO (a voltage control oscillator, a phase detector, and a low pass filter) has the ability to automatically lock itself to any given input frequency within a wide frequency range. The PLO can realize extremely narrow noise bandwidths and automatically track the spectrum of received signals, even in the presence of large doppler shifts and extremely low signal-to-noise ratios—attractive features for satellite communication systems and airborne data links.

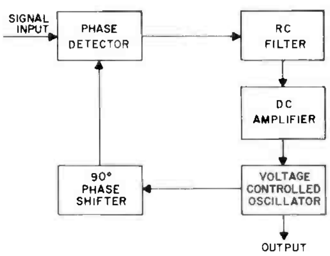


Fig. 2—Phase locked oscillator.

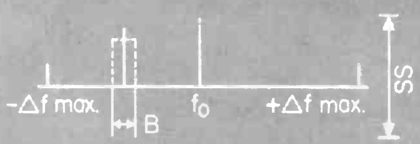


Fig. 5—Noise bandwidth and pull-in range of PLO.

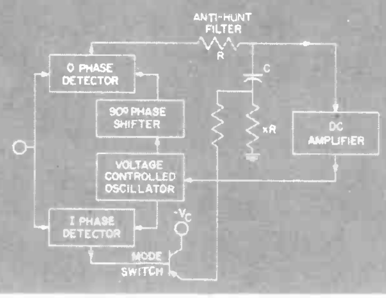


Fig. 6—Two-mode phase-locked oscillator.

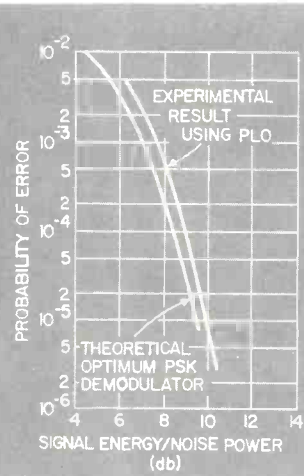


Fig. 7—Probability of error vs. ratio of signal energy per bit to noise power density.

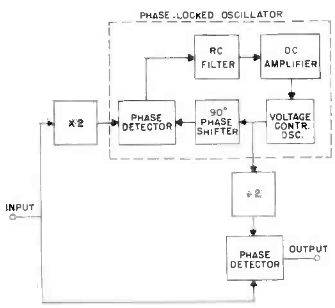


Fig. 3—PSK demodulator using a PLO filter.

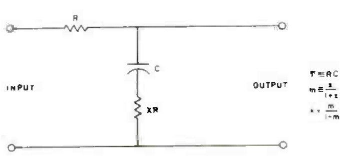


Fig. 4—Anti-hunt filter.

J. SCHANNE and W. HANNAN
Applied Research
DEP, Camden, N. J.

Digital communications may be carried on with a phase-modulated signal if the phase of the carrier wave is set to one of two or more phase positions to convey information. This is known as *phase shift keying* (PSK). Information is retrieved from the signal by comparison of the carrier phase with a phase reference.

The PSK is defined as being either *coherent* or *differentially coherent*. In coherent PSK, the data is transmitted by keying the phase of the carrier relative to a stable phase reference; in differentially coherent PSK, the data is transmitted by keying the phase of the carrier relative to the phase of the preceding transmitted bit. If there is relative motion between the two terminals of the communication link (the transmitter and receiver), the use of coherent PSK requires the transmission of a phase reference signal along with the digital information. Since this increases either channel bandwidth or transmission time, differentially coherent PSK (which is not subject to this disadvantage), is generally preferable for aerospace communications.

The phase positions used are generally separated by $360°/N$, where N is the number of phase positions. Therefore, a local reference signal in the differentially coherent PSK receiver may be generated by multiplying the frequency of the received signal by the factor N and dividing the frequency of the resulting wave by the same factor. The multiplication and division process results in removal of the phase modulation from the received signal, thus generating the required phase reference. Fig. 1 illustrates this technique for a binary PSK system, where the signal phases are separated by 180°.

PLO ADVANTAGES IN PSK

It is in the filtering of the phase reference signal from noise that the PLO offers a great advantage in a PSK system. A passive filter, such as a crystal filter or LC resonant circuit, introduces a phase shift which is a function of the input-signal frequency. Large frequency errors due to doppler shift and oscillator instabilities are inherent in aerospace communication systems. Therefore, the use of a passive filter to obtain a phase reference from a signal which is subject to significant frequency error is undesirable, since this would cause the reference itself to be subject to significant phase errors. As the bandwidth of a passive filter is reduced to improve the signal-to-noise ratio, the magnitude of this phase shift for a given frequency error becomes greater. Since aerospace communications are frequently carried on with low signal-to-noise ratios, the conflicting requirements of narrow filter bandwidth to improve the reference signal-to-noise ratio and wide filter bandwidth to accommodate frequency errors make it necessary to find another means for filtering the phase reference.

The PLO offers a solution to this problem. A PLO consists of a phase detector, a low-pass filter, an amplifier having response down to DC, a 90° phase shifter, and a voltage controlled oscillator connected as shown in Fig. 2. The PLO has the ability to track an input of varying frequency and to generate a signal having the same frequency with extremely small phase error. Fig. 3 shows how a PLO can be used in a binary PSK demodulator.

DESIGNING THE PLO

In order to optimize the performance of a PSK demodulator, careful design of the PLO is essential. Trade-offs must be made to establish the best compromise among static phase error, frequency pull-in range, lock-up time, and noise bandwidth. Approximate relationships (see references) among these parameters for a PLO employing the anti-hunt filter (Fig. 4) are given by:

$$P \simeq \frac{\triangle f}{G} \qquad (1)$$

$$\triangle f_{max} \simeq G\sqrt{2m} \qquad (2)$$

$$L \simeq x\,T\,\frac{(\triangle f/mG)^2}{1-\frac{1}{2m}\left(\frac{\triangle f}{G}\right)^2} \qquad (3)$$

$$B \simeq 1.25\sqrt{\frac{2\pi G}{(1+x)T}} \qquad (4)$$

Where: P = static phase error, $\triangle f$ = initial frequency error, G = loop gain, $\triangle f_{max}$ = pull-in range, L = lock-up time, m = ratio of AC to DC gain (see Fig. 4), $T = RC$ (see Fig. 4), $x = m/1\text{-}m$ (see Fig. 4), and B = noise bandwidth.

Critical damping, a design criterion which is usually desirable in order to optimize performance of PSK demodulators, requires that:

$$m = \frac{4}{\sqrt{2\pi GT}} \qquad (5)$$

If $m << 1$ and the PLO is critically damped, the noise bandwidth is approximately:

$$B \simeq 2mG \qquad (6)$$

Therefore, the ratio of noise bandwidth to pull-in range is:

$$\frac{B}{\triangle f_{max}} \simeq \sqrt{2m} \qquad (7)$$

If a value of m is chosen to provide critical damping, a ratio of $B/\triangle f_{max}$ on the order of 0.1 may be obtained. Thus, a very significant characteristic of a PLO is that it can be designed to have a noise bandwidth which is much smaller than its frequency tracking range. In effect, a PLO acts like a narrow bandwidth filter which automatically follows the input signal through its frequency excursions. The resulting capability of the PLO is illustrated in Fig. 5, where the passband of the loop may move anywhere within the pull-in range.

Using the above set of equations, the design of the demodulator proceeds as follows: First, maximum frequency error $\triangle f_{max}$ is estimated and maximum lock-up time L_{max} and maximum static phase error P_{max} are specified. In order to ensure reliable performance, the static phase error should not exceed 5°. Having specified P_{max} and $\triangle f_{max}$, the minimum loop gain can be determined by using Equation 1. Then, by trial and error, the values of G, T, and x can be traded to establish the desired compromise between noise bandwidth and lock-up time.

TWO-MODE PLO— THE QUADRICORRELATOR

If a satisfactory compromise among pull-in range, lock-up time, noise bandwidth, and static phase error cannot be physically realized, the a two-mode PLO, known as a *quadricorrelator*, may be used. The first mode is used to give a large pull-in range and short lock-up time. In this mode, the noise bandwidth must be relatively large. Once lock-up is achieved, the second mode, in which one or more loop parameters have been automatically changed, is used to narrow the noise bandwidth.

Fig. 6 illustrates how a two-mode PLO can be implemented. In this circuit, the output of the Q detector controls the local oscillator and the output of the I detector controls the mode of operation. When no signal is applied to the input, the average output signal from both phase detectors is zero; when the system is phase-locked, the output voltage from the Q phase detector is virtually zero, and the output voltage from the I phase detector is sufficient to drive the mode switch transistor from cutoff into saturation, thereby shunting resistor xR with another resistor. The result is an effective reduction of m and, therefore, a decrease in the noise bandwidth.

The experimental result shown in Fig. 7 indicates that performance within 1 db of that of the optimum PSK demodulator can be realized by a PSK demodulator employing a quadricorrelator.

BIBLIOGRAPHY

1. Crafts, C., "Phase Multilock Communication," *1958 Conf. Proc. Military Electronics*
2. McAleer, H., "A New Look at the Phase-Locked Oscillator," *Proc. IRE*, Vol. 47, June, 1959
3. Sonnenfeldt, R., "Automatic Phase and Frequency Control." *RCA Lecture Notes*, Lesson No. 44, January, 1957
4. Gruen, W., "Theory of AFC Synchronization," *Proc. IRE*, Vol. 41, Aug. 1953
5. Richman, D., "The DC Quadricorrelator: A Two Mode Synchronization System," *Proc. IRE*, Vol. 42, Jan. 1954
6. Lawton, J., "Comparison of Binary Data Transmission Systems," *1958 Conf. Proc. Military Electronics*
7. W. Hannan and T. Olson, "An Automatic-Frequency-Controlled Phase-Shift-Keyed Demodulator," *RCA Review*, Dec. 1961

J. F. SCHANNE received the BEE magna cum laude from Villanova University in 1960. He is a candidate for the MSEE degree from the University of Pennsylvania. Prior to graduation he spent four years in the U. S. Navy as an electronics technician, taught electronics for two years in the Naval Reserve, and worked as an engineering trainee for the Naval Air Material Center. He joined RCA after graduation. Since joining RCA Mr. Schanne has worked on mathematical and experimental studies of signal processing in high frequency magnetic tape recording and has participated in several analyses of military airborne and space communications systems. He has worked on development of a high speed printing process using electrofax techniques. He has conducted an experimental study of the applications of phase locked oscillators to communications reception at very low signal-to-noise ratios.

W. J. HANNAN graduated from the RCA Institutes in 1951, and then joined RCA Industrial Products. He contributed to the design of the RCA industrial TV camera chain, a general purpose monitor system, and the "Walkie-Lookie," a portable TV camera system used by NBC. He received his BSEE from Drexel Institute (evening college) in 1954. He was awarded an RCA Fellowship which he used to obtain an MSEE from the Polytechnic Institute of Brooklyn. After receiving his MSEE he was awarded a second Fellowship and continued graduate studies for another year. Mr. Hannan has been with DEP Applied Research since 1956. His work includes transistor TV circuits, digital communication receivers, and digital data processing equipment. He taught a transistor circuit theory course at RCA and at Rutgers University. He was project leader on the Combat Surveillance Data Link Program for the Signal Corps, a study program to evaluate how the parameters of a communication link affect the ability of a photo-interpreter to detect and recognize targets. He was project leader on the Extra-Wideband Closed-Circuit Television Study for Bell Aerosystems, an analysis of the current and future state-of-the-art television systems with regard to signal-to-noise ratio and resolution. He is currently project leader on a reading machine program for the Air Force, a study and experimental program which involves designing a machine to recognize all the characters of a Russian font.

J. F. SCHANNE

W. J. HANNAN

A CRYOTRON-CIRCUIT ENCODER

Use has been made of a superconducting phenomenon to develop a circuit that is capable of encoding an analog signal, representing a physical quantity, to a digital number. A useful application of this circuit would be as an input terminal to a superconducting digital computer. This encoder features circuit simplicity, low cost, negligible power drain, potential of high speed, and high reliability. Its main disadvantage is the need for low ambient temperature.

B. RABINOVICI
Systems Laboratory
Surface Communications Division, DEP, New York City, N. Y.

It is well known that when an external current flowing in a superconductor exceeds the critical value, resistance reappears[1]. In soft superconducting ribbons, this critical value of current I_v has been observed to change when brought into close proximity with another hard superconducting plane (Fig. 1).

This property is best explained with the aid of Fig. 2. The current distribution on a superconducting surface is analogous to the electrostatic charge distribution on a charged conductor, since both are represented by the same differential equation. The current density will be the highest at the edges of a superconducting film (Fig. 2a). If the ribbon carries a current larger than the critical current, the magnetic field caused by this current will switch the superconductor into the resistive state, from the edges toward the center. If a hard superconducting ground plane is brought into close proximity with the superconductor but insulated from it by a very thin film (Fig. 2b), the critical current of the superconducting ribbon will be increased. This is expected because the superconducting ground plane is impermeable to magnetic flux, and therefore, circulating supercurrents are set up on its surface to prevent magnetic flux from penetrating it. These circulating supercurrents have the effect of increasing the field in the gap between the superconducting film and the ground plane near the center of the ribbon. Since the line integral of the field around a closed path is equal to the current enclosed, i.e., $\int Hdl = I$, it can be seen by choosing a path enclosing only the ribbon, that if the field near the center of the gap is increased for a given value of current then the field near the edge must be decreased. As a result, the field around the film is made more uniform. Thus, with a ground plane, the superconducting strip can carry more current before its own field will switch it resistive.

Threshold current is approximately doubled. If, now, the geometry is changed slightly to conform to that shown in Fig. 2c, the same effect is noticed; namely, that with the ground shield present the critical current of the superconducting strip increases. Furthermore, when the superconducting plane also carries current then the critical current of the superconducting strip varies as a function of the current flowing in the superconducting plane (Fig. 1). This has been verified experimentally.

ENCODER DESIGN

The basic n^{th} circuit element of the encoder is shown in Fig. 3. It consists of strip A_n made of hard superconducting material (lead), in series with the soft superconducting gate (tin) of cryotron H_n. In parallel with it is the tin gate of cryotron G_n. A bit-subtraction reference current, I_{sn}, is applied to this parallel combination and it is steered either through A_n or G_n. In close proximity to A_n there is another strip, C_n, made of lead. Sandwiched between A_n and C_n is gate D_n, made of tin. A superconducting inductance, L_n, and the small threshold resistance, r_n, (a copper wire), are connected from point a to ground. The subtracting current, I_n, is fed to node a. Resistance r_n establishes the superconducting threshold and L_n acts as a current storage element. The analog current amplitude, i_{n+1}, remaining from the higher bits encoding operation m through $n + 1$ (where $|m - n| > 1$) is flowing in strip C_n through a control winding that crosses the gates of cryotrons E_n and F_n, which are in parallel.

The critical current of strip D_n, namely i_n, is thus proportional to the magnetic field produced by the difference of the currents flowing through strips A_n and C_n, i.e., $i_{n+1} - I_{on}$ (i_n is therefore proportional to the difference between the analog signal to be encoded and the quantized current, I_{sn}, equal in amplitude to the n^{th} order bit). When gate E_n is held resistive by the bit reference current, I_{on}, flowing through a central winding that crosses it, the gate current, I_{Gn}, is forced to flow through the branch containing gate F_n. Current I_{on} holds gate H_n resistive, and gate G_n is superconducting. The analog reference current must be introduced before i_n, to insure steering of gate current I_{Gn} through gate F_n.

The resultant magnetic field produced by i_{n+1} flowing through C_n, and by I_{on} flowing through A_n determines the critical current i_n that will flow through strip D_n. With reference to Fig. 4, it is clear that for values of $i_{n+1} < |I_{on}| - |I_c|$, no change occurs. For values of $i_{n+1} > |I_{on}| - |I_c|$, gate F_n becomes resistive, gate E_n changes to the superconducting state (note I_{on} and i_{n+1} are in opposite direction), and current I_{sn} switches from the branch containing G_n to the branch containing A_n. Current output, i_n, continues to flow to the next lower $(n\text{-}1)^{th}$ bit. Readout is obtained across the gate of cryotron V_n, which is resistive only when a *one* is encoded in that particular stage.

ACKNOWLEDGEMENT

The author wishes to thank C. V. Olson of the RCA Laboratories in Princeton, N. J., and Dr. A. Boornard of DEP Applied Research in Camden, N. J., for useful suggestions.

BIBLIOGRAPHY

1. D. Schoenberg, *Superconductivity*, The University Press, Cambridge, England, p. 130, 1952.

BENJAMIN RABINOVICI received an Engineering Diploma in E.E. from the Polytechnic Institute of Bucharest, Rumania, in 1948, and his MSEE from Columbia University in 1955. From 1950 to 1951 he was an Engineer with Teleking TV Company. From 1951 to 1956 he was a Senior Engineer in the Advance Development Lab. of CBS engaged in the development of TV circuitry. From 1956 to 1960 he was a Research Engineer and Group Leader with Underwood Corporation and IBM Watson Research Laboratories at Columbia University, working on acoustic delay lines, magnetic-core memories and cryogenic computer research. In 1960, he joined RCA in the DEP Surface Communications Systems Lab., New York, as Leader, Advanced Communication Techniques. He was recently named Senior Staff Scientist in Advanced Solid-State Techniques. He has authored several technical papers and holds a number of patents. He is currently participating in the David Sarnoff Industry Science Program (Cryogenics). He is Chairman, Membership Committee, IRE N. Y. Section, and lectures in the CCNY Graduate School of Technology on Solid State Electronics and Communication Engineering. Mr. Rabinovici is a Senior Member of the IRE, and a Member of the APS, AIEE and Eta Kappa Nu.

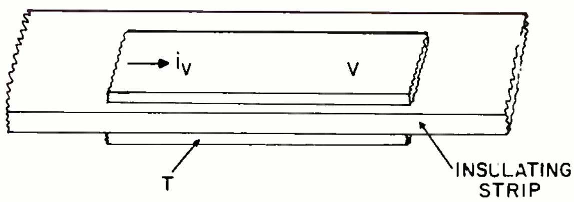


Fig. 1a—Strip configuration.

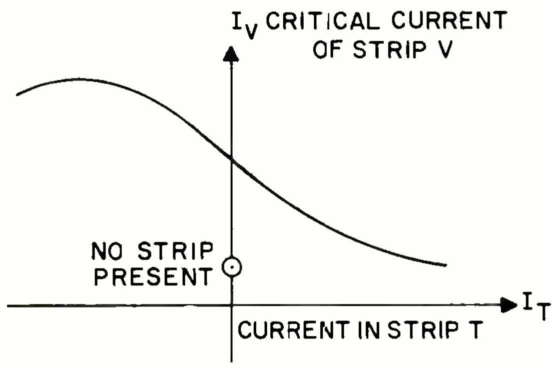


Fig. 1b—Critical current of strip *V* vs. current in strip *T* in close proximity (few μ separation).

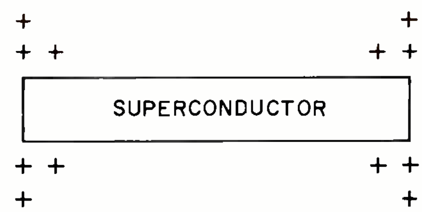


Fig. 2a—Areas of highest current flow in a superconductor.

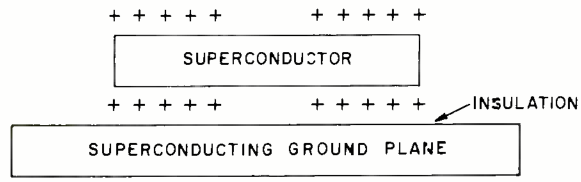


Fig. 2b—Current density in the proximity of a ground plane.

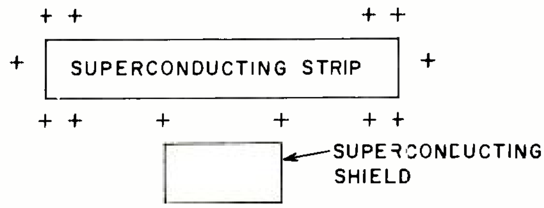


Fig. 2c—Current density in the proximity of a shield.

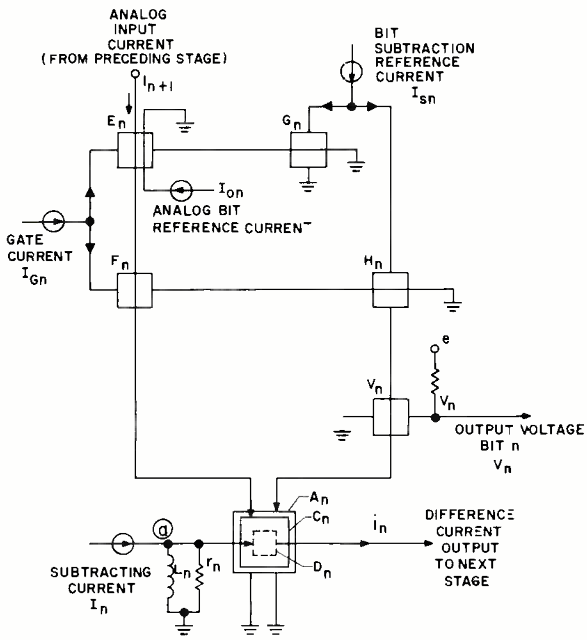


Fig. 3—One stage of a superconducting analog-to-digital converter.

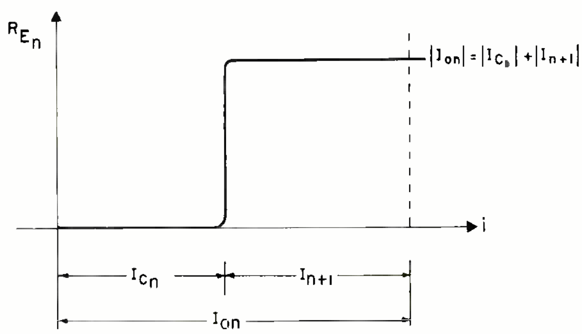


Fig. 4—Resistance of gate E_n vs. current on its control windings. Ic_n is critical current of gate E_n; and $I_n + 1$ is the quantized current value of the n^{th} stage. (Note: I_{n+1} is opposite to I_{on}.)

SPEECH CODING AND AUTOMATIC SPEECH RECOGNITION

Speech has long been known to be highly redundant. A startling indication of its redundancy is found in the statement that although present speech channels employ a bandwidth of 3000 or 4000 cps, speech can theoretically be transmitted with a bandwidth of only 5 cps. Such a figure is arrived at by considering speech to be composed of 40 phonemes,* spoken at the rate of 10 phonemes per second. Using information theory developed by Shannon which relates rate of flow of information to bandwidth and channel capacity, it can be shown that this rate of information transmission requires a 5-cps bandwidth with a 30-db signal-to-noise ratio.[1]

[**Phoneme* — the smallest unit of speech that in any given language distinguishes one utterance from another, as the *p* in pin and the *f* in fin, by which these two English words are distinguished from each other.]

It is to be realized, of course, that ideal coding and the transmission of the phoneme identity only are assumed. Thus other characteristics, such as naturalness, identity of the talker, inflection, and emotional content, would be missing. In addition, phoneme identification by machine is still not possible except to a very limited extent, as will be discussed later. Thus there is at the present time no way of implementing such a large step in elimination of redundancy in speech transmission; however, the very large potential in bandwidth saving does spur on efforts in this direction.

Actually, advantage was taken of the redundancy of speech with its attendant tolerance of distortion in many ways long before it could be expressed in a quantitative way. These have varied from simple bandpass filtering to elaborate bandwidth compression schemes which analyze the speech at the transmitting end, transmit a simplified description and then synthesize the speech at the receiver.

PURPOSE OF SPEECH CODING

Speech coding is generally done for one of two reasons: bandwidth compression or security. Because of security limitations, we can say little about the latter, except that the redundancy of speech makes it very difficult to encode speech for security by any simple technique. Techniques which are effective generally require an increase in bandwidth so that speech coding for bandwidth compression is often required in order to transmit secure speech over present channels.

Speech coding is done for security or for bandwidth economies; the ultimate in coding efficiency would be expected from automatic speech recognition if phonemes (basic speech elements) could be recognized. Other interest in automatic speech recognition arises from the potentials of phonetic typing, automatic translation from a spoken language with printed or speech output in a second language, and general interest in human-pattern recognition. This paper describes digital spectrograms and their analysis with an RCA 501 computer, the segmentation of speech elements, formant tracking, vowel identification programs, and studies of consonant recognition.

W. F. MEEKER
Surface Communications Division
Camden, N. J.

Automatic recognition of speech has occupied the attention of a number of investigators in several fields in the past decade.[1-7] There are several reasons:

1) Automatic speech recognition could provide for transmission of speech with the minimum possible bandwidth.
2) Automatic speech recognition would make possible the phonetic typewriter, a device into which one dictates and receives immediately a printed copy of the words spoken.
3) Automatic speech recognition combined with machine translation would permit speaking into the machine in one language and having the output either speech or printed text in another language.
4) There is much interest in pattern recognition by machine, adaptive logic, neuron model networks and other approaches to human performance and intelligence. Automatic speech recognition is considered a good problem area for studies of this nature.

A COMPLEX PROBLEM

Because of the redundancy of speech, a limited degree of speech recognition can be accomplished by very simple means, if the vocabulary is restricted. For example, a model railroad controller can employ a loud sound such as the spoken word *go* to actuate a start mechanism and the puff of air released from the *p* in *stop* to actuate the stop mechanism. Obviously such a mechanism would respond to many other words and could also be operated without producing meaningful sounds.

The success of the linguist or phonetician in analyzing speech as a succession of phonemes led initial workers in the field to believe that there were clearly defined acoustical counterparts to these phonemes which could be isolated, measured, and then identified. The situation turns out to be considerably more complex than was initially as-

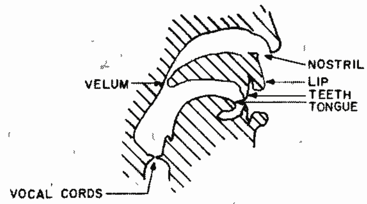
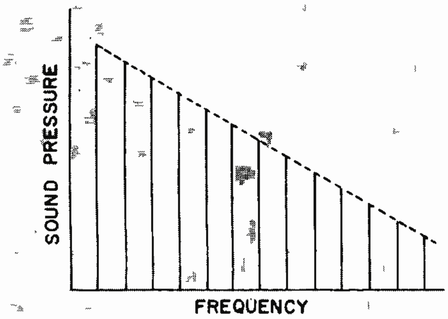


Fig. 1a—Above: The vocal tract.



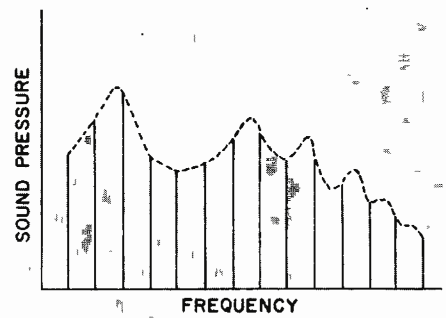


Fig. 1b—Left: Sound spectrum produced by the vocal chords before filtering by the vocal tract. Right: Same sound spectrum after filtering by the vocal tract.

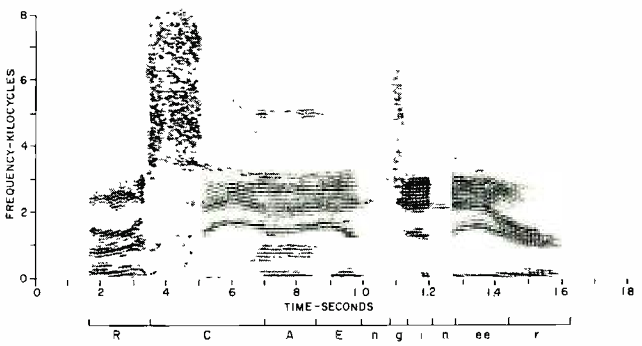


Fig. 2a—Sound spectrogram of the words "RCA ENGINEER" with an analyzing-filter bandwidth of 40 cps.

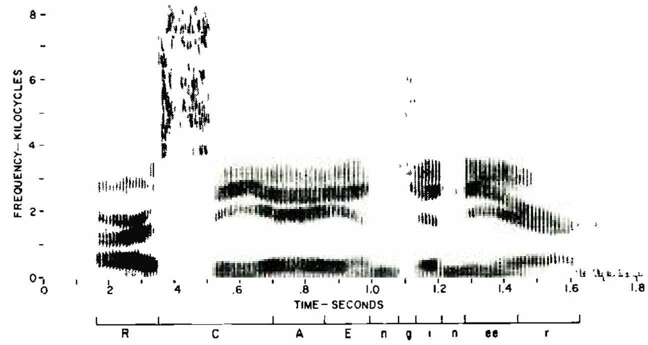


Fig. 2b—Same as Fig. 2a, except with an analyzing-filter bandwidth of 300 cps.

sumed. Tape splicing experiments, in which a given word is assembled from phonemes taken from other words, have shown that speech formed in this way loses considerable intelligibility.

One such experiment[3] showed that when *f* from *foe* was combined with the *o* from *so*, the resulting sound was identified as *θo*, which is pronounced *tho* with the *th* pronounced as in *thin*. Such experiments suggest that the phonetic analysis which the phonetician makes is more than simply the recognition of individual phonemes, at least for many sounds. It may be that some larger unit is first recognized, and the division into phonemes made as a second process, either my memory or by subsequent more detailed analysis. Nevertheless, individual phoneme recognition can be accomplished to some degree, as will be described.

BASIC NATURE OF SPEECH

Before going further, it is necessary to describe something of the speech producing process. Normally, most speech sounds originate from vibrations of the vocal cords. The vocal cord vibrations produce a "buzz," that is, a complex spectrum which is periodic but rich in harmonics. The fundamental rate of vibration is termed the pitch and varies during the course of speech to produce inflection and other quality attributes but has little, if any, bearing upon the intelligibility of speech—that is, identification of individual words. The complex sound spectrum produced by the vocal cords is modulated by the vocal tract to produce meaningful sounds. The movements of the lips, tongue, teeth, palate, and other elements of the vocal tract not only affect the intensity of the sound but also shape its frequency content. That is, the vocal tract has certain resonances which shape the complex spectrum produced by the vocal cords. These resonances vary as the vocal tract is manipulated to produce speech.

This process is indicated diagrammatically in Fig. 1a which shows the vocal tract and vocal cords. Fig. 1b indicates the sound spectrum produced by the vocal cords before and after filtering by the vocal tract. The spectrum is shown as a line spectrum because it is quasi-periodic. The dotted line indicating the envelope of the spectrum shows the resonances of the vocal tract.

So far, we have been talking only about *voiced* sounds, that is, sounds produced by vibrations of the vocal cords. Some speech sounds, *s* and *sh*, for example, are produced without vocal cord excitation and are termed *unvoiced* sounds. They are produced by turbulence generated somewhere in the vocal tract and resulting in an essentially random noise spectrum which is shaped by the vocal tract. In the case of *s* and *sh*, the noise is produced at the teeth and the spectrum shaped primarily by the lips. In the case of *h*, the noise is produced farther back in the throat and is shaped by the vocal tract in much the same way as the voiced sounds. With sounds such as *z* both vocal cord vibration and turbulent noise are present.

It was indicated earlier that the fundamental pitch of the voice contributed little if anything to intelligibility. This can be easily demonstrated by talking in a monotone. We come then to the big question—*just what is it that carries intelligibility? What are the information bearing elements of speech?*

At the present time this question can only be partially answered. Broadly, it can be said that the information is carried by the speech spectrum; that is, wave-form or phase are not primarily of importance. Beyond this, certain information resides in the shape of the spectrum and other information resides in the time variation of portions of the spectrum. The precise nature of this information is not known, although enough is known to permit a substantial degree of automatic speech recognition, as will be described below.

THE SOUND SPECTROGRAM

A representation of speech which is very useful in studies of speech characteristics is the sound spectrogram shown in Fig. 2. Here, the coordinate axes are frequency and time; the density in any frequency region is proportional to the energy in that region. In Fig. 2a, the bandwidth used in the analyzing filter is 40 cps; with this narrow bandwidth the individual harmonics are apparent. A somewhat clearer picture of the distribution of energy can be seen when the bandwidth of the analyzing filter is 300 cps, as shown in Fig. 2b. The dark bands are regions of greater energy density and represent resonances of the vocal tract, called *formants*. The lowest-frequency resonance is termed the first formant, the next the second, etc. The frequencies of the first and second formants are of primary importance for the identification of vowels and some vowel-like sounds; the third formant is of lesser importance except for certain sounds such as *l* and *r* where the primary distinction appears to be based upon the third formant.

An interesting consequence of the filter bandwidth used for Fig. 2b and the analysis instrumentation is that the voiced portions of speech are identifiable by the prominent vertical striations, and the distance between the striations corresponds to the period of the pitch. The distinction between voiced and unvoiced sounds is rather easily made by visual inspection of this display.

While this type of display has been very useful in studies of speech, it has two major disadvantages: 1) it re-

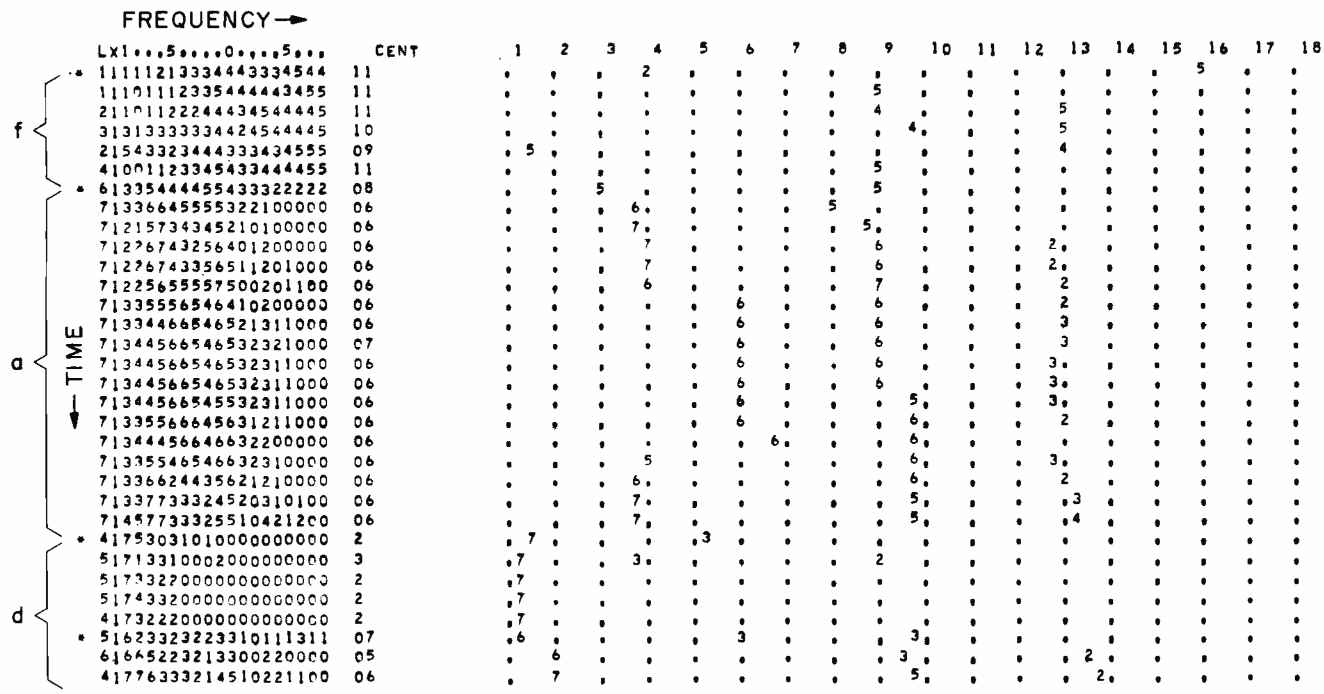


Fig. 3—Digital spectrogram (left) and formant plot (right) for the word "fad."

a) In the digital-spectrogram frequency-time data at left, the column marked L is the over-all level. (Column marked X may be ignored.) The columns marked 1 . . . 5 . . . , etc., correspond to the analyzer filter channels and cover the range from 200 to 6000 cps. Each row represents the spectrum samples at 20-msec intervals. Digits 0-7 represent the level in each channel, in 3.5-db steps.

b) The asterisks at left mark the phoneme boundaries as determined by the computer.

c) In the formant plot, at right, the column marked CENT is the computed centroid. Numbers 1-18 heading the formant plot are analyzer-channel numbers. The plot on the right is thus a frequency-vs.-time plot of the formants and is derived from the digital spectrogram.

quires something over 100 times real-time to make the analysis and display, and 2) it is difficult to extract quantative information.

It became apparent that modern data processing techniques offered the possibility of a fast quantative analysis of speech and plans were made to employ an RCA 501 computer for this purpose.

COMPUTER ANALYSIS OF SPEECH

The first problem to be faced was *how to get the speech data into the computer.* Some very basic questions had to be faced: In *what form should the input be?* (Speech signals are obtained in analog form; the computer requires digital input.) *Should the input speech waveform be converted to digital form and then all further analysis be done by computer or is some pre-processing in order?*

Initial Processing for Computer Input

Ideally, it seemed that a spectral analysis, with frequency and amplitude resolution approximating that of a human observer should be used. However, this approach would have resulted in greater complexity and in the generation of more data than seemed economically justifiable. A reasonable compromise appeared to be to make a frequency analysis using 18 bandpass filters covering the speech range of 200 to 6000 cps. It was known from experience with vocoders* that little intelligibility was lost when speech was reconstructed from an 18-band spectrum analysis. [*vocoder—a bandwidth compression device which analyzes and synthesizes speech.]

Further, the level in each band needed only to be specified to eight levels, provided the levels were in logarithmic steps and a sampling rate of 50 times per second were used. The basic spectral data were thus reduced to the form shown in the left-hand portion of Fig. 3, a digital spectrogram for the word *fad.* The numerical data *0* to *7* in the spectrogram represents the intensity, in 3.5-db steps, in each frequency band. The first column is the over-all level, that is, the level in the entire speech band. The second column is a spare and may be ignored. The next 18 columns show the level in each of the 18 frequency bands. The corresponding frequencies are shown in Fig. 4, which shows the filter characteristics. The block of figures in the left portion of Fig. 3 thus is a digital spectrogram of the word.

After deciding upon the frequency resolution, amplitude resolution, and sampling rate, the next problem involved making the conversion to digital form suitable for input to the 501 computer.

Assuming speech data in the form indicated, the actual data rate necessary to describe the input speech was 1000 characters per second (20 channels, one character per channel to represent levels 0 through 7, 50 samples per second.) This rate is too great to permit punching on cards or paper tape; these accept data at a relatively slow rate, something of the order of one character per second without a buffer or 100 characters per second with a buf-

Fig. 4—Responses of the analyzer filters.

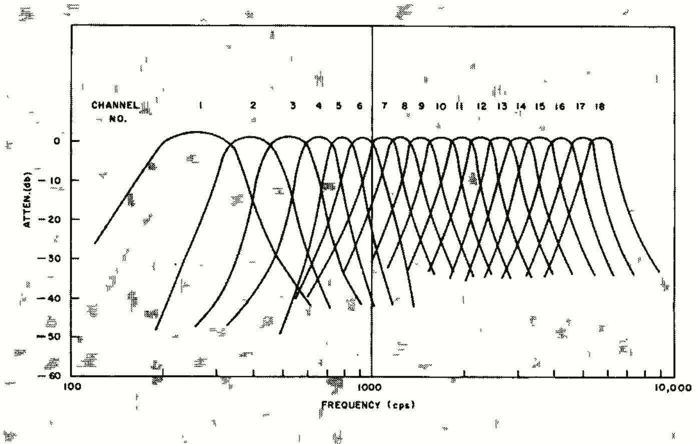


Fig. 5—The author, W. F. Meeker, shown here with the speech-analysis and digital encoding equipment.

WILLARD F. MEEKER received his BSEE from Ohio State University in 1939 and his MSEE from the University of Pennsylvania in 1958. He joined RCA in 1951 after having ten years of experience in electro-acoustic devices, speech intelligibility, speech communications systems for the military, and speech bandwidth compression. He was project engineer for the Study of Electro-acoustic Transducers for Voice Communications in Aircraft, a project on Active Ear Defender Systems, and a Study of Communications in High Ambient Noise, (among others). He has recently been in charge of the SurfCom speech analysis and speech compression program, supervising many of the studies and acting as acoustical consultant on a number of projects. He has authored many papers and holds nine patents in audio devices. He is a licensed professional Engineer in New York State, and s listed in the eighth edition of **American Men of Science**. He is a Member of the Institute of Radio Engineers, and the Acoustical Society of America, and has served on a number of technical committees, including ASA Subcommittee Z-24-W36 on "Methods of Calculating Speech Intelligibility."

fer. On the other hand, the RCA 501 computer accepts data at 33.333 characters per second. This disparity in data rate was overcome by recording the input speech data digitally on magnetic tape at 3 inches per second, then physically transferring the magnetic tape to the computer where it is played back at 100 inches per second. Fig. 5 is a photograph of the analyzing and encoding equipment.

Problem: No Model of Human Speech-Perception

The speech recognition problem differs from most computer problems. Normally, the process whereby a problem is solved is known and can be programmed directly. In the case of speech recognition, the process employed by a human listener in recognizing speech is not known. Even the magnitude of the problem is not known but there are indications that it may be exceedingly complex. For example, the number of hair cells in the organ of Corti (where sound may first be sensed) is about 20.000; there are about 27.000 cells in the spiral ganglion of Corti; the auditory nerve is composed of about 30,000 fibers. There are about 10 billion cortex brain cells. If one guesses that 10 per cent of these might be concerned with speech recognition, there would thus be one billion cells for this purpose. Thus, even if the mental process were accurately known, it might not be feasible to reproduce it.

Lacking a model of the perception process, one can only attempt to determine recognition criteria from information available regarding the characteristics of speech and from inspection of speech data. Thus the first application of the computer is that of organization of the data and print-out in a useful display. Then processing for recognition can be explored.

Segmentation—The Detection of Phonemes

One of the first problems in speech recognition is that of segmentation. Phoneticians consider that speech can be represented by about 40 phonemes. The problem is to determine where in the acoustical signal (or in the digital spectrogram) one phoneme ends and another begins. Actually, we now know that most speech is a continuous process and is not, in general, composed of discrete phonemes; nevertheless, fairly accurate segmentation can be achieved.

Fig. 3 shows the digital spectrogram for the word *fad*, with asterisks marking, at least approximately, the phoneme boundaries. This is automatically done by the computer as follows:

1) The change (difference) in channel level from one sample to the next is summed over all channels (differences of one are discarded).
2) Maxima in these summed differences are located and compared to a threshold which is 1.5 times the average difference for the whole word.
3) If the maximum in question exceeds the threshold, that sample is marked with an asterisk and presumably marks the border of a phoneme.

Basically, this process marks gross changes in the spectrum. Our experience to date indicates that this method is better than 90 percent effective, even with vowel-like consonants such as *r* and *l*.

After the segments are located, they are identified as voiced or unvoiced on the basis of the first moment, or centroid, of the spectrum. If a segment is voiced, the formants are located and printed out. This is done by a program which locates the frequency bands having maximum levels, then computing a weighted location to the nearest quarter-band by using the levels in the two adjacent bands. Certain amplitude comparisons are also made to eliminate minor maxima. The level number occurring in the channel having a local maximum is then transferred to a formant plot (right-hand portion of Fig. 3). All these operations are done by the computer.

Vowel Recognition

A substantial amount of the identity of speech sounds is determined by frequencies of the first and second formant. No simple relationship exists. This relationship was explored by Peterson-Barney for steady-state vowels by plotting the second formant versus the first and areas on such a plot corresponding to the vowels were found. We have adapted the Peterson-Barney data to our filter set, resulting in a plot as shown in Fig. 6. This has been used in an automatic vowel recognition program which functioned as follows:

1) The word was segmented as above.
2) The longest voiced segment was assumed to be the vowel.
3) The center sample in the longest voiced segment was located and the frequencies of the first and second formants located.
4) A point corresponding to the first and second formant was located on an F_1-F_2 table stored in memory.
5) The vowel corresponding to this location was printed out.

The program also compared the "recognized" vowel with the spoken vowel (according to a prepared list of spoken words), determined whether the recognition was correct or not and then tabulated the percentage of correct recognitions. Fig. 7 shows a portion of the print-out resulting from the vowel recognition program. The percentage of correct recognitions ranged from 85.0 to 21.6 percent for 10 talkers speaking 10 repetitions of a list of words composed of all combinations of six initial consonants, ten vowels, and one final consonant. The average score was 45.3 percent. It is estimated that by applying a duration criterion, the average accuracy for male talkers can be increased to better than 80 percent without adjustment for individual talkers.

Consonant Recognition

Criteria for consonant recognition were devised by examination of digital spectrograms and a study of characteristics reported in the literature. These criteria were programmed first for the six consonants, *s*, *sh*, *z*, *v*, *f*, *h*. The results are shown in Table I.

A second group of six consonants was studied and recognition criteria devised for these also (Table II).

Using the consonants *s*, *sh*, *z*, *v*, *f*, *h* a word-recognition routine was prepared which merged the vowel and consonant recognition programs. This routine provided completely automatic recognition of words which could be formed from the six initial consonants of Table I, ten vowels, and the final consonant *d*. Experience with this program has been limited. For one talker, the program correctly located and identified 80 percent of the initial consonants, 80 percent of the vowels, and 64 percent of the words (the final *d* did not enter into the program).

CONCLUSION

While substantial progress has been made, performance approaching that which the human listener achieves is still a goal rather than a reality.

A few observations are in order: First, while phoneme recognition is implied in much of the above and the recognition program is phoneme-oriented, it is fully realized that in some cases the phoneme may not be a suitable unit of recognition. In some cases, a smaller element may be more basic, while in other cases the basic unit may actually be two or more phonemes. Secondly, there are many approaches which permit recognition of a limited vocabulary, particularly if limited or adjusted to one person. Thirdly, a complete solution to the problem of speech recognition may be exceedingly complex. There is, at present, no logical basis for estimating its complexity since no complete perception model yet exists.

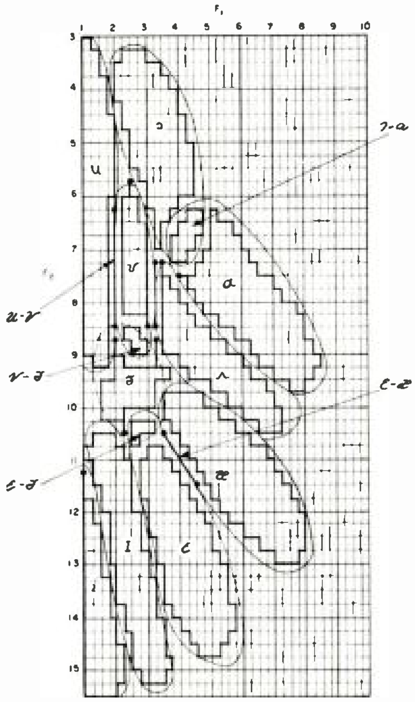


Fig. 6—The F_1, F_2 map used by the computer for vowel recognition. Symbols shown are the international phonetic symbols for the vowels.

Fig. 7—Portion of the computer printout for the vowel-recognition program. Columns marked *V* is the vowel spoken. If correctly recognized, it is marked with an asterisk. If incorrect, the word recognized is printed under *REC. AS*. Thus, for word No. 56, the program could not determine whether the vowel was AW or AH. And, for the word No. 59, *EE* was incorrectly recognized as *I*. The numbers at the bottom indicate that for this particular trial of 60 words, a total of 43 (or 71.6%) were recognized correctly.

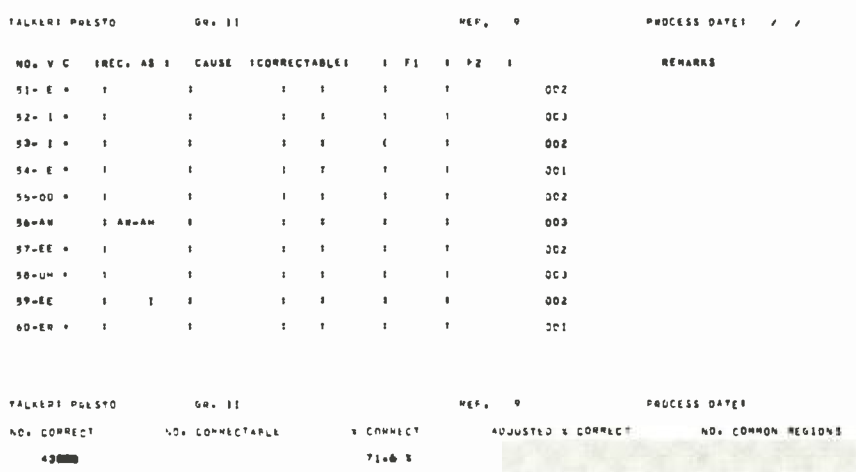


Table I—Recognition Achieved for Six Initial Consonants Spoken Ten Times Each by Ten Talkers in Combination with Ten Vowels and the Final Consonant d

Consonant	*% Correct Recognition*
s	48.1
sh	80.9
z	29.6
v	25.2
f	50.0
h	74.0

Table II—Percent Correct Recognition for Six Additional Consonants

Consonant	*% Correct Recognition*
j	77.4
w	62.1
r	74.7
l	26.0
m or *n*	70.6

Whether economically feasible speech recognition devices can be devised is yet to be determined.

ACKNOWLEDGMENT

The automatic speech recognition research described here was sponsored by the Air Research and Development Command, under Air Force contract number AF33(616)-6691. The computer programming was done by L. S. Green and R. L. McLaren. Also, P. B. Scott and A. L. Nelson contributed to the determination and evaluation of recognition criteria.

BIBLIOGRAPHY

1. Flanagan, J. L., *A Speech Analyzer for a Formant-Coding Compression System*, Acoustics Laboratory, Massachusetts Institute of Technology, Scientific Report No. 4, U.S.A.F. Contract No. AF 19(604)-626, May 1955.
2. Harris, C. M., "A Study of the Building Blocks in Speech," *J. Acoust. Soc. Am.*, *25*, 962-969, Sept. 1953.
3. Harris, K. S., "Cues for the Discrimination of American English Fricatives in Spoken Syllables," *Language and Speech*, *1*, 1-7, 1958.
4. Olson, H. F., and Belar, H., "A Phonetic Typewriter," *J. Acoust. Soc. Am.*, *28*, 1072-1081, 1956.
5. Fry, D. B., and Denes, P., "The Solution of Some Fundamental Problems in Mechanical Speech Recognition," *Language and Speech*, *1*, 35-38, 1958.
6. Dudley, H., and Balashek, S., "Automatic Recognition of Phonetic Patterns of Speech," *J. Acoust. Soc. Am.*, *30*, 721-723, 1958.
7. Olson, H. F., H. Belar and R. deSobrino, "Speech-Processing Systems," *J. Acoust. Soc. Am.*, *34*, 724, 1962 (Abstract).

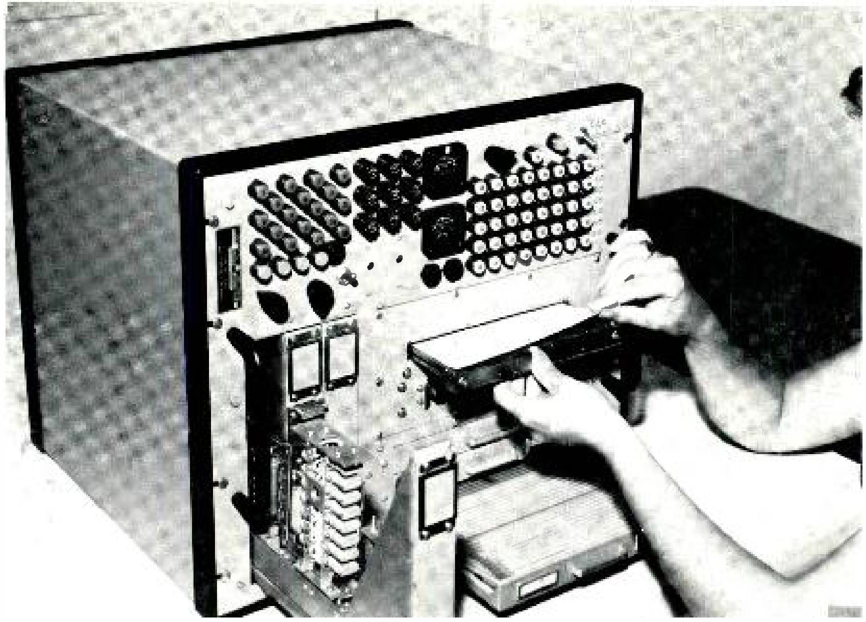


Fig. 1—The Data Link Module Analyzer which is programmed with punched cards.

DATA-LINK MODULE ANALYZER

W. MERGNER
Systems Support Engineering
Aerospace Communications & Controls Division
DEP, Camden, N. J.

Retention of experienced maintenance personnel is a serious problem made more acute by the drain of trained man-power into industry. Thus, test systems which can perform the tasks usually performed by highly skilled technicians are necessary. Such test equipment can automatically isolate faults and indicate the defective unit to an unskilled operator. The *Data Link Module Analyzer* (Fig. 1) developed by Systems Support Engineering, is an equipment of this type. It performs dynamic *go, no-go* tests on all removable modules in the Air Force Data Link Systems, both airborne and ground. It is completely self-contained and is programmed by the use of punched cards.

GENERAL OPERATION

In operation, the tester is similar to a tube tester. After a suspected module is removed from the Data Link equipment, the technician connects it to the proper connector in the module analyzer, selects the corresponding program card, and places the card in the switching device of the test set. The switching device senses the punched holes in the cards and allows the input signals, voltages, loads, and output evaluating and detecting circuitry be routed to the correct pins of the module under test. Printed on the punched program card together with the part number are the light patterns and meter readings to be observed by the technician. Fault isolation is accomplished by observing variations in these.

When circuits such as binary counters, flip-flops, or shift registers are tested, excitation signals similar in amplitude and rise time to the signals actually used in the system are provided. Repetition rates have been reduced as low as 1 cycle to allow simplified light readout of the module operation with a minimum of circuitry. Readout circuitry is designed to load the circuit under test as closely as possible to that encountered during system operation.

Digital-to-analog (DACON) circuits can also be checked. Since testing of this type of circuit is not easily done with light readouts, a meter has been provided on the front panel to indicate the DACON output. A typical DACON module used in Data Link Equipment converts eight digital bits of information into an analog voltage. The tester is capable of testing four DACON stages per card.

CAPABILITIES

The Data Link Analyzer is capable of testing approximately 180 different modules and three relay packs. The unit can be rapidly self-checked. The Analyzer is packaged compactly (75 lbs., 3.3 cu. ft.); a switching device in the form of the punched-card sensor directs any of 105 input signals to any of 64 output pins. The use of this relatively small and easy-to-operate sending device also obviates the use of patch boards which are both cumbersome and subject to human error.

The sensor can sense 765 holes in a standard card, with the 11th and 12th rows used for the printed instruction to the operator. The sensor is simple in construction. Its main parts are: 1) an upper movable plate with contact pins, 2) a lower stationary plate with a special board, and 3) a sliding drawer which positions the punched card properly between the plate and the printed board. A simple spring-lever system lowers and locks the top plate and allows the contact pins to sense the holes in the card. The operator can then read the printed data on the visible portion of the card and compare it to the repetitive light display.

HIGH RELIABILITY

High contact resistance or dust particles can interrupt a signal, particularly when the signal is in the form of a low-voltage, low-current wave shape. This is avoided in the punched-card sensor by the use of special chemically milled and plated contacts that impart a positive wiring action by virtue of their shape. Another area of difficulty is the extreme tolerance problem presented when attempting to get one pin into each hole. The problem is alleviated by having several common contacts wipe into each hole. It then becomes impossible for the contact to hang up on the edge of the hole in the card. The contacts in the sensor are clipped in place so that they can be easily replaced.

SUMMARY

The design concept used in the present tester permits the simplified testing of different size printed boards; connectors are mounted in three separate module drawers, each of which can be removed from the unit for servicing. When a board is no longer used, its connector and plate can easily be replaced by a new type by removing the module drawer.

WALTER MERGNER served as an Electronics Technician in the US Navy between 1951-1954. He was graduated from the University of South Carolina in 1958, receiving a BSEE. Upon graduation he joined RCA where he engaged in the design of the Time-Division-Data-Link series of test sets. He then became the engineer responsible for the electrical design of the Data-Link Module-Board-Analyzer. Following this he engaged in the electrical design of the Signal Corps Preflight Test Set. He is a member of Tau Beta Pi.

THE ENIGMA OF GaAs

Gallium Arsenide, as a material, still remains something of a mystery. This paper traces the research on its material properties, pointing out the surprises that this tricky semiconductor has provided for materials research scientists. Present status of this work is discussed, which makes it clear that gallium arsenide will continue to increase in importance in the device arsenal—but where its greatest impact will be is still undetermined.

L. R. WEISBERG

RCA Laboratories, Princeton, N. J.

"The best laid schemes o' mice
an' men gang aft a-gley."

NOW I CAN'T VOUCH for the mice, but for men carrying out research, Burns was right. The most difficult problems in research are frequently unforeseen, while conversely, the greatest benefits are oftentimes unpredicted. One of the most curious examples of this is that of research on gallium arsenide (GaAs).

Several years after the birth of the semiconductor field, a new class of semiconductors was discovered. These were binary compounds composed of elements from Groups III-B (B, Al, Ga, In) and V-B (N, P, As, Sb) of the Periodic Table, and therefore were called III-V compounds. These compounds had properties differing in some respects from those of the elemental semiconductors germanium and silicon, and the possibility existed that one of them might have properties superior to either germanium or silicon for devices. A survey of their properties was made, and by 1955 it was concluded by Jenny at RCA Laboratories that one of these compounds, GaAs, combined in a single material some of the best properties of both germanium and silicon. Its large energy bandgap (1.4 ev) indicated that device characteristics would be much more stable with respect to temperature variations than germanium or silicon, and devices would operate to above 400°C, as compared to 200°C for silicon and 100°C for germanium. The relatively high mobility of its electrical carriers, both electrons and holes, which determine applicability for high frequency operation, completely outclassed silicon, and was comparable to or even superior to germanium. Thus, GaAs was obviously the semiconductor of tomorrow, and its most enthusiastic prophets envisioned the day when germanium and silicon would be replaced by GaAs.

SINGLE CRYSTALS—HOW BIG?

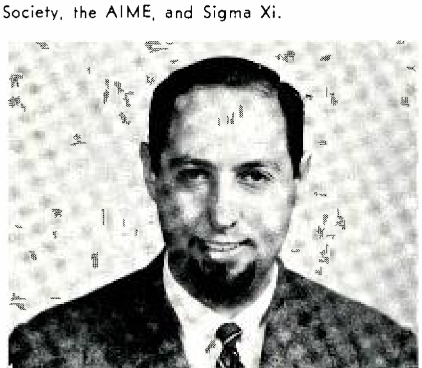
But it was realized that all *would not* be a bed of roses. To prepare devices, one needs large single crystals. To prepare large single crystals, it is most convenient to grow them from the melt. However, GaAs has the unfortunate habit of decomposing when it is melted (at 1238°C). The arsenic leaves the melt with a pressure close to one atmosphere, and to prevent this from happening, the melt must always be surrounded with arsenic gas at one atmosphere pressure. To achieve this pressure, solid arsenic must be heated to above 600°C, and at this temperature, arsenic is extremely uncooperative, attacking nearly everything in sight but carbon and ceramic- and glass-like materials.

And this brings us to our first surprise: soon, single crystals as large as 75 grams were being produced quite simply. This was accomplished by using the same Czochralski technique that was employed for germanium and silicon, but by constructing all parts out of quartz and enclosing the apparatus in a sealed quartz ampoule which is heated to 600°C.

We were also initially gratified to find that another fear appeared to be groundless. In every other class of inorganic compound semiconductors, the properties are greatly affected by deviations from stoichiometry—that is, instead of having the proper numbers of atoms in the crystal, there can be too many or too few of one of the atoms. This means that one has to exercise extreme precautions during crystal growth to adjust the atomic ratios.

However, just the opposite appeared to be true for GaAs. Even if there were extra amounts of gallium or arsenic in the melt, the crystal always seemed to come out with equal numbers of gallium and arsenic atoms within detection limits, so that it has been universally believed for several years, that deviations from stoichiometry just cannot occur in GaAs. However, just recently, we were shocked out of this complacency by discovering that GaAs actually can contain over 100 parts per million of stoichiometric deviations. The cause of this is still not clear, and whether or not they can be removed is still unknown, but realization of their existence may allow a better understanding to be achieved of the properties of GaAs.

LEONARD R. WEISBERG received the BA degree Magna Cum Laude from Clark University in 1950. His graduate work was carried out at Columbia University, and his PhD thesis was concerned with order-disorder phenomena in Cu_3Au. During 1953-55, he was a research assistant at the IBM Watson Laboratory in New York, working on the preparation and properties of germanium. Since 1955, he has been with RCA Laboratories, and has specialized in materials research on gallium arsenide and other III-V compounds. He received an RCA Laboratories Achievement Award in 1959 for research in this field. He has published twenty scientific papers, and is a member of the American Physical Society, the AIME, and Sigma Xi.



SINGLE CRYSTALS—HOW PURE?

Besides needing large single crystals to prepare devices, it is also necessary that the crystals be very pure, containing less than 1 part per million of impurities. The reason for this is that impurities markedly change the electrical properties of semiconductors, and to control the impurity concentrations, it is first necessary to reduce the background level of impurities. The technique that solved the problem for germanium and silicon was zone refining, and there seemed to be no reason why it shouldn't be just as successful for GaAs. Apparatus was constructed to carry out both ordinary and floating zone refining of GaAs. In both cases, the GaAs was contained within a sealed quartz ampoule to prevent the molten zone from decomposing. However, this has the consequence of trapping volatile impurities within the ampoule which then could not be removed from the GaAs. Furthermore, there were some impurities present that could not be efficiently removed by the zone refining. It is true to this day that, despite considerable work, zone refining has never provided for GaAs the purities achieved in germanium and silicon. This development forced us into the long and arduous task of separately purifying the component elements gallium and arsenic. Today, these two elements are available with a purity of 99.9999 per cent, but the purity problem still exists, and an increase in purity by a factor of ten is desired.

A major irritation in purification problems concerns oxygen, which is especially troublesome because it is ubiquitous. Furthermore, oxygen has been one of the most difficult elements to detect below 100 parts per million until the recent acquisition by RCA Laboratories of a special solids mass spectrograph. Several years after germanium and silicon were supposed to have been under good purity control, it was discovered that they actually contained many parts per million of oxygen. However, the oxygen was usually in a neutral state, and therefore caused no harm. With GaAs, however, there was no such luck. The oxygen appears to provide a deep trapping or recombination state which can adversely affect the electrical properties for some device operations. A major source of the oxygen is the quartz container, and a search still continues for a blameless container—which would have to be nonporous, highly pure, nonreactive, and not containing oxygen. Materials investigated have included, for example, aluminum nitride, boron nitride, sapphire, titania, beryllia, alumina, graphite, and vitreous carbon. While the first two have proved to be superior to quartz, none has yet completely solved the problem.

To add insult to injury, it was discovered after several years that the electrically active impurity content of the GaAs was not being properly determined. The main method of measuring the purity of a semiconductor is to measure the mobility of its electrons, since this property is strongly affected by impurities in a well understood manner. During research on germanium and silicon, measurements of mobility were routinely made, and the results were quite consistent and well behaved.

But not so for GaAs. In a given week, if five crystals were prepared on five consecutive days, the apparent impurity concentrations derived from the mobility measurements would appear to fluctuate wildly—by as much as a factor of 100. Because the mobility measurements had been established so well in the past, it seemed much more likely that some subtle errors were being made in the preparation of the crystals, rather than in the measurements. Furthermore, at the time there were no suitable analytical techniques that could provide a definitive answer to this problem. It was finally demonstrated, however, that the reverse was true—that there was a new mechanism affecting the mobility in GaAs that had never been detected as such before. The new effect was caused by the impurities being inhomogeneously distributed on a microscopic scale. These inhomogeneities are very difficult to control, and today the problem of the removal of these inhomogeneities still remains unsolved. Luckily, in a number of important device applications, this does not appear to be a problem.

SOLAR CELLS—GaAs vs. Si

Several years ago, it was realized by Rappaport and Loferski at RCA Laboratories that GaAs solar cells ought to have a higher energy-conversion efficiency than silicon solar cells. Because of this, research was soon initiated on GaAs solar cells, and considerable progress has been made at RCA Semiconductor and Materials Division with the result that GaAs solar cells have been constructed with efficiencies approaching that of silicon. However, GaAs solar cells today are especially important devices, since they are *about a factor of ten more resistant to the radiation damage that occurs in the Van Allen belts.* The existence of the Van Allen belts was entirely unknown when this research project was initiated. It is also significant that GaAs cells have superior temperature characteristics that will allow operation closer to the sun than with silicon-equipped space vehicles.

DIODES, TRANSISTORS, AND SURPRISES

The story of GaAs tunnel diodes has a double turn. Once again, tunnel diodes had not yet been invented when research of GaAs was begun. However, soon after the introduction of tunnel diodes, it became clear that GaAs was one of the best available tunnel diode materials. *First,* it provided very high peak-to-valley current ratios—ratios of 100:1 have been achieved at the RCA Semiconductor and Materials Division. *Second,* it provided a large voltage swing in the forward characteristics. *Third,* devices could be easily constructed, because high concentrations of zinc in GaAs were readily attainable. *Finally,* the high electron mobility and band gap would aid in frequency and temperature performance.

But again there was a surprise. It was soon discovered that the properties of the GaAs tunnel diodes degraded during certain types of operation, eventually ruining the diode. This degradation has been extensively studied, and progress is being made, so that GaAs still remains a very useful tunnel diode material. For example, no degradation in RCA diodes is observed in microwave applications.

For most semiconducting devices such as diodes and transistors, the material that is used has a low resistivity (about 10^{-3} ohm-cm). However, early in GaAs research, it was found that GaAs could be prepared with markedly different properties—with a resistivity exceeding 10^{8} ohm-cm, which resembles an insulator more than a semiconductor. We have carried out considerable research on this phenomenon, and it is now understood why the material can have such a high resistivity, and how to reproducibly prepare the material in this state. This has two important implications. First, it has great potential in the field of integrated electronics, since it can be used as the insulating base on which the electrically active components can be built. Secondly, the high resistivity GaAs can act as a photoconductor. GaAs has already been prepared with a photoconductive gain at low temperatures as good as the best CdS. In fact, today *GaAs is probably the best-understood high-sensitivity photoconductor.*

Now let us look back to the original reason why research on GaAs was initiated—to provide transistors and diodes superior to germanium and silicon. Part of this goal was achieved. Because of the high electron mobilities in GaAs, good microwave diodes have been constructed. Also, GaAs varactor diodes with cut-off frequencies exceeding 200 Gc are readily achieved at RCA. The importance of this device continues to grow. In contrast, more difficulty was encountered in the fabrication of transistors, principally because of the astonishingly small minority carrier lifetime in GaAs, which was orders of magnitude below values commonly observed in germanium and silicon. It had been expected that as research continued in GaAs, that this property would improve to desired values. However, it is now known that these values could never have been achieved, since the minority current carriers were "disappearing" by direct recombination, accompanied by the emission of infrared light. Nevertheless, through the use of ultra-control in device fabrication, this problem is presently being overcome, despite the small lifetime.

EL DIODES, INFRARED LASERS

This direct recombination which causes the low minority carrier lifetime has had great blessings. GaAs was not too seriously considered as an important electroluminescent material, since it is opaque to visible light; but it is transparent to infrared light. As early as 1955, Braunstein at RCA Laboratories measured the infrared light emitted from a GaAs p-n junction. Quite recently, Pankove at these laboratories has prepared p-n junctions in GaAs providing infrared light with an efficiency at the junction *approaching 100 percent.* Furthermore, because of the short lifetime, television signals can be transmitted using such an infrared light beam. Thus, the reversal is complete — the property that caused the greatest difficulty with transistors provides the greatest benefit for infrared electroluminescent diodes.

Of even greater significance is that GaAs infrared lasers utilizing this infrared emission have recently been constructed. The main advantage of the GaAs laser as compared to ordinary lasers is that no external light source is needed to provide the energy to operate the laser beam, but instead, one merely has to pass an electric current through the GaAs p-n junction. This device represents one of the most important advances in laser research since the construction of the first solid state laser. Once again, such a device *was not predicted* at the start of the GaAs research.

. . . IN CONCLUSION

As a material, GaAs remains somewhat of a mystery. However, GaAs devices are already playing a significant role and their importance will continue to grow in the future. *But exactly where and how GaAs will have its greatest impact is still undetermined.*

Engineering and Research NOTES

BRIEF TECHNICAL PAPERS OF CURRENT INTEREST

Heterodyne Receivers for RF-Modulated Light Beams


by D. J. BLATTNER AND
F. STERZER,
Electron Tube Division,
Princeton, N. J.

The heterodyne principle, widely used in RF receivers, can also be used in receivers for RF modulated light beams. The modulation frequency f_s on the light beams can be heterodyned to a new value $f_s \pm mf_{LO}$ (where m is an integer) by passing the beams through light modulators driven at frequency f_{LO}. This method can be used in detectors of light beams that are either intensity or polarization modulated.

In a heterodyne demodulator for an intensity-modulated light beam, (Fig. 1), the heterodyning takes place in a mixer that modulates the intensity of the incident light beam at frequency f_{LO}. For the particular case of a mixer consisting of a crystal that exhibits the linear electro-optic effect when placed between two crossed polarizers, the minimum conversion loss is approximately 5.4 db. The light beam modulated at the heterodyned frequencies is demodulated in a square-law detector; i.e., a detector whose output current is proportional to the intensity of the incident light. Detectors of this type include phototubes and semiconductor photoelectric cells.

In a heterodyne demodulator for a light beam whose intensity is constant, but whose polarization is modulated at frequency f_s, (Fig. 2), the heterodyning takes place in a mixer that modulates the polarization of the incident light beam. The mixer is followed by a Nicol prism that converts the polarization modulation into intensity modulation, so that a conventional square-law detector can be used to demodulate the light beam. The minimum conversion loss is approximately 2.4 db.

The most important applications of heterodyne light detection involve heterodyning to the difference frequency $f_s - f_{LO}$. When f_s is at microwave frequencies, for example, if no heterodyning is used the square-law demodulator must respond to variations of light intensity at microwave rates. Although experimental light detectors capable of microwave response have been reported, these devices are less sensitive than photomultipliers. The heterodyne system, by shifting the modulation down from the microwave range, permits use of conventional square-law detectors that operate only up to VHF.

For further details see Blattner and Sterzer, "Heterodyne Receivers for RF-Modulated Light Beams," *RCA Review*, Sept., 1962.

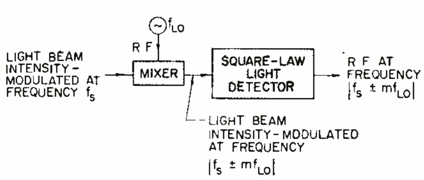


Fig. 1—Heterodyne light detector for intensity-modulated light. The mixer modulates the intensity of the light transmitted through it at frequency f_{LO}.

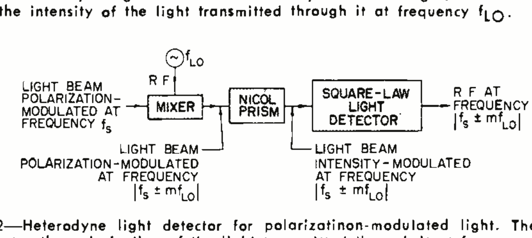


Fig. 2—Heterodyne light detector for polarizatinon-modulated light. The mixer modulates the polarization of the light transmitted through it at frequency f_{LO}.

Digital Microcircuit Packages Available From SC&M

by A. H. MEDWIN,
Semiconductor and Materials Division,
Somerville, N. J.

Digital microcircuits, which combine transistors, diodes, and resistors into functional circuit blocks, have been developed by the Semiconductor and Materials Division, Somerville, N. J. These low-cost, reliable microcircuits are now available in hermetically sealed eight-lead packages 0.36 inch in diameter and 0.1 inch high.

Advantages of Circuit Packages: A major advantage of such packages is the elimination of separate hermetically sealed packages and leads for each component, thus saving a large part of the comparable individual-component cost. More important is the reduction of manufacturing test costs. Instead of testing half a dozen or more parameters on each component, only a few tests of the entire microcircuit are necessary—typically static current and switching-speed, using a simulated load and degraded input pulse. As a corollary, because the system requirements for each component in a digital microsystem are fixed, the specification requirements for certain parameters, such as the reach-through voltage, may be relaxed. Circuit reliability is generally improved, since the component inter-connections are in the hermetically sealed atmosphere of the digital microcircuit package. In addition, because all components in digital microcircuits are located in the same plane, isolated from the case, and enclosed in a low-dielectric environment of dry nitrogen, propagation effects and capacitive coupling between circuit components are considerably reduced. As a result, a digital microcircuit is capable of faster switching than the same conventionally assembled circuit.

Package Configuration: Two basic package configurations are utilized: *The first,* (Fig. 1), uses a round ceramic wafer about 0.015 inch thick, with eight holes around its periphery. It is metallized on its bottom surface so that it can be fitted over the eight leads of a standard glass header and brazed to it. The required metallized-pattern circuit can be screened on the top surface of the wafer, providing design flexibility for custom-made microcircuits. *The second* (Fig. 2), was developed in cooperation with the Electron Tube Division, Harrison, and draws heavily on the ceramic technology used for nuvistor tubes. It consists of a ceramic disk having four metallized areas, eight leads, and a brazed metal flange. Because the ceramic materials require a smaller depth than glass for a hermetic seal, the total height of the package is only 0.1 inch.

A typical digital microcircuit is the DMC-100 *nand* gate (Fig. 3). In this microcircuit, two series diodes replace the conventional resistance-capacitance combination at the base of the transistor. The diodes have a built-in stored charge which is used to turn off the transistor quickly. Over-all microcircuit operation is the same as that of a conventionally assembled circuit; however, the total circuit dissipation is lower, and more important, a difficult-to-make capacitor is replaced by simpler diodes. For circuits which require capacitors, such as CRD gates, ceramic pellets having capacitances of up to 1000 pf are available.

TABLE I—Semiconductors Used in Digitol Microcircuits

Transistor Type	Type No.	Description
Low-Level Logic	2N709	Fast switch, low current
	TA2231	Fast switch, low to med. current
Logic	2N706	General purpose, high-speed logic
	2N1708	Epitaxial version of 2N706
	2N914	Med.-current 2N1708
	2N834	Faster switch, med. current
	TA2090A	Faster switch, intermediate current
	2N744	Faster switch, intermediate current
Core Driver	2N696	General purpose, memory
	2N697	General purpose, memory, higher voltage
	2N1613	Improved 2N697
	TA2095A	Fast core driver
P-N-P Logic	TA2009	p-n-p low-current switch
DIODE TYPE		
Logic Gate	1N914	Common cathode, or common anode
Stabistor	——	High stored charge diodes

Fig. 1—Ceramic-glass configuration, 0.36 inch diameter.

Fig. 2—Ceramic configuration, 0.36 inch diameter.

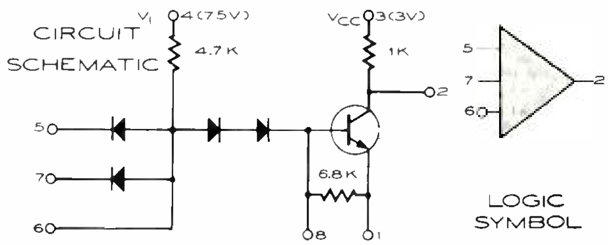


Fig. 3 — Typical microcircuit; the DMC-100 nand gate.

The semiconductor devices used in digital microcircuits are listed in Table I; all are silicon planar-epitaxial type. Resistors are Cermet (*ceramic-metal*), platinum-gold metallized at each end. These rods, 0.04 inch diameter and 0.03 inch long, have initial tolerances of ±2, ±5, or ±10% over a range from 50 to 100,000 ohms and a temperature coefficient of 300 ppm/°C.

The design approach used for digital microcircuits is extremely flexible; variations in sample lots and small production runs require no retooling. Eventually, as circuit designs become fixed and volume increases, several microcircuits can be combined in a single unit to form fully integrated devices.

Special Devices Service Available From RCA Labs

by Dr. J. T. Wallmark,
RCA Laboratories,
Princeton, N. J.

As a service to RCA groups active in circuit and equipment development, a *Special Devices* activity was established at RCA Laboratories in 1961 to supply experimental electronic devices not available commercially or otherwise. The intention is to facilitate advances in circuitry and product applications earlier than would normally be possible. Such devices may originate in research projects at RCA Laboratories, or in product divisions when shortcomings of existing devices are overcome or novel device features are innovated. Speed of delivery is usually considered more important then reproducible data, life test experience, or uniformity of the product.

While it is not the purpose of this activity to undertake research on new devices, it has access both to research results at RCA Laboratories and to the most advanced technology both there and in electronic-component product divisions of RCA. To disseminate information about new devices the activity distributes a *Special Devices Bulletin* to interested engineers in charge of circuit research or development projects in RCA.

An example of new devices distributed by the activity are the non-linear stabilizing resistors for tunnel-diode oscillators. The DC power losses of these devices are lower, by a factor of 3 to 6, than those of conventional resistors. The conventional method of stabilizing tunnel diode oscillators is with a resistance in parallel with the tunnel diode (Fig. 1). For stabilization, this resistance must be at least as low as the negative resistance of the tunnel diode. On the other hand, a low value of resistance gives large DC power loss in the resistor. Thus, adequate stabilization and low power consumption are in conflict. An effective compromise is obtained by the use of nonlinear stabilizing resistors, rather than conventional linear resistors. Such nonlinear resistors may be fabricated from semiconductors in the form of reverse-biased, heavily doped junctions operating in the tunneling region.

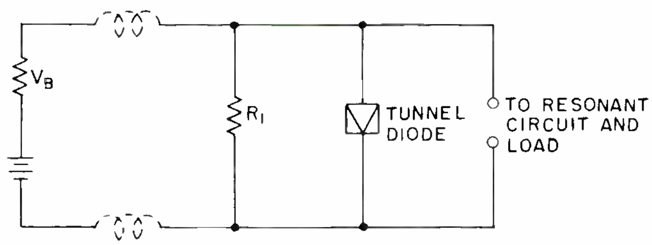


Fig. 1—Tunnel diode oscillator circuit.

For a GaAs tunnel diode with 50-ma peak current, the improvement in DC power loss by the use of this nonlinear resistor is approximately a factor of 6. For germanium tunnel diodes, which operate at a lower voltage, the improvement is approximately a factor of 3. In addition to the DC power saving, there is a reduced AC power loss which makes the location of the resistor less critical, so that it need not be exactly at an AC voltage node.

Lowpass-to-Bandpass Transformation by Switching Techniques

by A. Acampora, B. Rabinovici, C. A. Renton, *Systems Laboratory, Surface Communications Division, DEP, New York 13, New York*

The translation of a network function $H(\omega)$ in the frequency spectrum has been analytically treated.[1-3] By using a sequential sampling system,[4] a network can be translated in the frequency domain by multiples of the sampling frequency and will retain its exact normalized amplitude and phase response; that is:

$$H(\omega) \rightarrow H'(\omega - n\omega_o) + H'(\omega + n\omega_o).$$

Since lowpass filters can more easily be made to have desired skirt selectivities and time delay equalization, the technique of synthesizing bandpass filters by sequentially sampling identical lowpass filters can be very useful in SSB transmission. This *Note* describes a symmetrical bandpass filter centered about the switching frequency f_o by symmetrically sampling at f_o rate three identical channels, each containing a lowpass filter.

Fig. 1a — Lowpass filter. B is a coarse bandpass filter. L_1, L_2 and L_3 are identical lowpass filters. S are switches.

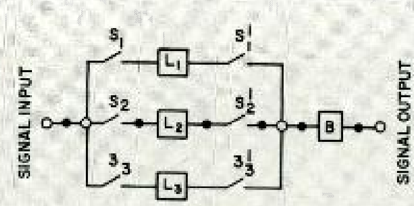
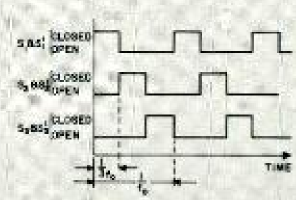


Fig. 1b — Timing sequence of switches at input and output of lowpass filters.



From Figs. 1a and 1b, it can be seen that the switching is performing a product modulation of the signal, with all the frequency components present in the switched signal. Furthermore, the phase of terms in the second channel is displaced by 120° with respect to the phase in the first channel, while the third channel is displaced by 240°.

Basically, operation of the bandpass filter can be understood by tracing a signal through the system. Consider a signal at frequency f close to f_o. The signal is divided into three channels. In the first channel, it is mixed by switch S_1, with frequency $f_o \angle 0°$, where $\angle 0°$ represents the phase angle in the first channel chosen for reference. The only output transmitted by the lowpass filter is $(f - f_o) \angle 0°$. After being mixed by switch S_1 with the same frequency $f_o \angle 0°$, the two signals present at the output of the bandpass filter are $f \angle 0°$ and $(2 f_o - f) \angle 0°$. In the second channel, f is mixed with $f_o \angle 120°$ by switch S_2. The output of the lowpass filter is thus $(f_o - f) \angle 120°$, which is again mixed with $f_o \angle 120°$ by switch S_2. This leads to two signals at the output of the bandpass filter of $f \angle 0°$ and $(2 f_o - f) \angle 240°$. Similarily, the third channel leads two outputs $f \angle 0°$ and $(2 f_o - f) \angle 480°$. Thus, the signal at frequency f appears in the same phase in all three channels, while the spurious signals at $(2 f_o - f)$ are 240° apart from each other in the three channels with a resultant vector equal to zero.

A 4-kc bandpass filter employing the above sampling technique was constructed in the laboratory for use in a FDM system. (Three identical lowpass filters of a Cauer type configuration were used in this model.) The measured amplitude and time delay response of the switching bandpass filter are illustrated in Fig. 2. A 0.2-db ripple in the amplitude response, too small to be observed on the scale of Fig. 2, has been measured in the region $\Delta f = \pm 1.5$ kc. To attain a high degree of cancellation of the center frequency and the undesired sidebands, it was essential to maintain the *on* and *off* switching times in each of the three channels nearly identical. This naturally places an upper limit on the frequency translation that one can achieve in practice. For similar reasons, it was necessary to have the attenuation and phase response of the three lowpass filters identical.

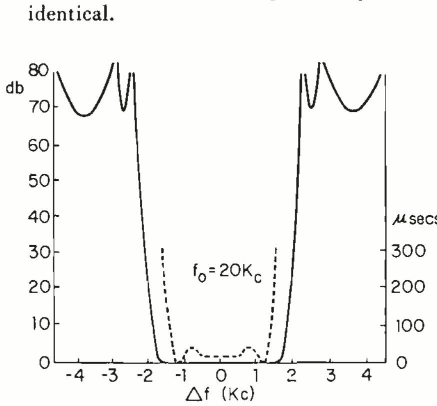


Fig. 2—Measured amplitude and time-delay response of the switching bandpass filter. The solid curve and left-hand scale is the amplitude response. The dashed curve and right-hand scale is the time delay response.

The main features of this switching bandpass filter are:

1) the stability requirements of the inductors and capacitors are very moderate as compared to a conventional bandpass filter, since the filtering action takes place at the low frequency;

2) the frequency stability of the bandpass filter is essentially determined by the accuracy of f_o, which can be controlled readily;

3) by changing f_o, one changes the bandpass center frequency and one can thus readily accomplish electronic tuning. The added switching circuitry does not materially augment the complexity of the system, since in a given FDM system there is a need for a large number of such bandpass filters to which the associated switching circuitry would be common.

Acknowledgement: The authors are grateful for the technical contributions of R. Stalemark, J. Sie and T. Marshall to this work.

1. D. K. Weaver, "A Third Method for Generation and Detection of SSB Signals," *Proc. IRE 44*. 1703 (1956).
2. I. F. MacDiarmid, D. G. Tucker, "Polyphase Modulation of Certain Filtration Problems in Telecommunications," *IEE 97*, Part 3, Sept. 1950.
3. N. F. Barber, "Narrow Band-Pass Filter using Modulation," *Wireless Engineer*, May 1947.
4. L. E. Franks, I. W. Sandberg, "An Alternative Approach to the Realization of Network Transfer Functions: The N-Path Filter," *B.S.T.J. 39*, 1351 (1960).

Automatic Flip-Flop Reset

by H. WEINSTEIN,
RCA Laboratories, Princeton, N. J.

Various digital systems require the readout of the state of an element in an array of flip-flops with reset of that element within a clock period—*without* an increase in hardware. Consider Fig. 1: A pulse may appear on any of the lines marked *X*. An output indication is required from the corresponding flip-flop if it is in the *set* state, with simultaneous *reset*. (The signal present on *X* cannot be applied directly to the reset terminal, since it is derived from another stage which uses the flip-flop output.) At first glance, the scheme shown in Fig. 1 seems to be contradictory. On the one hand, the flip-flop will be reset only upon enabling the corresponding *nand* gate. On the other hand, resetting the flip-flop will change polarities at the input of *nand*, such that it is no longer enabled upon arrival of the signal on *X*. Thus, usually two flip-flops with additional clock pulses are required per *X* row, in order to perform the desired function.

However, if use is made of the inherent delay in flip-flop operation, Fig. 1 may be realized, resulting in *faster operation and appreciable saving of components.* Since the delay involved in changing a state of a flip-flop is generally longer than the delay in enabling a simple gate, using the same components in both circuits (connecting two *nor* gates to form a flip-flop), the output *O* will rise to its desired logical level while resetting the flip-flop, and will then decay back. (See Figs. 2, 3a, 3b.)

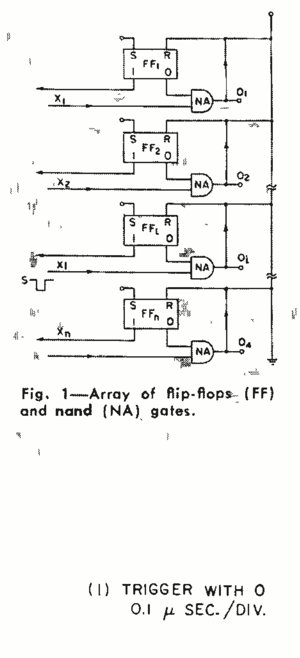


Fig. 1—Array of flip-flops (FF) and nand (NA) gates.

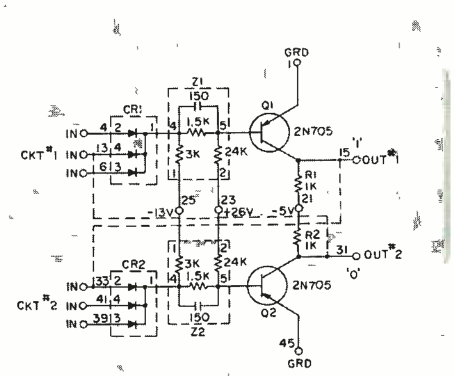


Fig. 2—Basic nor-module used for experimentation. A flip-flop may be realized by the dotted connections. A single flip-flop and nand gate interconnected as in Fig. 1 resulted in the waveforms of Fig. 3.

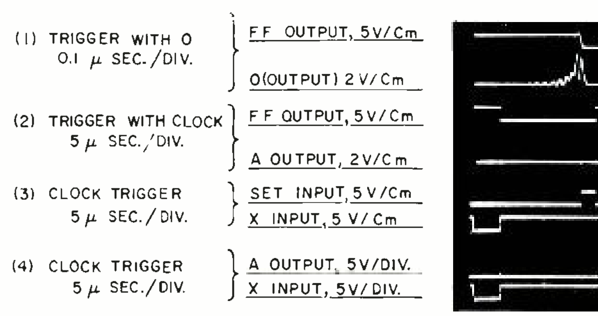


Fig. 3a—Traces 1 correspond to scope trigger from the O, while the remaining traces correspond to scope trigger from set (clock).

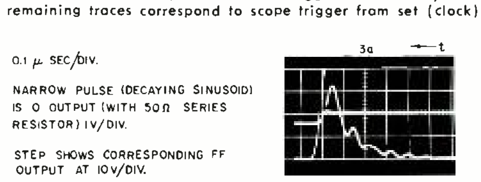
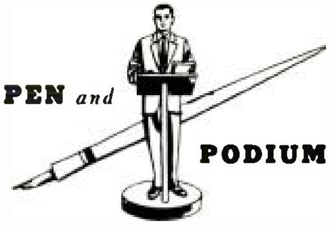


Fig. 3b—An expanded oscillogram of the output O of nand superimposed on the output of the flip-flop.

PEN and PODIUM



As Reported By Your Technical Publications Administrator

DEFENSE ELECTRONIC PRODUCTS

A System's View of the Personnel System Concept—Dr. R. L. Krumm: Human Factors Society Meeting, Nov. 28-30, 1962

Effect of Propagation Fading and Antenna Fluctuations on Communication Systems in a Jamming Environment A. B. Glenn and G. Lieberman: *IRE Transactions on Communications Systems*, March 1962

A Coherent Digital Amplitude and Phase Modulation Scheme C. N. Campopiano and B. G. Glazer: *IRE Transactions on Communications Systems*, March 1962

Subdivided Quadrature Detection—G. Lieberman: Fall URSI-IRE Meeting, Oct. 15-17, Ottawa, Canada

An Application of Inverse Probability to Fault Isolation F. D. Brown, N. F. McAllister and R. P. Perry: *IRE Transactions on Military Electronics*, July 1962

Nuclear Rocket Instrumentation—P. E. Brown: 17th Annual Instrumentation-Automation Conference, Instrument Society of America, Oct. 18, 1962

Information Systems Design and Techniques Dr. J. Minker: National Science Foundation, Univ. of Calif., Lake Arrowhead Conference, May 1962

Advanced Information Storage and Retrieval Systems—S. Kaplan: U.S. Naval Ordnance Laboratory Mathematics Dept., Colloquium, Oct. 1, 1962

Preventive Maintenance and Cost Control R. J. Goss: American Institute of Plant Engineers, Sept. 13, 1962

Management of the Ballistic Missile Early Warning System J. H. Sidebottom: National Advanced Technical Management Conference, Seattle, Wash., Sept. 4, 1962

Philosophy and Management of BMEWS Implementation H. W. Phillips: AIIE Section Mtg., Huntsville, Alabama, Sept. 10, 1962

RCA's Approach to Minimizing Technical Obsolence of Engineers A. Mason: Aerospace Technology Panel for Management, N.Y.C., Sept. 19, 1962

Reports as a Measure of Competence—W. B. Dennen: National Electronics Conference, Chicago, Ill., Oct. 10, 1962

Space Surveillance Systems Studies J. Breckman, and S. G. Miller: Air Force Association National Convention and First Space Communication and Electronics Seminar, Las Vegas, Nevada, Sept. 18, 1962

An RC Oscillator Driven Serial to Parallel Converter J. J. Kolarcik: *1962 MSEE Thesis*, Polytechnic Institute of Brooklyn

ELECTRONIC DATA PROCESSING

APEX—A Practical Approach to Responsible Reporting and Control Leonard Dinner: 1962 ACM National Conference, Syracuse, N.Y., Sept. 4-7, 1962

The Need for Precise Problem Definition Mary K. Hawes: CODASYL-JEG Symposium, Barbizon-Plaza Hotel, N.Y.C., N.Y.

BROADCAST AND COMMUNICATIONS PRODUCTS DIVISION

A Computer Type Monitor and Control System for the RCA MM-600 Microwave Beam System I. A. Fairnington: ASME Petroleum Mechanical Engineering Conference, Sept. 1962

Neutralization of Charge Induced Astigmatism in Apertures J. H. Reisner: 5th Int'l. Congress for Electron Microscopy, and Conference *Proceedings*, Aug. 1962.

Design Aspects of the Hot Stage for EMU-3 Series Electron Microscopes J. W. Coleman and A. J. Cardile: *Scientific Instrument News*, Sept. 1962

HOME INSTRUMENTS DIVISION

Seven Years of Significant Color TV Receiver Progress C. W. Hoyt: 16th Nat'l. Association of Broadcasters, Broadcast Engineering Conference, Conrad Hilton Hotel, Chicago, Ill., April 3, 1962

RCA LABORATORIES

Anomalous Mobility Effects in Some Semiconductors and Insulators L. R. Weisberg: *Journal of Applied Physics*, Vol. 33, No. 5, May 1962

Quantum Mechanical Effects in Stimulated Optical Emission R. C. Williams: *Physical Review*, May 1962

Optical Absorption of Arsenic Doped Degenerate Germanium J. I. Pankove and P. Aigrain: *Physical Review*, May 1962

Degenerate Germanium. I. Tunnel Excess, and Thermal Current in Tunnel Diodes D. Meyerhofer, G. A. Brown and H. S. Sommers, Jr.: *Physical Review*, Vol. 126, No. 4, May 15, 1962

Optical Spectra of Transition-Metal Ions in Corundum D. S. McClure: *Journal of Chemical Physics*, Vol. 36, No. 10, May 15, 1962

Beat Frequency Bridge for Large Signal Field Effect D. Gerlich: *Applied Physics*, May 1962

Electroluminescent Lines in Zns Powder Particles I. A. G. Fischer: Electro-Chemical Society Meeting, Los Angeles, Calif., May 1962

Ultraviolet Spectra of Stilbene, p-Monohalogen Stilbenes, and Azobenzene and the Trans to Cis Photoisomerization Process R. H. Dyck and D. S. McClure: *Journal of Chemical Physics*, Vol. 36, May 1, 1962

Adaptation and Feedback J. Sklansky: Joint Automatic Control Conference, New York Univ., June 29, 1962

Evaporation of Silicon and Germanium by rf Levitation E. A. Roth, E. A. Margerum and J. A. Amick: *Review of Scientific Instruments*, June 1962

Computer Memories—Possible Future Developments J. A. Rajchman: *RCA Review*, June 1962

Retrieval of Ordered Lists from a Content-Addressed Memory M. H. Lewin: *RCA Review*, June 1962

Simple Method of Registering Evaporation Masks G. W. Leck: *Review of Scientific Instruments*, Vol. 33, No. 6, June 1962

Tunnel-Diode Balanced-Pair Switching Analysis G. B. Herzog: *RCA Review*, June 1962

Preparation and Magnetic Properties of Some Hexagonal Magnetic Oxides I. Gordon, R. L. Harvey and R. A. Braden: *Journal of the American Ceramic Society*, June 1962

Properties of an As-S-Br Glass A. G. Fischer, A. S. Mason: *Journal of the Optical Society of America*, Vol. 52, No. 6, June 1962

The Space-Charge-Neutralized Hollow Cathode A. L. Eichenbaum: *RCA Review*, June 1962

Will They Bring Flat-Display TV? B. Binggeli and E. Fatuzzo: *Electronics*, June 1962

DATES and DEADLINES

Professional Meetings and Calls for Papers

Meetings

Jan. 8-10, 1963: Millimeter and Submillimeter Conf., IRE; Cherry Plaza Hotel, Orlando, Florida. *Prog. Info.:* J. J. Gallagher, MP-172, Box 5837, Martin Co., Orlando, Fla.

Jan. 21-24, 1963: 9th Natl. Symp. on Reliability and Quality Control, IRE-PGRQC, AIEE, ASQC, EIA; Sheraton Palace Hotel, San Francisco, Calif. *Prog. Info.:* L. W. Ball, Boeing Co., P. O. Box 3707, Seattle 24, Wash.

Jan. 27-Feb. 1, 1963: 1963 AIEE Winter General Mtg.; Hotel Statler-Hilton and Hotel New Yorker, New York, N. Y. *Prog. Info.:* E. C. Day, Ass't Secy., TOD, AIEE, 345 E. 47th St., New York 17, N. Y.

Jan. 30-Feb. 1, 1963: 4th Winter Convention on Military Electronics, IRE-PGMIL; Ambassador Hotel, Los Angeles, Calif. *Prog. Info.:* Dr. Fred P. Adler, Space Comm. Div., Hughes Aircraft Co., Culver City, Calif.

Feb. 11-15, 1963: 3rd Intl. Symp. on Quantum Electronics, IRE-SFER, ONR; Unesco Building and Parc de Exposition, Paris, France. *Prog. Info.:* Madame Cauchy, Secretaire, 3 eme congres d'Electronique quantique, 7 rue de Madrid, Paris 8 eme France.

Feb. 20-22, 1963: Intl. Solid State Circuits Conf., IRE-PGCT, AIEE; Sheraton Hotel and Univ. of Penn., Phila., Pa. *Prog. Info.:* S. K. Ghandi, Philco Scientific Digest Lab, Blue Bell, Penna.

March 25-28, 1963: IEEE Intl. Convention, all PG's; Coliseum and Waldorf-Astoria Hotel, New York. *Prog. Info.:* Dr. D. B. Sinclair, IRE Headquarters, 1 East 79th St., New York 21, N. Y.

Calls for Papers

April 14-18, 1963: The Electrochemical Soc., Inc., Penn Sheraton Hotel, Pittsburgh, Pa. *DEADLINE:* Triplicate copies of 75-wd abstract and 500-1000-wd abstract, **12/14/62,** to Society Headquarters, 30 E. 42nd St., New York, N. Y.

May 13-15, 1963: Naecon (Natl. Aerospace Electronics Conf.), IRE-PGANE, Dayton Sect.; Dayton, Ohio. *DEADLINE:* Approx. **12/15/62.** *For info:* IRE Dayton Office, 1414 E. 3rd St., Dayton, Ohio.

May 20-22, 1963: Natl. Symp. on Microwave Theory and Techniques, IRE-PGMTT; Miramar Hotel, Santa Monica, Calif. *DEADLINE:* 100-wd abstract, 1000-wd summary, in duplicate, with title, **1/15/63,** to Dr. Irving Kaufman, Space Tech. Labs, Inc., Space Pk., Redono Beach, Calif.

May 20-23, 1963: Natl. Telemetering Conf., IRE-PGSET, AIEE, IAS, ARS, ISA; Albuquerque, New Mexico. *DEADLINE:* Abstracts, **2/1/63.** *For info:* Thomas Hoban, Sandia Corp., Albuquerque, New Mexico.

May 27-28, 1963: 7th Natl. Conf. on Product Engineering and Production, IRE-PGPEP; Boston, Massachusetts. *DEADLINE:* Abstracts, Approx. **2/1/63.** *For info.:* Jack Staller, Sylvania Elec., Needham, Mass.

June 4-5, 1963: 5th Natl. Radio Frequency Interference Symp., IRE-PGRFI; Bellevue-Stratford, Phila., Penna. *DEADLINE:* Abstracts, Approx. **1/1/63.** *For info.:* Albert R. Kall, Ark Electronics Corp., 624 Davisville Rd., Willow Grove, Pa.

June 11-13, 1963: Natl. Symp. on Space Electronics and Telemetry, IRE-PGSET; Los Angeles, Calif. *DEADLINE:* Abstracts, Aprox. **12/15/62.** *For info.:* J. R. Kauke, Kanke and Co., 1632 Euclid St., Santa Monica, Calif.

July 9-11, 1963: PGAP Symp. on Space Telecommunications, IRE-PGAP; Central Radio Prop. Lab., NBS, Boulder, Colo. *DEADLINE: For info.:* IRE Headquarters, 1 E. 79th St., New York 21, N.Y.

Aug. 4-9, 1963: Intl. Conf. on Aerospace Support Systems, Washington, D.C. *DEADLINE:* 250-wd abstract, **12/3/62,** paper **2/18/63,** to Technical Sessions Committee Technical Papers, P.O. Box 6635, Washington 9, D.C.; *Further info.:* D. Dobson, ACC, RCA, Burlington, Mass.

Aug. 20-23, 1963: Wescon (Western Elec. Show and Conf.), IRE, WEMA, All PG's; Cow Palace, San Francisco, Calif. *DEADLINE:* Abstracts, Approx. **4/15/63.** *For info.:* Wescon, 1435 La Cienega Blvd., Los Angeles, Calif.

Sept. 9-11, 1963: 7th Natl. Convention on Military Electronics, IRE-PGMIL; Shoreham Hotel, Washington, D.C. *DEADLINE:* Abstracts, Approx. **5/1/63.** *For info.:* John J. Slattery, The Martin Co., Friendship International Airport, Md.

Sept. 18-19, 1963: 12th Ann. Industrial Electronics Symp., IRE-PGIE, AIEE, ISA; Mich. State Univ., E. Lansing, Mich. *DEADLINE:* Abstracts, Approx. **5/1/63.** *For info.:* L. J. Giacaletto, Mich. State Univ., EE Dept., E. Lansing, Mich.

Sept. 24-27, 1963: Intl. Telemetering Symp., IRE-PGSET, AIEE, IAS, ARS, ISA, IEE; London, England. *DEADLINE:* Abstracts, **2/1/63.** *For info.:* Dr. L. L. Rauch, Dept. of Aero Eng., Univ. of Mich., Ann Arbor, Mich.

Sept. 30-Oct. 1-2, 1963: Canadian Electronics Conf., IRE; Toronto, Ontario, Canada. *DEADLINE:* Abstracts, Approx. **4/1/63.** *For info.:* IRE; Canadian Elec. Conf., 1819 Yonge St., Toronto 7, Canada.

Oct. 7-9, 1963: 9th Natl. Communications Symp., IRE-PGCS; Utica, New York. *DEADLINE:* Abstracts, Approx. **6/1/63.** *For info.:* IRE Headquarters, 1 E. 79th St., New York 21, N.Y.

Oct. 21-23, 1963: East Coast Conf. on Aerospace and Navigational Electronics (Eccane), IRE-PGANE; Baltimore, Md. *DEADLINE:* Abstracts, Approx. **7/2/63.** *For info.:* IRE Headquarters, 1 E. 79th St., New York 21, N.Y.

Oct. 28-30, 1963: Natl. Electronics Conf., IRE, AIEE, et al.; McCormick Pl., Chicago, Ill. *DEADLINE:* Abstracts Approx. **6/1/63.** *For info.:* Natl. Elec. Conf., 228 No. LaSalle St., Chicago, Ill.

Oct. 31-Nov. 1, 1963: 1963 Electron Devices Mtg., IRE-PGED; Sheraton Park Hotel, Wash., D.C. *DEADLINE:* Abstracts, Approx. **8/1/63.** *For info.: IRE* Headquarters, 1 E. 79th St., New York 21, N.Y.

Nov. 4-6, 1963: Nerem (Northeast Research and Eng. Mtg.) IRE; Boston, Mass. *DEADLINE:* Abstracts, Approx. **6/1/63.** *For info.:* NEREM-IRE: Boston Office, 313 Washington St., Newton, Mass.

Nov. 10-14, 1963: 9th Ann. Conf. on Magnetism and Magnetic Materials, IRE-PGMTT, AIEE, AIP; Calfonte-Haddon Hall, Atlantic City, N.J. *DEADLINE:* Abstracts, Approx. **8/15/63.** *For info.:* IRE Headquarters, 1 E. 79th St., New York 21, N.Y.

Nov. 11-13, 1963: Radio Fall Mtg., IRE-PGBTR, RQC, ED; EIA; Hotel Syracuse, Syracuse, New York. *DEADLINE: For info.:* Virgil M. Graham, EIA, Eng. Dept., 11 W. 42nd St., New York 36, N.Y.

Nov. 11-14, 1963: Fall Joint Computer Conf., IRE-AFIPS (PGEC, AIEE, ACM); Las Vegas Conv. Center, Las Vegas, Nevada. *DEADLINE:* Abstracts, Approx. **6/1/63.** *For info.:* J. D. Madden, Systems Development Corp., Santa Monica, Calif.

Be sure DEADLINES are met — consult your Technical Publications Administrator for lead time needed to obtain required RCA approvals.

Photon Spectrum Outside the Earth's Atmosphere—J. J. Wysocki: Solar Energy, July 1962

Effects of Elevated Temperatures on the Fluorescence and Optical Maser Action of Ruby J. P. Wittke: *Journal of Applied Physics*, Vol. 33, No. 7, July 1962

On the Crystallinity of GaAs Grown Horizontally in Quartz Boats L. R. Weisberg, J. Blanc and E. J. Stofko: *Journal of the Electro-Chemical Society*, July 1962

Computations of Spherical Aberrations H. Weinstein: *Journal of the Optical Society of America*, July 1962

Field Effect Measurements of High-Resistivity p-type Silicon D. Gerlich: *Inter. Journal of the Physics and Chemistry of Solids*, July 1962

Networks of Threshold Gates R. O. Winder: Int. Fed. Info. Proc. Congress, Munich, Germany, Aug. 31, 1962

Surface Photovoltage Measurements on Cadmium Sulfide—R. Williams: *Intern'l. Journal of the Physics and Chemistry of Solids*, Aug. 1962

Limitations in Speed and Capacity of Computer Memories—J. A. Rajchman: IFIP Conference, Munich, Germany, Aug. 27, 1962

Speech Machine Considerations H. F. Olson: Intern'tl. Congress on Acoustics, Copenhagen, Denmark, Aug. 21, 1962

Paramagnetic Resonance of Divalent Holmium in Calcium Fluoride—H. R. Lewis and E. S. Sabisky: Seattle Meeting of A.P.S., Washington, Aug. 27, 1962

1. A Third Form of Zinc Phosphide. 2. Atomic Arrangement in Single Crystal Dimorphs of ZnP_2. 3. Some Optoelectronic Properties of ZnP_2 Dimorphs—I. J. Hegyi, J. G. White and E. E. Loebner: Physical Society Meeting, Seattle, Wash., Aug. 1962

Collective Excitation of Degenerate Plasmas in Solids—M. J. Harrison: *International Journal of the Physics and Chemistry of Solids*, Aug. 1962

Vapor Deposition of Nb_3Sn J. J. Hanak: AIME Meeting, Phila., Pa., Aug. 27, 1962

Rectification and Space-Charge-Limited Currents in CdS Films—J. Dresner and F. V. Shallcross: *Solid-State Electronics*, Vol. 5, July-August 1962

Effects of Composition on the Superconduction Properties of Nb_3Sn—J. J. Hanak, G. D. Cody, J. L. Cooper and M. Rayl: 8th Intern'l. Conference on Low Temperature, London, England, Sept. 1962

A Rigorous Large-Signal Analysis on Harmonic Generation Using Parametric Diodes—K. K. N. Chang and P. W. Chase: 4th Intern'l. Congress on Microwave Tubes, Hague, Netherlands, Sept. 1-7, 1962

ELECTRON TUBE DIVISION

X-Ray Methods for Determination of Plate Thickness—E. P. Bertin and R. J. Longobucco: *Metal Finishing*, Aug. 1962

The Distribution of Cathode Sublimation Deposits in a Receiving Tube as Determined by X-Ray Spectrometric Scanning—V. Raag, E. P. Bertin and R. Longobucco: National Conference on Tube Techniques, New York, Sept. 19-21, 1962

The Analysis of Major and Minor Constituents in Ceramic Materials by X-Ray Spectrometry R. J. Longobucco: *Analytical Chemistry*, Sept. 1962

Spectral-Line Interference in X-Ray Fluorescence Spectrometry—E. P. Bertin and R. J. Longobucco: *Norelco Reporter*, Sept. 1962

Emission Spectrographic Method for the Determination of Microgram Quantities of Ba, Sr, Mg, Mn, Si, and Ni in Sublimed Deposits on Micas, Grids, Plates, and Glass Bulbs of Electron Tubes—A. M. Liebman: *Analytical Chemistry*, Sept. 1962

Some Physical Aspects of Electron Receiving-Tube Operation M. Natapoff: *American Journal of Physics*, Sept. 1962

Nuvistors for VHF Applications R. M. Mendelson: Amateur Radio Association, Cleveland, Ohio, Oct. 13, 1962

Some Recent Developments in Photomultipliers for Scintillation Counting—R. M. Matheson: *IRE Transactions on Nuclear Science*, Aug. 1962

The Conduction Cooling of Power Tubes in Vehicular Communication Equipment J. W. Gaylord: *Electronic Equipment Engineering*, Aug. 1962

Electron Tube Applications of Ceramics M. Berg: Graduate Seminar on Ceramics, Rutgers Univ., N. J., Sept. 29, 1962

Photographic Processes in the Manufacture of Color-Television Picture Tubes A. E. Hardy: Society of Photographic Scientists and Engineers, Wash., D. C., Oct. 8, 1962

Microwave Theory and Techniques Session 7 Panel—C. L. Cuccia: Wescon, Los Angeles, Calif., Aug. 22, 1962

Extrinsix Photoconductors for the 3-5 Micron Spectral Region M. L. Schultz: IRIS Detector Specialty Group Symposium on Detectors, Syracuse, N. Y., Aug. 16-17, 1962

Some Photoconductive Properties of Cobalt-Doped Germanium M. L. Schultz: IRIS Detector Specialty Group Symposium on Detectors, Syracuse, N. Y., Aug. 16-17, 1962

Capabilities of Electrostatically Focused High-Power Traveling-Wave Tubes W. W. Siekanowicz: Symposium on High-Power Microwave Tubes, Fort Monmouth, N. J., Sept. 25-26, 1962

Stability of Tunnel-Diode Oscillators F. Sterzer: *RCA Review*, Sept. 1962

Heterodyne Receivers for RF-Modulated Light Beams—D. J. Blattner and F. Sterzer: *RCA Review*, Sept. 1962

SEMICONDUCTOR AND MATERIALS DIVISION

A 120-Watt 50-Megacycle Transmitter G. D. Hanchett: *Ham Tips*, Summer 1962

Alpha-Cutoff Test Set Checks VHF Transistors J. Lempner: *Electronic Design*, Aug. 2, 1962

A Non-Destructive Measurement of Carrier Concentration in Heavily Doped Semiconducting Materials and Its Application to Thin Surface Layers I. Kudman: AIME Meeting, Phila., Pa., Aug. 27-29, 1962

New Rechargeable Systems—E. F. Uhler and G. S. Lozier: *Proceedings of 1962 Power-Sources Conference*, Aug. 1962

Magnesium Primary Cells G. Lozier and R. Ryan: *Proceedings of 1962 Power-Sources Conference*, Aug. 1962

High Efficiency Gallium Arsenide Solar Cells—M. F. Lamorte: *Proceedings of 1962 Power-Sources Conference*, Aug. 1962

Neutron Activation Study of Gallium Arsenide Contamination by Quartz—W. Kern: *Journal of Electrochemical Society*, Aug. 1962

Consideration of Automobile AM/FM Receiver Design—H. Thanos and R. A. Santilli: *Semiconductor Products*, Aug. 1962

Semiconductor Digital Integrated Circuits R. D. Lohman: National Television Program, Milan, Italy, Sept. 10, 1962

The Design of Low-Level and RF Circuits Utilizing the RCA-2N2102 G. R. Levy: National Television Show, Milan, Italy, Sept. 10, 1962

Micromodule System Design R. DiStefano, Jr.: *Electronics*, Sept. 14, 1962

Investigation of the Doping of Silicon Epitaxial Layers with $SbCl_3$ and PCl_3 in $SiCl_4$ Solutions B. R. Czorny: Electrochemical Society Meeting, Boston, Mass., Sept. 16-20, 1962

Semiconductor Device Manufacturing M. N. Slater: Intercollegiate Chemical Society of Northeastern Pennsylvania, Kings College, Wilkes-Barre, Pa., Oct. 22, 1962

Etching Characteristics of Degenerately Doped P-N Junctions—R. Glicksman, E. Casterline and L. Verettoni: Electrochemical Society Meeting, Boston, Mass., Sept. 16-20, 1962

Solar Cell Design for Probing the Inner Regions of Solar Systems M. F. Lamorte: American Rocket Society Meeting, Santa Monica, Calif., Sept. 25-28, 1962

Evaluation of Semiconductor Epitaxial Layers—A. S. Rose: ASTM Symposium on Materials Processing for Electronics, Los Angeles, Calif., Sept. 30-Oct. 5, 1962

Minute Resistivity Variations in Germanium Crystals and Their Effect on Devices G. Meltzer: *Journal of Electrochemical Society*, Oct. 1962

Patents Granted

TO RCA ENGINEERS

As Reported By RCA Domestic Patents, Princeton

DEFENSE ELECTRONIC PRODUCTS

3,048,665—Magnetic Record Reproducing Apparatus, Aug. 7, 1962; R. C. Wilcox

3,048,754—Combination Motor Control System, Aug. 7, 1962; C. E. Hittle

3,050,722—Multiple Target Automatic Track-While-Scan Radar, Aug. 21, 1962; F. D. Covely

3,051,896—Frequency Detector (Class-Sub 324/071), Aug. 28, 1962; W. J. Rieganski

3,051,955—Error Indicating System (Class Sub 346/110), Aug. 28, 1962; F. W. Pfleger and R. Y. Noel

3,056,048—Pulse Generator Employing Negative Resistance Diodes to Effect High Voltage Output (Class 307/088.5), Sept. 25, 1962; E. P. McGrogan, Jr.

3,056,049—Circuit for Converting an Analog Quantity to a Digital Quantity (Class 307/088.5), Sept. 25, 1962; B. C. Baird

3,056,114—Magnetic Storage Device (Class 340/174), Sept. 25, 1962; M. L. Aitel

3,056,864 — Program Timer (Class 200/046), Oct. 2, 1962; A. C. Albee

3,056,950—Verification of Magnetic Recording (Class 340/174.1), Oct. 2, 1962; D. J. Birmingham, R. E. Montijo and J. P. Reid

3,057,071—Velocity and Distance Measuring System and Method (Class 033/046), Oct. 9, 1962; R. S. Sinn

RCA LABORATORIES

3,048,740—Electron Beam Convergence Apparatus, Aug. 7, 1962; M. D. Nelson

3,048,789—Pulse Counter Type Frequency Detector, Aug. 7, 1962; G. B. Herzog

3,048,797—Semiconductor Modulator, Aug. 7, 1962; E. G. Linder

2,996,640—Variable Beam Electron Gun (Reissue 25222), Aug. 14, 1962; A. L. Eichenbaum

3,050,574—Thermoelectric Elements Having Graded Energy Gap, Aug. 21, 1962; F. D. Rosi

3,050,633—Logic Network, Aug. 21, 1962; E. E. Loebner

3,050,700—Phase Shifting Circuit, Aug. 21, 1962; K. H. Powers

3,051,844—Parametric Oscillator Circuit with Frequency Changing Means, Aug. 28, 1962; W. R. Bean, F. Sterzer

3,052,232 — Voltage Sensing Apparatus, Sept. 4, 1962; V. K. Zworykin and F. L. Hatke

3,052,539—Electrostatic Printing, Sept. 4, 1962; H. G. Greig

3,052,540—Dye Sensitization of Electrophotographic Materials, Sept. 4, 1962; H. G. Greig

3,053,688—Electrostatic Printing, Sept. 11, 1962; H. G. Greig

3,054,018—Traveling Wave Amplifier Tube, Sept. 11, 1962; F. E. Paschke

3,054,034 — Semiconductor Devices and Method of Manufacture Thereof, Sept. 11, 1962; H. Nelson

3,054,067—Transistor Signal Amplifier Circuit, Sept. 11, 1962; J. B. Merrill and A. Macovski

3,054,073 — Angular-Velocity Modulation Transmitter, Sept. 11, 1962; K. H. Powers

3,054,852—Color Television, Sept. 18, 1962; A. C. Schroeder

3,055,833—Mixed Ferrospinels, Sept. 25, 1962; P. K. Baltzer

3,055,978—Control Circuit, Sept. 25, 1962; S. Sharin and T. R. Sheridan

3,056,039—Multi-State Switching Systems, Sept. 25, 1962; L. S. Onyshkevych

3,056,115—Magnetic Core Circuit, Sept. 25, 1962; A. W. Lo

3,059,056—Stereophonic Sound Signal Receivers, Oct. 16, 1962; L. A. Freedman and J. O. Preisig

3,059,189—Stereophonic Detecting and Matrixing Circuit, Oct. 16, 1962; J. O. Preisig

BROADCAST AND COMMUNICATIONS PRODUCTS DIVISION

3,049,695—Memory Systems, Aug. 14, 1962; A. L. Newhouse and W. L. McMillan

3,050,594—Position Control System, Aug. 21, 1962; J. D. Bick and J. L. Grever

3,054,072—Square Wave Generator with Constant Start-Stop Characteristics, Sept. 11, 1962; D. E. Beaulieu, I. Cimerman

3,052,773—Combined Sensing and Switch Device, Sept. 4, 1962; M. W. Teutsch

ELECTRON TUBE DIVISION

3,048,654—Television Projection Tube Alignment, Aug. 7, 1962; O. H. Schade, Sr.

3,051,864—Self-Indexing Electron Tubes and Sockets, Aug. 28, 1962; O. H. Schade

3,054,012—High Power Electron Discharge Device, Sept. 11, 1962; O. H. Schade

3,057,130—Apparatus For and Method of Processing Articles or Materials in a Continuous Flow Operation, Oct. 9, 1962; W. J. Helwig

ELECTRONIC DATA PROCESSING

3,048,717 — Peak Time Detecting Circuit, Aug. 7, 1962; R. H. Jenkins

3,050,637—Tunnel Diode Driver, Aug. 21, 1962; M. M. Kaufman

3,054,958—Pulse Generating System, Sept. 18, 1962; L. S. Bensky, D. L. Nettleton and A. D. Beard

3,059,221—Information Storage and Transfer System, Oct. 16, 1962; J. F. Page and Fernandes-Rivas (L.A.)

SEMICONDUCTOR AND MATERIALS DIVISION

3,050,981—Vaporization Rate Measuring Apparatus, Aug. 28, 1962; H. J. Schwarz

3,054,174—Method for Making Semiconductor Devices, Sept. 18, 1962; A. S. Rose and H. W. Bertram

HOME INSTRUMENTS DIVISION

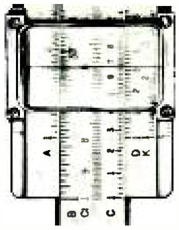
3,052,865—Power Cord Adaptors, Sept. 4, 1962; H. A. Pappano and G. J. Whitley

3,053,215—Apparatus for Soldering Printed Sheets, Sept. 11, 1962; B. J. Guty

3,058,749 — Automatic Phonograph Record Player, Oct. 16, 1962; J. A. Tourtellot

3,059,065—Stereophonic Signal Translating Circuits, Oct. 16, 1962; J. A. Tourtellot

3,059,185—Battery Operated Apparatus Including a Battery Operated Clock and Radio, Oct. 16, 1962; L. M. Krugman

Engineering  NEWS *and* HIGHLIGHTS

EDP TOP ORGANIZATION ANNOUNCED

A. L. Malcarney, Group Executive Vice President, has announced appointment of **A. K. Weber** as Division Vice President and General Manager, Electronic Data Processing. Mr. Weber will report to Mr. Malcarney. **E. S. McCollister** has been appointed Division Vice President, Business Planning and Marketing. In this capacity, Mr. McCollister will continue to be responsible for all EDP Marketing activities including sales and product planning. In addition, Mr. McCollister will assist Mr. Weber in developing broad business strategy for RCA's electronic data processing business. Mr. Weber's EDP organization is as follows:

- **A. D. Beard,** Chief Engineer, Engineering
- **K. U. Clary,** Manager, Personnel
- **E. D. Foster,** Division Vice President, Plans and Programs
- **K. Hesdoerffer,** Manager, Product Assurance
- **J. W. Leas,** Manager, Data Communications and Custom Projects
- **E. S. McCollister,** Division Vice President, Business Planning and Marketing
- **M. W. Poppei,** Manager, Special Assignments
- **J. A. Scarlett,** Manager, Operations—Palm Beach
- **J. H. Walker,** Controller, Finance
- **A. K. Weber,** Acting Manager, Production Planning and Projects

A. D. BEARD, CHIEF ENGINEER, EDP

In mid-1962, **A. D. Beard** was named Chief Engineer, Engineering, of RCA Electronic Data Processing. Mr. Beard, whose engineering career began and has continued

A. D. Beard

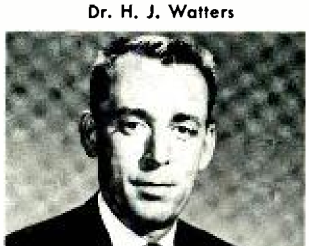
with RCA for the past 13 years, received his BEE (1947) and MEE (1949) from the Rensselaer Polytechnic Institute and was an EE instructor there in 1947-49. He joined RCA Advanced Development in 1949, later becoming Project Engineer on the prototype BIZMAC. He was then made responsible for advanced-development programs in military computers and displays. In 1958, he took over the Digital Development and Design activity at Moorestown, and in 1959 moved to the Data Systems Division, Van Nuys. He was Manager, Electronics Engineering there prior to being named EDP Chief Engineer. Mr. Beard is a member of the Eta Kappa Nu, Tau Beta Pi, Sigma Xi, and has ten patents.

DR. HARRY J. WATTERS APPOINTED CHIEF DEFENSE ENGINEER

Appointment of **Dr. Harry J. Watters** as Chief Defense Engineer was recently announced by **Walter G. Bain,** Vice President, RCA Defense Electronic Products. Dr. Watters was formerly assistant to the President of Polaroid Corporation, with emphasis on research, development and new product planning. Before joining Polaroid, Dr. Watters had been involved in scientific and technical matters of national importance.

Dr. Watters received his BS at Purdue University in 1949. His graduate work was conducted at the Massachusetts Institute of Technology where he majored in Physics and Electronics. He was awarded the MS in 1953 and continued his work in Physics to obtain a PhD in Physics at M.I.T. in 1955. From 1956 to 1960, Dr. Watters was Professor of Physics at Georgetown University, Washington, D. C. He is a member of numerous scientific and professional societies including the American Physical Society, Society of Sigma Xi, American Association of Physics Teachers, and the American Association for Advancement of Science.

Dr. H. J. Watters



McGROGAN HONORED FOR "BEST NEC PAPER"

E. P. McGrogan was selected as the winner of the annual award for the best original paper presented at the 1961 National Electronics Conference and published in the 1961 Conference *Proceedings.* He received the award October 10, 1962. The title of the paper was "Improved Transistor Neuron Models." [See paper by McGrogan, *et al.* in RCA ENGINEER Vol. 8, No. 1.]—*M. G. Pietz*

WOODWARD NAMED FELLOW, AES; ROYS INSTALLED AS PRESIDENT

J. G. Woodward, head of the Audio Recording Group of RCA Laboratories, Princeton, N.J., was named a *Fellow* of the Audio Engineering Society at the group's annual meeting in October. He was cited for his valuable advances in disk and magnetic recording and reproduction.

The Chairman of the annual meeting **H. E. Roys,** Chief Engineer of the RCA Victor Record Division, was installed as President of the Society. The principal address was by **George R. Marek,** Vice President and General Manager of the RCA Victor Record Division.

DEP MERGES MSD AND MM & SR; BROADENS SYSTEMS ENGINEERING

Two changes in the alignment of the RCA Defense Electronic Products organization have been announced by **Walter G. Bain,** Vice President, DEP.

1) Merger of the Major Systems Division (located in Moorestown) established originally to manage the BMEWS project (now nearing completion) with the Moorestown Missile and Surface Radar Division.

2) The Systems Engineering Evaluation and Research Organization, formerly the Systems Engineering group within MSD, will now report to Dr. **Harry J. Watters,** Chief Defense Engineer, DEP. This group will be headed by **David Shore.**

"The purpose of the change," Mr. Bain said, "is to make available to all DEP divisions the systems capability developed during the BMEWS project.

John H. Sidebottom has been appointed Vice President and General Manager of the combined divisions. The missile organization will be called the *Missile and Surface Radar Division* (MSRD).

S. N. Lev, formerly Vice President and General Manager, MM & SR, has been appointed Division Vice President, Defense Manufacturing and Program Management, a new position created to coordinate these activities in all five of the divisions comprising DEP.

Effective November 1, 1962, the organization of Defense Electronic Products reporting to **W. B. Bain,** Vice President, DEP, is as follows:

F. L. Ankenbrandt, Manager, Defense Product Assurance;

S. W. Cochran, Division Vice President and General Manager, Surface Communications Division;

J. M. Hertzberg, Division Vice President, Defense Marketing;

I. K. Kessler, Division Vice President and General Manager, Aerospace Communications and Controls Division;

B. Kreuzer, Division Vice President and General Manager, Astro-Electronics Division;

S. N. Lev, Division Vice President, Defense Manufacturing and Program Management;

T. W. Massoth, Manager Administration;

J. H. Sidebottom, Division Vice President and General Manager, Missile and Surface Radar Division;

H. J. Watters, Chief Defense Engineers, Defense Engineering;

H. R. Wege, Vice President and General Manager, Data Systems Division.

The Missile and Surface Radar Division will assume responsibility for: **J. J. Guidi,** Manager, BMEWS Program; and **W. L. Richardson,** Manager, Program Management. Both will report to **J. H. Sidebottom,** Division Vice President and General Manager, Missile and Surface Radar Division.

W. G. Bain, Vice President, DEP, also announced the following:

The MINUTEMAN program management (formerly in MSD) is now in the Surface Communications Division. **J. M. Osborne** continues as Program Mgr., and will report to **S. W. Cochran,** Division Vice President and General Manager, Surface Communications Division. The DYNASOAR program management (formerly in MSD) is transferred to the Aerospace Communications and Controls Division, Camden. **C. K. Law,** Manager, Programs Management, will continue his responsibility for the DYNASOAR Program. Mr. Law will report to **I. K. Kessler,** Division Vice President and General Manager, Aerospace Communications and Controls Division. The *706* program management (formerly MSD) is transferred to the Aerospace Communications and Controls Division, Burlington. **W. M. Pease** continues as Program Manager and will report to **I. K. Kessler,** Division Vice President and General Manager, Aerospace Communications and Controls Division.

SUCCESS CITED FOR THE MICROMODULE PROGRAM

The advent of the U.S. Army-RCA Micromodule Program entering a widespread industry-participation and mass-production phase was marked by a public-relations conference in New York on August 28. The conference brought a large audience of newsmen and editors from the daily press and national business and technical magazines. Main speakers at the conference were Major General Earle F. Cook, Chief Signal Officer, and Group Executive Vice-President **W. Walter Watts** of RCA.

In his speech, General Cook praised the achievements of the micromodule program in making possible the dramatic reduction in size and increase in reliability of electronic equipment. He announced that the Army anticipates committing some $8 million for equipment and systems in fiscal year 1963 and even more in 1964 and, with the addition of many more suppliers, achieve production rate of a million micromodules a year by June 1964.

Mr. Watts stated that, "through the micromodule program enormous benefits can be foreseen for vital areas of America's space-age thrust, as well as for down-to-earth advances in the whole art and science of electronics," and "while many other exciting techniques in microcircuitry are being researched and talked about, micromodules can be and are being produced right now." [See front cover, and paper on MICROPAC, by Rettig, in this issue for one important application.]—*C. W. Fields*

MINIATURE COMPUTER TEST SET USES MICROMODULES

A computer test set smaller than a shoe box is being built by the DEP Data Systems Division, Van Nuys, Calif., for the U. S. Navy Electronics Laboratory, San Diego, Calif., to monitor transmission within large data communications and processing systems. Through use of micromodules, the set's size will be kept to 4 x 4 x 8 inches and its weight to nine pounds.

The capability of this unit can presently be obtained only by utilizing large, separate, unwieldly equipment. This microminiature device will accommodate one output and 32 input signals, with a total of five distinct operating functions. This large capability in such a small box is made possible by the use of 94 micromodules incorporating 143 digital circuits.

SMALL, FLEXIBLE MORSE CODE TRANSLATOR DEVELOPED BY SURFCOM

An automatic Morse code translator, small enough to be carried by hand and capable of recognizing manually keyed telegraphic signals over a wide range of speeds without adjustments, has been developed by the DEP Surface Communications Division. The successfully tested laboratory model automatically translates the Morse signals into lighted letters and numerals on a panel from which a typist can copy them.

The unit, which incorporates about 120 transistors, is extremely small in comparison with other translating equipment now in existence, measuring roughly 5 x 5 x 8 inches. It operates on 9 watts.

RCA LABS' 20TH BIRTHDAY

On September 27, 1942, the RCA Laboratories, Princeton, were officially dedicated with Dr. Elmer W. Engstrom (now President, RCA) as first Director. Since then, the scientists working there have compiled a brilliant record of accomplishment that has made electronics history—and they continue to do so. In the photographic memento below, (l. to r.) Gen. J. G. Harbord, then RCA Board Chairman, David Sarnoff, RCA President (now RCA Board Chairman) and O. S. Schairer, then Vice President RCA Laboratories, are shown at the ground breaking ceremonies on August 8, 1941. At right in background is Dr. Engstrom.

WENTWORTH NAMED SMPTE FELLOW

John W. Wentworth, who manages the Educational Advisory Services division of the RCA Service Company, was named a *Fellow* of the Society of Motion Picture and Television Engineers earlier this year. In his present post, Mr. Wentworth, advises educators about the use of television and is responsible for the planning and development of new products and services for the educational market. He wrote the book *Color Television Engineering* (McGraw-Hill Company, 1955), was awarded *Honorable Mention* in the Eta Kappa Nu Recognition of the "Outstanding Young Engineer" for 1959, and won the *RCA Victor Award of Merit* for color television teaching activities in 1953.

BROADCAST DIVISION WEST-COAST FACILITIES DOUBLED

The Film Recording and West Coast Operations Department of RCA's Broadcast and Communications Products Division doubled the size of its faciilties in moving to new quarters at 2700 W. Olive Ave., Burbank, California. The move from the former location at 1560 N. Vine St., Hollywood was completed November 1, 1962.

The new facility in Burbank contains approximately 30,000 square feet of floor space and will house engineering, production and marketing activities. The department designs and produces Film Sound Recording Equipment, Television Film Recorders, Television Tape Recorders, TV Mobile Units and large custom Audio Systems for motion picture, radio and television studios. In addition, the department maintains a complete television systems engineering group which provides system design and assembly as well as installation supervision and checkout.—*C. E. Hittle*

MICROREPRODUCTION CENTER

The Microfilming Section of the RCA Service Company's Engineering and Technical Services at Cherry Hill, N. J., while supporting other RCA activities, also does work for other companies and government agencies. Most of the microfilming is done on engineering drawings, military specifications, etc., but actually almost any type of document can be, and is, microreproduced at Cherry Hill.

The process involves photographing the material and then attaching the microfilm negative to an "aperture card" which is punched for processing through automatic card-handling equipment. In this way, the document can be stored in minimum space, but can be quickly and easily located and reproduced, when needed.

ARE YOU REGISTERED?

In the June-July 1962 RCA ENGINEER the editorial by **J. C. Walter,** "Registered Professional Engineers in Industry" included a list of some 230 RCA engineers who were known to possess state licenses. The Editors realized the list was incomplete, and asked that readers who were licensed (and not included in that list) send that information in. Since then, an additional 94 have been listed. The following additions to the roster have been received in the past few weeks and bring the total listed to date to over 370. *If you are licensed and have not yet informed the* RCA ENGINEER, *send that information to:* RCA ENGINEER, 2-8, Camden, N. J.

M. E. Ames, DEP, PE-8695, *Pa.*
A. S. Baron, Svc. Co., PE-3183, *Maryland*
S. N. Berliner, DEP, PE-11251, *Mass.*
S. P. Clurman, AED-DEP, PE-27050, *N. Y.*
G. Cohen, SC&M, PE-35070, *N. Y.*
E. G. Crane, Jr., DEP, PE-27053, *N. Y.*
S. Z. Daroff, DEP, PE-14769, *Pa.*
W. J. Davis, DEP, PE-13332, *Texas*
L. Davne, Pr. Labs., PE-15275, *Pa.*
D. A. V. Eckhardt, DEP, PE-10242, *N. J.*
R. J. Farquharson, DEP, PE-11352, *N. J.*
S. V. Forgue, Pr. Labs., EE-11525, *Ohio*
W. A. Glazer, SC&M, PE-8417, *Mich.*
L. S. Greenberg, SC&M, PE-11061, *Mass.*
H. B. Grossman, DEP, PE-11840, *Pa.*
G. A. Hagopian, DEP, PE-28264, *N. Y.*, PE-452, *Wyo.;* PE-4510, *Colo.;* PE-3582, *Conn.*
W. Hall, DEP, PE-11650, *N. J.*
Dr. J. Hilibrand, SC&M, PE-37383P-E. *N. Y.*
L. Hoffman, RCAC, PE-39507, *New York*
W. D. Hudgins, DEP, PE-6453-E, *Pa.;* PE-E-250, *Calif.;* PE-435, *Wash., D. C.*
I. Katz, DEP, PE-33984, *N. Y.*
W. E. Keating, DEP, PE-8458, *Mich.*
H. W. Kuzminski, ETD, EE-8736, *Pa.*
J. M. Leopold, DEP, PE-4795, *Wash., D. C.*
C. N. Lusty, DEP, PE-2071, *Ill.;* PE-10573, *Mich.;* PE-8898, *Ind.*
C. G. Mayer, Int'l., PE-23013, *N. Y.*
J. H. Moyer, Jr., SC&M, E-8784, *Pa.*
S. Nozick, DEP, PE-4249, *Ariz.;* PE-E-6069, *Calif.*
G. A. Nylander, DEP, PE-9496, *N. J.;* PE-33473, *N. Y.*
D. B. O'Brien, DEP, PE-11856, N. J.
P. A. Rey, EDP, PE-5194-E, *Pa.*
P. G. Rhodes, RCA Svc., PE-5471, *Conn.*
E. W. Riedweg, H. I., PE-6470, *Ind.:* PE-19434, *Ohio*
W. Rose, DEP, PE-22538, *Ohio*
C. A. Runyon, DEP, PE-4404E, *Wash., D. C.*
H. P. Schiefer, ETD, PE-2379-E, *Pa.*
R. L. Schmoyer, ETD, PE-7972, *Pa.*
H. J. Shay, BCC, PE-10836, *N. J.*
B. P. Silverman, EDP, EE-5168, *Calif.*
F. J. Somers, NBC, PE-19792, *N. Y.;* E-4973, *Calif.*
W. M. Swarthout, DSD-DEP, EE-5352, *Calif.;* PE-29940, *N. Y.*
C. F. Thomas, DEP, PE-M8081, *Calif.*
F. L. Ulrich, ETD, PE-9026, *N. J.*
W. J. Vallette, DEP, PE-12177, *Mass.*
G. J. Waas, EDP, PE-31494, *N. Y.*
H. J. Wesolwoski, SC&M, PE-12720, *Mass.*
C. C. Wilson, ETD, PE-10783, *N. J.*
J. R. Wolfskill, DEP, PE-11144, *Mass.*
F. O. Ziegler, DEP, PE-6346, *N. J.*

...PROMOTIONS...

to Engineering Leader and Manager

As reported by your Personnel Activity during the past two months. Location and new supervisor appear in parenthesis.

Surface Communications Division, DEP

F. Assadourian: from Ldr., Tech. Staff to *Sr. Staff Scientist* (A. Mack, Mgr., of Systems Integration)

J. Acunis: from Ldr., Tech. Staff to *Mgr. Systems Engineering* (A. Mack, Systems Integration, N.Y. Systems Labs)

M. Masonson: from Ldr., Tech. Staff to *Sr. Staff Scientist* (A. Mack, Systems Integration, N.Y. Systems Labs)

B. Rabinovici: from Ldr., Tech. Staff to *Sr. Staff Scientist* (W.Y. Pan, Advanced Solid State Techniques, N.Y. Systems Labs)

H. Straube: from Sr. Project Member to *Staff Scientist* (S. J. Mehlman, Advanced Circuit Techniques, N.Y. Systems Labs)

D. P. Goodwin: from Engr. to *Ldr., Design and Development Engrs.* (M. Gottlieb, Camden)

Missile and Surface Radar Division, DEP

J. S. Degnan: from Engr. to *Ldr., D. & D. Engineering* (J. L. Sullivan)

L. H. Simon: from Engr. to *Ldr., Systems Engineering* (R. W. Ekis)

D. F. Bowman: from Engr. to *Ldr., D & D Engineering* (F. Klawsnik)

J. J. Bisaga: from Engr. to *Ldr., D & D Engineering* (E. S. Lewis)

H. C. Montgomery: from Engr. to *Ldr., Engineering Systems Projects* (D. T. Vermilye)

Aerospace Communications and Controls Division, DEP

H. A. Brill: from Engr. to *Ldr., D & D Engineering* (D. Westwood, Camden)

A. T. Wenda: from Engr. to *Ldr., D & D Engineering* (T. P. Speas, Camden)

RCA Communications, Inc.

J. C. Hepburn: from Ass't Mgr., Station Facilities Equipment and Systems to *Mgr., Station Facilities Equipment and Systems* (Vice President, Station Engineering)

RCA Service Company

L. F. Menice: from Engr., BMEWS to *Ldr., Engrs., BMEWS* (D. L. Lyndon, Fylingdales, England)

J. Kuzma: from Assoc. Engr. to *Mgr., C & E Engineering* (G. B. Finigan, Anchorage, Alaska)

H. L. Chadderton: from Installation and Modification Engr. to *Mgr., ComLogNet Site Services* (J. M. James, ComLogNet)

L. W. Faulkner: from Mgr., ComLogNet to *Mgr., ComLogNet Site Services* (J. M. James, ComLogNet)

D. E. Heins: from Field Engr. to *Mgr., ARIS Navigation and Data Handling* (S. L. Candler, ARIS)

H. D. Masch: from Field Engr. to *Ldr., Field Svc. Engineering* (C. Sharp, Maintenance Engineering)

C M. Hall: from Engr. to *Ldr., Engrs. BMEWS* (S. N. Levy, Operation and Maintenance, BMEWS Project)

A. B. Jarvis: from Systems Service Engr. to *Ldr., Engrs.* (J. M. James, ComLogNet)

J. F. Linsalata: from Engr. to *Ldr., Engrs.* (E. L. Klein, Aerospace and Communications Project)

M. E. Stetser: from Systems Service Engr. to *Ldr., Engrs.* (J. M. James, ComLogNet)

D. L. Swartz: from Engr. to *Tech. Operations Mgr.*, Langley Space Chamber (H. Reese, Jr., Nuclear and Scientific Services)

Electron Tube Division

J. R. Bumke: from Engr. Manufacturing to *Mgr., Production Engineering-Chemical* (L. F. Hopen, Mgr., Process and Production Engineering)

S. W. Lefcourt: from Manufacturing Engr. to *Mgr., Glass or Special Tube Production Engineering* (H. R. Snow, Tube Production Engineering, Harrison)

RCA Victor Co., Ltd.

E. Lurion: from Engr. to *Administrator, Educational Electronics* (C. F. Whittaker)

L. Slaven: from Engr. to *Ldr., Filter Plant* (G. F. Baylis)

L. A. Keyes: from Engr. to *Ldr., Microwave Communications* (G. F. Baylis)

D. F. Russell: from Ldr. to *Supervisor, Microwave Communications* (G. F. Baylis)

Astro-Electronics Division, DEP

F. A. Beisel, Jr.: from Ldr., Engrs. to *Mgr. R-F Equipment Engineering* (R. B. Marsten, Mgr., Space Communication Systems)

D. G. Shipley: from Engr. to *Ldr., Engrs.* (F. A. Beisel, Jr., Mgr., R-F Equipment Engineering)

J. H. Waite: from Sr. Engr. to *Staff Engr.* (V. D. Landon, Mgr., Tech. Advisory Staff)

Home Instruments Division

J. B. Schultz: from Member, Tech. Staff to *Ldr., Product Design and Development* (R. D. Flood, Mgr., Electrical Engineering, RV)

E. J. Evans: from Ldr., Liaison Engrs. to *Mgr., Resident Engineering* (L. M. Krugman, Mgr., RV Product Engineering)

Semiconductor and Materials Division

B. Walmsley: from Engr., Product Development to *Engineering Ldr.* (E. Karlin, Somerville)

W. Totten: from Engr. Manufacturing to *Engineering Ldr.* (M. Geller, Somerville)

E. W. Karlin: from Engineering Ldr., Manufacturing to *Mgr., Test and Reliability Engineering* (L. Shardlow, Somerville)

A. A. Dunham: from Engr. Manufacturing to *Engineering Ldr. Manufacturing* (M. Geller, Somerville)

Data Systems Division, DEP

R. J. Allen: from Principal Member, Systems Engineering Staff to *Staff Engineering Scientist* (Dr. Nolde)

K. C. Gaspar: from Sr. Member, Project Engineering Staff to *Administrator, Value Engineering* (L. Jacobs, Van Nuys)

R. Guirell: from Sr. Member, Project Engineering to *Ldr., Project Engineering* (N. Vrabel, Van Nuys)

R. E. Richards: from Sr. Member, D & D Engineering to *Ldr., D & D Engineering Staff* (D. Byrne, Van Nuys)

J. C. Meagher: from Sr. Member, D & D Engneering Staff to *Ldr., D & D Engineering Staff* (G. Haramia, Van Nuys)

NEW RCA WEST COAST FACILITY

A $2 million West Coast Headquarters for RCA West Coast Corporate functions, Electronic Data Processing sales activities, and RCA Victor Record Division Recording Studios is planned in Hollywood, Calif. Construction of the nine-story, 76,000-square-foot structure is expected to begin in December 1962 with completion late in 1963.

RCA-MONTREAL EARNS PLAUDITS IN ALOUETTE, FIRST CANADIAN SATELLITE PROGRAM

The RCA Victor Company, Ltd. of Montreal designed and produced the 136-Mc 2-watt solid-state true FM telemetry transmitter which is now in orbit aboard the ALOUETTE topside sounder satellite. The ALOUETTE, which was sent aloft on a Thor-Agena-B rocket, is of wholly Canadian design and manufacture. It is instrumented to investigate the upper side of the ionosphere and the recently-created man-made radiation belt. It is in a very nearly circular orbit at 593 to 615 miles from the earth's surface.

The telemetry transmitter, designed in the RCA Victor Research Laboratories by a small team under **J. M. Stewart,** weighs 13.5 oz. and is 5 inches long. From a power input of about 8 watts at 28 volts it gives a minimum output of 2 watts at 136 Mc over a temperature range −50°C to +75°C. The true FM modulation is flat from 0.25 cps to 70 kc with a ±50-kc deviation.

This transmitter, believed to be the *first* of its kind to pass NASA tests and to be fired into orbit, was designed, developed, tested, and delivered *within the remarkably short period of four months. The total interval between the first approach to RCA Victor and the firing of the satellite into orbit was six months.*

Latest word from the Defense Research Board Ground Station in Ottawa is that the telemetry channel is working *beyond expectation* and that data recording is possible from horizon to horizon when the orbit passes directly overhead. All those associated with the design, development, production, inspection and testing of this transmitter are to be congratulated for an outstanding achievement.—*H. J. Russell*

FIRST CANADIAN PLASMA PHYSICS SYMPOSIUM HELD AT RCA-MONTREAL LABS.

The first Canadian Plasma Physics Symposium sponsored by the Defense Research Board of Canada was held at the Research Laboratories of RCA Victor Company Ltd. in Montreal in July. This meeting gathered delegates from various universities in Canada as well as from the Government Laboratories to outline the various research programs on plasma physics and discuss the problem of mutual interest. The meeting was concluded by a tour of the Research Laboratories with particular emphasis on the numerous plasma physics experiments in progress at RCA Victor Company Ltd.—*H. J. Russell*

SECOND COLOR-TV TUBE MANUFACTURING FACILITY PLACED IN OPERATION AT MARION, INDIANA

The Electron Tube Division has placed in operation on an around-the-clock basis its second color television tube manufacturing facility to help fill the rising backlog of orders from set manufacturers.

This new facility in ETD's Marion, Ind. plant is the second major addition within the year to color tube production facilities to meet a heavy industry demand that is expected to continue through 1963 and beyond. It represents a $1.7 million expansion in facilities. Earlier this year, ETD made a $1.5 million expansion of its plant in Lancaster, Pa.

PROFESSIONAL ACTIVITIES

ETD, Lancaster: On Sept. 13, **C. M. Sinnett,** Director, Product Engineering Professional Development, spoke on "Professional Development," as the introductory lecture for both the second *1962 Engineer Orientation Series* and the Lancaster *General Lecture Series.* The Orientation series consists of 14 hourly sessions for 35 recently hired engineers, covering all product lines.

Twenty Lancaster engineers are attending the 96-hour *EIT Review Course* at Penn State, in preparation for the June 1963 Pennsylvania Professional Engineer examinations.

A 32-hour course, *Statistical Design of Experiments* is underway at Lancaster for 30 engineers, taught by Prof. Wescott of Rutgers U. graduate school.—*G. G. Thomas*

DEP Applied Research, Camden: **D. J. Parker,** Mgr., Applied Physics, has been elected a Director of the newly formed Philadelphia Chapter of the Optical Society of America.—*N. G. Pietz.*

DEP-ACCD, Camden.: **R. Mirshky** was General Chairman of the 22nd National Meeting of the Operations Research Society of America, Philadelphia, Nov. 7-9. **P. E. Brown** will serve as General Program Committee Chairman of the Nuclear Industries Division of the Instrument Society of America for 1962-63. **R. Lending** was elected Program Chairman of the Philadelphia Chapter, IRE-PGCS-PGVC.—*G. Lieberman.*

Broadcast Div., Camden: **Dr. H. N. Kozanowski** is Chairman of the upcoming SMPTE Convention, scheduled for Atlantic City in April 1963.

A *Semiconductor Circuit Design* course is underway for 130 engineers of the Division, consisting of 14 lectures extending through fall and winter, 1962-63. Instructors include **R. N. Hurst** and **A. C. Luther.**

A new development and assembly building is now in use at the Gibbsboro, N. J., antenna test site.—*R. N. Hurst and C. D. Kentner.*

DEP-DSD, Bethesda: **D. Climenson,** Ldr., Language Analysis and Document Handling, was selected to head the Information Storage and Retrieval Hall of Discussion session at the ACM Conference, Sept. 4, 1962. **Dr. J. Minker,** Mgr., Information Technology, was an invited participant in a panel discussion at a Conference sponsored by the National Science Foundation and the University of California at Lake Arrowhead. Dr. Minker has also been elected Vice Chairman of the Special Interest Group for Information Retrieval, Association for Computing Machinery (ACM.)—*H. J. Carter.*

DEP-SurfCom, Camden and New York: **J. E. Eiselein,** Mgr. Engineering Support and Administration, SurfCom, was re-elected National Chairman of IRE-PGIE for 1963. **H. O. Dietze** has been named Chairman of the IRE-PGA, Philadelphia Chapter, for 1963. **B. Sheffield** is serving on the IRE Transmitter Committee, as Definitions Coordinator. He also serves as Financial Officer of the Northern N. J. Chapter of the IRE-PGCS, and a member of the Board of Officers of the New York Chapter of Eta Kappa Nu. **R. Knuth** has been named to the Administrative Committee of the Philadelphia Chapter, IRE-PGEWS.—*C. W. Fields.*

WES FIELDS, SURFCOM ED REP, RATES CREDITS FOR THIS ISSUE

C. W. Fields

C. W. (Wes) Fields, senior RCA ENGINEER Editorial Representative in the DEP Surface Communications Division, rates honors for his efforts in coordinating the papers on digital communications appearing in this issue, and for arranging the cover photo. Further credit is due for his continuing work in actively promoting the technical-papers program among SurfCom engineers. Since joining SurfCom in 1956, Wes has been instrumental in helping SurfCom engineers compile an enviable record of writing and placing technical articles in journals and trade magazines—through his editorial guidance and well-placed needling. As SurfCom Engineering Editor, and a member of **F. W. Whitmore**'s DEP Editorial Board, his regular duties include editing, review, and coordination of technical papers, *TR* and *EM* reports, proposals, and technical promotion activities. He has published some 15 articles of his own. Wes graduated from Temple University in 1955 with BS in Journalism, and has since taken courses in electronics and technical writing. A Member of the IRE, he is Secretary-Treasurer of the Philadelphia Chapter of the IRE Professional Group on Engineering Writing and Speech, and is an Associate Editor of the IRE-PGEWS *Transactions.*

RADAR SYMPOSIUM HELD AT MOORESTOWN

On October 17 and 18, 1962, more than 180 military representatives attended a symposium, "TRADEX Results—Impact on Future Systems" held at the Moorestown plant.

Talks were given by key RCA project and design engineers on the capabilities and performance of the TRADEX radar recently installed on Roi-Namur. [See RCA ENGINEER, Oct.-Nov. 1962.] Although not yet officially "delivered" to the government, this radar has, as a part of checkout and evaluation, tracked the moon, ECHO I, and participated in several missile tracking missions. Some of the most interesting data obtained was presented during these meetings. During the afternoon, demonstrations of advanced radar techniques and hardware were presented to the attendees in small groups throughout the Moorestown plant. An example of these was the display of the TRADEX high-speed, wide-band, precision tape recorder. Eight TV programs were simultaneously displayed on eight TV sets; these programs had been previously recorded on eight of the fifteen available recording channels of this recorder.—*T. G. Greene*

RCA PLAYS MAJOR ROLE IN MAINTAINABILITY CONFERENCE SLANTED TO DESIGN ENGINEER

RCA was strongly represented at the Fourth Electronics Industries Association Conference on Maintainability of Electronic Equipment, at the University of Colorado at Boulder on August 28-30, 1962. The theme of the conference, attended by about 260 engineers, was specification of maintainability requirements to the design engineer. A Conference *Proceedings* will be published.

F. L. Ankenbrandt, Manager, Defense Product Assurance, was General Chairman. **H. S. Dordick** of ACCD was Chairman of the Design Configuration session and Workshop Leader, Aerospace Equipment In-Flight Maintenance. **R. E. Purvis** of Service Company, Cherry Hill, gave a talk on a maintainability prediction technique. Other RCA participants functioning as Workshop Leaders were: **E. Leshner,** DEP, Modularization Trade-offs; **M. F. Bondy,** SurfCom, Ground Communications Equipment and Trade-off of Maintainability Against System Parameters; **W. G. Sommer,** ACCD, Aerospace Equipment (Transmitter) Field Level; **G. Sandler,** MSD, Test Equipment Trade-offs; and **C. S. Valesky,** MSR, Ground Operational Equipment (Radar) Organizational Level.—*C. W. Fields*

TIROS—SIX FOR SIX

The Sept. 18, 1962 orbiting of TIROS VI kept the record perfect—the sixth successful launching in six attempts in weather observation satellite program. (The DEP Astro-Electronics Division, Princeton, N.J., has developed, designed, and built all six TIROS spacecrafts for NASA's Goddard Space Flight Center, Greenbelt, Md.)

The series has grown from an experimental project into a program which is providing considerable operational weather data, not only for the United States but other countries as well, while it continues to serve as a vehicle for research and development. Several more spacecraft are scheduled to be launched before a "second generation" satellite is ready. [See also RCA ENGINEER papers in *Vol. 7 No. 4,* and *Vol. 6 No. 5,* on TIROS.]

PROPOSAL COST-SAVING WINNERS

Winners of a Surface Communications Division cost-saving contest conducted among a proposal-writing team were: **H. Weiss, J. Idema, E. Probst,** and **C. Arnold.** Their winning suggestions were for design changes and cost controlling. **R. W. Greenwood,** SurfCom Operations Manager, initiated the competition to elicit cost-saving suggestions in the earliest possible stage—the proposal preparation.—*C. W. Fields.*

HALLOWS HONORED FOR SMPTE PAPER

Raymond L. Hallows, Jr., of the DEP Astro-Electronics Division, Princeton, recently received a *1962 Honorable Mention Award* from the Society of Motion Picture and Television Engineers for his paper, "Electronic Brightness Contouring." The award was presented at the 92nd Semiannual Convention of the SMPTE in Chicago, Oct. 23, 1962.

L. E. BARTON HONORED

Loy E. Barton, former RCA Laboratories sceintist and a graduate of the University of Arkansas, B.E.E. 1921, was honored in the 1962 *Razorback,* the college yearbook, as a distinguished alumnus in science. Mr. Barton developed and built RCA's first portable transistor broadcast-band radio receiver. "Class B" Barton (Loy is the inventor of the Class-B audio-amplifier circuit) came to RCA in 1929, and joined RCA Labs in 1946. He holds some 75 patents on radio devices; is listed in *Who's Who in Engineering;* and received RCA Laboratories *Achievement Awards* in 1951, 1956, and 1962. Mr. Barton retired in December 1962.—*C. W. Sall*

Editorial Representatives

The Editorial Representative in your group is the one you should contact in scheduling technical papers and announcements of your professional activities.

DEFENSE ELECTRONIC PRODUCTS

F. D. Whitmore *Chairman, Editorial Board, Camden, N. J.*

Editorial Representatives

J. B. Rippere *Aerospace Comm. & Contr. Div., Camden, N. J.*

W. M. Morsell *Design-Devel. Eng., Aerospace Comm. & Contr. Div., Camden, N. J.*

D. B. Dobson *Systems Support Eng., Aerospace Comm. & Contr. Div., Burlington, Mass. and Camden, N. J.*

G. Lieberman *Systems Eng., Aerospace Comm. & Contr. Div., Camden, N. J.*

Miss C. Cloud, *Aerospace Comm. & Contr. Div., Burlington, Mass.*

R. Glendon *Aerospace Comm. & Contr. Div., Burlington, Mass.*

I. N. Brown *Missile & Surface Radar Div., Moorestown, N. J.*

T. G. Greene *Missile & Surf. Radar Div., Moorestown, N. J.*

D. J. Oda *Data Systems Div., Van Nuys, Calif.*

H. J. Carter *Data Systems Center, Data Systems Div., Bethesda, Md.*

C. W. Fields *Surf. Comm. Div., Camden, N. J.*

M. P. Rosenthal *Surf. Comm. Div., New York, N. Y.*

J. F. Gibbings *Surf. Comm. Div., Tucson, Ariz.*

P. J. Riley *Surf. Comm. Div., Cambridge, Ohio*

L. A. Thomas *Astro-Elec. Div., Princeton, N. J.*

M. G. Pietz *Applied Research, Def. Eng., Camden, N. J.*

J. J. Lamb *Central Eng., Def. Eng., Camden, N. J.*

BROADCAST AND COMMUNICATIONS PRODUCTS DIVISION

C. E. Hittle *Closed Circuit TV & Film Recording Dept., Hollywood, Calif.*

C. D. Kentner *Brdcst. Transmitter & Antenna Eng., Camden, N. J.*

R. N. Hurst *Brdcst. Studio Eng., Camden, N. J.*

ELECTRONIC DATA PROCESSING

T. T. Patterson *Technical Publ. Admin., EDP Eng., Pennsauken, N. J.*

R. R. Hemp *Palm Beach Engineering, West Palm Beach, Fla.*

B. Singer *Data Communications Engineering, Pennsauken, N. J.*

D. R. Crosby *Advanced Development Engineering, Pennsauken, N. J.*

RCA COMMUNICATIONS, INC.

W. C. Jackson *RCA Communications, Inc., New York, N. Y.*

RCA LABORATORIES

C. W. Sall *Research, Princeton, N. J.*

ELECTRON TUBE DIVISION and SEMICONDUCTOR & MATERIALS DIVISION

J. F. Hirlinger *Chairman, Joint Editorial Board, Harrison, N. J.*

Editorial Representatives, Electron Tube Div.

J. D. Ashworth *Kinescope Operations, Lancaster, Pa.*

G. A. DeLong *Conversion Tube Oper., Lancaster, Pa.*

G. G. Thomas *Power Tube & Oper. Svcs., Lancaster, Pa.*

T. M. Cunningham *Receiving Tube Operations, Harrison, N. J.*

H. J. Wolkstein *Microwave Tube Operations, Harrison, N. J.*

J. Koff *Receiving Tubes, Woodbridge, N. J.*

J. H. Lipscombe *Kinescopes, Marion, Ind.*

R. J. Mason *Receiving Tubes, Cincinnati, Ohio*

M. N. Slater *Electron Tubes, Mountaintop, Pa.*

Editorial Representatives, Semiconductor & Materials Div.

H. Carter *Semiconductor Devices, Somerville, N. J.*

R. Samuel *Microelectronics, Somerville, N. J.*

J. D. Young *Semiconductor Devices, Findlay, Ohio*

M. N. Slater *Semiconductor Devices, Mountaintop, Pa.*

G. R. Kornfield *Memory Products Operation, Needham, Mass., and Natick, Mass.*

RCA VICTOR HOME INSTRUMENTS

K. A. Chittick *Chairman, Editorial Board, Indianapolis*

Editorial Representatives

R. C. Graham *Radio "Victrola" Product Eng., Indianapolis, Ind.*

P. G. McCabe *TV Product Eng., Indianapolis, Ind.*

J. Osman *Electromech. Product Eng., Indianapolis, Ind.*

L. R. Wolter *TV Product Eng., Indianapolis, Ind.*

J. J. Armstrong *Resident Eng., Bloomington, Ind.*

D. J. Carlson *Advanced Devel., Princeton, N. J.*

RCA SERVICE COMPANY

W. W. Cook *Consumer Products Svc. Dept., Cherry Hill, N. J.*

J. J. Lawler *EDP Svc. Dept., Cherry Hill, N. J.*

E. Stanko *Tech. Products Svc. Dept., Cherry Hill, N. J.*

M. W. Tilden *Govt. Svc. Dept., Cherry Hill, N. J.*

N. C. Colby *Mobile Communications Engineering, Meadow Lands, Pa.*

RCA VICTOR RECORD DIVISION

M. L. Whitehurst *Record Eng., Indianapolis, Ind.*

NATIONAL BROADCASTING COMPANY INC

W. A. Howard *Staff Eng., New York, N. Y.*

RCA INTERNATIONAL DIVISION

C. G. Mayer *Product Planning & Devel., Clark, N. J.*

RCA VICTOR COMPANY, LTD.

H. J. Russell *Research & Eng., Montreal, Canada*

RCA ENGINEER

A TECHNICAL JOURNAL PUBLISHED
BY PRODUCT ENGINEERING.
"BY AND FOR THE RCA ENGINEER"

RADIO CORPORATION OF AMERICA

Form 3P4420 Trademark(s) Registered® Marca(s) Registrada(s) Printed in U.S.A.